

PVPS

annual report 2018

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 2018

COVER PHOTO:

GREEN ENERGY PARK – A First Model in Africa

The Green Energy Park photovoltaic plant, inaugurated by His Majesty King Mohammed VI in January 2017, is a unique model in Africa. The plant, with a total capacity of 250 kW, installed and connected to the grid is composed by different sub-systems with capacities varying between 5 kW and 30 kW. Its outdoor test platforms are designed in collaboration with the Fraunhofer CSP institute, and combine a multitude of test-set-ups, in order to investigate and characterize PV modules in harsh weather conditions and to obtain valuable data about their performances onsite.

Located in the Green City of Ben Guerir, it covers the electrical needs of the Green Energy Park platform laboratories. It covers an area of approximately 1,5 ha.

The plant, considered as a living laboratory by itself, contributes to R&D projects for the determination and identification of the most suited technologies for local conditions. It also gives the opportunity for national and worldwide PV module producers to test and characterize their photovoltaic technologies in real conditions. The plant is owned and operated by the Green Energy Park platform.

KEY POINTS

- Installed in self-consumption configuration to cover the R&D platform needs in terms of electricity;
- Composed of many types of technologies (crystalline, thin film, CPV, fixed static structures, trackers);
- Total area 1,5 ha;
- 25 solar string inverters with different capacities are used and distributed for each sub-system;
- Test of photovoltaic technologies at module level to identify the degradation mechanisms occurring on the different components of the PV modules in real conditions;
- Test of photovoltaic technologies at string level to characterize their behavior in terms of power ratio and degradation mechanisms on the different component of PV plants in real local conditions.

The Green Energy Park is the unique model of its kind in Africa, which allows, on the one hand, the creation of synergies and the mutualization of infrastructures of several Moroccan research institutions in order to create a critical mass and achieve excellence; and on the other hand, the acquisition of knowledge and know-how by the various partner universities as well as Moroccan industries.

A multitude of advanced equipment and high technology lets it cover the entire value chain of research and helps to make Morocco a leading country in the field of solar energy.

Credits: Cover photo and above, courtesy of IRESEN



CHAIRMAN'S MESSAGE



The Photovoltaic Power Systems Technology Collaboration Programme, the IEA PVPS TCP, under the auspices of the International Energy Agency, is pleased to provide its 2018 annual report to you. This report provides you with the latest results from our global collaborative work as well as developments in PV research and technology, applications and markets in our growing number of member countries and organizations worldwide.

2018 has confirmed the strong development of the global photovoltaic (PV) market of previous years and the continuous increase in competitiveness of solar photovoltaic power systems whereby PV is rapidly entering the energy world in many of our member countries. Achieving levelized costs of electricity from PV as low as under 2 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 global collaborative efforts.

Similar to 2017, our market analysis for 2018 estimates close to 100 GW installed worldwide, raising the cumulative installed capacity to above 500 GW respectively half a Terawatt (TW). China, India, the USA and Japan represented the largest markets in 2018, accounting for more than 70 % of the additional installed capacity in these four countries alone. 32 countries had at least 1 GW of cumulative PV systems capacity at the end of 2018 and 10 countries installed at least 1 GW in 2018. Meanwhile, in 29 countries, PV contributes with 2 % or more to the annual electricity supply. In 2018, PV has contributed to roughly 2,5 % of the world's electricity generation.

These dynamic market developments, progress in PV technology and industry and a rapidly changing overall framework form the basis for the activities of the IEA PVPS Programme. In 2018, the IEA PVPS TCP started implementing its new strategy for the term 2018 – 2023, focussing on the integration of PV in the energy system as a whole. Indeed, as PV is increasingly becoming a part of the energy system, integration at all levels becomes a key strategic matter. Keeping our overall mission to foster global cooperation and working on both technical and non-technical issues, IEA PVPS widens its scope, both in content and in cooperation with other organizations. Our key collaborative projects are related to environmental assessment of PV, reliability and performance investigations, cost reduction, grid and building integration, best practice in various applications, as well as the rapid deployment of photovoltaics. Anticipating future needs, IEA PVPS also 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. During 2018, IEA PVPS started working on its new collaborative project Task 17 on PV and Transport, thereby marking the trend of PV entering an even broader range of applications.

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 fostering an increased cooperation within the IEA technology network, stronger ties are being built with organizations such as IRENA and the IEC, as well as with the utility sector.

Interest and outreach for new membership within IEA PVPS continued in 2018. With Morocco becoming a PVPS member in 2018, IEA PVPS confirms its global expansion across all five continents. At the end of 2018, IEA PVPS had 32 members and is one of the largest IEA technology collaboration programmes (TCPs). Exploration for membership continues with India, New Zealand, Singapore and ECREEE (ECOWAS Regional Centre for Renewable Energy and Energy Efficiency). IEA PVPS maintains its coverage of the majority of countries active in development, production and installation of photovoltaic power systems. 85 % of the global installed PV capacity is in IEA PVPS member countries.

The detailed results of the different PVPS projects are presented in the Task reports of this annual report and all publications can be found at the PVPS website (www.iea-pvps.org). Learn about the current status of photovoltaics in all PVPS member countries 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, Colleagues in the PVPS Management Board, Operating Agents and Task Experts, for their ongoing and dedicated efforts for a unique and truly global cooperation!

A handwritten signature in black 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 IEA'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 Energy End-Use Technologies, Fossil Fuels, Renewable Energy Technologies 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 nine renewable energy agreements and is supported by the Renewables and Hydrogen Renewable Energy Division at the IEA Secretariat in Paris, France.

IEA PVPS

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the Technology Collaboration Programmes (TCP) 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 end 2018, seventeen Tasks were established within the PVPS programme, of which seven are currently operational.

The thirty-two PVPS members are: Australia, Austria, Belgium, Canada, the Copper Alliance, Chile, China, Denmark, European Union, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, SEIA, SEPA, SolarPower Europe, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey and the United States of America. Morocco joined PVPS in 2018.

IEA PVPS CURRENT TERM (2018 – 2023)

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 serve as a **global reference on PV for policy and industry decision makers** from PVPS TCP member countries and bodies, non-member countries and international organisations; with the

addition of its most current PVPS TCP members, it embraces all continents and subcontinents;

- to provide 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;
- to act as an **impartial and reliable source of information** for PV experts and non-experts concerning worldwide trends, markets and costs;
- to provide meaningful **guidelines and recommended practices** for state-of-the-art PV applications in meeting the needs of planners, installers and system owners;
- to contribute to 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;
- to establish a fruitful **co-operation between expert groups on decentralised power supply** in both developed and emerging countries;
- to provide an overview of **successful business models** in various markets segments;
- to support the **definition of regulatory and policy parameters** for long term sustainable and cost effective PV markets to operate.

Therefore, in this term, the IEA PVPS TCP is placing particular emphasis on:

New CONTENT:

- More focus on the role of PV as part of the futures **energy system**;
- PV interaction with other technologies (storage, grids, heat-pumps, fuel cells, bioenergy, etc.);
- Integration of PV into buildings, communities and cities, the mobility sector, industry and utilities.

New ways of COLLABORATION, to closely collaborate with other partners in the energy sector:

- Increase the IEA internal collaboration, with the IEA Secretariat, other TCPs, other international energy organisations and agencies;
- To link PVPS even more closely to national PV associations, in order to provide reliable and unbiased facts and practices;
- With specific sectors such as utilities and regulators, the mobility sector, the building sector and the industry sector;
- Open up **more cooperation possibilities** beyond the usual partners until now; e.g. non-IEA PVPS countries, non-PV networks and associations, etc.

Supported by new ways of COMMUNICATION:

- The adapted work needs significantly adapted ways to communicate our work (broader target audience, wider view of PV in the energy system, etc.);
- Changes in communication concern all tools used: website, newsletters, webinars, report summaries, one-pagers, press releases, conferences, workshops, social media, etc.



52nd IEA PVPS Executive Committee Meeting, Marrakech, Morocco, November 2018.

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.

IEA PVPS OBJECTIVES

The IEA PVPS programme aims to realise its mission through the following objectives related to reliable PV power system applications, contributing to sustainability in the energy system and a growing contribution to CO₂ mitigation:

- PV technology development
- Competitive PV markets
- An environmentally and economically sustainable PV industry
- Policy recommendations and strategies
- Impartial and reliable information.

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 (concluded in 2018);
- 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. PV Sustainability. Begun in 2007;
- Task 13. Performance, Operation and Reliability of Photovoltaic Systems. Begun in 2010;
- Task 14. Solar PV in the 100 % RESP Power System. 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 in 2016;
- Task 17. PV and Transport. Begun in late 2017.

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.

TASK STATUS REPORTS

TASK 1 – STRATEGIC PV ANALYSIS & OUTREACH

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

Task 1 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, policies and industry development.
- Task 1 serves as 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 into 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 and globally. 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 the countries participating in the IEA PVPS Programme. The NSRs are funded by the participating countries and provide a wealth of information. These reports are available on the PVPS public website www.iea-pvps.org and are a key component of the collaborative work carried out within the PVPS Programme. The responsibility for these national reports lies firmly with the national teams. Task 1 participants share information on how to most effectively gather data in their respective countries including information on national market frameworks, public budgets, the industry value chain, prices, economic benefits, new initiatives including financing and electricity utility interests.

23rd 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

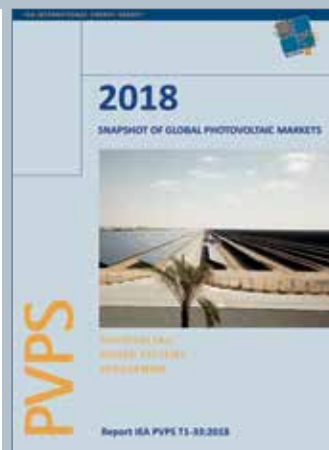


Fig. 1 – PVPS Report: A Snapshot of Global PV 1992-2017; Report IEA PVPS T1-33:2018.



Fig. 2 – PVPS Report: Trends in Photovoltaic Applications – Survey Report of Selected IEA Countries between 1992-2017; Report IEA PVPS T1-34:2018.

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, 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 and analyses the complete global PV market and industry.

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. Since 1995, twenty-three issues of *Trends* have been published. They are all available on the IEA PVPS website.

A Snapshot of Global PV Report

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

Review of PV Self-Consumption Policies

This report, available on the IEA PVPS website, 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



Fig. 3 – Joint IEA PVPS Task 1 & Task 14 Experts Meeting, Kuching, Malaysia, April 2018.



Fig. 4 – Speakers of SNEC Special Forum, "PV WE CLASS 14-One Step Away from PV Parity Era & Diversity of Distributed PV", co-hosted with China PV Society, May 2018.

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 2018 several subjects that led to specific activities.

- *PV for Transport*: the electrification of transport is one of the key elements to decarbonize that sector. The connections between PV and electric vehicles are numerous: from embedded PV cells in cars, bus, trucks, trains or planes to the use of e-mobility as an accelerator of PV development, all these subjects will be part of our research activities in the coming months and years.
- *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 continuous interest. Again in 2018, Task 1's work was focused on studying emerging models 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 that respect, Task 1 organized several workshops where utilities and PV experts exchanged information and visions about the role of utilities. The last one took place in Munich, Germany. IEA PVPS will continue to provide a platform where these actors can meet and exchange information.
- *Solar Fuels*: for the first time in 2018, Task 1 focused on the opportunities to produce solar fuels with PV and convert, store and transport such fuels. This research will continue to highlight the combined potential of solar PV and fuels to accelerate the energy transition.
- *Recommendations and Analysis*: PV's fast development on all continents requires 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 over the last several years.

SUBTASK 1.3: Communication Activities

Task 1 aims at communicating about the main findings of the IEA 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 in events during energy or PV-related conferences and fairs. Workshops are organized on various subjects, sometimes in cooperation with other IEA PVPS Tasks or external stakeholders. In 2018, the following workshops were organized in several locations around the world:

- Kuching, Malaysia: During 3rd ISES Conference in Malaysia, several IEA PVPS Task 1 representatives were invited as guest speakers.
- Shanghai, China: Co-hosted with the China PV Society, Task 1 held a workshop, inviting local experts and the Solar Impulse team (see Figure 4).
- Waikoloa, Hawaii, USA: During the 7th WCPEC World Conference, IEA PVPS Task 1, together with IEA PVPS Task 12, organized a one-day workshop composed of three sessions. In addition to industry subjects, the workshop focused on past scenarios for PV development on all continents and lessons learned for the future forecasts.
- Munich, Germany: The IEA PVPS PV and Utilities Workshop was organized during the Intersolar Conference with European utilities in order to exchange insights on business models for PV managed by utilities.
- Brussels, Belgium: A workshop during the 35th EU-PVSEC on PV market development, costs and new applications for competitive PV was presented in Brussels.
- In addition, IEA PVPS was partner in several events in 2018. Task 1 speakers represented the programme in several conferences in various places.

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

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

Website and Social Networks: Task 1 manages the IEA PVPS programme's website www.iea-pvps.org. IEA PVPS is also present on Twitter and LinkedIn.



Fig. 5 – Special session organized by PVPS at WCPEC-7, Waikoloa, Hawaii, June 2018.



Fig. 6 – IEA PVPS Task 1 Experts Meeting, Brussels, Belgium. September 2018.

PVPower Newsletter: Three issues appeared in 2018, with the ambition to provide accurate and complete information about the IEA PVPS programme, 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 contact list is expanded with more media from Asian, African and Latin American countries in a progressive way. Translations of press releases are done by some countries to expand the visibility.

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 place with:

- The IEA itself, for market data and system costs and prices;
- Other IEA Technology Collaboration Programmes;
- Stakeholders outside the IEA network, such as IRENA, ISES, REN21, etc.

SUMMARY OF TASK 1 ACTIVITIES AND DELIVERABLES PLANNED FOR 2019

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 other stakeholders. In addition to the recurrent market and industry analysis, Task 1 will continue to study the evolution of business models, the role of utilities and policies enabling PV as a key component of the energy transition.

SUBTASK 1.1: Market, Policies and Industrial Data and Analysis

National Survey Reports will start to be published from Q3 2019 on the IEA PVPS website.

The target date for publication of the 6th edition of the *Snapshot of Global PV* report is the end of Q1 2019.

The target date for publication of the 24th issue of the *Trends in Photovoltaic Applications* report is the Q4 2019. Other smaller reports are foreseen.

SUBTASK 1.2: Think Tank Activities

The main subjects to be developed in 2019 within the Think Tank activities of PVPS can be described as follows:

- Expand the analysis on self-consumption based business models, including DSM and storage capabilities. PV for transport and the built environment, solar fuels and other enablers of the energy transition are foreseen. A focus on registering PV systems and grid costs is part of the work.
- The role of utilities with regard to PV development continues to be a cornerstone of the activities.
- 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 2019. 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 IEA PVPS programme.

SUBTASK 1.4: Cooperation Activities

Task 1 will continue to cooperate with adequate stakeholders in 2019. It will reinforce the link with IEA in particular and enhance its cooperation with IRENA, ISA, REN21, ISES and other organizations. Regarding the cooperation among other IEA Technology Collaboration Programmes (IEA TCPs), a special focus could be put on subjects such as heating & cooling in buildings and clean mobility.

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 (2018 AND PLANNED 2019)

The 50th Task 1 Experts Meeting was held in Kuching, Malaysia, in April 2018.

The 51st Task 1 Experts Meeting was held in Brussels, Belgium, in September 2018.

The 52nd Task 1 Experts Meeting is foreseen in Montreux, Switzerland, in April 2019.

The 53rd Task 1 Experts Meeting is foreseen in Xian, China, in November 2019.

TASK 1 PARTICIPANTS IN 2018 AND THEIR ORGANIZATIONS

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

COUNTRY OR SPONSOR MEMBER	PARTICIPANT	ORGANIZATION
Australia	Warwick Johnston	SUNWIZ
Austria	Hubert Fechner	University of Applied Sciences Technikum Wien
Belgium	Gregory Neubourg	APERe
Canada	Christopher Baldus-Jeuren	NRCAN/RNCAN
Chile	Guillermo Jiménez Estévez	University of Chile
China	Lyu 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	Tristan Carrere	ADEME
Germany	Georg Altenhöfer-Pflaum	Forschungszentrum Jülich
Israel	Honi Kabalo	PUA
	Yael Harman	Ministry Of Energy
Italy	Francesca Tilli	GSE SpA
	Luisa Calleri	Elletricità Futura
	Andrea Zaghi	RSE SpA
	Goisuè Maugeri	
Japan	Osamu Ikki	RTS Corporation
	Izumi Kaizuka	
	Masanori Ishimura	NEDO
Korea	Chinho Park	Yeungnam University
Malaysia	Wei Nee Chen	SEDA
Mexico		
Morocco	Ahmed Benlarabbi	IRESEN
Norway	Øystein Holm	Multiconsult
Portugal	Pedro Paes	EDP
SolarPower Europe		SolarPowerEurope
South Africa	Kittessa Roro	CSIR
Spain	José Donoso	UNEF
Sweden	Johan Lindahl	Swedish Solar Association
Switzerland	Lionel Perret	PLANAIR
Thailand	Pathamaporn Poonkasem	Department of Alternative Energy Development and Efficiency
	Thidarat Sawai	
The Netherlands	Otto Bernsen	Agentschap NL
Turkey	Kemal Gani Bayraktar	Gunder
USA	David Feldman	NREL
	Christopher Anderson	DoE

TASK 12 - PV SUSTAINABILITY

INTRODUCTION

The deployment of photovoltaic (PV) systems has followed an exponential growth pattern over the last years. In order to support the decarbonization of the global energy system towards the middle of the century, that growth is bound to continue over the next decades, eventually leading to multiple Terawatts of installed PV capacity. 2018 marks the second year with approximately 100 GWp of new deployed PV capacity, bringing the cumulative installed capacity globally closer to the Terawatt which might be in range by end of this decade.

An increasing interest of stakeholders from society, regulatory bodies and non-governmental organizations on sustainability performance of these technologies can be ascertained from public tenders, commercial power purchase agreements in the business-to-business segment, international standards and regulations. Discussions on eco-design requirements, eco-labels and environmental footprinting have gained significant momentum in many world regions over the last years. Regulators are stepping up to influence the sustainability profile of this key technology for the global energy transition – 2018 saw the launch of an ambitious and comprehensive Eco-Design, Eco-Labeling, Energy Labeling and Green Public Procurement study of the European Commission, furthering that trend. Shaping and channeling the transformation of the global energy system requires an understanding of the sustainability of PV – the environmental, resource and social implications – which should be made accessible to a variety of societal, political and scientific stakeholders. Informing such assessments through development of methods, case studies, international guidelines and research is the mission of Task 12, which started working on the next work plan in 2018, which will progress through 2022.

OVERALL OBJECTIVES

Within the framework of PVPS, Task 12 aims to foster international collaboration in the area of photovoltaics and sustainability and to compile and disseminate reliable environment, health, and safety (EH&S) information, as well as providing insight to social and socio-economic implications associated with the life cycle of photovoltaic technology to the public and policy-makers. Whether part of due diligence to navigate the risks and opportunities of large PV systems, or to inform consumers and policy makers about the impacts and benefits of residential PV systems, accurate information regarding the environmental, health and safety impacts and social and socio-economic aspects of photovoltaic technology is necessary for continued PV growth. By building consumer confidence, as well as policy-maker support, this information will help to further improve the uptake of photovoltaic energy systems, enabling the global energy transition. 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.

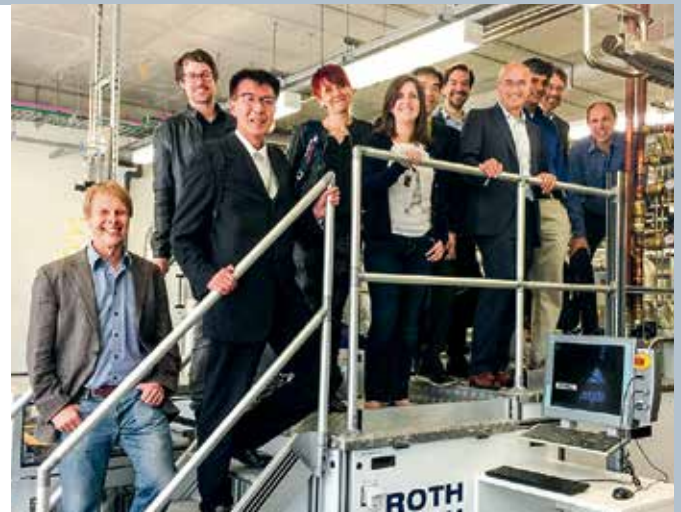


Fig. 1 – Task 12 experts on tour of University of New South Wales's PV fabrication lab after a workshop on recycling of PV modules, November 2018.

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 assessing economics and environmental performance as well as supporting development of technical standards;
3. distinguish and address actual and perceived issues associated with the EH&S, social and socio-economic aspects of PV technology that are important for market growth; and
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 – and the establishment of globally harmonized methodology guidelines and inventories for the different PV components. The successful finalization of the Product Environmental Footprint Pilot Phase and the publication of the Product Environmental Footprint Category rules under the leadership of PVPS Task 12 in 2018 marks an important milestone for this objective.

The second objective is accomplished by proactive research and support of industry-wide activities (e.g. analyzing and developing technology roadmaps for PV recycling technologies, visualizing trends in different PV markets on regulatory and technology developments on end-of-life management of PV systems) to further evolve best practices and establish national and international standards.

The third objective is addressed by advocating best sustainability practices throughout the solar value chain, exploring and evaluating frameworks and approaches for the environmental, social and socio-economic assessment of the manufacturing, installation and

deployment of PV technologies and thus assisting the collective action of PV companies in this area. Developing human health risk assessment frameworks for PV systems when it comes to EHS aspects is an important work product, serving this objective in the current work plan.

The fourth objective 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.

Task 12 has been 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-PVP'S TASK 12

SUBTASK 1: Recycling of Manufacturing Waste and Spent Modules

Life cycle management in photovoltaics has become an integral part of the solar value chain, and an active area of research for Task 12. Regulators around the world are evaluating the introduction of voluntary or mandatory frameworks for starting regionalized learning curves for end-of-life management and recycling of PV system components. With its long history on bringing the issue (and opportunities) of PV module recycling to the fore, the Task 12 group continues to foster scientific and societal exchange on the topic. The publication of the report **"End-of-Life Management: PV Modules"** in collaboration with the International Renewable Energy Agency, has been downloaded well over 100,000 times, providing the first ever global waste projection for PV modules and marking a major milestone achievement of this subtask. Building on this seminal report, Task 12 followed in 2018 with a report analyzing the trends in PV recycling technology development from private and public perspectives (**End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies**, T12-10:2018).

As an example of an integration of subtask 1 and 2, Task 12 experts have also begun to evaluate environmental benefits and impacts of module recycling through two reports published in 2018. The first collected data on energy and material flows through several current recycling facilities used for WEEE compliance in Europe, creating a life cycle inventory for these recycling systems servicing waste crystalline silicon modules (**Life Cycle Inventory of Current Photovoltaic Module Recycling Processes in Europe**, T12-12:2017). These LCI data for c-Si module recycling along with published data from First Solar on cadmium telluride module recycling then formed the basis of a life cycle assessment on each approach (**Life Cycle Assessment of Current Photovoltaic Module Recycling**, T12-13:2018).

Additional work items under this subtask which are planned for completion in 2019 include the assessment of re-use potential for PV system components, the development of an end-of-life decision support tool as well as an update to the global waste projection, including Balance of System components.

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. One of the flagship activities under this subtask was the leadership of European Commission Pilot Phase *Environmental Footprint Category Rule for PV Electricity*. This project was successfully concluded in November 2018, with the presentation and acknowledgment of the developed **"Product Environmental Footprint Category Rules for Photovoltaic Modules used in Photovoltaic Power Systems for Electricity Generation"** (Version 1.0, published 9.11.2018, validity: 31.12.2020). The acknowledgement was given by all EU Member States, the European Commission and involved societal and scientific stakeholders and the developed rules are now being applied in the ongoing preparatory work for potential eco-design, eco-labeling, green public procurement and energy labelling measures for PV modules, systems and inverters.

Task 12 experts participated in developing two international PV sustainability standards. The first, was completed at the end of 2017, resulting in the publication of a new ANSI standard: **NSF 457 – Sustainability Leadership Standard for PV Modules** (see link within <https://blog.ansi.org/2018/02/solar-photovoltaic-sustainability-leadership-ansi/#gref>). This standard establishes criteria and thresholds for determining leadership in sustainable performance that is meant to identify the top third of the market. Availability of this standard will allow large purchasers to more easily incorporate sustainability criteria in their purchasing requests. 2018 saw the opening of the process to extend this leadership standard to cover inverters as well, hence providing a sustainability metric for the most important components of a PV System.

The planned update of Life Cycle Inventory data for the supply chains of c-Si PV technologies, which was originally foreseen for 2018, has been postponed to 2019 in an attempt to utilize new and potentially more up-to-date data sources from the regulatory agencies in the IEA PVPS signatory countries as well as through utilization of market intelligence data.

SUBTASK 3: Safety

With the publication of the first part of the Human Health Risk Assessment Methods for Photovoltaics (**Human Health Risk Assessment Methods for Photovoltaics – Part 1: Fire Risks, T12:14-2018**), Task 12 extended the library of health and safety related reports this year. The report comprehensively addresses stakeholder concerns, which have been expressed regarding the potential exposure to hazardous materials resulting from fires involving PV modules. By reviewing the existing and established health risk assessment frameworks in relation to fire emissions, and leveraging recent empirical data on emissions from modules exposed to fire, the report presents the results of a case study, portraying how to apply these risk assessment framework in the context of PV systems – including estimation of mass emission rates from fire testing,

Gaussian plume dispersion modelling, fate and transport analysis to soil and groundwater and the evaluation of potential emissions of Lead, Cadmium and Selenium resulting from c-Si, CdTe and CIS PV modules.

This series of reports will be completed in 2019 with a report on leaching to rainwater from broken modules that remain in the field (Part 2) as well as on leaching in module disposal scenarios (Part 3).

ACTIVITIES IN 2018

2018 was characterized by the start of several multi-year projects which are foreseen in the work plan – bringing in new experts and contributors from PVPS countries.

The successful recruitment of experts for participation in the Task 12 expert group from countries not previously involved in Task 12 – Sweden, Belgium – and the identification of new or additional experts from existing member countries – Germany, France, Netherlands, China – yet again demonstrates the growing importance of the topic of PV sustainability in the context of the global energy transition and the development of regulatory frameworks for the terawatt age, and brings new, expanded energy to the Task 12 team.

Following the Task 12 meeting in Spring 2018 in Brussels, hosted by SolarPower Europe, Australia hosted the Autumn Task 12 meeting in Sydney in November 2018.

Governance, Dissemination and Next Meetings

Membership:

Total membership stands now at 13 countries and 1 industry association, with ~20 active experts. Belgium, Sweden and Germany have joined most recently.

Next meetings:

Next to continuation of the regular cadence of expert meetings – the Spring meeting being hosted by Sweden in Eskilstuna in June 2019, and China has invited Task 12 for a joint Task meeting adjacent to the Asia PVSEC in Xiang in Autumn.

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K. Komoto, J.-S. Lee, J. Zhang, D. Ravikumar, P. Sinha, A. Wade, G. Heath, 2018, End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies, IEA PVPS Task 12, International Energy Agency Power Systems Programme, Report IEA-PVPS T12-10:2018. <http://www.iea-pvps.org/index.php?id=459>

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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, 2nd edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report T12-03:2011. ISBN: 978-3-90642-01-5

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

Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity, 1st edition, IEA PVPS Task 12, International Energy Agency Photovoltaic Power Systems Programme. Report T12-01:2009.

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 Jäeger-Waldau, Christopher Jones,

Arthur Keller, Enrica Leccisi, Pierluigi Mancarelli, 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>

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TABLE 1 - TASK 12 PARTICIPANTS

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	Xinyu Zhang	Zhejiang Jinko Solar Co., Ltd
Solar Power Europe	Andreas Wade	Solar Power Europe
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	Françoise Burgun	Department of Solar Technologies – CEA-LITEN
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	Wiltraud Wischmann	ZSW
Japan	Satoru Shimada	NEDO (New Energy and Industrial Technology Development Organisation)
	Keiichi Komoto	Mizuho Information & Research Institute, Inc. (MHIR)
Korea	Jin-Seok Lee	Korea Institute of Energy Research (KIER)
Spain	Marco Raugei	ESCI (Escola Superior de Comerç Internacional) and Oxford Brookes University
	Vacant	CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas)
Sweden	Linda Kaneryd	Swedish Energy Agency
Switzerland	Rolf Frischknecht	treeze Ltd., fair life cycle thinking
The Netherlands	Mariska de Wild-Scholten	SmartGreenScans
	Frank Lenzen	Energy Research Center of the Netherlands (ECN)
USA	Garvin Heath	National Renewable Energy Laboratory (NREL)
	Parikhit Sinha	First Solar

TASK 13 – PERFORMANCE, OPERATION AND RELIABILITY OF PHOTOVOLTAIC SYSTEMS



Fig. 1 – Task 13 Expert Meeting at ISFH, Hamelin, Germany, 10-12 October, 2018 (Photo: ISFH).

INTRODUCTION

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.

Together with Task 1, Task 13 will continue to be needed for the predictable future of PV, and is of critical importance to the health of the PV industry. The reliability of PV plants and modules has been, and will continue to be an issue for investors and users. The PV industry continues to undergo rapid changes, both in magnitude with a near-doubling of global capacity every 3-4 years, and new technology uses (e.g. changing cell thicknesses, PERC technology uptake, bifacial cells) and new deployment locations and methods, such as floating PV and agricultural PV.

The impact of these combined effects is that the reliability and performance of PV modules and systems requires further study to ensure that PV continues to be a good investment, as past performance of similar technologies is not guaranteed to be a complete/reliable predictor of future performance of new installations.

Performance and reliability of PV modules and systems is a topic that is attracting more attention every day from various stakeholders. In recent times it also comes in combination with the terms of quality and sustainability. Task 13 has so far managed to create the right

framework for the calculations of various parameters that can give an indication of quality of components and systems as a whole. The framework is now there and can be used by the industry who has expressed in many ways appreciation towards the results included in the high quality reports.

Presently, there are 80 members from 47 institutions in 21 countries collaborating in this Task, which started its new phase of activities in September 2018. The third phase of Task 13 work will be continued with a new work programme until September 2021.

OVERALL OBJECTIVES

The general setting of Task 13 provides a common platform to summarize and report on technical aspects affecting the quality, performance, and reliability of PV systems in a wide variety of environments and applications. By working together across national boundaries, Task 13 can take full advantage of research and experience from each member country and combine and integrate this knowledge into valuable summaries of best practices and methods for ensuring PV systems perform at their optimum. Specifically, Task 13 aims to:

- Gather the most up-to-date information from each member country on a variety of technical issues related to PV performance and reliability. This will include summaries of different practices from each country, experiences with a variety of PV technologies and system designs.
- Gather measured data from PV systems from around the world. This data will be used to test and compare data analysis methods for PV degradation, operation & monitoring (O&M), performance and yield estimation, etc.
- Communicate to our stakeholders in a number of impactful ways including reports, workshops, webinars, and web content.

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.

- The industry has a continued high interest in information on performance and reliability of PV modules and systems. In addition, financial models and their underlying technical assumptions have gained increased interest in the PV industry, with reliability and performance being key parameters used as input in such models.
- Companies, which have the respective data of reliability and performance at their disposal, however, tend to be reluctant to share this information. This is particularly true, if detailed numbers in question allow for financial insights.
- Here, legal contracts that restrict partners to secrecy on financial details often prohibits data sharing, even if project partners are highly motivated to share data in general terms.

Task 13 is subdivided into three topical Subtasks reflecting the 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: New Module Concepts and System Designs

PV technologies are changing rapidly as new materials and designs are entering the market. These changes affect the performance, reliability, and lifetime characteristics of modules and systems. Such information about new technology is of great importance for investors, manufacturers, plant owners, and EPCs. These stakeholders are keenly interested in gaining more information about such technological innovations. But new technologies also present challenges to current practices and standards.

Subtask 1's objectives are to gather and share information about new PV module and system design concepts that enhance the value of PV by increasing either the efficiency/yield/lifetime or by increasing the flexibility or value of the electricity generated. This Subtask will focus on four specific activities. ST1.1 will investigate new module concepts, designs, and materials. Specific innovations related to new functional materials and module designs will be reviewed and presented in a report and as part of a workshop. Subtask 1.2 will focus on quantitative studies of bifacial PV performance from fielded systems around the world and will also investigate new bifacial PV module and system designs. Subtask 1.3 will focus on how to characterize the performance of innovative parts in PV systems where the current methods cannot be applied (e.g., PV with integrated energy storage). Subtask 1.4 will focus on the service life prediction of PV modules. It will assemble data and models for service life predictions, as well as explore methods used to accelerate the ageing of PV modules. For PV modules the principal areas of technological development are in the use of new materials and new methods for cell interconnection. Subtask 1.1 will explore work in this area being done around the world. Researchers are investigating a number of new encapsulants to replace EVA in order to extend the module lifetime. Some of these new materials include polyolefines, thermoplastics, and combined encapsulant-backsheets. Researchers are working to create materials with selective permeability, optical properties, while being fire resistant. New methods for cell interconnections include shingled designs using electrically conductive adhesives, lead-free solder, multi-wire, MWT cells with conductive back sheets, etc. Designs that result in lower internal stress from thermal cycling or wind loading (e.g., back contacted cells) may lead to longer module lifetimes and thus lower LCOE. Also, designs that include alternate cell stringing patterns or embedded power electronics to reduce the effects of partial shading will be examined. In addition, efforts at building lightweight modules without glass, or using very thin glass-glass modules are also of interest.

Subtask 1.2 will focus on bifacial PV performance, characterization, and modeling. This Subtask will collect field data from international outdoor bifacial experiments and summarize their results. This is foreseen to help illustrate the relationship between bifacial performance gains and fundamental module and system design parameters such as ground albedo, height, GCR, tilt, azimuth, system size, etc. In addition, the Subtask will review recent standards developed for bifacial PV modules and systems as well as methods for simulating bifacial PV performance (e.g., view-factor vs. ray-tracing approaches).

Subtask 1.3 will focus on new PV system designs that integrate new components (e.g., battery storage, DC/DC optimizers, etc.) and systems that are installed in new environments such as agricultural PV (a-PV), floating PV, etc. (Figure 2). There is a need to collect and summarize international efforts at developing a standard methodology for measuring and modeling the performance of such systems. Contributors will describe methods being used in different countries to characterize the performance of these complex systems.



Fig. 2 - Demonstration floating PV system in China (Photo: taken at GCL Future Energy Exhibition Hall, Suzhou, China, J. Stein, SANDIA).

Subtask 1.4 will provide a scientifically validated background and review of various service life models for PV modules and systems exposed to different climatic conditions (temperature, humidity, UV, etc.) and operating conditions (e.g., voltage and current levels). In addition, this Subtask will develop best practice recommendations for accelerated lifetime testing for PV modules. This information will help support the development of a service life prediction rating for PV modules and systems.

SUBTASK 2: Performance of Photovoltaic Systems

Subtask 2's objectives are to study the uncertainty related to the main parameters affecting yield assessment and long-term yield prediction (Figure 3). This will in turn have an impact on the LCOE and on the business model selected. As availability has an important impact on yield and failure avoidance hence early fault detection and fault avoidance through predictive monitoring will be studied. Based on real case studies the effectiveness of predictive monitoring in

avoiding failures will be analyzed. Finally, the possibility to integrate the approaches in monitoring platforms, data loggers and inverters will be assessed and the possible impact on O&M strategies evaluated.

Large impact on the energy yield certainly comes from the different climate related parameters. Investigations on all technology related influencing factors are planned to reduce uncertainties of energy yield predictions in different climates. From operational data of PV plants and based on local experience, it is evident that also soiling and snow losses do play a major role in affecting energy yield outcome and thus, the operational expenses (OPEX) of a project.

Potential energy yield losses of PV plants in high and moderate risk zones (as derived from satellite derived global risk maps) will be estimated in the activity and an outlook into the future is given with link to Subtask 3 in terms of what economic impact will soiling and snow have. Finally, all the degradation factors will be taken into account to analyse performance loss rates on large amount of high quality and low quality data to shed light on the impact data quality to the evaluation of operational data. This analysis will include the data collected in the past and provided in the Task 13 PV Performance Database.

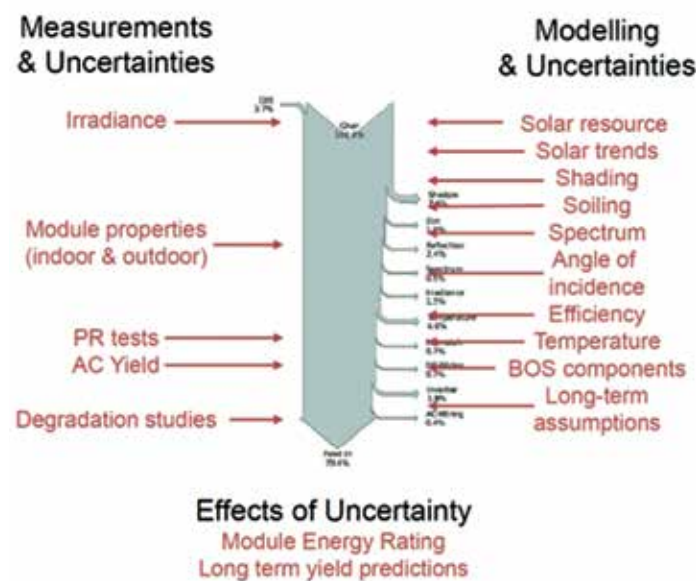


Fig. 3 - Energy flow diagram of uncertainties in PV system yield predictions and assessments. Report IEA-PVPS T13-12: 2018 (see [3] below) provides insights into the field of uncertainties of several technical aspects including solar resources and long-term trends, PV module properties as well as PV system output and performance.

In 2018, the focus of the activities was in defining the outline for the various reports, to identify the responsible experts for providing data and methodologies and to agree on the timeline to produce those documents.

The idea is to continue the previous work reported in "Uncertainties in PV System Yield Predictions and Assessments" and translate the findings into real examples of the influence of various parameters on yield assessments. The first step is to identify PV plants and data needed to be able to perform independent yield assessments. The results will be used to carry out a benchmarking exercise and to see in which aspects yield assessments can be improved. The studied real cases will be analysed also from an economic viewpoint by looking at indicators such as P90/P50, internal rate of return (IRR), etc.

The activity's focus is also on increasing the knowledge at the international level on the use of artificial intelligence to reduce the time to detect failures and to prevent failures based on real field data. There was a discussion focused on definitions needed to classify algorithms and methods related to fault avoidance and to early fault detection. To this extent, the state-of-the-art was collected through a survey filled in by the international partners.

As a final objective, the activity focuses on the assessment of Performance Loss Rates (PLR) on a large amount of PV plants by looking at high quality data (meteorological and production data coming from "research" PV plants, with high time resolution, eventually with IV curves) and low quality data (data coming from PV plants with limited information available, eventually absence of meteo data and low time resolution). As a first step, various methodologies have been collected as state of the art. Data included in the Task 2/Task 13 PV Performance Database was used to run preliminary analysis for system degradation in different climates. Data from several other countries will be made available for benchmarking activities to define the uncertainty related to the calculation of PLR and also gain insight on the accuracy of the calculated values.

SUBTASK 3: Monitoring - Operation & Maintenance

Subtask 3 aims to increase the knowledge of methodologies to assess technical risks and mitigation measures in terms of economic impact and effectiveness during operation (Subtask 3.1). Special attention will be given to provide best practice on methods and devices to qualify PV power plants in the field (Subtask 3.2). To compile guidelines for operation & maintenance (O&M) procedures in different climates and to evaluate how effective O&M concepts will affect the quality in the field (Subtask 3.3) The latter will include best practice recommendations for the assessment of energy losses due to soiling and snow. Task 13 aims at contributing with the O&M guidelines to its objectives and to improve the communication among the different stakeholders.

In Subtask 3.1, the most important risks will be investigated by collecting real case studies and building up a database with the acquired information. In order to quantify the risk, the risk itself and its structure has to be defined. The main criteria are the probability of the occurring failure and the expected losses. The probability can be determined by statistical surveys. The losses can be divided into smaller fragments, e.g. yield loss, repair cost, labour cost or

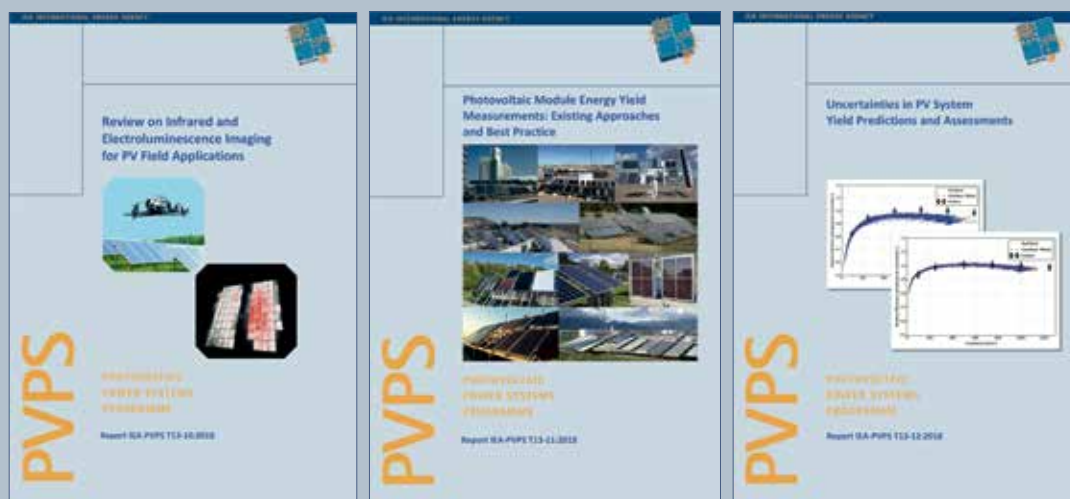


Fig.4 - Three Technical Reports published by Task 13 in 2018 and available at: <http://www.iea-pvps.org/index.php?id=483>.

substitution cost, and further translated into economic loss. These parameters need to be defined and their values shall be determined by collecting and analysing real case studies. The collected data shall be stored in a database.

Most of the risks can be mitigated with appropriate O&M measures. These O&M measures will be introduced in Subtask 3.3. For the most important measures, the cost range shall be collected and implemented in the subsequent cost-benefit analysis of the O&M measures. The theoretical approach to estimate the effectiveness of the mitigation measures shall be compared with several real case studies.

Subtask 3.2 will provide good practice on methods for portable devices to qualify PV power plants. This Subtask will collect and share, along with other participants' data, data from PV power plant inspections per country, which were collected by mobile test devices. A list of existing sources of literature/market research for mobile test devices will be compiled.

The mobile measurement devices and inspection methods in the field (I-V curve data, dark I-V data, EL images, IR images, UV FL images, and spectroscopic methods) will be discussed and assessed regarding different quality levels and involved costs.

Subtask 3.2 will evaluate uncertainties of mobile devices for characterizing modules in PV power plants and comparison to laboratory methods. Thereby the uncertainty, the required calibration procedures and the strengths & weaknesses of the field measurements will be derived.

Subtask 3.2 will develop recommendations and guidelines for best practices to qualify PV power plants using mobile devices. These guidelines will provide harmonized methods to handle warranty claim issues for different target audiences. For aerial inspection methods, the legal framework conditions in different countries will be considered.

Subtask 3.3 will give contributions and experiences on O&M procedures in different countries and climates. The existing O&M guidelines on national and international level will be summarized highlighting the similarities and differences. We will evaluate how an effective operation and maintenance concept will affect the quality

of PV power plants in the field. Procedures for plant monitoring and supervision, methods of performance analysis as well as procedures for preventative and corrective maintenance measures will be evaluated and assessed in terms of economic impact in different climates and countries.

Subtask 3.3 will provide recommendations for the assessment and mitigation of revenue losses due to soiling. This Subtask will focus on when is the best time to clean – that might depend on what kind of quantity one wants to optimize: is it the energy yield or the revenue? Depending on per-site constraints, such as local labour costs, local feed-in-tariffs, water availability and local weather forecast, this question might be answered by a suitable socio-economic model. From this rating, best practice guidelines on O&M procedures will be developed for specific countries in order to optimize energy production and revenues and to reduce technical and economic risks during the important operation & maintenance phase.

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 expert workshops, conference presentations, technical reports and international webinars.

The following Technical Reports were published in 2018:

- [1] Report IEA-PVPS T13-01:2018. ISBN 978-3-906042-53-4
Review on Infrared and Electroluminescence Imaging for PV Field Applications
Ulrike Jahn, Magnus Herz, Marc Köntges, David Parlevliet, Marco Paggi, Ioannis Tsanakas, Joshua S. Stein, Karl A. Berger, Samuli Ranta, Roger H. French, Mauricio Richter, Tadanori Tanahashi
For download at: <http://iea-pvps.org/index.php?id=480>
- [2] Report IEA-PVPS T13-11:2018. ISBN 978-3-906042-52-7
Photovoltaic Module Energy Yield Measurements: Existing Approaches and Best Practice
Gabi Friesen, Werner Herrmann, Giorgio Belluardo, Bert Herteleer
For download at: <http://iea-pvps.org/index.php?id=493>
- [3] Report IEA-PVPS T13-12:2018. ISBN 978-3-906042-51-0
Uncertainties in PV System Yield Predictions and Assessments
Christian Reise, Björn Müller, David Moser, Giorgio Belluardo, Philip Ingenhoven
For download at: <http://iea-pvps.org/index.php?id=477>

The Expert Workshops took place at the following events in 2018:

- Swiss PV Conference, Bern, 19-20 April, 2018
- Intersolar Europe Conference, Munich, 19 June, 2018
- EU PVSEC 2018, Brussels, 24-28 September, 2018
- Workshop "UV Fluorescence Measurements for Damage Assessment of PV Modules", ISFH, Hamelin, Germany, 12 October, 2018 (Figure 5)
- IEC TC82 PV Plenary Meeting, Busan, Korea, 15-18 October, 2018
- 3rd International Workshop on the Sustainable Actions for "Year by Year Aging" under Reliability Investigations in Photovoltaic Modules - SAYURI-PV 2018, Tsukuba (Ibaraki), Japan, 30-31 October, 2018
- SUPSI Industry Day 2018, Canobbio, Switzerland, 09 November, 2018
- 2018 Asia-Pacific Solar Research Conference, University NSW, Sydney, Australia, 04-06 December, 2018.

All publications and Task 13 presentations from the expert workshops held in 2018 are publicly available for download at the workshops section on the IEA PVPS website: <http://www.iea-pvps.org/index.php?id=464>.

MEETING SCHEDULE (2018 AND PLANNED 2019)

The 18th PVPS Task 13 intermediate Experts' Meeting took place in Hawaii, USA, 10 June 2018.

The 19th PVPS Task 13 intermediate Experts' Meeting took place in Munich, Germany, 19 June 2018.

The 20th PVPS Task 13 Experts' Meeting was hosted by ISFH and took place in Hamelin, Germany, 10-12 October 2018.

The 21st PVPS Task 13 Experts' Meeting will take place in Utrecht, The Netherlands, 2-4 April 2019.

The 22nd PVPS Task 13 Experts' Meeting will take place in Santiago, Chile, 22-25 October 2019.



Fig. 5 - 60 participants from Europe, the US, Asia and Australia at PVPS Task 13 Workshop on UV Fluorescence Measurements for Damage Assessment of PV Modules at the Institute for Solar Energy Research (ISFH), Hamelin, Germany, 12 October, 2018.

TABLE 1 – TASK 13 PARTICIPANTS IN 2018 AND THEIR ORGANIZATIONS

COUNTRY	ORGANIZATION
Australia	<ul style="list-style-type: none"> Ekistica Murdoch University The University of New South Wales (UNSW)
Austria	<ul style="list-style-type: none"> Austrian Institute of Technology (AIT) Österreichisches Forschungsinstitut für Chemie und Technik (OFI) Polymer Competence Center Leoben (PCCL) GmbH
Belgium	<ul style="list-style-type: none"> 3E nv/sa Interuniversity Microelectronics Centre (imec) Tractebel – Engie
Canada	<ul style="list-style-type: none"> CANMET Energy Technology Centre
Chile	<ul style="list-style-type: none"> Atacama Module System Technology Consortium (AtaMoS-TeC)
China	<ul style="list-style-type: none"> Institute of Electrical Engineering, Chinese Academy of Sciences (CAS)
Denmark	<ul style="list-style-type: none"> SiCon • Silicon and PV Consulting
Finland	<ul style="list-style-type: none"> Fortum Power & Heat Oy Turku University of Applied Sciences
France	<ul style="list-style-type: none"> Electricité de France (EDF R&D)
Germany	<ul style="list-style-type: none"> Fraunhofer Institute for Solar Energy System (ISE) Institute for Solar Energy Research Hamelin (ISFH) TÜV Rheinland
Israel	<ul style="list-style-type: none"> M.G.Lightning Electrical Engineering
Italy	<ul style="list-style-type: none"> European Academy Bozen/Bolzano (EURAC) Gestore dei Servizi Energetici – GSE S.p.A. IMT Institute for Advanced Studies Lucca Ricerca sul Sistema Energetico – RSE S.p.A.

COUNTRY	ORGANIZATION
Japan	<ul style="list-style-type: none"> National Institute of Advanced Industrial Science and Technology (AIST) New Energy and Industrial Technology Development Organization (NEDO)
Morocco	<ul style="list-style-type: none"> l'Institut de Recherche en Energie Solaire et Energies Nouvelles (IRESEN)
Netherlands	<ul style="list-style-type: none"> Utrecht University, Copernicus Institute
South Africa	<ul style="list-style-type: none"> CSIR Energy Centre
Spain	<ul style="list-style-type: none"> National Renewable Energy Centre (CENER)
Sweden	<ul style="list-style-type: none"> EMULSIONEN EKONOMISK FORENING Mälardalens Högskola (Mälardalen University) Paradisenergi AB PPAM Solkraft Research Institutes of Sweden RISE
Switzerland	<ul style="list-style-type: none"> Berner Fachhochschule (BFH) CSEM PV-Center and EPFL Photovoltaics Laboratory Institut für Solartechnik (SPF) Scuola Universitaria Professionale della Svizzera Italiana (SUPSI) Zürcher Hochschule für Angewandte Wissenschaften (ZHAW)
Thailand	<ul style="list-style-type: none"> King Mongkut University of Technology Thonburi (KMUTT)
USA	<ul style="list-style-type: none"> Case Western Reserve University (SDLE) National Renewable Energy Laboratory (NREL) Sandia National Laboratories (SNL)

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

TASK 14 – SOLAR PV IN A FUTURE 100 % RES BASED POWER SYSTEM

INTRODUCTION

Following its ongoing growth, PV has today become a visible player in the electricity generation not only on a local, but also on nationwide levels 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.

To ensure further smooth deployment of PV and avoid potential need for costly and troublesome retroactive measures, proper understanding of the key technical challenges facing high penetrations of PV is crucial. Key issues include the variable nature of PV generation, the "static generator" characteristics through the connection via power electronics, the large number of small-scale systems located in the distribution grids typically designed only for supplying loads. Power system protection, quality of supply, reliability and security may all be impacted.

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

OVERALL OBJECTIVES

As part of the IEA PVPS programme, the main objective of Task 14 in the upcoming Phase 3 of its work programme is to prepare the technical base for PV as major supply in a 100 % RES based power system. Task 14 focuses on working with utilities, industry, and other stakeholders to develop the technologies and methods enabling the widespread and efficient deployment of distributed as well as central PV technologies into the electricity grids.

Tackling these urgent issues, Task 14 addresses high penetration PV throughout the full interconnected electricity system consisting of local distribution grids and wide-area transmission systems. Furthermore, also small-scale island and isolated grids in emerging regions are within the scope of Task 14 where such power systems form significant parts of the national electricity system.

From its beginning as global initiative under the PVPS TCP, Task 14 has been supporting stakeholders from research, manufacturing as well as electricity industry and utilities by providing access to comprehensive international studies and experiences with high-penetration PV. Through this, Task 14's work contributes to a common understanding and a broader consensus on methods to adequately evaluate the value of PV in a 100 % RES based power system. The objective is to show the full potential of grid integrated photovoltaics, mitigate concerns

IEA-PVPS Task 14 High Penetration PV Workshops and Conference Sessions

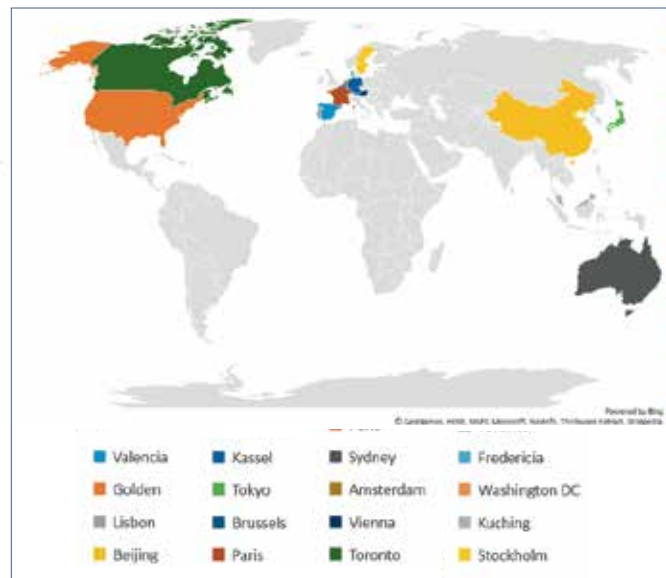


Fig. 1 – IEA PVPS Task 14 High Penetration PV Workshops and Conference Sessions (Source: IEA PVPS Task 14).

of PV to the benefit of a large number of countries and link technical expertise on Solar PV integration available within Task 14 with complementary initiatives (e.g. WIND Annex 25).

Through international collaboration and its global members, Task 14 provides an exchange platform for experts from countries, where Solar PV already contributes a significant share to the electricity supply and countries with emerging power systems and a growing share of variable renewables.

SUBTASKS AND ACTIVITIES

The massive deployment of grid-connected PV in recent years has brought PV penetration into the electricity grids to levels where PV – together with other variable RES such as Wind – has become a visible player in the electricity sector. This fact not only influences voltage and power flows in the local distribution systems, but also affects the overall bulk power system. Together with other variable renewables, particularly wind, Solar PV today influences the demand-supply balance of the whole system in several regions around the globe.

Against this background, the work programme for the Phase 3 which started in mid-2018 is strongly dedicated to preparing the technical base for Solar PV in a future 100 % RES based power system. This widening of the scope not only resulted in changing the title of the Task from "High Penetration PV in Electricity Grids" to "Solar PV in a future 100 % RES based power system" but also resulted in a new organizational structure. The new Subtasks will focus on integrating distribution and transmission aspects, operational planning and management of power grids with 100 % RES based supply.



Fig. 2 – IEA PVPS Task 14 and IEA WIND Task 25 Experts at their Joint Meeting at KTH, Stockholm, Sweden, October 2018 (Photo: IEA PVPS Task 14).

Task 14's work programme addresses foremost technical issues related to the grid integration of PV in high penetration scenarios, particularly in configurations with a major share of the energy provided by variable renewables:

The main topics for the upcoming phase 3 include Transmission – Distribution Grid Planning and Operation with high penetration RES, Grid Stability, grid codes and regulatory frameworks and the integration of Local Energy Management with PV and storage. The integration of decentralized solar PV which is interlinked with the development of (future) smart grid complements the research in Task 14. To ensure that PV grid integration solutions are well-aligned with such comprehensive requirements, it is indispensable to analyse also in detail the challenges and solutions for the PV grid integration from a smart grid perspective and to suggest future-compliant solutions.

Within a dedicated Subtask, appropriate control strategies and communication technologies to integrate a high number of distributed PV in smart electricity networks are being analyzed and eventually formulating smart PV grid recommendations for different kinds of infrastructures.

PROGRESS AND ACHIEVEMENTS

Besides the conclusion of the activities of the second phase which ended in mid-2018, the main strategic activity in 2018 was related to the final detailing of the work programme for the Phase 3 of Task 14 and the securing of the resources required for its implementation. Following the official endorsement of the work programme for the next phase in April 2018, Task 14's work will be strongly dedicated to preparing the technical base for Solar PV in a future 100 % RES based power system. This reshaping of the main objectives also results in a new organizational structure, which will focus on integrating distribution and transmission aspects, operational planning and management of power grids with 100 % RES based supply.

In parallel to the strategic work on the upcoming Phase 3, Task 14 activities in 2018 also continued at the technical level with a focus on Solar and Wind studies and TSO/DSO cooperation aspects:

- As part of the long-term collaboration between IEA-PVPS Task 14 and IEA-WIND Task 25 ("Design and Operation of Power Systems with Large Amounts of Wind Power") a first joint report has been prepared by experts from both TCPs. The "Expert Group Report on Recommended Practice for Wind/PV Integration Studies" presents

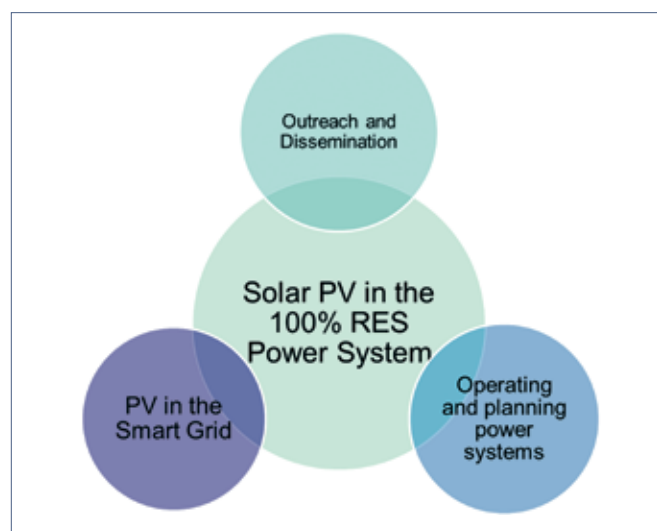


Fig. 3 – IEA PVPS Task 14 Organization in Phase 3 2018-2022.

a best practice for performing integrated Solar PV and Wind grid integration studies. The report has been approved by the Executive Committees of both TCPs and will be published as an IEA PVPS Report in 2019.

- Related to the Interactions between Distribution Network and Transmission Network, which is of relevance for Solar PV and is typically connected to the distribution systems, a dedicated report on "International Activities - Interactions between Distribution Network and Transmission Network" was published. This report presents current practices of TSO/DSO cooperation through a collection of international R&D projects, with a focus on advanced TSO/DSO cooperation procedures. 19 international R&D projects from the United States, Europe, and Japan are identified and their objectives, key findings, and recommendations are collected and summarized. In detail the status and development of TSO/DSO cooperation depends on many impact factors, for example on the addressed grid operation challenges, the applied communication technologies and standards, the addressed voltage levels and DER types (e.g. residential, commercial, utility-scale PV), and especially the national/ regional regulatory framework and requirements and overarching policy objectives. Overall, a major part of the identified R&D projects is ongoing and still a significant research and development demand is identified for an advanced TSO/DSO cooperation.

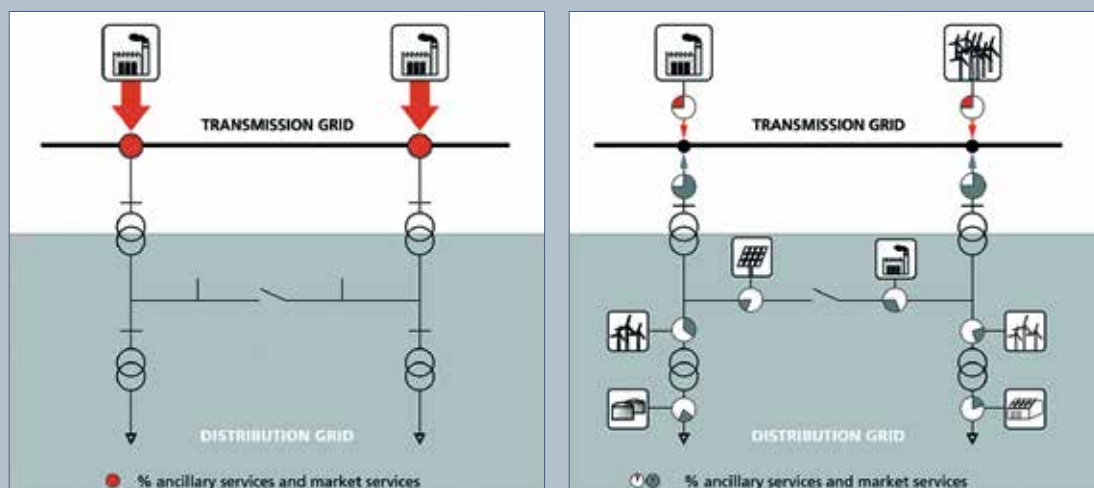


Fig. 4 – Provision of ancillary services for the transmission grid in the past (left) and for future smart grid applications (right) (source: Project SysDL2.0).

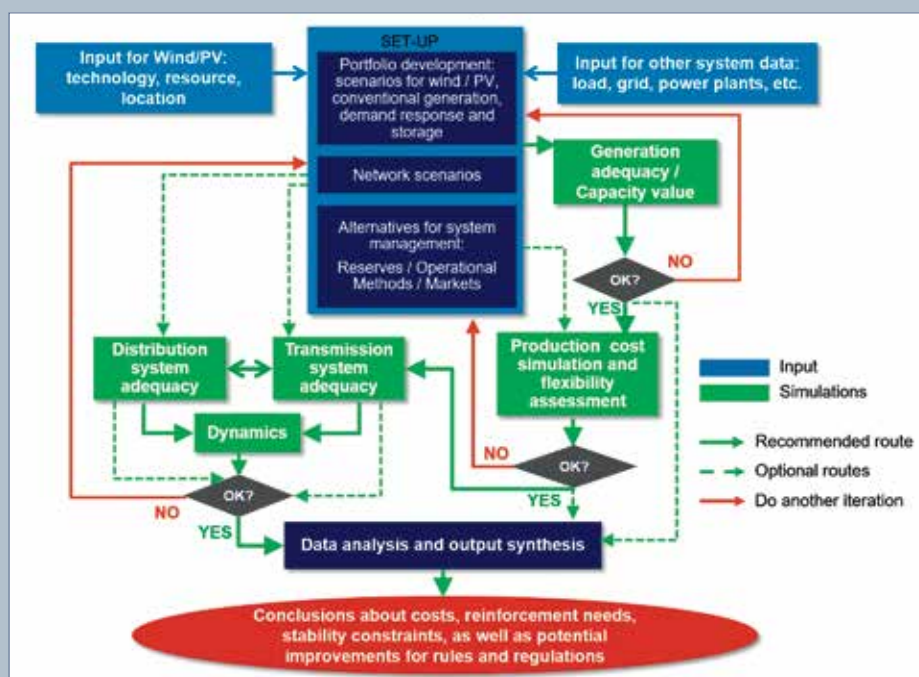


Fig. 5 – Wind/PV integration study components; flow chart showing a recommended route with iteration loops and possible routes when not all components are studied (Source: IEA Wind and IEA PVPS Expert Group Report 16.2 Recommended Practises for Wind and PV Integration Studies).

Complementing its technical work, Task 14 continued contributing to conference sessions with the following well received events in Asia and Europe:

- In April 2018, Task 14 contributed to the "International Solar Energy Symposium" 2018, organized by SEDA, Malaysia in Kuching, Malaysia. As part of the "Deep Dive Workshop" on "Integrating Large Scale Distributed Solar PV Systems to the Grid" the presentation from Task 14 highlighted the importance of appropriate Grid Codes for the sustainable grid integration of Solar PV at high penetration levels.
- In October 2018, Task 14 together with IEA WIND Annex 25 organized a joint session on Solar PV and Wind integration experiences at the 2018 Wind Integration Workshop (WIW2018), Stockholm, Sweden. In a series of presentations from experts of both TCPs, latest results and country case studies were presented, highlighting the importance of an integrated view on RES integration to the electricity system

Task 14 Workshop presentations are publicly available for download from the Workshops section of the IEA PVPS website.

SUMMARY OF TASK 14 ACTIVITIES PLANNED FOR 2019

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 participate in the Task 14 group.

Based on the results achieved so far within the Task 14, further activities towards integrating industry are constantly being organized, such as special workshops for intensive knowledge exchange. The utility interest in Task 14 work is also highlighted by the broad attendance of utility representatives at the recent events organized by Task 14.

Furthermore, the workshops also form the basis to present national activities related to the grid integration of Solar PV, together with other relevant international projects which address research and demonstration of Solar PV and variable RES.

PUBLICATIONS AND DELIVERABLES

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

In 2018 Task 14 produced two official reports:

- Report T14-11 2018 "International Activities – Interactions between Distribution Network and Transmission Network" was published in October 2018.
- Report IEA-PVPS T14-10:2018 "Expert Group Report on Recommended Practice for Wind/PV Integration Studies" was approved by the IEA-PVPS ExCo in October 2018 and will be published in February 2019.

Besides PVPS related dissemination activities, Task 14 experts contributed to several national and international events and brought in the experience from the Task 14 work. Highlights include:

- 7th World conference on Photovoltaic Energy Conversion, Hawaii, USA (WCPEC-7), 10-15 June 2018
 - Self-consumption of electricity produced from PV systems in apartment Buildings – Comparison of the situation in Australia, Austria, Denmark, Germany, Greece, Italy, Spain, Switzerland and the USA, A. J. Waldau, C. Mayr, et.al.
- Swiss PVPS dissemination event, Bern, Switzerland, Sept 7, 2018
 - IEA PVPS Task 14, From High Penetration in Electricity Grids to Solar PV as major source in the 100 % RES Power System, R. Bründlinger (OA)
 - Task presentations from Swiss Task 14 experts
- Solar Integration Workshop, Stockholm, 16-17 October 2018:
 - "Implementation of the European Network Code on Requirements for Generators on the European National Level – Current Status – Trends and Challenges", presented by R. Bründlinger (AIT)
 - "Secure Energy Information Network in Germany – Demonstration of Solar -, Storage- and E-Mobility Application", presented by G. Heilscher (HS ULM)
- Wind Integration Workshop, Stockholm, Joint session of IEA Wind Task 25 & IEA PVPS Task 14: "Highlights and trends from international collaboration on solar and wind integration", 17-19 October 2018
 - Introduction: Summary of Wind and Solar Integration Study Results – IEA WIND Task 25 and IEA PVPS Task 14 Collaboration

- Country Highlights and Trends on Solar and Wind Integration – Country experts from – USA (B.-M. Hodge, NREL), Japan (Y. Ueda, Tokyo University of Science), Denmark (A. Orths/ P. Borre Eriksen – Energinet dk, Denmark),- Portugal (A. Estanqueiro – LNEG, Portugal)
- Coordination between Distribution Network and Transmission Network Operation – Relevance for Solar and Wind Integration, IEA-PVPS Task 14

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

The successful series of utility workshops related to high PV penetration scenarios in electricity grids will be continued in 2019, 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 (2018 AND PLANNED 2019)

The 17th Experts' Meeting was held in Kuching, Malaysia, 8-9 April 2018, hosted by SEDA in the range of the ISES2018 conference. In addition, a joint session with Task 1 as well as a special Deep Dive Workshop were organized in conjunction with the Task 14 meeting.

The 18th Experts' Meeting was held in Stockholm, Austria, 14-15 October 2018, hosted by the Swedish Energy Agency and the KTH. On 15 October, a joint workshop with the expert group from the IEA-WIND Task 25 was organized to share experiences, visions and discuss plans for future collaboration.

The 19th Experts' Meeting is planned to be held on El Hierro Island, Spain, hosted by University Las Lagunas and the Government of El Hierro, 24-25 March 2019.

The 20th Experts' Meeting is planned to be held in Xian, China, November 2019.

TABLE 1 – LIST OF TASK 14 PARTICIPANTS 2018 (INCLUDING OBSERVER)

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Iain McGill	University of NSW
	Navid Haghdadi	
Austria	Roland Bründlinger	AIT Austrian Institute of Technology
Canada	Patrick Bateman	CANSIA
Chile	Ana Maria Ruz Frias	Comité Solar
China	Wang Yibo	Chinese Academy of Science
	Yang Zilong	
Denmark	Kenn H. B. Frederiksen	Kenergy
EC	Arnulf Jäger-Waldau	European Commission
Germany	Gunter Arnold	Fraunhofer IWES
	Martin Braun	
	Bernhard Ernst	
	Markus Kraiczy	
	Gerd Heilscher	Hochschule Ulm
Italy	Giorgio Graditi	ENEA-Portici Research Centre
	Adriano Iaria	RSE – Ricerca Sistema Elettrico
Japan	Toshiyuki Kuroyagi	NEDO
	Kazuhiko Ogimoto	The University of Tokyo
	Yuzuru Ueda	
Malaysia	Akmal Rahimi	SEDA
	Koh Keng Sen	
Spain	Ricardo Guerrero Lemus	University of La Laguna
Switzerland	Christof Bucher	Basler & Hofmann AG
	Lionel Perret	Planair SA, Switzerland
	Marine Cauz	
United States	Barry Mather	National Renewable Energy Laboratory NREL
	Tom Key	EPRI
	Ben York	
Singapore (observer)	Thomas Reindl	SERIS
	Yanqin Zhan	

TASK 15 – ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV

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 numbers in the world's population, as well as improved standards of living, and will confront us with energy shortage in the future and negative climate changes already in the present. There is ample evidence that the current energy system is not sustainable and that we have to shift to a system based on renewable sources, such as the sun.

Solar PV energy systems, applied in the built environment, offer the possibility of renewable energy generation closely located to the consumer, avoiding transportation losses and contributing to solving the challenges of climate change and energy shortage. To facilitate large-scale introduction of these systems, integration in the built environment is crucial. 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, that 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 very small market, but huge potential. To fully grasp this potential, a transition in the built environment has to be realized, in which regulatory barriers, economic barriers, environmental barriers, technical barriers and communicational barriers have to be 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 and 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.



Fig. 1 – IEA PVPS Task 15 Experts visit to the Environmental Energy Innovation Building (BIPV installed in 2012), Tokyo, Japan.

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:

- BIPV project database – Designers and architects;
- Economic transition towards sound business models – Business developers / project managers;
- International harmonization of regulations – BIPV product manufacturers / installers;
- BIPV environmental assessment issues – Policy makers, building environmental assessors;
- 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 breached. In 2019, the first phase of this Task will be analysed and completed, and based on input from the PVPS Executive Committee and Task 15 experts the continuation in a second phase is being investigated and will be discussed during a Task definition workshop in June 2019, Montreal, Canada.



Fig. 2 – IEA PVPS Task 15 Experts visit to the Taisei Corporation Technology Center ZEB Demonstration Building (BIPV installed in 2014), Tokyo, Japan.



Fig. 3 – IEA PVPS Task 15 Experts at the Task 15 Meeting in Vienna, Austria, June 2018.

ACTIVITIES OF IEA PVPS TASK 15 IN 2018

SUBTASK A: BIPV Project Database

This Subtask's aim is to create awareness through an information portal for BIPV application in building projects, led by the Netherlands. To realize this aim, 'story telling' is developed, based on successful BIPV projects which are replicable. Subtask contact persons from all countries have been requested to send in 10 BIPV projects that are representative for their country and suitable for international comparison and dissemination. Fourteen countries have responded at the moment of writing, and in total, over 145 projects have been received so far.

Out of these projects a selection is made by the country representatives for a total of 25 projects that have been analyzed in detail.

A questionnaire to analyze these projects was developed and used as a guideline for in-depth project interviews.

The focus in the case studies is the ability to interview the main actors in the process of introducing and applying BIPV in the project. The goal is to learn from their motivation and decision making with the purpose to make interesting cases available for other decision makers. Most in depth interviews were completed before the Task Experts' Meeting in Vienna (June 2018). Based on this information, additional project material was requested and received. In the Task Experts' Meeting in Copenhagen (November 2018), the draft book was presented and discussed in the Task 15 experts meeting plenary and in the editing board (Netherlands, Denmark, Italy and Switzerland). After the meeting, the draft version of the book was sent around for reviewing by each country. Also a copyright form was produced and sent around to cover copyright issues on image use.

The final publication of the book is expected in June 2019. Parallel to the development of the book, all information of the BIPV projects investigated is posted on an interactive database developed by Task 15 members and hosted by Italy, based on the same questionnaire as used for the book.

SUBTASK B: Transition towards Sound BIPV Business Models

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

Subtask B is led by Sweden with experts from seven other countries active in Task 15, covering the BIPV manufacturing industry, consultants and researchers.

Several decisions were made in 2018:

1. Activity B.3 will deliver a guide for BIPV business model development.
2. Responsibilities for different chapters and business models in the B.3 report were divided among the experts in the STB team.
3. Activity B.3 and B.4 are combined due to limited time and funding for STB experts.
4. Monthly plenary teleconferences for STB participants continued.

Subtask B is further sub-divided into the following four activities:

B.1 – Analysis of Status Quo

Based on a selection of existing projects that are representative BIPV solutions/applications, Subtask experts have performed a detailed analysis and description of values and motives behind the projects, of the stakeholders that are economically involved, and of the overarching Business Model that prevails for establishing the financial viability of the solution.

B.2 – Analysis of Boundary Conditions

Subtask experts have analysed the current and forecasted evolution of the boundary conditions determining the financial attractiveness of BIPV solutions in this activity. These include the nature and 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.

- Report B.1/B.2 was published in April 2018, title: Inventory on Existing Business Models, Opportunities and Issues for BIPV.
- The report and its results were presented at a webinar in September 2018.

B.3 – Development of New Business Models

This is the Subtask's core activity. It will in particular perform an in-depth analysis on the definition of the true economic value of BIPV. It will analyze how new business models can be derived to fully exploit



Fig. 4 – IEA PVPS Task 15 Experts at the Task 15 Meeting in Copenhagen, Denmark, November 2018.



Fig. 5 – IEA PVPS Task 15 Experts visit the skateboard arena "Wonderland" (BIPV installed in 2018), in Christiania, Copenhagen, Denmark, November 2018.

the values of BIPV 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.

- The B.3 report, expected to be published during spring 2019, will be a guide for all stakeholders interested in BIPV business models. The basis for business model development is the value of BIPV and this has a separate chapter in the report.
- Key recommendations already delivered in the first report with B.1 and B.2, can be complemented.
- A workshop using business model canvas was held in connection to the Task 15 meeting in Uppsala, Sweden, September 2017. The workshop methodology and results have been used and developed further during 2018.
- The B.3 report includes guiding business model canvas examples for three categories of business models; residential buildings with project based business models, commercial buildings with product based business models and commercial buildings with service based business models.

SUBTASK C: International Framework of BIPV Specifications

The aim of this subtask is to develop an international framework for BIPV specifications and policy recommendations. This subtask is divided in 4 activities, of which the current status is indicated below. With the subtask leader able to attend all three meetings and chair ten conference calls during 2018, progress within this subtask has accelerated significantly. About 15 – 20 persons from 12 countries have regularly participated as authors or reviewers to the various reports that Subtask C prepared this year. Most current participants have indicated interest in continuing their co-operation in a second phase of Task 15 within the proposed Subtask E on "Pre-normative international research on BIPV characterisation methods", which has been outlined in a one-page sketch.

Interaction between Subtask C participants and IEC PT 63092 members continues to be intensive, as preparation of the IEC standard 63092 continued throughout the year, with face-to-face meetings being held in conjunction with the IEA-PVPS Task 15 meetings in Tokyo, Vienna and Copenhagen. PT 63092 is entitled "Photovoltaics in buildings" and consists of Part 1: Building integrated photovoltaic modules and

Part 2: Building integrated photovoltaic systems. The international input from Subtask C participants, particularly the information summarised in the draft C2 report, has substantially supported the work on PT 63092.

Subtask C activities and status:

- C.0 International definitions of "BIPV" – final report available on the IEA PVPS website.
- C.1 Analysis of user needs for BIPV & BIPV functions – final report entitled "Compilation and Analysis of User Needs for BIPV and its Functions" has been balloted by the PVPS Executive Committee and is ready for distribution.
- C.2 BIPV technical requirements overview – draft report entitled "Analysis of requirements, specifications and regulation of BIPV" has been distributed to Task 15 participants for review.
- C.3 Multifunctional BIPV evaluation – Two questionnaires formulated and distributed; first responses received.
- C.4 Suggest topics for exchange between different standardization activities on international level – report structure is being reviewed and content is in preparation.

The next planned steps within Subtask C are:

- Complete reports on activity C.2, taking review results into account.
- Continue to provide input to IEC 63092.
- Analyse experience with implementation of EN 50583 and submit this as a short C.3 report
- Classify and identify potential for multifunctional BIPV evaluation; submit C.4 report with this content.
- Elaborate proposal for a new Subtask on "Pre-normative international research on BIPV characterisation methods" within a second phase of Task 15.

SUBTASK D: Environmental Aspects of BIPV

This Subtask's aim is to develop an international framework for the methodology of LCA of BIPV based on a number of case studies, in close collaboration with IEA PVPS Task 12.

13 persons from eight countries (Austria, Switzerland, Sweden, Denmark, Korea, Netherlands, Norway, Spain, Italy) are active in this Subtask, led by France.

The state of the art report (report D.1) is completed but still under correction. The objective of the revision is to simplify the report in order to ensure exhaustibility of the state of the art as well as a clear identification of the parameters strongly influencing performances of the BIPV in collaboration with IEA PVPS Task 12. In order to reflect the double role of the BIPV in the building, results are presented following three "functional units": the unit of one "product" BIPV, one square meter of replaced surface (roof or façade) with and without BIPV, and one square meter of building during its whole life with and without BIPV.

Two case studies have been finalized, corresponding to different type of buildings:

LOCATION	SWEDEN	SPAIN
TYPE OF USE	Multi-family residential, with preschool and shops at bottom floor	Residential building
INSTALLATION OF BIPV	Façade	Roof
BIPV TECHNOLOGY	Thin film CIS	Crystalline silicone

From these two case studies, several important parameters influencing the environmental performances of BIPV have been identified:

- Type of building function identified and the replaced material.
- Calculation of electricity exported to the grid and type of system extension (electricity substitution) applied.
- Perimeter of the study including material supply and module production, installation and mounting, dismantling and end of life both for building and PV system.
- Life duration of the PV integrated in the building and modelling of the replacements.
- Type and coherence of the used background datasets.
- Coherence in the definition of the perimeter of the modelling of the use of the building (including heating of apartments).
- Covering the whole PV system including edging material and electronic system with replacement during the whole life of the building.
- Solar irradiation, theoretical and actual efficiency of the PV electricity production.

All these parameters can affect strongly the performances of the BIPV. The additional case studies that are modelled during the first semester of 2019 will have to specially focus on these parameters in order to bring relevant insight in the final methodology report D.2.



Fig 6 – BIPV installation at the Copenhagen International School, Copenhagen, Denmark. BIPV developed by Anders Smith and realized in 2017.

Further steps: The diversity of profiles of participants involved in Task 15 requires more time to ensure convergence of views and a proper consideration of each position. The methodology report D.2 will be based on properly integrated outcomes from the case studies.

These important aspects were discussed at the Task 15 experts meeting in November 2018 in Copenhagen and it confirms the work plan made during the Task 15 experts meeting in June 2018 in Vienna:

1. Gathering all methodology proposals from all participants.
2. Selecting from these methodological inputs all key parameters and assumptions that have to be tested.
3. Identifying and assessing as many case studies as possible in order to ensure a proper testing of all parameters in very different situations.
4. Based on these results we will propose a methodology for environmental assessment of BIPV.

In terms of time plan, 2 case studies have already been tested. Finalization of all case studies for a presentation and publication in the report D.3 is planned for June 2019.

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

This Subtask's aim is to exchange experience and improve international collaboration for BIPV implementation. 35 experts from 11 countries are involved in this subtask. Based on an inventory of existing test and demonstration sites, objectives are to identify assessment methods and performance characterization of BIPV solutions to highlight "reference technical solutions" and contribute to dissemination of reliable BIPV solutions.

The work in this Subtask is carried out taking into account the developments of Subtasks B (business model) and Subtask C, mainly to take into account the international definition of BIPV, based on EN 50583 as well as the European Construction Product Regulation CPR 305/2011.

Subtask E (STE) is sub-divided in five activities. Each activity is led by a person in charge of coordinating corresponding work and ensures the follow-up of the workplan in consultation with the responsible for STE. Each activity leader has identified and leads his or her working group, and collects contributions for the reports.

To form the working groups, surveys distributed among all Task 15 participants were conducted to identify the contributors to subtask E and in which activities they wish to participate actively. The mapping

of the participants is thus defined on the basis of the answers obtained and working groups constituted. Then, a dedicated list of participants involved for each activity is carried out, updated after each progress meeting.

Subtask E – Activities and Status:

E.1 – Inventory of Existing Test Sites

SEAC (NL) initially led this action, in order to carry out a mapping of institutes involved in the field of research and development of BIPV components, and was finalized by Technikum Wien. A second version of the E.1 report is finished and ready for publication.

E.2 – Comparison Fields and Reliability Tests

This action is led by OFI and TECHNIKUM WIEN, and brings together the work implemented within the framework of the E.1 action by carrying out important updates, notably by identifying the institutes and laboratories specifically involved in BIPV applications. A round-robin test activity has been conducted and presented at the EU PVSEC 2018. This activity is initiated between different laboratories involved in the assessment of BIPV facade components. This work aims to identify the climatic sensitivity and aging of these BIPV components. A final report is expected in 2019.

E.3 – Installation and Maintenance Issues

This action is led by CSTB and focuses on the definition of a data collection solution to identify issues encountered by BIPV solutions, during installation and/or during maintenance. The objective is to identify in each contributing country the feedback on PV installations integrated into buildings. A main questionnaire in numerical form is carried out with prior validation of the active contributors of the STE. Then, a national manager is identified in each country to distribute this questionnaire. All data collected are centralized to identify returns by country and thus are able to define the classes of issues encountered according to BIPV solution. The comparison of these returns will establish a critical scale of BIPV solutions and identify the quality criteria to support the BIPV and recommend methods for implementation and maintenance.

E.4 – Diversity of Product

This action is led by OFI and TECHNIKUM WIEN, and presents an investigation on the innovative components under development within the framework of the BIPV international market and to make an inventory (shape, color, materials). This overview of the diversity of BIPV products available or in the process of being deployed will help to define the scientifically key steps for validating these new components for BIPV applications according to the needs of the market and international standards. The first version of the report is distributed to Task 15 experts and will be finalized in 2019.

E.5 – BIPV Design and Simulation

This action is led by POLIMI, and proposes to make a state of the art of the present software solutions and to suggest a classification on their capacity to answer the specific application of BIPV components.

Particular attention will be paid to the specific validation needs of the BIPV models (inputs and outputs), depending on the integration (level of details) solutions selected. This work also focuses on the strengths and weaknesses of all these software to define the necessary and expected improvements. A new and improved tool specifically developed for BIPV applications is expected for the end of this Subtask.

Selection of Outreach Events – 2018

- 5 February 2018, BIPV outreach event, Tokyo, Japan.
- 15 June 2018, BIPV outreach event, Vienna, Austria.
- 12 September 2018, Leonardo webinar on BIPV business models
- 25 September 2018, EU-PVSEC parallel session and poster presentation, Brussel, Belgium.
- 4 November 2018, BIPV outreach event, Cyprus.
- 22 November 2018, BIPV outreach event, Copenhagen, Denmark.

SUMMARY OF TASK 15 ACTIVITIES PLANNED FOR 2019

The activities planned for the Subtasks are the following:

- Finalizing lay-out of the BIPV database book, resulting in 2/3 projects per country in a final version of the book.
- Finalizing Task 15 BIPV online database.
- Finalizing report B.3.
- Finalizing reports C.2 – C.4.
- Actively providing input from Subtask C to the IEC standardization PT 63092.
- Finalizing report on D.1 – D.3.
- Finalizing report E.2.2 – E.5.
- Elaborating the Workplan for a proposed second phase of Task 15.

PUBLICATIONS AND DELIVERABLES

- Report B.1/B.2, "Inventory on Existing Business Models, Opportunities, and Issues for BIPV".
- Report C.0, "International definitions of "BIPV"".
- Report C.1, "Compilation and Analysis of User Needs for BIPV and its Functions".
- Report E.1, v.2, "Inventory of Existing BIPV Research and Development Facilities".

MEETING SCHEDULE (2018 AND PLANNED 2019)

The 7th Task 15 Experts Meeting was held in Tokyo, Japan, 5–8 February 2018.

The 8th Task 15 Experts Meeting was held in Vienna, Austria, 13–16 June 2018.

The 9th Task 15 Experts Meeting was held in Copenhagen, Denmark, 20–22 November 2018.

The 10th Task 15 Experts Meeting will be held in Montreal, Canada, 4–7 June 2019.

The Task definition workshop for T15.2 will be held in Montreal, Canada, 7 June 2019.

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

COUNTRY	PARTICIPANTS	ORGANISATION
Australia	Rebecca Yang	RMIT University
Austria	Peter Illich	University of Applied Sciences Technikum Wien
	Karl Berger	AIT - Austrian Institute of Technology - Energy Department
	Astrid Schneider	
	Gabriele Eder	OFI - Austrian Institute for Chemistry and Technology
	Susanne Woess- Gallasch	Joanneum Research
	Gerhard Peharz	
	Philipp Rechberger	FH Upper Austria (formerly ASiC - Austrian Solar Innovation Centre)
	Dieter Moor	ERTEX Solar GmbH
Belgium	Patrick Hendrick	Université libre de Brussels
	Philippe Macé	Becquerel Institute
Canada	Veronique Delisle	Natural Resources Canada
	Costa Kapsis	Canadian Solar Industries Association
China*		
Denmark	Karen Kappel	Solar City Denmark
	Kenn Frederiksen	Kenergy
Germany (lead subtask C)	Helen Rose Wilson	ISE Fraunhofer
	Johannes Eisenlohr	
France (lead subtask D and E)	Simon Boddaert	Division Energies Renouvelables / Innovation Photovoltaïque, Centre Scientifique et Technique du Batiment
	Jerome Payet	Cycleco
	Francoise Burgun	CEA/INES
Italy	Francesca Tilli	GSE
	Alessandra Scognamiglio	ENEA Research Center Portici
	Laura Maturi	EURAC
	Stefano Avesani	
	Nebosja Jakica	Politecnico di Milano, Architecture Dept.
	Silke Krawietz	SETA Network
Japan	Hiroko Saito	Photovoltaic Power Generation Technology Research Association (PVTEC)
	Hisashi Ishii	Research and Development Division LIXIL Corporation
	Seiji Inoue	AGC Glass Building & Industrial General Division ASAHI GLASS CO., LTD

COUNTRY	PARTICIPANTS	ORGANISATION
Korea	Jun-Tae Kim	Kongju National University
	Jae-Yong Eom	Eagon Windows & Doors Co.
The Netherlands (OA and lead subtask A)	Michiel Ritzen	Zuyd University of Applied Sciences
	John van Oorschot	
	Tjerk Reijenga	BEAR
Norway	Anne Gerd Imenes	Teknova
	Anna Fedorova	NTNU
	Reidun Dahl Schlanbusch	SINTEF
	Tore Kola	
Spain	Nuria Martin Chivelet	CIEMAT
	Estefania Caamano	Technical University of Madrid
	Javier Neila Gonzales	
	Francesca Olivieri	Technical University of Madrid
	Machado Maider	Tecnalia Research & Innovation
	Eduardo Román	
	Ana Belen Cueli Orradre	CENER
	Ana Rosa Lugasnas	
Sweden*	Bengt Stridh	ABB
	Peter Kovacs	RISE
	Rickard Nygren	White arkitekter
	Jessica Benso	RISE
Switzerland	David Larson	Solkompaniet
	Francisco Frontini	SUPSI
Pierluigi Bonomo		
Observers		
Lithuania	Juras Ulbikas	PVTP Mirror group national representative
Singapore	Dr Veronika Shabunko	Solar Energy Research Institute of Singapore (SERIS)

** To provide formal participation to the IEA.*

* To provide formal participation to the IEA.

TASK 16 – SOLAR RESOURCE FOR HIGH PENETRATION AND LARGE SCALE APPLICATIONS

INTRODUCTION

Solar resource Tasks have a long tradition in IEA Technology Collaboration Programs (TCP). The first Task dealing with resource aspects was IEA Solar Heating and Cooling (SHC) Task 4, which started in 1977. The Task on this topic, IEA SHC TCP's Task 46 "Solar Resource Assessment and Forecasting" ended in December 2016. The latest solar resource Task, "Task 16", was started in the IEA PVPS TCP in mid-2017.

IEA PVPS Task 16 supports different stakeholders from research, instrument manufacturers as well as private data providers and utilities by providing access to comprehensive international studies and experiences with solar resources and forecasts. The target audience of the Task includes developers, planners, investors, banks, builders, direct marketers and maintenance companies of PV, solar thermal and concentrating solar power installation and operation. The Task also targets universities, which are involved in the education of solar specialists and the solar research community. In addition, utilities, distribution (DSO) and transmission system operators (TSO) are substantial user groups.

IEA PVPS Task 16 is a joint Task with the IEA SolarPACES TCP (Task V). It also maintains collaboration with the IEA Solar Heating and Cooling (SHC) TCP – the TCP of the preceding solar resource and forecast Tasks. Meteotest leads IEA PVPS Task 16 as the Operating Agent, with support of the Swiss Federal Office of Energy (SFOE). Manuel Silva of University of Sevilla, Spain leads the IEA SolarPACES Task V.

OBJECTIVES

The main goals of Task 16 are to lower barriers and costs of grid integration of PV and lowering planning and investment costs for PV by enhancing the quality of the forecasts and the resources assessments.

To reach this main goal the Task has the following objectives:

- Lowering uncertainty of satellite retrievals and Numerical Weather Prediction (NWP) models for solar resource assessments and nowcasting.
- Define best practices for data fusion of ground, satellite and NWP data (re-analysis) to produce improved datasets, e.g. time series or Typical Meteorological Year (TMY).
- Develop enhanced analysis of long-term inter-annual variability and trends in the solar resource.
 - Develop and compare methods for:
 - Estimating the spectral and angular distributions of solar radiation (clear and all-sky conditions)
 - Describing the spatial and temporal variabilities of the solar resource
 - Modelling point to area forecasts
 - Probabilistic and variability forecasting
- Contribute to or setup international benchmark for data sets and for forecast evaluation.

Task 16's scope of work will concentrate on meteorological and climatological topics needed to plan and run PV, solar thermal, concentrating solar power stations and buildings. As in the previous Task IEA SHC solar resource assessment and forecasting are the main focus.

However, IEA PVPS Task 16's work is more focused on user viewpoints and on topics, which can only be handled with help of international cooperation, which is aside the international exchange of knowledge the major use of such a Task.

To handle this scope the work programme is organized into three main technical Subtasks (Subtasks 1 – 3) and one dissemination Subtask (Subtask 4):

- Subtask 1: Evaluation of Current and Emerging Resource Assessment Methodologies.
- Subtask 2: Enhanced Data & Bankable Products
- Subtask 3: Evaluation of Current and Emerging Solar Forecasting Techniques
- Subtask 4: Dissemination and Outreach

Whereas Subtasks 1 and 3 are mainly focused on ongoing scientific work, Subtasks 2 and 4 are mostly focused on user aspects and dissemination.

APPROACH

On one hand, the Task 16 work programme addresses on one side scientific meteorological and climatological issues on high penetration and large scale PV in electricity networks, on the other hand, it also includes a strong focus on user needs and for the first time, a special dissemination Subtask. Dissemination and user interaction is foreseen in many different ways from workshops and webinars to papers and reports.

The project requires the involvement of key players in solar resource assessment and forecasting at the scientific level (universities and research institutions) and at the commercial level (companies). In the former Task IEA SHC 46 this involvement was achieved. Now, all major partners are extending their work in the IEA PVPS Task 16 and many newcomers are interested in participating.

The Workplan is also focused on work that can only be done by international collaboration, such as definition and organization of benchmarks, definition of common uncertainty and variability measures. E.g. the measure *P10/90 years*, which is often used today, lacks a commonly accepted definition until now.

TABLE 1 – TASK 16's SUBTASKS AND ACTIVITIES

SUBTASK	ACTIVITY
Subtask 1: Evaluation of Current and Emerging Resource Assessment Methodologies	1.1 Ground Based Methods
	1.4 Numerical Weather Models
	1.3 Satellite-based Methods
	1.4 Benchmarking Framework (currently on hold)
Subtask 2: Enhanced Data & Bankable Products	2.1 Data Quality and Format
	2.2 Merging of Satellite, Weather Model and Ground Data
	2.3 Spatio-temporal High Variability
	2.4 Long-term Inter-annual Variability
	2.5 Products for the End-users
Subtask 3: Evaluation of Current and Emerging Solar Resource and Forecasting Techniques	3.1 Value of Solar Power Forecasts
	3.2 Regional Solar Power Forecasting
	3.3 Variability Forecasting and Probabilistic Forecasting
Subtask 4: Dissemination and Outreach	4.1 Produce a Task Brochure
	4.2 Produce a Periodic (6-month) Task Newsletter
	4.3 Conduct Periodic (Annual) Subtask-level Webinars and/or Conference Presentations
	4.4. Update of Solar Resource Handbook

Whereas Subtasks 1 and 3 are mainly focused on ongoing scientific work, Subtask 2 and 4 are mostly focused on user aspects and dissemination. Table 2 shows the scopes of the three scientific activities.

TABLE 2 – SCOPE OF THE SUBTASKS

SUBTASK	SCOPE
Subtask 1: Evaluation of Current and Emerging Resource Assessment Methodologies	This Subtask is focusing on the evaluation of current and emerging resource assessment methodologies. Different methodologies are analysed and conclusions are formulated in the form of best practices guidelines and/or standards. The three methods (ground based methods, Numerical Weather Prediction models (NWP) and satellite-based methods – are evaluated in this Subtask. For each methodology a separate activity is defined.
Subtask 2: Enhanced Data & Bankable Products	Subtask 2 is mainly dedicated to end-users, notably in the PV domain. It is focusing on the main PV applications of the different types of solar resource products and datasets. End-users needs in concentrating solar thermal, solar heating and buildings will also be considered.
Subtask 3: Evaluation of Current and Emerging Solar Resource and Forecasting Techniques	Subtask 3 focuses on different aspects of forecast evaluation and comparison. In particular, the economic value of solar forecasting for a variety of different applications, the topic of regional forecasting important for transmission operators and variability and probabilistic forecasting are addressed. Depending on the application and the corresponding forecast horizon, different models and input data are applied for solar irradiance and power forecasting. These include numerical weather predictions for several days ahead, satellite based cloud motion forecasts for several hours ahead, and sky imager forecasts for high resolution intra-hour forecasting, as well as statistical models for measurement based forecasting and post-processing of physical model forecasts. Each of the Subtask 3's activities includes all of these different forecasting approaches.

ACCOMPLISHMENTS OF IEA PVPS TASK 16

IEA PVPS Task 16 is among the biggest Tasks in PVPS TCP concerning number of participants (57) and countries (20). Additionally, financial resources are not adequate in many countries. Both issues make operating the Task a challenging topic. Missing resources and confirmation led also to re-organization and changes of activity and Subtask leads during 2018. Until the end of 2018, the Task 16 Workplan could be kept as initially planned – aside from Activity 1.4, which was postponed due to missing resources and lead.

In 2018, two Expert meetings (Paris, France and Rapperswil, Switzerland (Figure 1)), two workshops and a webinar have been organized as foreseen by the Workplan. No reports have been due yet. Scientific work has started in most fields. Therefore, this report consists of one highlight per Subtask, showing preliminary work done, as well as an abstract of the workshops organized by Task 16.



Fig. 1 – Task 16 experts at the 3rd Task 16 Experts Meeting, in Rapperswil, Switzerland (September 2018).

SUBTASK 1: Evaluation of Current and Emerging Resource Assessment Methodologies

Update of ISO 9060:2018 Standard on Radiometer Classification

Standardisation is also in Task 16 an important topic – mainly in the field of instruments.

Task 16's participants contributed to the update of the ISO 9060 standard on radiometer classification (<https://www.iso.org/obp/ui/#iso:std:iso:9060:ed-1:v1:en>). The ballot of the update was approved and the standard has been published in November 2018. The new version includes silicon based pyranometers or any technology that reaches the limits from the classification. Also, correction functions are allowed as a basis for the classification. The spectral error is used for classification based on the subordinate spectra for AM1.5 and AM5 as described in Jessen et al. 2018 and Wilbert et al, 2017.

The main changes include:

- Instruments such as SP Lite, rotating shadow bands and other irradiance instruments, that didn't have a class, can be classified with the new ISO 9060.

- The classifications "secondary standard", "first class" and "second class" are well accepted by users, but the nomenclature as such is confusing for newcomers. That's why the new instrument classes are "A", "B", "C".
- Per class A, B, C, there is an addition: either "spectrally flat" or "fast response".
- The term "spectrally flat" is introduced to make clear that an instrument is provided with a black absorber (with or without diffusor) that does not need post processing of data to achieve good results under different sky conditions. Excluded from the spectrally flat group, are instruments such as rotating shadow bands or photo diode based instruments with a limited spectral range that use or need corrections with airmass or cloud coverage.
- For class A pyranometers, there is a new requirement for individual testing and reporting of temperature response and directional response.

Workshop on Uncertainty of Solar Datasets from Satellite and Re-analysis Products

Philippe Blanc of Mines Paristech organised a workshop in Paris, March 9, 2018. About 33 participants from Task 16 as well as one participant from Task 13 (Fraunhofer ISE) attended the workshop.

The workshop was used as a first "round table" of discussions of new protocols, criteria, analysis for a better understanding and modelling of the uncertainty of solar datasets from satellite & re-analysis products. Pros and cons of new approaches and metrics – such as the Taylor diagram – have been discussed.

One big unsolved issue is the uncertainty of ground measurements – generally used as ground truth for validations – but far from having no uncertainty itself.

The work on this topic of two other groups was presented and discussed. The first was the Committee on Earth Observation Satellites (CEOS), of which Bureau of Meteorology (BoM) is part. It assesses also "land products" – the area closest to solar data. The other group is IEA PVPS Task 13 – presented by Fraunhofer ISE, which published reports on bankability during the last Task period.

The workshop didn't lead to concrete results, but showed, that further work on basis of the work done by preceding solar Tasks and EU project MESoR is needed.

SUBTASK 2: Enhanced Data & Bankable Products

Quality Control of Global Solar Radiation Data with Satellite-based Products

Historically, ground data were used to correct and check satellite data. Today the methods for satellite based products are stable and quality high enough to do validation also vice versa.

JRC published a paper about quality control of ground data with help of satellite products (Urraca et al., 2017).

Several quality control (QC) procedures are available to detect errors in ground records of solar radiation, mainly range tests, model comparison and graphical analysis, but most of them are ineffective in detecting common problems that generate errors within the physical and statistical acceptance ranges. Herein, we present a novel QC method to detect small deviations from the real irradiance profile. The proposed method compares ground records with estimates from three independent radiation products, mainly satellite-based datasets, and flags periods of consecutive days where the daily deviation of the three products differs from the historical values for that time of the year and region. The confidence intervals of historical values are obtained using robust statistics and errors are subsequently detected with a window function that goes along the whole time series. The method is supplemented with a graphical analysis tool to ease the detection of false alarms. The proposed QC was validated in a dataset of 313 ground stations. Faulty records were detected in 31 stations, even though the dataset had passed the Baseline Surface Radiation Network (BSRN) range tests. The graphical analysis tool facilitated the identification of the most likely causes of these errors, which were classified into operational errors (snow over the sensor, soiling, shading, time shifts, large errors) and equipment errors (miscalibration and sensor replacements), and it also eased the detection of false alarms (16 stations). These results prove that our QC method can overcome the limitations of existing QC tests by detecting common errors that create small deviations in the records and by providing a graphical analysis tool that facilitates and accelerates the inspection of flagged values.

SUBTASK 3: Evaluation of Current and Emerging Solar Forecasting Techniques

Probabilistic Forecasting of Solar Power, Electricity Consumption and Net Load: Investigating the Effect of Seasons, Aggregation and Penetration on Prediction Intervals

Probabilistic forecasting is one of the upcoming hot topics of forecasting and different groups are working on this. Below is an example of the work done by the University of Uppsala, Sweden. The paper of van der Meer et al. (2018) presents a study into the effect of aggregation of customers and an increasing share of photovoltaic (PV) power in the net load on prediction intervals (PIs) of probabilistic forecasting methods applied to distribution grid customers during winter and spring. These seasons are shown to represent challenging cases due to the increased variability of electricity consumption during winter and the increased variability in PV power production during spring.

They employed a dynamic Gaussian process (GP) and quantile regression (QR) to produce probabilistic forecasts on data from 300 de-identified customers in the metropolitan area of Sydney, Australia. In case of the dynamic GP, they also optimize the training window width and show that it produces sharp and reliable PIs with a training set of up to three weeks. In case of aggregation, the results indicate that the aggregation of a modest number of PV systems improves both the sharpness and the reliability of PIs due to the smoothing effect, and that this positive effect propagates into the

net load forecasts, especially for low levels of aggregation. Finally, they show that increasing the share of PV power in the net load actually increases the sharpness and reliability of PIs for aggregations of 30 and 210 customers, most likely due to the added benefit of the smoothing effect.

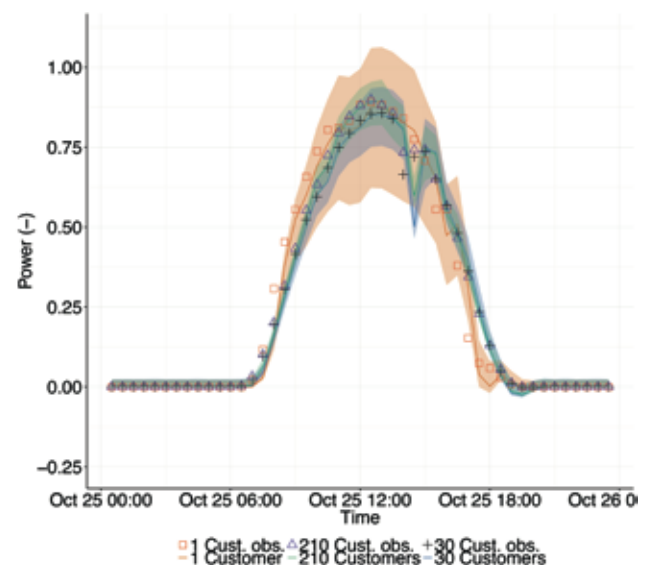


Fig. 2 - Probabilistic forecasts of PV power based on dynamic Gaussian process during a day in spring. The prediction intervals with nominal coverage level of 80 % are depicted using the shaded colours. The effect of aggregation becomes clear, in particular in terms of the width.

Workshop on Solar Forecast Requirements & Value for Grid Applications

R. Perez of SUNY, together with the Task 16 Operating Agent, organised a workshop on "Solar Forecast Requirements & Value for Grid Applications" as a side event of Intersolar 2018 Conference (Munich, June 21, 2018). About 35 people attended the workshop.

The forecast providers, Clean Power Research' Skip Dise, and Fraunhofer ISE's Elke Lorenz, presented applications of their operational solar forecast products, discussed their accuracy, geographic applicability from single plants to regional and national markets, and the influence of current pricing & regulations on value; e.g., the self-consumption market optimization can greatly benefit financially from accurate forecasts with current regulations.

Both stressed the importance of model blending in deterministic accuracy and the importance of probabilistic forecasts; e.g., for congestion planning. Examples of grid congestion management and intraday market spikes traceable to forecast uncertainty were presented.

On the grid operator front, Eammon Lannoye (EPRI) and Michael Osmann (EnergiNet) placed the solar power forecasts in a TSO time horizon perspective, with time horizons extending from multiple years (production modeling) to one year (fuel hedging) to seasonal

(maintenance) to days (market scheduling) up to near real-time. PV power forecast only pertains to the short operational horizons (< days), although PV deployment forecasts (not weather related) obviously influence multi-year horizons. Examples of comprehensive deterministic forecast evaluation and operational grid balancing with 50 % wind and 5 % PV in Denmark were presented.

Michael Osmann of energinet.dk showed, that the future has already arrived in Denmark. Situations with very high shares (> 100 %) of renewables happen regularly – with 44 % average wind power and 3 % average PV power. A mix of pragmatic handling, pro-active measures and good international grid connections helps to tackle the issues linked to the variability.

The gap between the needs of the grid operators and the possibilities of forecast providers gets smaller. Stronger collaboration between them is one key point.

SUBTASK 4: Dissemination and Outreach

The Task 16 has been presented at the following occasions:

- Workshop on uncertainty, part of the 2nd Task 16 Experts Meeting, Paris, France, March 2018
- IEA PVPS Executive Committee Meeting, Kuching, Malaysia, April 2018
- 5th ICEM, Shanghai, China, May 2018 (Dave Renné)
- ISES Webinar on the State of Task 16, May 2018
- Workshop, parallel to Intersolar / EES, Munich, Germany, June 2018
- EURO Operations Research Conference, Sevilla, Spain, July 2018
- Solar 2018 (ASES), Boulder CO, USA, August 2018
- EU PVSEC 2018, Brussels, Belgium, September 2018 (Remund et al, 2018)
- SolarPACES 2018, Casablanca, Morocco, October 2018
- IEA PVPS presentation for Belgium partners, October 2018
- IEA PVPS presentation at IEA Networking Event Switzerland, Neuchatel, Switzerland, October 2018
- IEA PVPS Executive Committee Meeting, Marrakech, Morocco, November 2018

GOVERNANCE AND NEXT MEETINGS

Membership

Total membership stands now at 20 countries with 57 active participating organizations. Some delays in confirmation and funding and other circumstances have limited progress on certain topics; thus, some changes were required in the Task 16 Workplan during 2018.

Publications

The following list includes only the references of this report. As part of the scientific work many additional papers have been published.

Jessen, Wilko, Stefan Wilbert, Christian A. Gueymard, Jesús Polo, Zeqiang Bian, Anton Driesse, Aron Habte, Aitor Marzo, Peter R. Armstrong, Frank Vignola, and Lourdes Ramirez, 2018. "Proposal and evaluation of subordinate standard solar irradiance spectra for

applications in solar energy systems." Solar Energy. doi: <https://doi.org/10.1016/j.solener.2018.03.043>.

Remund, J., Blanc, P., & Richard, P., 2018. IEA PVPS TASK 16 and IEA SolarPACES V: State of the project. 35th EU PVSEC, 24 - 28 September 2018, Brussels, Belgium.

Urraca, R., Gracia-Amillo, A. M., Huld, T., Martinez-de-Pison, F. J., Trentmann, J., Lindfors, A. V., Sanz-Garcia, A. (2017). Quality control of global solar radiation data with satellite-based products. Solar Energy, 158 (August), 49–62. <http://doi.org/10.1016/j.solener.2017.09.032>

van der Meer, D. W., Munkhammar, J., & Widén, J. (2018). Probabilistic forecasting of solar power, electricity consumption and net load: Investigating the effect of seasons, aggregation and penetration on prediction intervals. Solar Energy, 171, 397–413. <https://doi.org/10.1016/j.solener.2018.06.103>

Wilbert, Stefan, Wilko Jessen, Christian Gueymard, Jesús Polo, Zeqiang Bian, Anton Driesse, Aron Habte, Aitor Marzo, Peter Armstrong, Frank Vignola, and Lourdes Ramirez, 2017. "Proposal and Evaluation of Subordinate Standard Solar Irradiance Spectra with a Focus on Air Mass Effects." Solar World Congress. doi: doi:10.18086/swc.2017.21.06

PLANS FOR 2019

Task 16 will continue its work in 2019. A benchmark of sky cams will be organized in Plataforma Solar de Almería. One report (as a chapter of the final report) on "Advanced Measurements for Solar Resource Assessment" is planned for summer 2019.

Four workshops are planned:

- Workshop on "Best Practices for Automatic and Expert Based Quality Control Procedures and Gap filling Method"; planned June 2019 at ICEM 2019 Conference. Lead: P. Blanc, Mines Paristech, France.
- Workshop on "Re-analysis Benchmarking"; planned September 2019 at EUPVSEC 2019, Marseille France. Lead: open
- Workshop on "Probabilistic Forecasting"; planned September 2019 at EU PVSEC 2019, Marseille, France. Lead: S. Cros, Reuniwatt, France.
- Workshop on "Benchmarking of Site Adaptation Methods"; planned November 2019 at SWC 2019, Santiago, Chile. Lead: Jesus Polo, CIEMAT, Spain.

MEETING SCHEDULE (2018 AND PLANNED 2019)

The 2nd Task 16 Experts Meeting took place at Mines Paristech in Paris, France, March 7 – 9, 2018.

The 3rd Task 16 Experts Meeting took place at SPF/HSR in Rapperswil, Switzerland, September 17 – 19, 2018.

The 4th Task 16 Experts Meeting shall be organized by the University of Utrecht and held in Utrecht, the Netherlands, April 2-4, 2019.

The 5th Task 16 Experts Meeting shall be organized by Pontificia Universidad Católica de Chile and held in Santiago de Chile, Chile November 11-12, 2019.

TABLE 3: TASK 16 PARTICIPANTS

COUNTRY	TCP	ORGANIZATION
Australia	PVPS	<ul style="list-style-type: none"> Bureau of Meteorology University of South Australia CSIRO
Austria	PVPS	<ul style="list-style-type: none"> Fachhochschule Oberösterreich (FH OOE) Blue Sky Wetteranalysen
Switzerland	PVPS	<ul style="list-style-type: none"> Meteotest Univ. of Applied Sciences Rapperswil HSR / SPF
Chile	PVPS SolarPACES	<ul style="list-style-type: none"> Pontificia Universidad Católica de Chile
Germany	PVPS SolarPACES	<ul style="list-style-type: none"> Fraunhofer (ISE & IWES) [not officially confirmed] DLR (both TCP) Suntrace GmbH (both TCP)
Denmark	PVPS	<ul style="list-style-type: none"> Danish Meteorological Institute (DMI) Technical University of Denmark (DTU) Energinet.dk (TSO of Denmark)
Spain	PVPS SolarPACES	<ul style="list-style-type: none"> CIEMAT (both TCP) CENER Public University of Navarra University of Jaen Universidad Complutense de Madrid University of Seville (US) Irsolav
EU	PVPS	<ul style="list-style-type: none"> JRC
France	PVPS	<ul style="list-style-type: none"> MINES ParisTech Laboratoire PIMENT, Université la Réunion, EDF Univ. des Antilles et de la Guyane Reuniwatt Sunpower / Total Solar Ecole Polytechnique à Palaiseau
Italy	PVPS	<ul style="list-style-type: none"> i-em Univ. Roma 2 RSE
Netherlands	PVPS	<ul style="list-style-type: none"> Univ. Utrecht
Norway	PVPS	<ul style="list-style-type: none"> Arctic University
Sweden	PVPS	<ul style="list-style-type: none"> SMHI, Univ. Uppsala, Afconsult

COUNTRY	TCP	ORGANIZATION
USA	PVPS	<ul style="list-style-type: none"> National Renewable Energy Laboratory (NREL) National Aeronautics and Space Administration (NASA) State Univ. of New York at Albany (SUNY) Univ. of California San Diego (UCSD) University of Oregon Clean Power Research (CPR) Vaisala/3Tier Solar Consulting Services (SCS)
Great Britain	SHC	<ul style="list-style-type: none"> Peakdesign Ltd. Rina Consulting World Energy & Meteorology Council (WEMC) Univ. East Anglia (UEA) Weatherquest Ltd.
Slovakia	SHC	<ul style="list-style-type: none"> Solargis [not officially confirmed]
Greece	SolarPACES	<ul style="list-style-type: none"> Univ. of Patras
Mexico	SolarPACES	<ul style="list-style-type: none"> Universidad Nacional Autónoma de México [not officially confirmed]
Morocco	SolarPACES	<ul style="list-style-type: none"> IRESEN
UAE	SolarPACES	<ul style="list-style-type: none"> Masdar Institute [not officially confirmed]

TASK 17 – PV AND TRANSPORT

OVERALL OBJECTIVES

The main goal of Task 17 is to deploy PV in the transport sector, which will contribute to reducing CO₂ emissions of transport and enhancing PV market expansions. To reach this goal, Task 17 has the following objectives:

- Clarify expected/possible benefits and requirements for PV-powered vehicles;
- Identify barriers and solutions to satisfy the requirements;
- Propose directions for deployment of PV equipped charging stations;
- Estimate the potential contribution of PV in transport;
- Realize above in the market; contribute to accelerating communication and activities going ahead within stakeholders such as the PV industry and transport industry.

Task 17's results will contribute to clarify the potential of utilization of PV in transport and to propose how to proceed toward realizing the concepts.

Task 17's scope includes PV-powered vehicles such as PLDV (passenger light duty vehicles), LCVs (light commercial vehicles) and other transport and PV applications for electric systems and infrastructures such as charging infrastructures, with PV and batteries, as well as other power management systems.

Task 17 consists of following four Subtasks under the Workplan, from October 2018 to September 2021.

- Subtask 1: Benefits and Requirements for PV-powered Vehicles
- Subtask 2: PV-powered Applications for Electric Systems and Infrastructures
- Subtask 3: Potential Contribution of PV in Transport
- Subtask 4: Dissemination

SUMMARY OF TASK 17 ACTIVITIES FOR 2018

Task 17 was approved at the 50th IEA PVPS ExCo meeting in December 2017. Physical meetings and other communications in the first half of 2018, led to Task 17's kick-off of concrete actions in October 2018.

SUBTASK 1: Benefits and Requirements for PV-powered Vehicles

In order to deploy PV-powered vehicles, Subtask 1 will clarify expected/possible benefits and requirements for utilizing PV-powered vehicles for driving and auxiliary power. Targeted PV-powered vehicles are passenger cars (PHVs and EVs) and commercial vehicles currently, and other vehicles (buses, trains, ships, airplanes, etc.) may be included in the future.

Subtask 1 consists of following activities:

- Activity 1.1: Overview and Recognition of Current Status of PV-powered Vehicles
- Activity 1.2: Requirements, Barriers and Solutions for PV and Vehicles
- Activity 1.3: Possible Contributions and Benefits
- Activity 1.4: Other Possible PV-powered Vehicles -> PV-powered Commercial Vehicles



Fig. 1 – IEA PVPS experts at the Task 17 Kick-off Meeting in Burgdorf, Switzerland, 12 October 2018.

Task 17 has started to investigate the current status of PV-powered vehicles including PLDV, LCV and other types of vehicles, to review academic papers, technical presentation, and public announcements. The amount of technical information on PV-powered vehicles is increasing rapidly in recent years.

Furthermore, Task 17 has been discussing a procedure to make clear the expected/possible benefit and requirement for PV and other components. It is important to conduct a case study to identify the energy balance between the PV power generation and vehicle energy requirement under the actual data of solar radiation and the driving patterns representing actual driving conditions which include driving range, time based driving pattern, time in the shade and solar radiation for the vehicle. Data of actual driving patterns will be surveyed.

Task 17 has changed Activity 1.4's title to "PV-powered Commercial Vehicles" because of the focus on LCVs in this activity. Regarding other applications such as trucks, buses, trains, ships, etc., they will be developed when the project will be proposed.

SUBTASK 2: PV-powered Applications for Electric Systems and Infrastructures

For promoting electrification of vehicles, not only charging electricity by itself on board, but also charging renewable electricity at the environmental friendly infrastructure, e.g. PV-powered charging stations, will be feasible. Subtask 2 will discuss energy systems to design PV-powered infrastructures for EVs charge.

Task 17 has been developing detailed action plans, which include overviewing the current status and identifying requirements, barriers and solutions for PV-powered infrastructure for EV charging.

SUBTASK 3: Potential Contribution of PV in Transport

For reducing CO₂ emissions from transport, changing energy sources from conventional to renewable energy, especially PV which have a good track record in supplying electricity by utility-scale, should be accelerated. Also, new social models through innovations in 'PV and Transport' are expected. In parallel with Subtask 1 and Subtask 2, Subtask 3 will develop a roadmap for deployment of PV-powered vehicles and applications.

Task 17 has been developing detailed action plans, which will include following contents:

- R&D scenario of PV-powered vehicles and applications;
- Deployment scenario of PV-powered vehicles and applications;
- Possible contribution to energy and environmental issues;
- Social and business models.

SUBTASK 4: Dissemination

A considerable amount of new knowledge is expected to be developed within Task 17. It is important that this knowledge is disseminated to the general public and end users in a timely manner. Subtask 4 will focus on information dissemination procedures that effectively release key findings to stakeholders such as PV industry, transport industry such as the automobile industry, battery industry, and energy service providers.

Task 17 supported the Solar Mobility Forum at SQUARE in Brussels, Belgium on 25 September 2018, which was organised as a side event of 34th EU-PVSEC. Task 17 members from Japan and the Netherlands contributed and made presentations respectively, entitled "Realizing PV-Powered Mobility," "PVPS Task 17: PV and Transport" and "Solutions for a Fully Integrated Solar Electric Car Roof."

Task 17 held a joint workshop with IEA HEV on 'PV and Transport' in Burgdorf, Switzerland on 12 October 2018. 24 people participated in the workshop and discussed Task 17 activities, as well as potential collaboration between IEA PVPS Task 17 and IEA HEV.

ACTIVITIES PLANNED FOR 2019

Task 17 will continue to develop detailed activities aimed at accomplishing the PV and Transport's objectives and will start taking actions for technical reports. Dissemination activities at the international conferences and communication with stakeholders will be organized, as well.

MEETING SCHEDULE (2018 AND PLANNED 2019)

A Task 17 preparatory meeting was held in Al Haag, the Netherlands, 1 June 2018.

The **1st Task 17 Experts' Meeting** (Kick-off Meeting) was held in Burgdorf, Switzerland, 12 October 2018.

The **Task 17 Regional (Asia and Pacific) Meeting** was held in Kawasaki, Japan, 5 March 2019.

The **2nd Task 17 Experts' Meeting** will be held in Munich, Germany, 13-14 May 2019.

The **3rd Task 17 Experts' Meeting** will be held in fall 2019 (TBD).

DISSEMINATION ACTIVITY SCHEDULE IN 2019

IEA PVPS Task 17 Technical session at the InterSolar Europe 2019 in Munich Germany, 14 May 2019.

IEA PVPS International Workshop at the 46th IEEE-PVSC in Chicago, USA: June 2019.

EXPECTED DELIVERABLES

September 2020	Analysis by Case Study of Energy Balance for PLDV and LCV
September 2021	Requirements for PV and Other Components

TABLE 1 - LIST OF TASK 17 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Australia	Julia MacDonald	IT Power Australia
	Nicholas (Ned) J. Ekins-Daukes	University of New South Wales
China	Yang Zilong	Institute of Electrical engineering Chinese Academy of Sciences
Germany	Robby Peibst	Institut für Solarenergieforschung GmbH
Japan	Toshio Hirota	Waseda University
	Keiichi Komoto	Mizuho Information & Research Institute, Inc.
	Kenji Araki	Toyota Technological Institute
Morocco	Kawtaw Benabdelaziz	IRESEN
The Netherlands	Anna J. Carr	ECN part of TNO
	Bonna K. Newman	

AUSTRALIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

RENATE EGAN, UNIVERSITY OF NEW SOUTH WALES

WARWICK JOHNSTON, SUNWIZ

Annual Installations by Sector (MW)

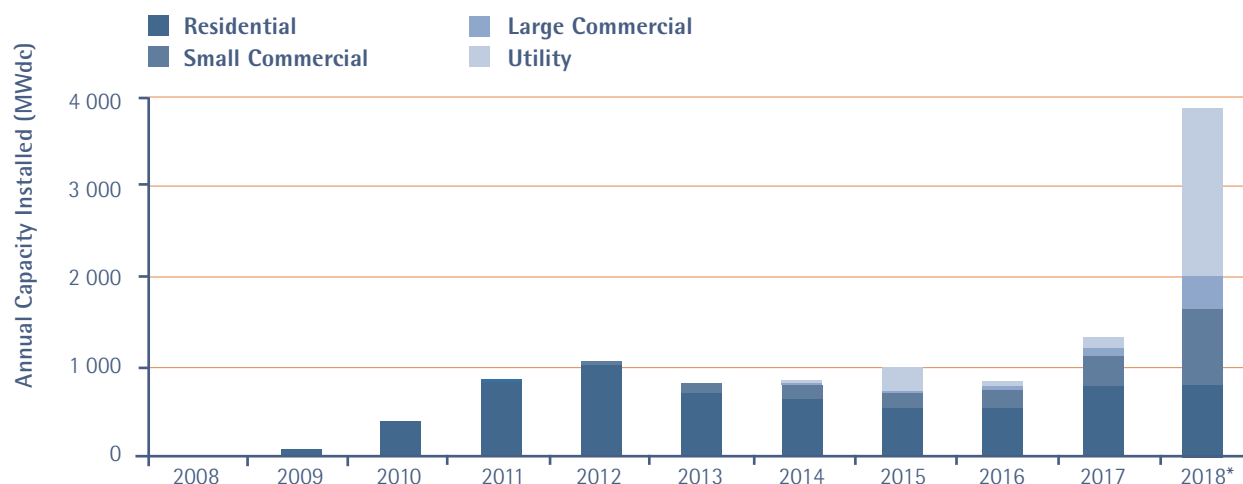


Fig. 1 - Historic trends in annual PV installations in Australia by sector.

GENERAL FRAMEWORK AND IMPLEMENTATION

2018 was by far a record year for Australian PV installations, with record volumes in every market segment, and every state bar one. A combined 3.9 GW was commissioned. 2018's record volume was driven by high electricity prices, continued reduction in PV system prices, an increasing awareness of the benefits of PV to businesses and increasingly large corporations, plus solar farm deployments to meet the rapid ramp-up of the Renewable Energy Target (RET).

Over 2 million Australian homes and businesses are now powered by their own PV system – over 210 000 of which were added in 2018. Residential penetration levels average 20 % of households and reach over 50 % in some urban areas. 890 MW of commercial PV was added in 2018, with many shopping centre owners rolling out MW-scale solar across their entire portfolio. Over 1.8 GW of solar farms were commissioned in 2018, with an even greater volume under construction at year's end.

Solar continues to be supported with Renewable Energy Certificates for solar systems large and small. The federal government attempted to solve the energy trilemma – affordability, reliability, and environment – through a National Energy Guarantee, but dropped the policy due to insufficient support. This leaves the large-scale solar industry with no replacement support mechanism on the horizon when the Renewable Energy Target is met in 2021. However, sub-100 kW systems continue to be supported by a significant but gradually declining subsidy, on top of which Victorian households can receive a new subsidy. Additionally, a few state governments introduced subsidies for home energy storage in 2018.

Further growth in the Australian rooftop solar market is expected in 2019, with market fundamentals likely to remain steady for the coming year. Solar farms will deploy in even greater volume in 2019, though there are 33 GW of potential solar farms that will stall unless they can find an alternative driver, now that the Renewable Energy Target has been met by projects that have already been financed. The market has turned to Corporate Power Purchase Agreements, though these have proved challenging to execute.

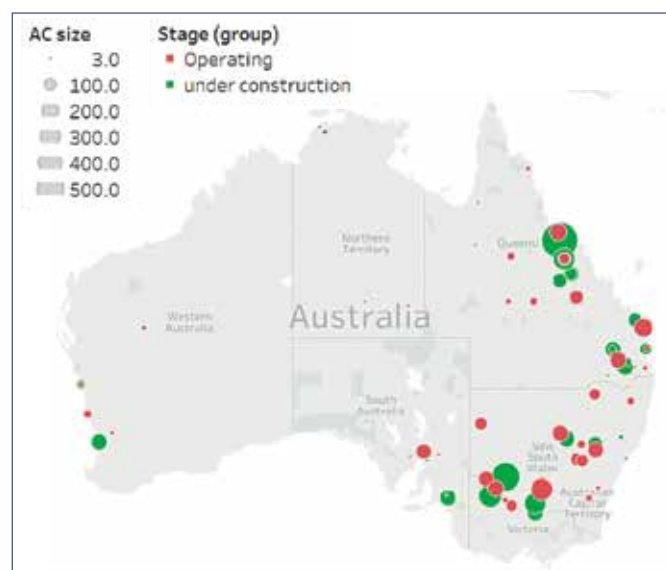


Fig. 2 - Map of Australian solar farms operating and under construction at the end of 2018.



Fig. 3 – Wicks Winery Estate, Woodside, South Australia. Sold and Installed by Venergy Australia (Photo: Matt Wilkins, Venergy Australia).

NATIONAL PROGRAMME

The main support for PV at a national level remains the RET. Support for large systems is via the Large-scale RET (LRET) which will incentivise 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). All PV systems up to 100 kWp are also able to claim STCs up-front for the amount of generation they will be deemed to produce until the end of 2030. This means that the STCs for small systems act as an up-front capital cost reduction.

Deployment of large scale solar receives ongoing support from by the Clean Energy Finance Corporation (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. The CEFC invested 2 300 MAUD in 2017-18 to accelerate Australia's clean energy investment into low carbon electricity, towards total project value of 6 700 MAUD. This included 582 MAUD financing towards nine large-scale solar projects.

Additionally, the Australian Renewable Energy Agency (ARENA) committed 265 MAUD for new projects in 2017-18. Of these 36,8 MAUD were for solar PV projects.

RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2018, research was funded by the Australian Research Council, Co-operative Research Centres and ARENA. ARENA is the largest funder of photovoltaics research in Australia. During 2017-18, ARENA directed 29 MAUD to 20 solar PV research and development projects. ARENA's support has helped 139 Patents be filed, 19 licenses entered into, 1 183 Journal publications, 183 PhDs, and 158 Postdocs/other researchers – all related to PV.

INDUSTRY AND MARKET DEVELOPMENT

2018 saw record volumes in every sector of the PV market. Residential PV (<10 kW) grew by 42 % to 1 115 MW, small commercial (10-100kW) grew by 57 % to 528 MW, large commercial (101 kW-5 MW) also grew by 313 % to 361 MW, and utility-scale grew 1 553 % to 1 886 MW. Average system sizes in the sub-100 kW market grew to 7,1 kW/system, off the back faster growth in commercial installations, plus growth in the typical size of residential systems as householders prepared their homes for future addition of batteries and electric vehicles.

Average residential solar PV system prices continued to decline in 2018, to 1,20 AUD per Watt including STCs, or 1,75 AUD/Watt without STC support.

The Australian storage market did not grow as much as anticipated in 2018. This was due to battery price increases, customers delaying purchases until announced subsidies were enacted, plus distraction from the white-hot solar market. The Australian storage market remains favourably viewed by overseas battery/inverter manufacturers due to its high electricity prices, low feed-in tariffs, excellent solar resource, and large uptake of residential PV.

2019 looks certain to be another record year for Australian PV. Notwithstanding that a record volume of utility scale PV will be deployed, the economic fundamentals for residential and commercial PV are outstanding. Australia's high electricity prices and inexpensive PV systems means payback can commonly be achieved in 3-5 years, a situation that looks set to continue in 2019. Commercial PV deployment is likely to accelerate as solar awareness grows, and corporate interest in solar PPAs is building. However, the RET will soon be met by currently committed projects, leaving over 33 GW of PV projects searching for an alternative pathway towards commercialisation. Though a policy gap may occur, there is acceptance amongst incumbent electricity businesses and regulators that renewable energy is the least cost source of new-build electricity, and will soon outcompete Australia's existing generation fleet that are progressively needing refurbishment.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

HUBERT FECHNER, TPPV – TECHNOLOGIEPLATTFORM PHOTOVOLTAIK ÖSTERREICH



Fig.1 – Electricity from the building envelope (Photo: © Kioto)

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

100 % electricity from renewables by 2030 is the official target of the current government in Austria. Currently, this process starts from about 75 %, predominantly composed of hydro power at about 60 %, wind energy at about 11%, some bio-electricity and a rising amount of photovoltaics at currently close to 2 % in 2018. Austria has never produced electricity from nuclear energy and has a clear policy against nuclear.

Many national energy and climate studies have meanwhile clearly indicated that PV has the highest potential for increase. The "Technology Roadmap for Photovoltaics in Austria", published by the Federal Ministry of Transport, Innovation and Technology in 2016 described a 15,3 % share of PV until 2030 as feasible. This share is not only needed to replace fossil energy power plants but to cope with a significant growth of electricity which is expected; due to the mobility sector (electric vehicles), the heating and cooling sector (heat pumps), as well as due to digitalisation. In line with this, 15 GW until 2030 is the target of the federal Association PV Austria, which came up with a detailed programme on how to reach this ambitious goal.

A total of approximately 1,5 GW of PV power had been installed in Austria by the end of 2018; Reaching the political targets would require an increase in the installation rate by at least a factor of six compared to the last years, leading to installation rates of 1 GW annually on average.

Besides some possible simplifications in legal frame conditions and bureaucratic measures, Austria's support schemes are essential for the installation rates. Along with some regional support mechanisms, three federal support schemes are still dominating:

- The feed-in-tariff system is designed only for systems larger than 5 kWp; Feed-in Tariff is provided via the national green-electricity act; The "new RES" are supported by this act mainly via up to 13 years guaranteed feed-in tariffs; the annual cap, which started with 50 MEUR in 2012 is reduced every year by one million; photovoltaics receives 8 MEUR out of this. 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 2018 the tariff was set with 7,91 EURcent/kWh for PV at buildings and no incentive for PV on open landscape; an additional 250 EUR subsidy per kWp (or 30 % of total invest cost) was offered.
- About 4,6 MEUR were dedicated to PV investment support for small systems up to 5 kWp in 2018 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 rooftop systems and 375 EUR per kWp for building integrated systems, the support per kWp was the same as in 2017. This support has led to about 3 600 new PV systems with a total capacity of 20,2 MWp in 2018.
- For the fourth time, there was an additional offer for the agricultural sector. Systems from 5 kWp to 50 kWp, owned by farmers, obtained the same incentive per kWp (275/375 EUR) as other private owners, which may have led to approx. 4,3 MWp installed in 2018. Regions that participate in the Programme "Climate and Energy Pilot Regions" are eligible to receive funding for PV installations that are in special "public interest". In 2018, 50 PV installations were funded with 0,53 MEUR. In total, 1,4 MW were submitted.

Besides the above-mentioned funding, some provinces provide PV support budgets as well, amongst them very specific support e.g. only for municipal buildings or for tracked PV systems.

The mean system price for private systems slowly went further down to 1,645 EUR/kWp (excluding VAT) for a 5 kW system.

In 2018, support schemes for battery storage systems in combination with PV systems were offered by several provinces. This scheme is dedicated for small, mainly private systems, the support schemes are very different, typically ranging up to storage capacities of up to a maximum of 10 kWh. Up to now, these initiatives led to about 4 000 storage systems until the end of 2017. In 2018, a federal subsidy system for battery storage systems in combination with PV systems was introduced. The total budget was 6 MEUR (500 EUR per kWh of storage capacity, max, 40 % of investment cost). This budget was by far not sufficient to fulfil the requests; finally, only 11% of the applications could obtain the support.

RESEARCH AND DEVELOPMENT

In May 2018, Austria officially joined the "Mission Innovation" network aiming at more research and the energy and climate sector. Austria will participate in Challenges 1 on Smart Grids, 7 on Affordable Heating and Cooling of Buildings, and the newly established Challenge 8 on Renewable and Clean Hydrogen. In all three Mission Innovation challenges, where Austria will participate, there is a clear link to PV innovations. So far, the intended duplication of the national energy research budget has not materialized.

The National Photovoltaic Technology platform, founded in September 2008 and exclusively financed by the participating industry, research organisations and universities is aiming at creating a better coherence of the national PV research. The platform experienced again a good development in 2018; initially supported by the Ministry of Transport, Innovation and Technology, this loose platform has been acting as a legal body since 2012. The PV Technology Platform brings together about 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 necessary increased awareness aiming at further improving the frame conditions for manufacturing, research and innovation in Austria for the relevant decision makers. In March 2018, the first "Innovation Award for Building Integrated PV" was presented to the winner by the Federal Minister of Transport Innovation and Technology. The target of "PV Integration" covers two aspects: integration from the point of architecture into the built environment, as well as integration energetically, into the local energy system by optimally providing energy on the site. 51 BIPV projects with Austrian participation were submitted. This award will continue on a biannual basis.

The research organisations and industrial companies are participating in various national and European projects as well as in different IEA PVPS Programme's 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, cover quite broad research items on energy technologies, including PV.

The total expenditures of the public sector for energy research in Austria was about 139 MEUR in 2017; out of that, about 21,4 MEUR was dedicated to Renewable Energy with a share of 7,1 MEUR for photovoltaics, which is a decrease of about 1/3 compared to the years before.

Within IEA PVPS Austria is leading the Task 14 on "Solar PV in a Future 100 % RES Based Power System", as well as actively participating in Task 1, 12, 13, 15 and 16.

The national RTD in Photovoltaics is focusing on materials research, system integration as well as more and more also on building integration, where integration is seen not only from architectural aspects but from systemic aspects including the local electricity generation for mobility.

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

IMPLEMENTATION

Self-Consumption is generally more and more an additional driver of the PV-development. However, a self-consumption tax was introduced in 2014, for annual production, which exceeds 25 000 kWh; since this is far beyond the typical production by private PV systems, which are dominating the Austrian market. Traditionally, this tax does not influence the development of private PV storage systems. Nevertheless, it has an effect on larger systems in industry, as well as on small and medium enterprises; self-consumption is mainly seen as the decisive factor for amortisation of larger PV systems in Austria. In late 2017, the new government published plans to abolish this self-consumption tax for PV systems completely, however, until the end of 2018, this tax was still in effect.

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

MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria (PV 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 between business and the political and public sectors. Its focus is 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 2018, the association counted 220 companies and persons involved in the PV and storage industry as its members.

The 16th annual national photovoltaic conference took place in Krems, in 2018, once again as a two-day event that was organised by the Technology Platform Photovoltaic and supported by the Ministry of Transport, Innovation and Technology. This strategic conference has been established as THE annual come together of the innovative Austrian PV community, bringing together about 200 PV stakeholders in industry, research and administration.

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

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 for PV systems. Usually it only takes some hours until a new power plant is sold out.

FUTURE OUTLOOK

Initiatives for local energy communities where PV together with storage, heat pumps, electric-vehicles and other technologies are in the center of a new energy system, offer a wide spectrum for new activities. Many of the 95 existing Climate and Energy model regions, coordinated by the Austrian climate and energy fund, are about to create first initiatives in this context.

Furthermore, PV is seen as an important cornerstone in a new digital energy world. The clear tendency of private consumers to achieve a high degree of energy autonomy supports this process. PV in combination with storage systems, where both technologies have shown significant cost digression in recent years, offers new opportunities. Along with these trends, discussions about the further role and the further financing of the public grid are emerging.

"Photovoltaic Integration" with the meaning of aesthetic architectural integration as well as integration from the system point of view into the local energy system needs to stay in the focus of further PV deployment. Meanwhile, the much lower cost of PV-systems and the ambition to optimise systems for self-consumption purposes might open new opportunities for the private sector, as well as for small and medium enterprises and for the industry.

In 2017, a revision of the Austrian ELWOG-law (electricity economy and organisation law) has opened the possibility for multifamily houses to jointly use and distribute PV electricity. The enlargement of these self-consumption possibilities to neighbourhoods is under discussion. However, up to the end of 2018, only a few projects had been established.

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

Storage Systems will enable increased energy autonomy and might become a main driver in the sector, currently mainly driven by private consumers; hydrogen solutions are to be discussed with electricity production by renewables where photovoltaic will again have a crucial role.

Electric cars are subsidised in Austria since March 2017, with up to 5 000 EUR. About 21 000 fully electric cars are registered in Austria at the end of 2018; a further strong growing E-vehicle sector might have a significant influence on PV development, moreover since the decision for getting subsidy depends on proof of using 100 % electricity from renewable energy (e.g. supply-contract with a 100 % green electricity provider).

PV research and development will be further concentrated on international projects and networks, following the dynamic expertise and learning process of the worldwide PV development progress. Mainly within IEA PVPS Task 14 on "Solar PV in a Future 100 % RES Based Power System", commenced in 2010 and led by Austria, is a focal point of the international research activities in the topic of smart electricity systems. However, the national energy research programmes are also dedicated to PV issues, with many larger projects just in operation.

Smart city projects are supported by the Ministry of Transport, Innovation and Technology, as well as by the Austrian Climate and Energy fund. Within the broad range of city relevant research, PV plays more and more a role as a significant and visible sign of 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., besides their main purpose which is renewable energy generation.

Several renewable energy education courses and trainings are already implemented, some new 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. At several universities, Bachelor and Master courses in Renewable Energy, Energy Efficient Building Technologies with Solar, and specifically, PV systems, as single core elements are offered.

BELGIUM

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

BENJAMIN WILKIN, APERE ASBL, BRUSSELS

GENERAL FRAMEWORK

Belgium reached a cumulative installed PV capacity of approximately 4,25 GWp at the end of December 2018, according to the latest figures from the three regional regulators.

The country added around 367 MWp in 2018, a strong growth compared to 2017 (296 MW) and the best year since 2012. The Belgian PV park is still characterized by a large share of small systems, with one-tenth of households owning a PV system. The total installed capacity reached 374 MWp per inhabitant in 2018.

In Flanders, the market for small systems (< 10 kWp) was slightly smaller than in 2017 (-4 %).

In 2018, the market for large systems (> 10 kW) was more dynamic (+26 MW, or + 72 %). These systems are not subject to a net-metering or prosumer fee, but they benefit from a self-consumption scheme and from an additional green certificate (GC) support scheme to ensure that investors have an Internal Rate of Return (IRR) around 5 % considering a time period of 15 years. The level of support is recalculated every 6 months.

In terms of installed capacity, Flanders installed about 218 MWp in 2018 (213 MWp in 2017), going beyond 3 GWp of cumulative installed power capacity. The installation of small systems (< 10 kW) represents 59 % of the installed capacity. The large plants (> 250 kW) and the commercial segments (10-250 kW) represent respectively 22 % and 19 % of the total installed capacity.

In Wallonia, the Quali watt support plan for small systems (\leq 10 kW) introduced in 2014 was ended after the 30 June 2018. This means that there is no more support scheme other than net-metering for these systems from 1 July 2018. Consequently, there was a huge demand for new installations before this date with around 8 700 PV systems installed within 6 months (this approximately represents the number

of installations for the whole year 2017). In 2018, the market regulator of Wallonia (CWaPE) defined a new grid fee that should be applied to prosumers (\leq 10 kW) in 2020.

For large systems in Wallonia, 2018 was the second-best year ever (behind 2013) with 332 new large systems (+56 MW). This growth mainly took place during the first half of the year, as the support scheme was diminished by 25 %, on average, for large systems installed after 30 June 2018.

In terms of installed capacity, Wallonia installed about 133 MWp in 2018, going up to 1,14 GWp. The installation of small systems (< 10 kW) represents 79 % of the installed capacity. The large plants (> 250 kW) and the commercial segment (10-250 kW) represent respectively 5 % and 16 % of the total installed capacity.

Brussels is the last region where green certificates support remains operational for small PV systems (< 10 kW), and its installation market has remained stable since 2016. It guarantees a seven-year payback time for the PV installations. It was planned to end the net-metering system for small PV systems (< 5 kVA) in July 2018, but the implementation was postponed to mid-2020.

In terms of installed capacity, 2018 is the second-best year after 2013, and about 16 MWp were installed, reaching a cumulative capacity of 83 MWp. The installation of small systems (< 10 kW) represents 15 % of the installed capacity. The large plants (> 250 kW) and the commercial segments (10-250 kW) represent respectively 56 % and 30 % of the total installed capacity.

NATIONAL PROGRAM

The Belgian National Renewable Energy Action Plan has set 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.

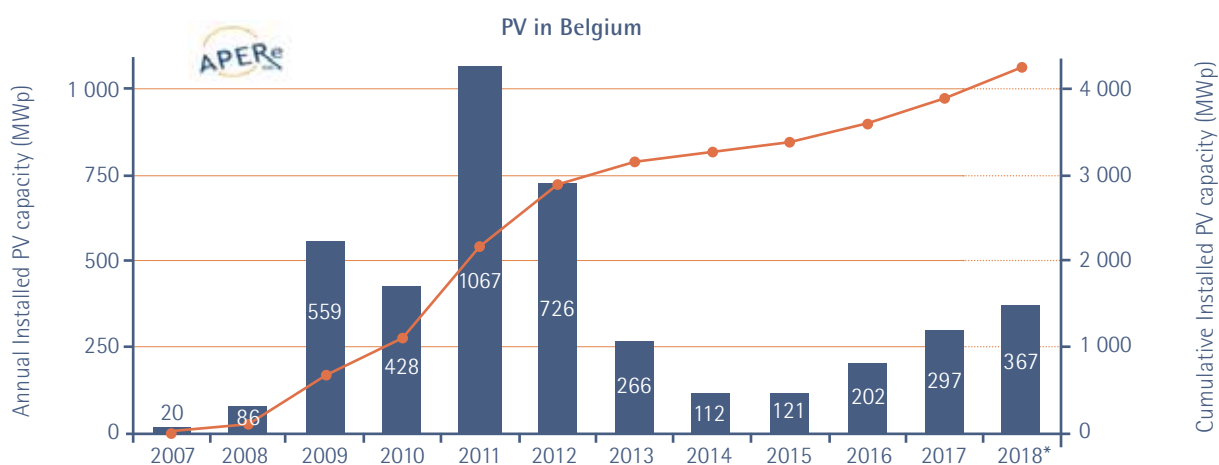


Fig. 1 – Belgium's Annual Installed PV Capacity and Cumulative Installed PV Capacity (MWp).



Fig. 2 - PV Project at School: Ecole St. Anne in Brussels, realized through crowdfunding from school and parents. Installation in 2018.

In December 2018, Belgium introduced its Climate-Energy National Plan to the European Commission for approval. The new objectives for photovoltaic included in this plan aim for an annual PV energy production of 4 820 GWh for 2020 (5 GW), 7 267 GWh for 2025 (8 GW), and 9 729 GWh in 2030 (11 GW). To reach these targets, the annual installation rate should be around 558 MW/year between 2020 and 2030, considering that the new 2020 goal will be reached. In Flanders, this would mean 4 GWp in 2020. The annual growth for the next two years should be around 482 MWp/year (2019 and 2020) to reach the new objectives by the end of 2020. Beyond 2020, the annual growth should be around 270 MW/year to reach the 2030 target.

Wallonia should reach 1,37 GWp by the end of 2020 through an installation rate of 117 MWp/year. After 2020, the annual growth should be around 213 MW/year to reach the 2030 target.

In Brussels, these objectives mean reaching 107 MWp at the end of 2020 through the installation of 24 MWp within two years (12 MWp/year). After 2020, the annual growth should be by 10 MW/year to reach the 2030 target.

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 done on Smart PV modules that would embed additional functionalities as micro-inverters (mainly IMEC Research Center), on smart grids that include decentralized production in their models (EnergyVille) and on recycling (PVSEMA and SOLARCYCLE projects).

Looking at new market design, the Walloon Government has initiated the first steps in drafting a decree about the new local renewable electricity market (including solar PV generation), in the framework of the "Collective virtual self-consumption market". This regulation would be effective in 2021 at the earliest and is planned to be effective in both medium and low-voltage grids.

INDUSTRY

There are two producers of classical modules in Belgium: Issol and Evocells, although Issol mainly develops BIPV products. With Soltech and Reynaers, they are the three main companies focusing on BIPV applications. Derbigum is specialized in amorphous silicon.

Apart from these five big companies, many other 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-scale projects (< 10 kW) account for 63 % of the installed capacity with around 513 000 installations, which represents one household out of 10. The other 37 % includes about 8 700 large-scale projects.

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

YEAR	ANNUAL GROWTH (MWP)	CUMULATIVE (MWP)
2007	20,1	24
2008	85,7	110
2009	559,3	669
2010	428,3	1 097
2011	1 067,0	2 164
2012	726,5	2 890
2013	265,5	3 156
2014	112,0	3 268
2015	120,9	3 389
2016	201,7	3 591
2017	296,8	3 888
2018*	367,2	4 255

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

The report was prepared by CanmetENERGY in Varennes and the Canadian Solar Industries Association (CanSIA). CanmetENERGY-Varennes is a research centre part of Natural Resources Canada, and is specialized in renewable energy integration, energy efficiency in buildings, improvement of industrial processes, and renewable energy project assessment. CanSIA is a national trade association that represents the solar industry throughout Canada and works to promote the expansion of solar technologies.

As part of its commitments under the Paris Agreement, the Government of Canada, in collaboration with provinces and territories, has developed the Pan-Canadian Framework on Clean Growth and Climate Change (PCF). Released in December 2016, the PCF has set ambitious greenhouse gas (GHG) reduction targets of 30 % below 2005 levels by 2030 [1]. While Canada is a global leader in the generation of clean electricity with 80 % of our electricity coming from non-emitting sources, Canada has committed to a target of 90 % by 2030. The PCF identifies clean, non-emitting electricity systems as critical to environmental and economic wellbeing, stating that new capacity will be supplied by renewables such as solar and wind. Progress on the PCF is assessed in annual reports, the most recent of which was published in December 2018 [2]. Ongoing implementation of the PCF includes the 2018 federal adoption of the "Greenhouse Gas Pollution Pricing Act," followed by the announcement of how this carbon pollution pricing system will be administrated. Examples of specific investments made so far under the "Investing in Canada Infrastructure Program," over a 12-year period, include 9,2 BCAD for green infrastructure projects and 20,1 BCAD in funding of public transportation. The Low Carbon Economy Fund provided 1,1 BCAD in funding for provincial and territorial projects for energy efficiency retrofits in the residential and commercial building sector. These are important developments and illustrate meaningful emissions reductions. Nevertheless, despite the progress emphasized in the synthesis report, the March 2018 publication by the Office of the Auditor General of Canada, "Perspectives on Climate Change Action in Canada," highlights that far more needs to be done, both at the federal and provincial level, if the 2030 targets are to be reached [3]. In this context, increased adoption of PV and other renewables such as wind, hydro, and geothermal will help Canada deliver on its commitments.

NATIONAL PROGRAMME

Ontario: Ontario, Canada's most populous province, had five contract programs covering solar, wind, bioenergy, and hydroelectricity projects. The largest of these for solar was the Feed-in Tariff (FIT) and microFIT programs, which were launched in 2009 to generate clean electricity in order to phase out coal-fired generating capacity. After 2016 and 2017, no further contracts were accepted for FIT and microFIT, respectively. However, both FIT programmes provide contract periods for PV for 20 years, and fixed prices for renewable electricity sold to the province. For example, for a 500 kW project, electricity prices ranged from 65,3 CADcents/kWh in 2009 to 20,7 CADcents/kWh in 2017. Other support programs for PV were the Green Energy Investment Agreement (GEIA), the Renewable Energy Standard Offer

Programme (RESOP) and the Large Renewable Procurement program (LRP). However, a recent discontinuation of all PV support in Ontario creates an uncertainty for future renewable energy projects in this province. As a result, Ontario is transitioning from a FIT system to a net metering program. In 2017, approximately 84 % of Ontario's PV capacity was connected to the distribution grid (embedded generation), whereas the remaining 16 % consisted of transmission-connected utility-scale arrays. It is expected that in 2018, most of Ontario's capacity growth occurred on the distribution side.

Québec: 2018 marked the beginning of large-scale deployment for solar PV in this province as the cumulative number of grid-connected residential prosumers increased from 150 in 2017 to 694 in 2018. This growth can be partly linked to a significant decrease in installation costs and the ever increasing variable rate of electricity which means residential systems 6 kW and above can now be installed below the grid parity price of 2,66 CAD per Watt. In addition, Québec city's Simons department store inaugurated the largest PV system in the province (1 060 kW) installed on its roof and on its electric vehicle carport.



Fig. 1 – Simons department store 1,060 MW PV system located in Québec City is Québec's largest PV system.

British Columbia: For residential and commercial consumers, solar energy incentives are limited. The public utilities such as BC Hydro and Fortis BC have net metering programs and offer a rebate for home renovation and various energy efficiency upgrades. As of 2018, over 1 330 customers participated in the BC Hydro net metering program, and 95 % of these customers chose to install a photovoltaic system [4].

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Through science, the Renewable Energy Integration (REI) Program of CanmetENERGY strives to improve sustainable, reliable and affordable access to renewable energy. To this end, the REI program leads solar PV research activities related to the performance and quality of PV systems and components as well as their integration to buildings and electricity grids. CanmetENERGY also leads research dealing with solar PV integration in the Arctic, particularly in remote communities

in Nunavut, Yukon, and the Northwest Territories with the objective of reducing their dependence on fossil fuels, and evaluating performance, cost, and durability of photovoltaics in this climate.

In 2014, a partnership between government and business created the Refined Manufacturing Acceleration Process (ReMAP), which is supported by 7,7 MCAD over a five-year period. The ReMAP network utilizes 38 laboratories and manufacturing lines across the country to aid product commercialization in the renewable energy sector, healthcare, communications technologies, and aerospace [5]. In terms of government policies to support renewable energy, PV programs are developed independently by the provinces and territories. The policy programs in Canada, and particularly in Ontario, over the past decade have been effective in catalyzing PV growth.

INDUSTRY AND MARKET DEVELOPMENT

Although not all provinces and territories have yet reported their PV capacity for 2018, the total capacity in Canada can be estimated at around 3,04 GWp. Approximately 97 % of PV installation is in Ontario. Outside of Ontario, the continued phase-out of fossil fuel electricity generation will encourage further growth. The provinces of Québec and Manitoba showed rapid PV capacity expansion in 2018 compared to the previous year. A map of the distribution is given in Figure 2. Annual investments in the PV sector exceeded 1 BCAD and the labour force in manufacturing and installation is estimated at around 10 000 jobs [6]. Examples of several large PV manufacturers active in the Canadian market include Canadian Solar, Heliene, and Silfab. Producers active in the field of concentrating solar and sun-tracking systems include Trace and Morgan Solar.

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Fig. 2 - This graph shows installed photovoltaic capacity (in megawatt DC) and the number of utility interconnected systems as of December 31, 2017, for all provinces and territories. However, Manitoba, Nova Scotia, Alberta, and Ontario have already reported updated capacities for 2018 and these figures are included in the inset graph showing the estimated total Canadian photovoltaic capacity as of December 31, 2018.

CHILE

PV TECHNOLOGY STATUS AND PROSPECTS

ANA MARIA RUZ, TECHNOLOGY DEVELOPMENT DIRECTOR, SOLAR ENERGY COMMITTEE, CHILEAN ECONOMIC DEVELOPMENT AGENCY (CORFO), CHILE



Fig. 1 - First version of Atacama module (ATAMO) in Antofagasta solar testing platform developed by ATAMOSTEC Consortium. Delfina Muñoz, Pierre Jean Ribeyron (CEA-INES) and Enrique Cabrera (ISC Konstanz) consortium technology partners.

GENERAL FRAMEWORK AND IMPLEMENTATION

The Energy Roadmap - *Leading people-centered modernization*, was developed by the Ministry of Energy through a participatory process and it seeks to define the energy pathways and priorities for the period 2018 - 2022 in order to achieve energy sustainability. The four-year work plan was designed around seven pillars: energy modernization, energy with a social seal, energy development, energy low in emissions, efficient transport, energy efficiency and energy education and training. These pillars were developed under the logic of an adequate integration of the three sustainable development goals, where environmental and social issues allow for a proper internalization of the externalities from the economic pillar, thereby contributing to a true sustainable development of the energy sector in Chile.

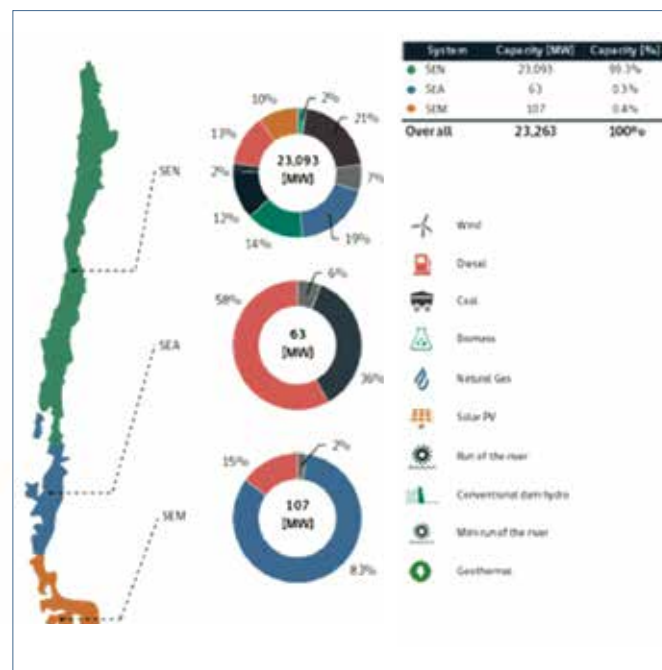
Chile ratified the Paris Agreement in 2017 and committed to reduce its CO₂ emissions per GDP unit by 30 % below their 2007 levels by 2030. Additionally, and subject to the grant of international funds, the country is committed to reduce its CO₂ emissions per GDP until it reaches a 35 % to 45 % reduction with respect to the 2007 levels; in both cases, considering a future economic growth which allows to implement adequate measures to achieve this commitment.

In 2008, Chile passed a law requiring generation companies to produce 5 % of their electricity from non-conventional renewable energy (NCRE), with the target rising incrementally by 0,5 % per year up to 10 % by 2024. This law was updated in 2013, redefining the target to 20 % of

total energy generation coming from non-conventional renewables by 2025 (raising also the corresponding year incremental targets). This goal has been already partially reached between September and December 2018, when non-conventional renewable energy (NCRE) supplied more than 20 % of National Electric System (SEN) generation for the first time, giving a positive signal of pre-compliance of the 2025 goal. More ambitiously, the Energy Policy of Chile [1] has set a target for 70 % of total electricity generation coming from renewable energy sources by 2050.

The total installed capacity of photovoltaic solar power plants as of December 2018 was 2,4 GW [2] corresponding to 125 installations, 80 % of these are located in the northern regions and 10 % in the Metropolitan region of Santiago. The total solar PV energy generation during 2018 was 5 43TWh, equivalent to 7 % [3] of total generation in the National Electricity System [4], which corresponds to 99,3 % of the total installed capacity in the country. The two small electricity systems in the southern region, called Aysén and Magallanes Electricity Systems respectively, do not have reported solar energy generation, although they only account for 0,7 % of total installed capacity in the country. See Figure 2.

PV distributed generation facilities have been increasingly reported between 2015 and 2018, reaching a total accumulated of 22 MW corresponding to more than 3 800 installations of less than 100 kWp



Notes: SEN: Sistema Eléctrico Nacional; SEA: Sistema Eléctrico Aysén; SEM: Sistema Eléctrico Magallanes. Source: CEN (National Independent System Operator), CNE (National Energy Commission).

Fig. 2 - Total net installed capacity by technology, 2018 (Source: Ministry of Energy).

[1] <http://www.energia2050.cl/en/>

[2] Reporte mensual Sector Energético Enero 2019

[3] Resumen Ejecutivo de operación 31 Diciembre 2018. Coordinador Eléctrico Nacional

[4] North and Central Power Systems were connected on November 2017

with 78 % of facilities located in the Atacama, Metropolitan, Valparaíso and Maule regions. See Figure 3. In January 2018, a series of modifications to distributed generation law were passed, with the most important being: a) to raise the capacity limit of generators from 100 kW to 300 kW in order to support the development of bigger self-consumption project for benefitting productive activities, and; b) in order to reinforce the objective of promoting self-consumption (instead of energy commercialization) surpluses of electricity supply can be deducted from electricity bills from establishments owned by the same owner if serviced by the same distribution company.

NATIONAL PROGRAMME

The Ministry of Energy, created in 2010, is responsible for developing and coordinating plans, policies, and regulations for the proper operation and development of the country's energy sector.

The Sustainable Energy Division of the Ministry of Energy contributes to the development and implementation of public policies that allow for the sustainable and efficient development of the energy sector, and particularly for renewable energy deployment. They generate the information for the design, implementation and follow up processes of

policies, plans, programs and standards associated with sustainable energy. They also implement programs for mitigating the barriers that limit the efficient development of markets associated to sustainable energy.

The Forecasting and Regulatory Impact Analysis Division of the Ministry of Energy focuses on generating strategic energy information, on developing analyses on energy topics with prospective capabilities that anticipate challenges in the energy sector allowing for efficient and timely decision-making, on the development of regulatory impact analyses, and on the design of long-term energy policies. This Division is also responsible for developing a "Long-Term Energy Planning" process, which is reviewed every five years for different energy scenarios of expansion of generation and consumption projected for thirty years. These scenarios are considered in the planning of the electricity transmission systems carried out by the National Energy Commission. The results of the Long-Term Energy Planning delivered in December 2017 projected a massive entry of solar generation systems, up to 13 GW of photovoltaic systems, and 8 GW of solar power concentration systems by 2046.

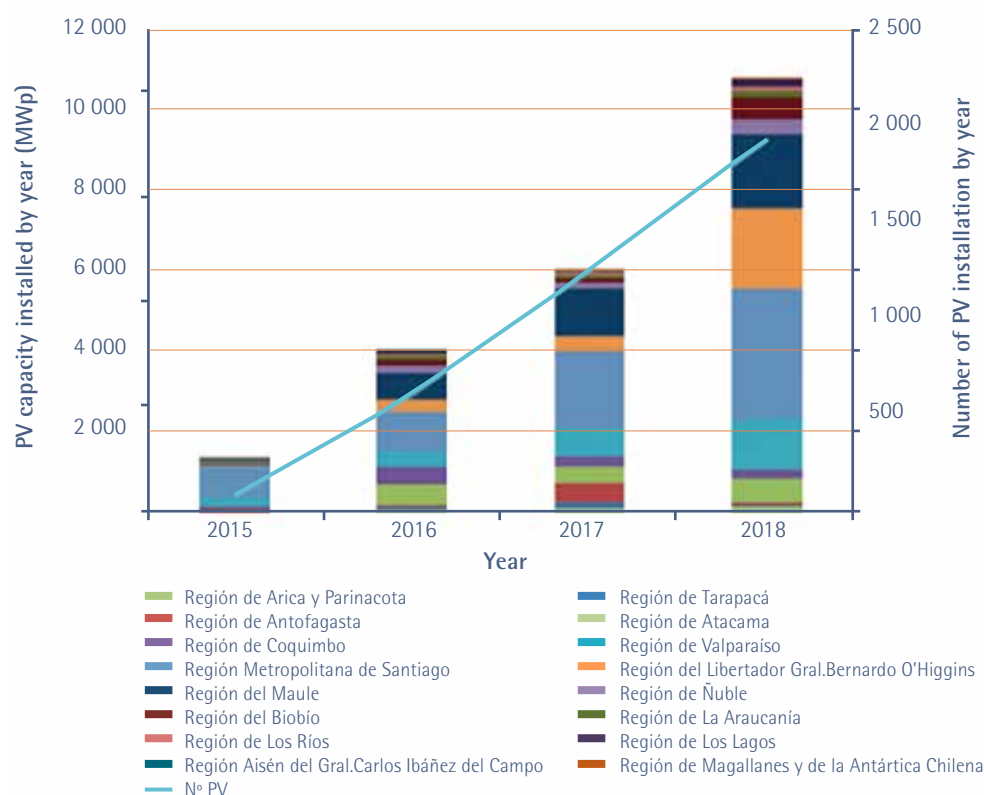


Fig. 3 – Evolution of installed and declared distributed generation with power less than 100kW (2015-2018) (Source: Minister of Energy).



Fig. 4 – Quilapilun Solar PV plant 40 kilometers north of Santiago, 110 MWp operated by EDF Energies Nouvelles.



Fig. 5 – CINTAC PV rooftop plant located in Maipu industrial sector, south of Santiago city, grid connected 2,78 MWp.

The National Energy Commission (CNE), under the Ministry of Energy, is the technical institution responsible for analysing prices, tariffs, and technical standards that energy production, generation, transport and distribution companies must comply with, in order to ensure that energy supply is sufficient, safe and compatible with the most-economic operation. Likewise, the CNE designs, coordinates and directs the bidding processes to provide energy to regulated consumers. The public tenders for regulated clients that took place between 2015 and 2017 were considered very successful, as they received multiple bids resulting in considerably lower energy prices, mainly thanks to the development of the solar industry in the country.

R&D, D

The Solar Energy Research Centre (SERC Chile [5]) is the most relevant among solar R&D organizations in Chile. It is financed by the National Commission for Scientific and Technological Research (CONICYT), and was integrated by six Chilean universities from 2013 – 2017. Currently, SERC Chile has started a new administrative cycle of five years (2018 –2022), bringing together one additional university and Fraunhofer CSET Chile. The Centre's productivity in 2018 is evidenced by the 67 ISI publications and 131 international conference presentations, the publication of two book chapters and the launching of the book called "Atrapando el sol en los sistemas de potencia" (Catching the sun in power systems) written by Brokering and Palma. The aforementioned book chapters were drafted according to empirical results obtained at SERC, particularly on the topics of energy storage and on the incorporation of electricity generated through solar devices into power systems.

The Atacama Module System Technology Consortium (AtaMoSTeC) is a project that has undertaken the challenge of developing photovoltaic systems for the high radiation conditions of the Atacama Desert, at a levelized cost of energy less than 25 USD/MWh. AtaMoSTeC is a technological programme with CORFO's co-financing for 12 MUSD and private contributions of 5 MUSD. It is managed by the University of Antofagasta and has the participation of companies including Colbún, Mondragón, Vidrios Lirquén and CINTAC, along with 15 small national companies entering the solar market of goods and services.

During 2018, the first version of ATAMO, a bifacial module glass-glass frameless was sent by the international partners CEA INES and ISC Konstanz to the Antofagasta test site for performance monitoring in the Atacama Desert Solar Platform.

INDUSTRY AND MARKET DEVELOPMENT

With the highest solar potential and the largest metallic mining district in the world, as well as a strong position in non-metallic mining, Chile has the potential for making strong contributions to the increasing demand for electric vehicles, the hydrogen-based economy and the production of low-emission copper. In order to take advantage of such opportunities, adding value to the economy and developing the local industry, Chile has sustainability challenges to face, particularly in the mining sector. On one hand, the country needs to develop capacities to become a minerals provider of materials such as battery grade lithium carbonate and hydroxide in the long run, as well as to add value to lithium-based products such as battery components. On the other hand, renewable energy costs need to further decrease and fossil fuels have to be replaced.

To address these challenges, Corfo has decided to contribute to the creation of the largest Clean Technology Institute ever created in the country, which will have a strong industrial focus on development, scaling and adoption of technological solutions in solar energy, low emission mining and advanced materials of lithium and other minerals following a two-stage application process. The call for the Request for Interest (RFI) stage was launched in Antofagasta on November 2018 and the Request for Proposals stage will be launched on June 2019.

[5] <http://sercchile.cl/en/>

CHINA

PV TECHNOLOGY AND PROSPECTS

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GENERAL FRAMEWORK

New Policy

PV FIT for 2019 has not been issued by the end of January 2019. According to the document of NDRC issued on December 19, 2017, the 2018 feed-in tariff (FIT) of PV for the three solar resources regions would be 0,55, 0,65 and 0,75 CNY/kWh, and for the self-consumption projects, the subsidy for total PV electricity would be 0,37 CNY/kWh. According to the NEA's document, building PV and residential PV will not be controlled by quota, and the quota for ground mounted PV plants should be as shown in Table 1:

TABLE 1 – QUOTA FOR PV PLANTS (2017-2020)

YEAR	2017	2018	2019	2020
QUOTA (GW)	14,4	13,9	13,0	13,0

On May 31, 2018, NDRC&NEA suddenly issued the "Notification of 2018 PV Relevant Issues" (NDRC/NEA [2018] 823). The main issues of the document are as follows:

- Cancellation of the 2018 quota for PV plants;
- Building and residential PV will be controlled within 10 GW and if the projects can't get grid connection before May 31, there will be no subsidy to the projects;
- After May 31, Feed-in Tariff will be reduced to 0,5, 0,6 and 0,7 CNY/kWh and subsidy for the self-consumption will be reduced to 0,32 CNY/kWh.

Notice: the deadline was adjusted from May 31, 2018 to June 30, 2018; several months later.

This document, issued on May 31, is known as the **5,31 new policy** and this policy is aimed at slowing down the speed of PV market expansion in China. Why the 5,31 new policy? Because the government has to reduce the requirement of subsidy, for the gap of subsidy is getting larger and larger. The incentive policies for wind and PV in China have been so effective that wind and PV have not developed slowly, but, instead, too quickly! By the end of 2018, the installed capacity of wind power was 180 GW and PV was 175 GW. Both of these figures for China mean they are in the number one position in the world for these types of renewables. In 2018, the total power generation from wind and PV was about 530 TWh, and required about 120 BCNY of subsidy funding just for 2018. Even though, China has surcharge policy to collect funds from the end users of electricity; about 70 BCNY (about 10 BUSD) was collected in 2018, but there is still a shortage of 50 BCNY. It is very difficult for the government to bear such a huge amount. Therefore, China has to look at the market without subsidy.

"Grid Parity" is Coming

Fortunately, PV cost in China is very close to "grid-parity". It can be seen that PV will be in no need of subsidy in two years. The current FIT of coal fire power and grid selling prices in China are shown in Table 2:

TABLE 2 – FIT AND GRID SELLING PRICES

FIT of Coal-Fire Power (Yuan/kWh)	0,30 – 0,45
GRID SELLING PRICE (YUAN/KWH)	
Agriculture	0,35 – 0,45
Residential and Public Service Units	0,45 – 0,65
Industry and Commercial Units	0,60 – 1,20

By the end of 2018, PV module prices were already lower than 2 CNY/Wp, and the system price was lower than 4 CNY/W. It is more likely, the electricity price of PV will be lower than 0,4 CNY/kWh by 2021, even in the 3rd solar region (<1 200 kWh/kW per year). That means by 2021, in all of China and for all end users, PV power shall be cheaper than purchasing electricity from grid. In 2018, the lowest bidding result of the Top Runner Plan in Qinghai was 0,31 CNY/kWh, which is lower than the local FIT of coal fire power 0,3247 CNY/kWh). This means no subsidy is required for this project.

It is estimated that in 2019, there will be 1/3 of the PV market in China shared by the projects without subsidy. In 2020, there may be 50 % of the PV market without subsidy and in 2021, there will be no subsidy at all for PV in China.

NATIONAL PROGRAM

Incentive Policies

China now is the largest PV producer and the largest PV market in the world. The main driving force is from the Chinese government's incentive policies, which are:

- Renewable Energy Law valid on January 1, 2006;
- Surcharge policy to collect funds: according to the Renewable Energy Law, the surcharge was collected since 2006 from end users of electricity. The surcharge level was adjusted five times: 0,001, 0,002, 0,004, 0,008, 0,015, 0,019 CNY/kWh. In 2018, 70 BCNY was collected and by the end of 2018, and a total of 400 BCNY of surcharge was collected to support wind, PV and biomass power generation.

- Feed-in Tariff (FIT) policy to enlarge the market. The first FIT of PV was set in 2008, 4 CNY/kWh. In 2011, a FIT of 1,15 CNY/kWh for all of China was launched and in 2013, and a FIT according to solar regions was issued: 0,9, 0,95 and 1 CNY/kWh. In 2018, the FIT of PV was set at the level of 0,5, 0,6 and 0,7 CNY/kWh.
- Specific government sponsored projects.
- Incentive policies from relevant ministries: MOF, MIIT, SAT, MLR, etc.
- Incentive policies from local government.

Mandatory Share of Renewable Energy and Non-Renewable Energy Power

On November 13, 2018, NEA issued the draft of "Mandatory Share of Renewable Energy Power" (MSREP) to invite comments. MSREP is just like RPS in western countries and the document will be formally issued in 2019. MSREP is an effective policy to promote renewable energy power distribution by forcing local governments to collect duty of consuming renewable energy power in certain amounts. The draft document assigns the duty of renewable energy power and non-hydro renewable energy power, mainly of wind and PV, to all provinces. The mandatory share duty of renewable energy and non-hydro renewable energy power is based on the government energy transition target of 2020: the non-fossil energy will share 15 % of total energy consumption by 2020, so that the non-hydro renewable energy power generation must share 9 % in total power consumption in China by 2020, accordingly.

Government Sponsored Projects

Government sponsored projects are very important in technology demonstration, testing the reality of policies and gaining experiences. The main government sponsored projects are listed below:

- **Concession bidding** for Dun Huang 10 MW PV plant in 2008, 2 x 10 MW in total and the FIT bidding result is 1,0928 CNY/kWh.
- **Concession bidding** for 13 PV plants in 6 western provinces in 2010, 280 MW in total and the FIT bidding results are between 0,7288 – 0,9907 CNY/kWh.
- **Golden-Sun Demonstration and PV Building project** during 2009 – 2013, mainly BAPV and BIPV projects and 6,33 GW in total.
- **PV Poverty Alleviation:** the government will build around 5 kW PV for each poor family and the family can earn 3 000 CNY each year by selling PV electricity to grid. This project will help 2,8 million poor families and 15,5 GW of PV already approved.
- **Top Runner Plan:** "PV Top Runner Plan" is to encourage PV companies to upgrade technologies through innovation. The Top Runner Plan started in 2015. The total installed PV capacity for the 1st and 2nd phases was 6,5 GW. The capacity of the 3rd phase was 6,5 GW (5 GW for Top-Runner and 1,5 GW for Super Top-Runner). The 4th phase of this plan will start in 2019.



Fig. 1 - PV Poverty Alleviation (Photo: PVmen).



Fig. 2 - Top Runner Project, Baicheng (Photo: PVmen).

RESEARCH & DEVELOPMENT (R&D)

Leading by the "Top Runner Plan", PV technologies have made great progress in PV cell efficiencies and mass production of hi-efficiency PV modules is being achieved. The upgrade progress data is listed below:

TABLE 3 – CAPACITY FOR HIGH-EFFICIENCY TECH

TECHNOLOGY	MANUFACTURE CAPACITY (MW)
P-PERC	60 000,0
N-PERT	4 000,0
HJT	600,0
IBC	100,0
MWT	1 500,0
Bifacial Modules	15 000,0

Source: CPVS

Table 4 shows the highest Lab. level cell efficiencies in China for various types of PV efficiencies in China for various types of PV cells. In Table 5, the industry level average cell efficiencies are provided.

TABLE 4 – LAB. LEVEL HIGHEST CELL EFFICIENCY

NO.	TECHNOLOGY	CELL EFFICIENCY (%)	AREA (CM ²)
1	P-PERC (mono)	23,1±0,46	244,37
2	P-PERC (multy)	22,0±0,44	245,83
3	N-PERT	23,1±0,45	244,1
4	IBC	25,0±0,30	243,2
5	HJT	23,7	242,5
6	GaAs (1-Junction)	28,9±0,20	1
7	GaAs (2-Junction)	31,6±1,90	1
8	GaAs (3-Junction)	34,5±4,00	1,002
9	CIGS	21,2±0,42	1
10	Perovskite	23,32	0,0739
1. Longi 2. Jinko 3. Trina Solar 4. Trina Solar 5. Hanergy 6. Hanergy 7. Hanergy 8. Derong Tech 9. Hanergy 10. Institute of Semiconductor, CAS			

Source: CPVS

TABLE 5 – INDUSTRY LEVEL CELL AVERAGE EFFICIENCY

NO.	TYPE	TECH.	CELL EFFICIENCY (%)
1	P-Multi-Si	PERC	20,3
2	P-Mono-Si	PERC	21,8
3	N-Mono-Si	N-PERT	21,5
4	N-Mono-Si	HJT	22,5
5	GaAs		25,1
6	CdTe		14,5
7	CIGS (glass assembly)		18,7
8	CIGS (flexible)		17,8
9	Perovskite		16,0

Source: CPVS

INDUSTRY AND MARKET DEVELOPMENT

PV Industry in China

China has been the largest producer of PV modules in the world since 2007. PV productions of the entire manufacturing chain in 2018 are shown in Table 6:

TABLE 6 – PV PRODUCTION AND CHINA'S SHARE IN 2018

SECTORS	WORLD	CHINA	SHARE (%)
Poly-Silicon (103 Ton)	447,9	258,9	57,80
Silicon Wafer (GW)	121,9	109,2	89,58
PV Cells(GW)	120,2	87,2	72,55
PV Modules (GW)	119	85,7	72,02

Source: CPIA

PV Market Development

In 2018, even the PV market in China suffered from the 5.31 new policy. However, the total annual installation still reached 44,26 GW. Among the market, the distributed PV was 20,96 GW; shared 47,4 %.

TABLE 7 – PV INSTALLATION BY SECTORS IN 2018

MARKET SECTOR	ANNUAL (MWP)	CUMULATIVE (MWP)	SHARE (%)
Off-Grid		360	0,2
Distributed	20 960	51 250	29,2
Power Plant	23 300	123 730	70,6
Total	44 260	175 340	100

Source: CPIA



Fig. 3 – PV Home Systems (Photo: Solarq).



Fig. 4 – PV Home Systems at Quzhou, Zhejiang Prov.

Energy Transition Target and Future Forecast

The Chinese government offers the target of energy transition: by the year of 2020, 15 % of total energy consumption will come from non-fossil fuels, which includes renewable energy and nuclear energy; by the year 2030, 20 % of total energy consumption will come from non-fossil fuels and by the year 2030, the emission of CO₂ will reach the top and will be going down later on.

TABLE 8 – ROADMAP OF POWER GENERATION IN CHINA (2020, 2035, 2050)

YEAR	INSTALLED POWER (GW)	POWER GENERATION (TWH)
2017	1 746	6 313
2020	2 122	8 065
2035	4 256	11 824
2050	5 626	13 848

Source: ERI, NDRC

TABLE 9 – ROADMAP OF PV POWER GENERATION IN CHINA

YEAR	INSTALLED PV AND SHARE (GW)	PV GENERATION AND SHARE (TWH)
2017	130 (7,4 %)	151 (2,4 %)
2020	227 (10,7 %)	285 (3,5%)
2035	1486 (34,9 %)	1836 (15,5 %)
2050	2157 (38,3 %)	2672 (19,3 %)

Source: ERI, NDRC

Thus it can be seen that by the year 2035, 1 kW per person in China will be achieved.

ABBREVIATIONS:

NDRC: National Development and Reform Commission

NEA: National Energy Administration

CPIA: China PV Industry Association

CPVS: China PV Society

MOF: Ministry of Finance

MIIT: Ministry of Industry and Information Technology

SAT: State Administration of Taxation

MLR: Ministry of Land and Resources

ERI: Energy Research Institute

COPPER ALLIANCE

THE COPPER ALLIANCE'S ACTIVITIES

FERNANDO NUNO, PROJECT MANAGER, EUROPEAN COPPER INSTITUTE



Fig. 1 - Calama Solar 3. The excellent local radiation conditions, in combination with the one-axis tracking systems, makes this 1 MW plant to deliver an outstanding annual generation of 2 900 MWh.



Fig. 2 - Calama Solar 3. This 1 MW power plant provides electricity to the industrial facilities of División Chuquibambilla (the largest open-pit copper mine in the world) in Chile.

Copper Alliance is supported by 43 industry members, active in various stages of the copper value chain. Through its market development programme, 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 reduction 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, electric mobility, renewable energy systems and demand-side management.

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

- Analysis of how to improve the inherent flexibility of the electricity system and enhance its ability to cope with variable production in preparation for a near 100 % renewable electricity system;
- Study of avenues for electrification of industrial processes which, together with demand-side management, can deliver an effective decarbonisation of the sector and support the integration of renewables;
- Promotion of electric mobility using sustainable materials in a circular economy system;
- Capacity building and knowledge transfer on best practices on renewables through application notes, webinars and e-learning programs.

PV RELATED ACTIVITIES

Copper Alliance supports PV development through various streams:

- Policy advocacy, notably in the context of the Clean Energy reform in Europe;
- Regular and active involvement in standardisation activities at IEC level;
- Advocacy on new business models for PV. As an example, Copper Alliance supports the design of economically-sustainable incentive schemes for PV through the grid parity monitor (www.leonardo-energy.org/photovoltaic-grid-parity-monitor), which also contributes to improving public acceptance.
- Training engineers and policymakers 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 four webinars:

- Past and future trends of PV industry developments (2017 and 2018 reports).
- Investigating business models for building integrated photovoltaics.
- Best practices for solar and wind power system case studies (joint webinar with IEA Wind).
- Together, these sessions received more than 1,600 registrations of energy professionals around the world.

ABOUT COPPER ALLIANCE

Headquartered in New York, NY, USA, the organisation has divisions in Asia, Europe and Africa, Latin America, and North America. It incorporates a network of regional offices and copper promotion centres in nearly 60 countries, which promote the Copper Alliance™ brand and are responsible for programme development and implementation, in close cooperation with their partners. Through this international network, Copper Alliance has built up a comprehensive resource of more than 500 programme partners from all over the world.

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK

The Danish government launched its energy plan called Our Energy in November 2011, with the vision of a fossil free energy supply by 2050 and interim targets for energy efficiency and renewable energy by 2020 and 2035, e.g. by 2020, 50 % of the electricity shall come from wind turbines. The energy plan was finally agreed upon in March 2012, by a broad coalition of parties both inside and outside the government. The plan, which reaches up to 2020, was further detailed in the government's energy statements. In the latest PV relevant statements of September - October 2017, a new support model has been agreed upon for the promotion of renewable energy (RE), in particular PV and wind. The model is based on so called technology neutral tenders, initially for the years 2018 and 2019. The tenders will be launched with a defined public economic support ceiling, and interested stakeholders can submit their bids. The bids with the lowest cost per kWh produced and exhibiting a solid base will win. The aim is to get as much RE energy for the public money as possible leaving the market to decide technology within some framework conditions. The first such auction round encompassing on-shore wind and PV was held September-November 2018, resulting in 17 bids. Of these, three contracts on both wind (165 MW) and PV (104 MW) are expected requesting in average a price adder of 0,0228 DKK /kWh (0,003 EUR) on top of the market price per kWh – far below expectations. With regard to RE, this 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. A new energy plan covering 2020 – 2030 has been politically negotiated in mid-2018, and inter alia confirms the principle of technology neutral auctions over the 10-year period. Furthermore, coal will be phased out, three large scale off-shore wind farms will be established – however, no targets have been set for PV.

Renewable energy is very much a present and considerable element in the energy supply. By the end of 2018, more than 45 % of the national electricity consumption was generated by renewable energy sources including incineration of waste. During 2018, PV provided 2,8 % of the national electricity consumption. Ongoing research, development and demonstration of new energy solutions including renewable energy sources have in principle high priority in the energy plans, however the amount of R&D funding allocated to RE exhibits only modest increases, following previous reductions. Renewable energy technologies, in particular wind, play an important role with PV still seen as a minor option suffering from go-stop political interventions preventing a stable market development despite a proven growing degree of competitiveness. However, the above 2020-2030 plan with its technology neutral auction scheme may provide a firmer base for a PV market.

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; with several municipalities having presently reduced or stopped PV deployment.



Fig. 1 - PV system for Øresundsbroen (the bridge between Denmark and Sweden). The power of the system is 255 kWp. System delivered by Helge Andersen, Solarpark DK A/S, Denmark.

NATIONAL PROGRAM AND IMPLEMENTATION

Denmark has no unified national PV programme, but during 2018, a number of projects supported mainly by the Danish Energy Authority's EUDP programme, and some additional technology oriented support programmes 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 EUR/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 for 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 time of the decision and follow up measures were found to be necessary. By June 2013, the new regulations were finally in place including transitory regulations, effectively putting a cap on future PV installations under the net-metering scheme in terms of an overall maximum installed capacity of 800 MW by 2020; for municipal PV installations the cap was set at an additional 20 MW by 2020. 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 EURcent) for the first 10 years and 0,40 DKK/kWh (5,4 EURcent) the following 10 years.



Fig. 2 - Roof top system from the hospital in the city Skive. The power of the system is 61 kWp. System delivered by Helge Andersen, Solarpark DK A/S, Denmark.

The above mentioned market uncertainties combined with reduced R&D funding has effectively put the PV market on hold also in 2018; only about 91 MW installed capacity was added leading to a total installed capacity of just around 1 GW by end of 2018. 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 PVs in Denmark has been identified as building applied or integrated systems. However, since 2016 some ground based centralised PV systems in the range of 50 to 100 MW have been commissioned and later extended. The above mentioned technology neutral auction scheme can be expected to stimulate this trend.

The Danish Energy Agency commissioned a revision of the national PV Strategy in 2015. This revision, which was 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, nor has there since been updates of same strategy.

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. So far, there seems to be little, if any, political impact from these forecasts.

RESEARCH AND DEVELOPMENT

R&D efforts are concentrated on silicon processing, crystalline Si cells and modules, polymer cells and modules and power electronics. R&D efforts exhibit commercial results in terms of export in particular for electronics but also for other custom made components. PV-T modules have received increasing interest.

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. The Danish TSO has published a study indicating that up to 7,5 GW PV can be accommodated in the national grid system without serious problems; 7,5 GW PV will correspond to almost 20 % of the national electricity consumption.

As mentioned above, R&D funding for RE and PV appears to exhibit lower political priority after 2016, although future increases have been indicated.

INDUSTRY AND MARKET DEVELOPMENT

A Danish PV Association (Dansk Solcelle Forening) was established in late 2008. With 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 15 % of the electricity coming from PV by 2035, 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 and has initiated a national PV/solar energy conference held in January 2018, highlighting the possible role of PV/solar energy in the future energy system.

A few PV 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 start-ups have disappeared.

Danish investors have entered the international PV scene acting as holding companies, e.g. for cell/module manufacturing in China and the EU and are increasingly 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 2018 is very difficult to estimate with any degree of accuracy due to the small market of around 90 MW and to the commercial secrecy of the PV sector both domestically and internationally. The cumulative installed PV capacity in Denmark (including Greenland) by end of 2018 was estimated to be at around 1 GW.

FUTURE OUTLOOK

The present liberal government has announced the intention to keep the present level of the annual government funds allocated to R&D into energy and renewables with slight increases indicated, and has shown little interest in PV as such. However, the before mentioned technology neutral auction scheme launched in 2018 may provide new opportunities for PV. Then, by mid-2018, the decided energy plan covering 2020 – 2030 may provide new opportunities for PV, as well.

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.

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 a strategy for making energy more secure, affordable and sustainable in the EU Countries [1]. This strategy is made up of five closely related and mutually reinforcing dimensions:

- security, solidarity and trust: diversifying Europe's sources of energy and ensuring energy security through solidarity and cooperation between EU countries;
- a fully integrated internal energy market: enabling the free flow of energy through the EU through adequate infrastructure and without technical or regulatory barriers;
- energy efficiency: improved energy efficiency will reduce dependence on energy imports, lower emissions, and drive jobs and growth;
- decarbonising the economy;
- research, innovation and competitiveness: supporting breakthroughs in low-carbon and clean energy technologies by prioritising research and innovation to drive the energy transition and improve competitiveness.

Since the Energy Union strategy was launched in February 2015, the Commission published several packages of measures to ensure the Energy Union is achieved. The EU concluded the negotiations of the "Clean Energy for All Europeans package" end of 2018. The Clean Energy package includes a revised Energy Efficiency Directive, a revised Renewable Energy Directive, the Energy Performance in Buildings Directive, a new Electricity Regulation and Electricity Directive and new Regulations on Risk Preparedness and on the Agency for the Cooperation of Energy Regulators (ACER). The package is completed by the Regulation on the Governance of the Energy Union and Climate Action [2]. The formal adoption of all the new rules will be completed in the first few months of 2019, marking a significant step towards the creation of the Energy Union and the delivering on the EU's Paris Agreement commitments. It empowers European consumers to become fully active players in the energy transition and fixes two new targets for the EU for 2030: a binding renewable energy target of at least 32 % and an energy efficiency target of at least 32,5 %. For the electricity market, it confirms the 2030 interconnection target of 15 %, following on from the 10 % target for 2020. These ambitious targets will stimulate Europe's industrial competitiveness, boost growth and jobs, reduce energy bills, help tackle energy poverty and improve air quality. Once these policies are fully implemented, they will lead to steeper emission reductions for the whole EU than anticipated – some 45 % by 2030 relative to 1990 (compared to the existing target of a 40 % reduction).

DEPLOYMENT

The annual maximum deployment of PV installations in Europe was reached in the year 2011, when more than 22 GW were installed. After that year, much reduction in annual installations has been observed. In 2017, the newly installed solar photovoltaic capacity in the European Union basically stagnated at about 5,9 GW.

The cumulated PV capacity installed in some EU Member States is reported in Figure 1.

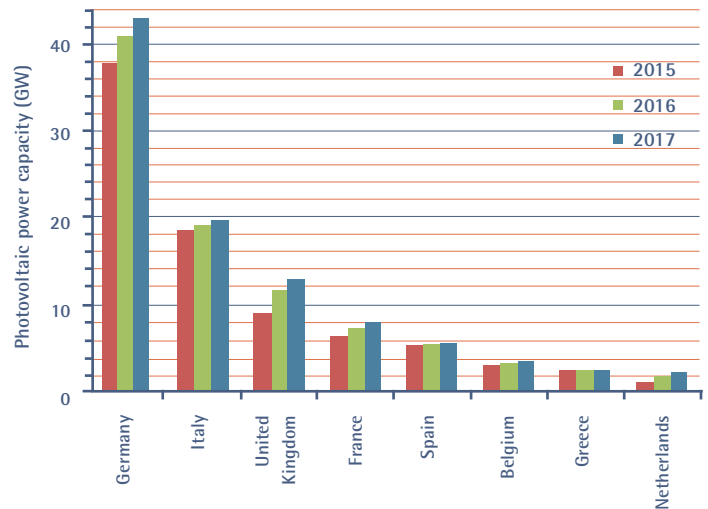


Fig. 1 - Cumulative installed photovoltaic capacity in some EU countries [3].

The installed PV power capacity in the EU at the end of 2017 could generate around 120 TWh of electricity or about 4,5 % of the final electricity demand in the Union. A more complete and detailed analysis of the EU PV market is given elsewhere [4].

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].

An overall view of the budget which is currently being invested on photovoltaics, under different Horizon 2020 activities, is provided in Figure 2.

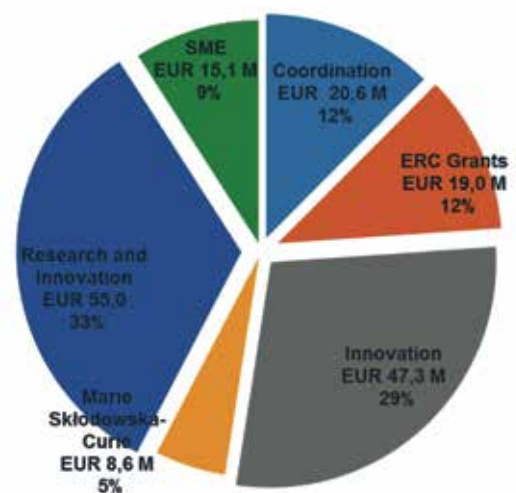


Fig. 2 - Ongoing photovoltaic projects funded under Horizon 2020.

A total EU financial contribution of about 165,6 MEUR is being invested, under H2020, on activities which are related to photovoltaics¹. This contribution is mostly spent for research and innovation actions (33 %), innovation actions (29 %) and grants to researchers provided by the European Research Council (12 %). Fellowships, provided under Marie Skłodowska-Curie actions, absorb 5 % while actions for SME are at 9 % of the overall investment. Coordination actions, such as ERA-NET, represent 12 % of the budget.

SET-PLAN ACTIONS AND INITIATIVES

The SET Plan is the implementing tool for the research, innovation and competitiveness dimension of the Energy Union. It aims at supporting and strengthening partnerships among national governments, industry and research actors to enable R&I actions that contribute to deliver on the EU energy objectives. The SET Plan focuses on development of technologies that have the highest and most immediate systemic potential for GHG emission reductions, cost reductions and improvement of performance.

The SET Plan has proved to be a successful platform for inclusive, joint decision making on concrete R&I activities, through the endorsement of its Implementation Plans (IPs) [6], covering all energy R&I priorities of the Energy Union. Countries aim at mobilising funding at national level but also through partnerships with other countries on R&I activities that had been previously outlined within the SET Plan Actions.

Briefly, the IP for PV identifies a set of 6 technology-related priority activities for the future development of PV technologies and applications in Europe [7]:

- 1) PV for BIPV and similar applications,
- 2) Technologies for silicon solar cells and modules with higher quality,
- 3) New technologies and materials,
- 4) Development of PV power plants and diagnostics,
- 5) Manufacturing technologies (for cSi and thin films),
- 6) Cross-sectoral research at lower TRL.

Across the proposed actions, the overall volume of investment to be mobilised has so far been identified in broadly 530 MEUR, with the main contribution expected from the SET Plan countries involved, then from industry, finally from the H2020 Framework Programme. Some of the actions are already running.

After the delivery of the PV IP by the ad hoc PV Temporary Working Group in November 2017, a new structure has been put in place to the purpose of the effective execution of the IP. This body, denominated PV Implementation Working Group (IWG), has become operational in May 2018. Its membership comprises 9 SET Plan countries (Cyprus, Belgium – Walloon region, Belgium – Flemish region, France, Germany, Italy, Norway, the Netherlands, Turkey and Spain) as well as 12 representatives from the European Technology and Innovation Platform for Photovoltaics (ETIP PV), industry and research institutions. The European Commission, represented by the Directorate-General

for Research and Innovation, the Directorate-General for Energy and the Joint Research Centre, participates throughout this process as a facilitator, also providing guidance. The PV IWG is co-chaired by Germany and the ETIP PV.

The IWG is expected to target the following areas of activity:

- (a) Monitoring national support for the PV IP,
- (b) Monitoring (global) progress of PV on a technological and economical level,
- (c) Stimulating additional national or European support for the PV IP,
- (d) Outreach and dissemination.

The European Commission intends to facilitate this process through a Coordination and Support Action (CSA) whose call has been published in the 2018-2020 Work Programme of Horizon 2020 [8]. A project proposal for PV has been selected under this call. The project, currently under negotiation between the consortium and Commission services, will receive an EU grant of about 1 MEUR. Activities are expected to support and complement the work of the IWG by e.g. structuring research proposals, gathering project partners, stimulating private investment, and developing a metrics for progress monitoring.

The experience gained in developing the SET Plan IPs will be key in advancing specific technology and innovation as well as system integration in general, and will also be instrumental in further alignment of energy technology and innovation policies at national and EU level.

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FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - Solar PV ground installation at Mikkeli, Finland (Photo: Etelä-Savon Energia Oy; Heidi Mikkonen).

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

So far there is no specific national strategy nor objectives for photovoltaic power generation in Finland. Instead, 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 up to 50 % of the total work cost including taxes resulting up about 10–15 % of total PV system costs.

R&D

In Finland, the research and development activities on solar PV are spread out over a wide array of universities. Academic applied research related to solar economy, solar PV 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



Fig. 2 - LUT University solar PV wall installation in Lappeenranta, Finland (Photo: Jero Ahola).

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 at universities is mainly funded by the Academy of Finland and Business Finland, which also finances company-driven development and demonstration projects. In Finland, there are no specific budget lines, allocations or programs for solar energy R&D&I, but PV is funded as part of open energy research programs. In 2018, Business Finland's public research and development funding for solar energy was just under 2 MEUR, and energy aid 6,4 MEUR.

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. Since 2010, the number of grid-connected PV systems has gradually increased. Presently, the market of grid-connected 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. The first multi-megawatt ground-mounted solar PV plant, with the total power of 4,4 MW, was built in Finland during years 2017–2018 in Nurmo. By the end of 2018, the installed grid-connected PV capacity was estimated to be approximately 130 MW and the number of PV plants at more than 10 000.

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

MELODIE DE L'EPINE, HESPUL



Fig. 1 – Urbasolar's 854 kWp solar canopy over the employee parking lot at the NTN-SNR Cévennes St. Privaden site in France (Photo: Urbasolar/M. Colin).

GENERAL FRAMEWORK AND IMPLEMENTATION

For the first time in many years, 2018 was a year with few regulatory changes affecting photovoltaics. Whilst market share for self-consumption systems continued to grow, and the implementation of virtual and collective self-consumption were focal points for many actors, the national market was relatively stable.

The national solar energy working group, initiated by the government with a stated goal of reducing administrative barriers to accelerate the deployment of photovoltaics, announced late 2017, ran from April through to June 2018 with a series of thematic meetings and plenary sessions. Subjects ranged from permitting procedures to remuneration mechanisms. The resulting engagements, a package of actions to be undertaken both by the legislator and stakeholders, were published in June as the PlaceAuSoleil initiative. Announcements included large public and private landholders engaging in solar investments (the French Army, supermarkets, etc.), the clarification of permitting procedures for solar parking canopies and greenhouses, and the facilitation of third-party investment in self-consumption systems. Proposed measures to maintain property tax exemptions for public buildings equipped with solar were passed in the 2019 budget.

Details of the new Energy Programme Decree (PPE) for photovoltaics were announced late November, as part of the National Low Carbon Strategy.

National photovoltaic capacity grew by 862 MW, compared to 875 MW in 2017, for a cumulative capacity of 8 917 GW.

NATIONAL PROGRAMME

The new Energy Programme Decree (PPE) for photovoltaics was announced after a public debate. Whilst the 2023 target of 20,6 GW was close to previous targets (up from the previous PPE's 18,2 GW to 20,2 GW), the 2028 target of 35,6 GW to 44,5 GW is significantly higher. These targets may be ambitious, considering the current

combined commissioned and project (grid connection queue) volume of approximately 13 GW. The PPE maintains and strengthens the priority given to the development of less costly ground based and parking canopy systems. A number of different measures were announced within this framework, building on the PlaceAuSoleil initiative. These include:

- increasing the maximum size limit for systems in the self-consumption call for tenders to 1 MW, up from 500 kW;
- encouraging investments in innovative agri-voltaic or floating photovoltaics systems, as well as more citizen orientated measures such as affirming support for both local government and citizen investment in photovoltaics;
- enlarging the geographical perimeter for virtual collective self-consumption projects to better include urban development zones and eco-villages, and a dedicated call for tenders for these systems.

There were 10 national calls for tenders over 2018, with results published for nine, including the innovation and the technology neutral competitive wind energy/ground-based solar energy tenders, for which all winning tenders were for solar power.

However, the national Energy Regulator, CRE, has emitted strong reserves on the building mounted systems for self-consumption tenders, as the average tendered rate was four times higher in the 2nd Call than the 1st. Significantly under-subscribed and with high tendered prices, the CRE recommended declaring the 3rd Call unsuccessful and suspending further Calls, citing high capital remuneration and lack of competition. The CRE reiterated these recommendations for the 4th Call, insisting on the economic feasibility of self-consumption systems competing in the tenders without any subsidies. The national government has chosen to continue the tenders, and has raised the maximum size to 1 MW, as part of its engagements in the PlaceAuSoleil initiative.

The feed-in tariff bonus for small building integrated systems was finally phased out in October, marking the end of more than a decade of targeted support mechanisms for building integration PV (BIPV). Feed-in tariffs were mostly stable, with a 0 % to less than 1 % variation across all segments. The tariff revision mechanism is based on the volume of grid connection requests and general inflation – a low variation indicates low grid connection request volumes.

In September, the French Environment and Energy Management Agency (ADEME) organised a collaborative workshop with both industry and market actors as a first step to updating its Strategic Roadmap for Photovoltaics, that should be published in 2019. Stakeholders discussed subjects on a wide variety of topics, from life-cycle manufacturing environmental excellence to social acceptability and consumer confidence.

TABLE 1 – COMPETITIVE TENDERS – VOLUME, CALENDAR AND RECENT AVERAGE BID LEVELS

System type and size	Building mounted systems and parking canopies	Building mounted systems	Ground-based systems and parking canopies	Building mounted systems for self-consumption	Innovative solar systems	Wind and/or ground-based photovoltaic systems
Individual system size limits	100 kW to 500 kW	500 kW to 8 MW	Ground: 500 kW to 30 MW Canopies: 500 kW to 10 MW	100 kW to 1 MW	100 kW to 3 MW	5 MW to 18 MW
Support Mechanism	Call for Tenders 2017–2019	Call for Tenders 2017–2019	Call for Tenders 2017–2019	Call for Tenders** 2017–2020	Call for Tenders 2017–2019	Call for Tenders 2018
Volume	825 MW in 9 calls of 75 MW to 100 MW	1 050 MW in 9 calls of 75 MW to 150 MW	3,92 GW in 6 calls of 500 MW to 850 MW	450 MW in 9 calls of 50 MW	210 MW in 3 calls of 70 MW	200 MW in 1 call
Remuneration type	PPA***	FIP****	FIP	Self-consumption + bonus on Self-consumption + FIP	PPA (5 MW) FIP (65 MW)	FIP
Average tendered price (or bonus for self-consumption)	4 th call: 82,7 EUR/MWh	4 th call: 72,24 EUR/MWh	4 th call: 58,2 EUR/MWh	4 th call: 29,8 EUR/MWh	1 st call: 80,7 EUR/MWh	54,94 EUR/MWh

** Call for Tender is not limited to photovoltaics systems; other RES technologies are eligible

*** PPA = Power Purchase Agreement at tendered rate

**** FIP = Market sales + Additional Remuneration (Feed in premium) Contract at tendered rate

TABLE 2 – PV FEED-IN-TARIFFS FOR THE 4TH QUARTER OF 2018 (EUR/KWH)

TA (NO SELF-CONSUMPTION) TARIFF Q4 2018	POWER OF PV INSTALLATION (KW)	PA (PARTIAL SELF-CONSUMPTION) TARIFF Q4 2018
0,1859 EUR/kWh	≤3 kW	0,10 EUR/kWh (+0,39 EUR/W installed)
0,158 EUR/kWh	3 kW to 9 kW	0,10 EUR/kWh (+0,29 EUR/W installed)
0,1207 EUR/kWh	9 kW to 36 kW	0,06 EUR/kWh (+0,09 EUR/W installed)
0,1119 EUR/kWh	36 kW to 100 kW	0,06 EUR/kWh (+0,09 EUR/W installed)
Average selling price (EUR/Average kWh) 0,0827 (4 th Call)	Call for Tenders 100 kW to 500 kW	Average selling price (EUR/Average kWh) 0,0827 (4 th Call)

R&D

Research and Development for photovoltaics in France ranges from fundamental materials science, to pre-market development and process optimisation – but also includes social sciences. The National Alliance for the Coordination of Research for Energy (ANCRE) is an alliance of 19 different research or tertiary education organisations, with the goal of coordinating national energy research efforts. Members include the CEA (Atomic Energy and Alternative Energies Commission) and the CNRS (National Center for Scientific Research), whilst the research financing agencies ADEME (Environment and Energy Management Agency) and ANR (National Research Agency) are members of the coordination committee.

The two major centres for collaboration on photovoltaics, the Institut Photovoltaïque d'Ile-de-France (IPVf) and the Institut National de l'Energie Solaire (INES) include significant industrial research platforms, working with a number of laboratories and industrials across France.

The IPVf, an industrial-academic partnership, inaugurated its new experimental research platform in 2018. This year's highlights for it include an efficiency record for the patented new solar cell architecture in III-V material by MBE growth (Molecular Beam Epitaxy).

INES works with industrial partners on subjects from building integration components to grid integration and storage technologies, as well as fundamental research on silicon and cell technologies. In 2018, its work for spatial applications saw the validation of large, flexible, modules for the Thales Alenia Space Stratobus project – at under 4 g/W, these modules, based on technologies for terrestrial applications, will equip the project's stratospheric dirigible in 2022.

France's 2018 National Budget has an account dedicated to Energy Research, with a specific mention for the CEA (Atomic Energy and Alternative Energies Commission) working on developing very-high-yield PV cells (heterojunction and backside contact) and building integration. The CEA has teams working in a number of joint research units, laboratories and facilities.

The principal state agencies financing research are:

- **The National Research Agency (ANR)**, which finances projects through topic-specific and generic calls and also through tax credits for in-company research. Projects awarded or begun in 2018 through ANR calls include both fundamental materials research and photovoltaics-specific research (organic, Perovskite, etc.) and social sciences (economics and risks, international studies).
- **The French Environment and Energy Management Agency (ADEME)** runs its own Calls for R&D on renewable energies and has an active policy supporting PhD students with topics related to PV, as well as being the French relay for the IEA PVPS and SOLAR-ERA.NET pan-European network.

ADEME also manages the State's 3rd "Investing in the Future" programme (Investissements d'Avenir) that is financing innovative pre-industrial technologies (for ecological transition topics). In 2018, ADEME ran two different calls related to photovoltaics within the Investissements d'Avenir programme. The call for Renewable Energy Projects targeted reducing the cost of energy production (through the development of new products and improving the reliability of RES systems) and reducing the environmental footprint of RES systems, with a strong accent on replicable actions. Other eligible subjects included adapting production sources and developing control units to facilitate the integration into smart grids. The two Innovation Competition calls were part of the SME Initiative that is jointly managed with bpiFrance (see below), and aims to help French companies develop innovative products and services and champions the emergence of international players.

Other calls that interacted with photovoltaics include the Call for Research projects, with a section for active building integration products and active control systems.

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

The first results for the national Innovative Solar Call in the framework of the national call for tenders were published in February. There were 164 submissions. However, of the 85 lowest-bidding candidates, 35 projects were judged ineligible, a rather high rate. More than 70 % of the winning candidates will receive the citizen investment bonus. Successful candidates include floating PV, linear bifacial systems, agri-voltaics, and systems or component innovations. Despite the national Energy Regulator's (CRE) proposition to end competitive tenders for innovative systems, as estimating the cost of experimental systems involves a high level of uncertainty, the 2nd call was not cancelled, but postponed to mid-2019 in order to be reshaped.

The major show-cases 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

Both industry and market stakeholders were present in the government's solar energy working group that ran from April to June, with three convergent claims: an extension of with open-ended feed-in tariffs to systems up to 500 kW or 1 MW, regional tariffs (through regional Tenders or region-based bonuses on tariffs) and a modification to energy and financial regulations to allow third-party investment in self-consumption systems (direct sales with no excessive charges and taxes). Only the last subject is currently being studied by the government, in line with EU directives.

2018 saw an increased concentration of the photovoltaic energy production market with over 29 % of the commissioned capacity in the hands of 10 companies [1] – and the top 6 are French. Two major players were acquired – one by Engie, one by Total, consolidating Engie's position as the major PV generator – but also developer – in France, with nearly twice the installed capacity as the next company, EDF EN. Two major financial funds, the state's Caisse des Dépôts and Mirova, the "responsible investment" branch of national corporate banking and investment firm Natixis, have entered the top 25 through minority participation in a large number of projects.

The self-consumption calls were under-subscribed, with less than 50 % of the target volumes – and candidates were predominately for systems on supermarkets, or, less common, on industrial sites. The low level of interest may be attributed to several factors: an uncertain and costly tender process, metering requirements that increase installation costs, and individual capacity limits that both limit scaling economies and may not be significant in terms of surface coverage for potential sites. The combination of these factors could be resulting in system over-costs, when compared to unsubsidised self-consumption systems, which are higher than the subsidy gains. The next tender period, with individual size limits raised to 1 MW, may see a change in subscription rates.

Carbon footprint and environmental impacts have been a subject in 2018, with both industry action (the inauguration of France's first photovoltaics recycling plant in southern France, operating on behalf of PV Cycle), contributions to the European Preparatory Study on a PV EcoDesign and Eco-Label, exchanges on photovoltaics carbon footprint calculations for the national E+C- building label, the continuation of environmental criteria in Tenders and a dedicated discussion group at the ADEME collaborative workshop for the revision of its Strategic Roadmap for Photovoltaics.

Photovoltaics, and their building integration or on-roof installation accessories, are not considered "traditional building techniques" in France, and as such require individual material and installation procedure certification (Avis Technique) before being accepted as viable solutions by most insurers. Obtaining an Avis Technique is a lengthy process, and cost returns are not evident when there is only a small market. The insurer representative body Agence Qualité Construction (AQC), placed most BIPV systems *under observation* [2] on the 1st of January, increasing the difficulty of finding decennial building liability insurance for professionals installing building integrated photovoltaics systems. Whilst a number of manufacturers demonstrated the quality of their products to the satisfaction of the AQC and had their systems exempted (placed on a Green List), others struggled through the year. Installers were also handicapped as no roof mounting kits were certified in 2018, limiting the number of solutions they could present to clients. The AQC published a study on preventing electrical risks and has commissioned further studies on risk factors as part of their prevention work.

The French Building Federation's photovoltaics branch (GMPV) upped their investment in accompanying installers and building professionals, with a number of working groups and workshops, for example on installation techniques and insurability.

Total grid connections added decreased slightly through each quarter in 2018, and whilst both the commercial segment of systems from 100 kW to 250 kW and the domestic segment of systems up to 9 kWc doubled the annual capacity installed in 2018 as compared to 2017, all other segments stagnated. Overall grid connected volumes grew by an estimated 862 MW in 2018 as compared to 875 MW in 2017 and 587 MW in 2016. Commercial and industrial systems continue to dominate grid connections, with 72 % of new capacity for 624 MW.

TABLE 3 – GRID CONNECTED CAPACITY AT THE END OF DECEMBER 2018 (PROVISIONAL)

POWER CATEGORY	CUMULATIVE POWER (MW)	CUMULATIVE NUMBER OF SYSTEMS (NUMBER)
Up to 9 kW (Ta FiT)	1 337 (15 %)	383 668 (90 %)
9 kW to 100 kW (Tb FiT)	1 668 (19 %)	33 023 (8 %)
Above 100 kW	5 912 (66 %)	8 114 (2 %)
Total (provisional)	8 917	424 805 installations

Source: SDES (Department for data and statistical studies, Ministry for the Ecological and Inclusive Transition).

[1] Analysis Finergreen March 2018

[2] See the 2017 report: "under observation" indicates that the AQC considers that these types of systems may lead to serial liability claims.

GERMANY

PHOTOVOLTAIC BUSINESS IN GERMANY - STATUS AND PROSPECTS

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Fig. 1 - PV integrated sound protection wall (Photo: © BMWi / Maria Parussel).

GENERAL FRAMEWORK AND IMPLEMENTATION

The expansion of renewable energies is one of the central pillars in Germany's energy transition. The overall objective is an environmental friendly, reliable and economical feasible energy supply. Accordingly, Germany's electricity supply is becoming "greener" every year as the contribution made by renewable sources is constantly growing. In 2018, approximately 38 % of the gross electricity consumption was covered by renewable energy. This makes renewables an important source of electricity in Germany. Thereof 8 % are generated by

photovoltaic (PV) systems. At the same time, there is a reduction of the net installed electricity generation capacity of fossil (-1,1 GW) and nuclear (-1,3 GW) power plants [1, 2].

In 2018, a capacity of 2,96 GW PV power (as a first estimate) has been newly installed in Germany (see Figure 2) which is a noticeable increase compared to the previous years and in good accordance with the intended annual additions of 2,5 GW. This results into a total installed PV capacity of 45,3 GW connected to the German electricity grid [3].

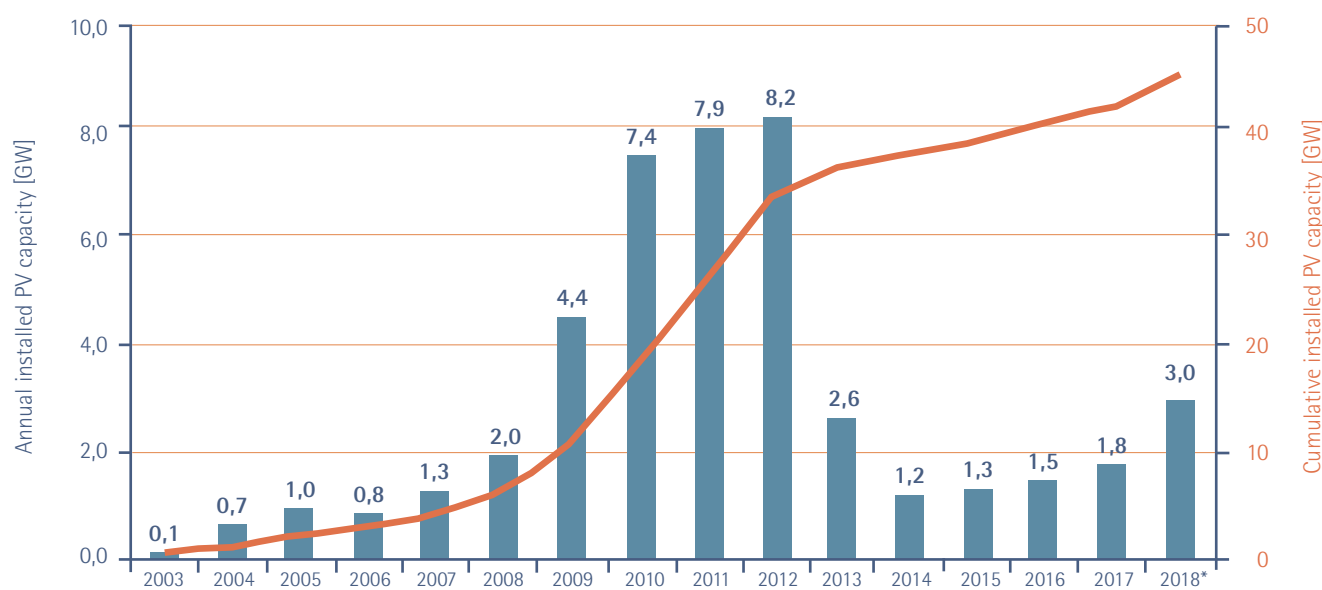


Fig. 2 - Development of grid connected PV capacity in Germany, *first estimate as of January 2019.

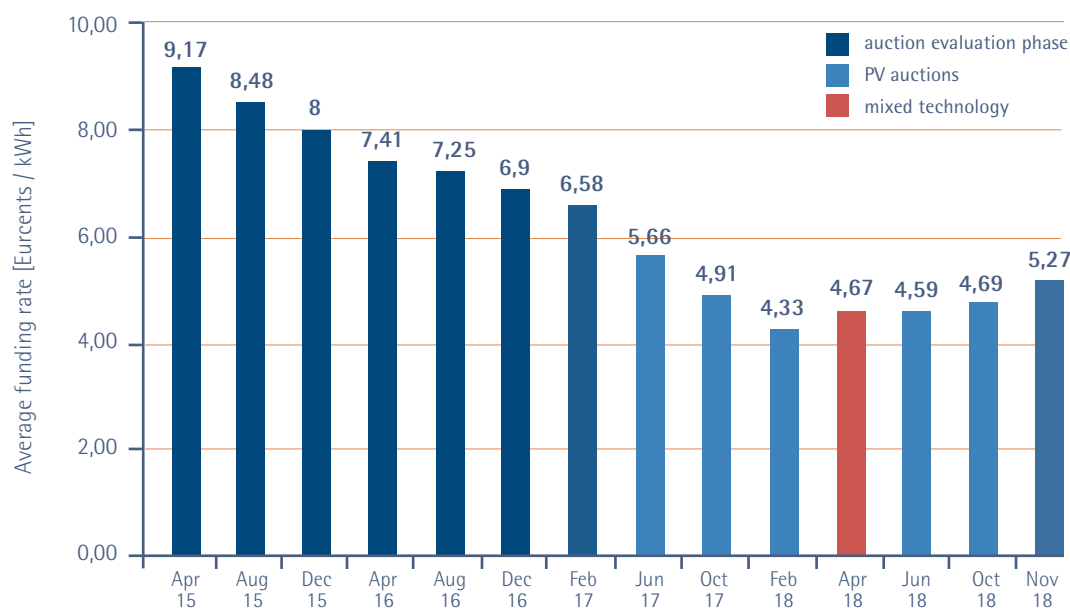


Fig. 3 - Average funding awarded in the auctions for ground-mounted PV installations.

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 [4]. The 2017 revision of the Renewable Energy Sources Act is the key instrument to achieve effective annual quantitative steering and to bring renewable energies closer to the market. Funding rates for renewable electricity systems with more than 750 kW installed power are determined via a market-based auction scheme [5]. In 2018, a total volume of approx. 575 MW was awarded in three auctions for ground-mounted photovoltaic installations. Additional 400 MW of two technology independent mixed auctions (PV and onshore wind) were solely awarded to PV systems. The calls were characterized by a high degree of competition. The proposed capacity was significantly over-subscribed. The average funding awarded in the auctions for ground-mounted PV installations can be found in Figure 3 which shows a good efficiency of the process [6].

Medium size photovoltaic systems below 750 kW are still eligible with a guaranteed Feed-in-Tariff (FiT) for a period of 20 years. Systems with more than 100 kW power capacity 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 [7]. Table 1 shows the development of the FiT for small rooftop systems (< 10 kW) installed since 2002.

Moreover, investments in residential PV installations are attractive even without financial support by a Feed-in-Tariff. Offers for PV rooftop systems of 10 kW with a price of 10.000 EUR are accessible. The Levelized Costs of Energy (LCOE) for these systems are around 12 EURcents / kWh whereas the average electricity price for a private household is around 29 EURcents / kWh [8]. Therefore, private homeowners have an interest in maximizing the self-consumption from their PV systems. Nearly every second new residential PV system is now installed with a battery storage system, too.

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) [9]. The program is equipped with a sum of 30 MEUR and is designed to run from March 2016 until end of 2018.

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

YEAR	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012*	2013*	2014*	2015*	2016*	2017*	2018*	2019*
EURcents/ kWh	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	12,20	11,47

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

RESEARCH AND DEVELOPMENT

After conducting a broad and thorough consultation process amongst all stakeholders from industry, research, society and administrations, in September 2018, the Federal Government adopted the 7th Energy Research Programme entitled "Innovations for the Energy Transition" [10]. It defines the guidelines for energy research funding in the coming years. In the context of the 7th Energy Research Programme, the Federal Government earmarked around 6,4 BEUR for innovation activities. Within the framework of the new Energy Research Programme, the BMWi as well as the BMBF (Federal Ministry of Education and Research) support R&D on different aspects of PV. The main parts of the programme are administrated by the Project Management Organisation (PtJ) in Jülich.

Funding Activities of the BMWi

In conjunction with the new Energy Research Programme, the BMWi released a new call for tenders in October 2018 which reflects the targets of the new energy research program. Concerning PV, the call addresses specific focal points which are all connected to applied research:

- Efficient process technologies to increase performance and reduce costs for silicon wafer and thin film technologies
- New PV materials and cell concepts (e.g. tandem perovskite solar cells)
- Quality and reliability issues of PV components and systems
- System technology for both, grid-connection and island PV plants,
- Cross-cutting issues like Building Integrated PV (BIPV), Vehicle-integrated PV (ViPV) or avoidance of hazardous materials and recycling of PV systems.

In 2018, the BMWi support for R&D projects on PV amounted to about 76,9 MEUR shared by 433 projects in total. That year, 98 new grants were contracted. The funding for these projects amounts to 84,7 MEUR in total. The development of funding activities is summarized in Figure 4. The German contributions to most of the PVPS Tasks are part of the programme. Details on running R&D projects can be found via a web-based database of the Federal Ministries [11].

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 [12].

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

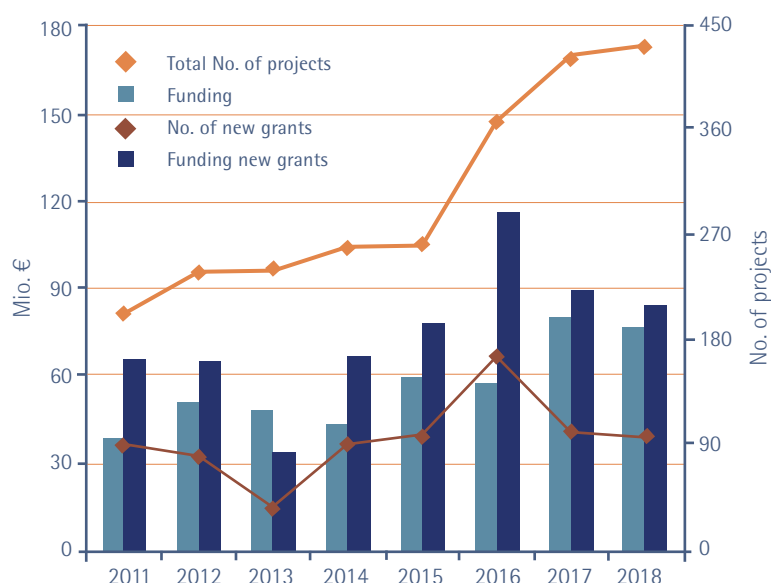


Fig. 4 – R&D support and quantity of PV projects funded by BMWi (BMU) in the 6th and 7th EFP.

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. Two recent major outcomes are the expert recommendations for the consultation process towards the 7th Programme on Energy Research mentioned above and a position paper on PV production technologies [13]. The Research Network is an open expert forum for all interested stakeholders. In Germany more than 2 000 researchers and more than 65 companies are active in research for photovoltaics.

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.

INDUSTRY AND MARKET DEVELOPMENT

In 2018, once again a significant drop of approximately 25 percent in module prices was observed. This requested for additional cost savings and put not only the German but also the global PV industry under pressure. At the same time, German manufacturers of components, machines and plants still benefit from a continued global investment of the solar industry in photovoltaic-equipment. The VDMA (Verband Deutscher Maschinen- und Anlagenbau, Mechanical Engineering Industry Association) specialist group on PV reported in the first three quarters of 2018 an 41 percent increase in sales compared with the previous year [14]. Beside these activities, significant added



Fig. 5 - Building integrated PV facade on a multi-storey car park (Photo: © PtJ / Klaus Prume).

value arises from industrial engagement in poly-silicon and module production, inverter technologies and the installation, operation and maintenance of systems. Together with a strong research community a workforce of approximately 35 800 people were employed in the solar industry in 2016 [15].

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ISRAEL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

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GENERAL FRAMEWORK

In 2016, the Israeli government decided on a series of steps designed to ensure that Israel meets its target of 17 % Renewable Energy (RE) electricity production (in energy terms), and 17% reduction in electricity use by 2030, compared to business as usual [1]. The RE target includes interim targets of 10 % in 2020 and 13 % in 2025. During 2016-2017, the Public Utility Authority (PUA) allocated a quota of 1 600 MW for PV, which led, in 2018, to the installation of 475 MW. The total RE capacity in Israel has increased accordingly to 1 450 MW, a 37 % increase in total solar capacity compared with 2017; a fourfold increase in annual installations compared with the previous year, and twice the installations of the former best year (2015). Overall, Israel has reached the level of about 4 % of RE electricity generation in 2018.

PV systems are still the most abundant RE resource in Israel, accounting for approximately 95 % of installed capacity.

Two large PV projects started construction in 2017: 60 MW in Mashabei and 120 MW in Tze'elim. Both projects are expected to be gridconnected in 2019. Two more projects, the largest CSP fields in Israel, 242 MW in total, located at Ashalim, are in their final testing phases, and are expected to be fully operational early in 2019. Combined with other projects in development, PV installations in 2019 might reach 700 MW.

During 2018, several steps were taken to simplify new PV construction and strong incentives were given to rooftop PV, as it is the easiest and quickest to install (in comparison to solar fields). The rooftop efforts are expected to yield approximately 480 MW in 2019.

Although renewable energy is more competitive than ever, it is clear that in order to achieve a high percentage of electricity production from variable RE, Smart Grid is essential. Initial steps to support Smart Grid have been taken by the Office of the Chief Scientist at the Ministry of Energy (mainly through funding of R&D and pilot projects).

Beginning in 2016, the electricity price in Israel started to increase. In 2018, the price of electricity increased by 2,9 % to 0.47 ILS (excluding VAT), yet it is still lower than the price in 2006.

Israel continued its trend of switching from coal to natural gas. In 2018, 70 % of the electricity production came from gas. In 2018 Natural Gas price in Israel for electricity generation was for about 4,8 USD per MMBTU.

NATIONAL PROGRAMME

2018 marked a significant change in Israel's energy market with a major reform in the Israeli energy market, the publication of the 2030 objectives for the energy market, and strong promotion for rooftop solar.

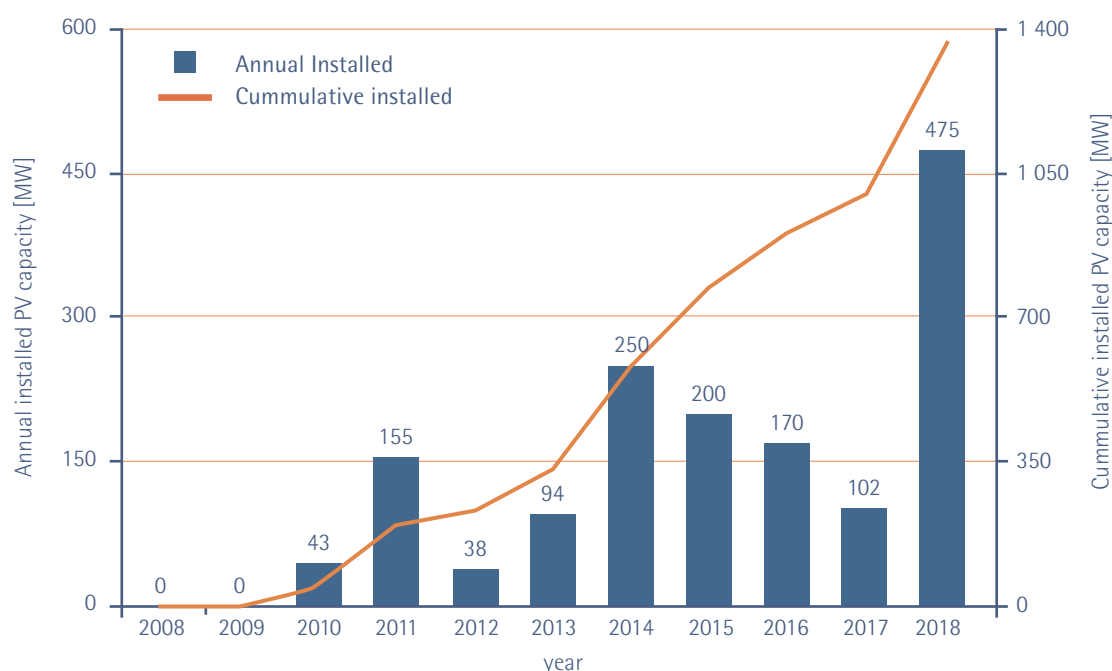


Fig. 1 – Development of grid connected PV capacity in Israel through 2018.

[1] Among the steps that were taken was an allocation of funds for energy efficiency projects

Reform in the Electricity Market

The electricity sector in Israel is dominated by the vertically integrated Israel Electric Corporation (IEC). On June 2018, the Israeli government approved a reform initiated by the Ministry of Energy, Ministry of Finance, and the PUA. The reform was designed to increase competition in the electricity generation market by reducing IEC shares in the generation segment, separate the system operator activity from the IEC, open the supply segment to competition, and strengthen IEC in the transmission and distribution segment. The reform provides great opportunities for new players in the market and is expected to have a significant impact on the electricity market in Israel.

Publication of the Ministry of Energy Plan for the Year 2030

In 2018, the Ministry of Energy published its long-term plan to "Rescue Israel from Polluting Energy"

- **Discontinuation of the Use of Coal:** By the year 2030, Coal will not be used in electricity production, except perhaps as emergency backup.
- **Integration of Renewable Energy:** A target of 17 % production from renewable energy by the year 2030 with interim targets of 10 % by the year 2020 and 13 % by 2025. The plan specifies that the targets will be re-evaluated in 2022, with the option to raise them, if technologically favorable.
- **Transition to Clean Transportation:** Electricity and Natural Gas. By the year 2030, import of gasoline- or diesel-fueled automobiles to Israel will be prohibited.
- **Transition to Clean Energy in the Industrial Sector** based on natural gas.
- **Promotion of Energy Efficiency** to meet the goal of electricity consumption reduction objective of at least 17 % by the year 2030.

1,6 GW Regulatory Framework for Rooftop Solar

In 2018, the PUA published a new rooftop regulatory framework for the next three years. The scheme included net metering, FITs for small-scale solar, and a series of tenders. The scheme regulates the installation PV on household roofs, commercial and industrial facilities, public buildings, parking lots, pergolas, water reservoirs and fish ponds. Under the new framework, PV projects up to 15 kW will be eligible for net metering [2], or apply for a 25-year FIT (not indexed to inflation) of 0,48 ILS (0,137 USDcents)/kWh. Furthermore, the framework will support PV systems ranging in size from 15 kW to 100 kW, with a 25-year FIT of 0,45 ILS (0,129 USDcents)/kWh (not indexed to inflation). The framework entails a series of tenders, starting in the upcoming summer. The minimum capacity to be allocated in a single tender will be 50 MW. A participant can either sell all electricity to the grid at the winning tariff, or sell the electricity to other consumers who are connected to same solar rooftop. Lastly, the PUA permits construction of PV outside of the framework for self-consumption with a low tariff of only 0,16 ILS (0,045 USDcents)/kWh for the surplus. This is a major change of PUA

rules, as in Israel the bilateral sale of renewable electricity was not allowed prior to the introduction of these new provisions. Quota for net-metering were finished in 2018 and are not expected to be extended.

RESEARCH AND DEVELOPMENT

The Ministry of Energy supports R&D under three main programs, which are operated by the Office of the Chief Scientist at the Ministry:

- Direct support for academic research - support is 100 % for research projects.
- Support for startup companies - support is 62,5 % for projects with technology innovation.
- Support for Demonstration and Pilot programs - support is 50 % for commercial deployment of novel technologies.

To facilitate higher penetration of PV systems, high priority research topics include improved efficiency of PV systems, and storage.

In 2018, the Office of the Chief Scientist received a relatively large numbers of academic proposals especially in the fields of tandem cells and combination of CS and PV to increase efficiency. The office supported six projects related to solar and PV with total investment of ~1 M\$ out of total budget of ~10 M\$.

Among the current supported projects are:

SolCold Ltd: SolCold is developing a nano-based coating material that creates cooling when exposed to sunlight. As cooling expenses are increasing year after year, the proposed technology reduces cooling costs and saves energy. The technology is a multi-layered material activated by anti-stokes fluorescence in response to sunlight, thus converting the internal heat into radiation and cooling below the ambient temperature. The cooling power is expected to reach 20 W/m², which may save up to 60 % in air-conditioning costs. The material can be applied to buildings, cars, trucks, containers, airplanes, clothes, and many more items.



Fig. 2 – SolCold's logo for its new coating material.

Luminescence Solar Power: The two biggest challenges in solar energy today are how to increase its efficiency and how to store utility-scale electricity at competitive prices. Until now, the only method to reliably store such energy has been thermal energy storage (TES) which is combined with Concentrated Solar Power (CSP). Yet, while the demand for CSP is increasing, the combined production and storage cost is still much higher than photovoltaics.

[2] A quota of 400 MW was set for net metering. This quota was already claimed in full. A quota of 400 MW was set for net metering. This quota was already claimed in full. A quota of 400 MW was set for net metering. This quota was already claimed in full.

A patented method combines the strengths of CSP and PV technology. Using a Luminescence Solar Power (LSP), the ground-breaking scientific methodology promises to deliver clean, storable energy at record low costs.

The method uses photoluminescence to separate between the thermal portion and the free energy portion of each single solar photon. The free energy is harvested by PV while the heat, that is 50 % of the energy and which reaches 600° C, is converted to electricity using a turbine at 40 % efficiency, which doubles the overall efficiency. The team is now demonstrating the technology in a real environment, building a 0,1 MW demonstrator with double efficiency that is more than with conventional CSP. The research is led by Prof. Carmel Rotschild from the [Excitonic Lab](#) at the Technion.

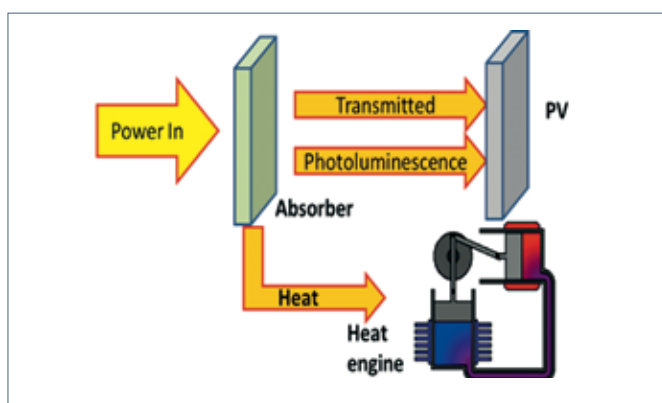


Fig. 3 – Luminescence solar power method.

Volex Power Ltd: The penetration of distributed energy resources (DER) causes local voltage instabilities. The **Volex Power** solution enhances existing and installed distribution transformers into smart Hybrid Electronic Transformers (HET) for real-time voltage control in the localized grid, with high efficiency and reliability. Moreover, **Volex Power HET** can also mitigate harmonics and regulate load imbalances thereby increasing stability in distributed generation and allow for integration of a much higher percentage of renewable into the power grid.



Fig. 4 – Volex Power's hybrid electronic transformer.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

EZIO TERZINI, ENEA

SALVATORE GUASTELLA, RSE

Cumulative Photovoltaic installations 2012-2018 (GW)

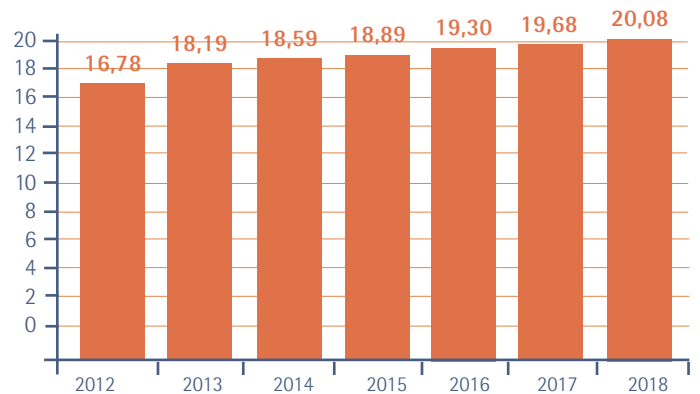
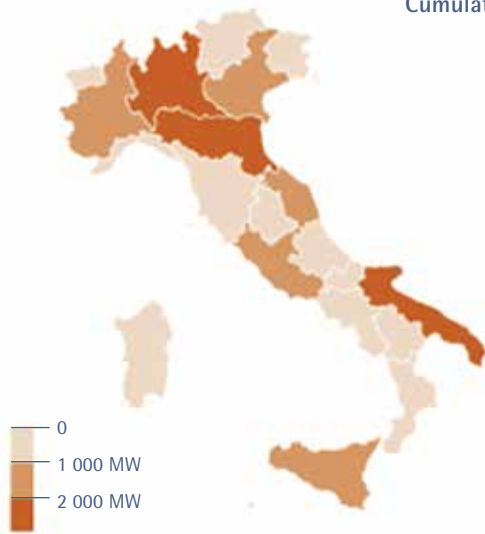


Fig. 1 – Regional distribution and trend of PV installations in Italy (updated in November 2018) (Source: TERNA Sistema elettrico).

GENERAL FRAMEWORK AND IMPLEMENTATION

In Italy, the year 2018 has been marked by a slight growth of PV installations, almost equaling that of the last year. Nevertheless, the context of PV market in Italy is rather lively, due to the Italian government's energy plan (outlined in the "National Energy Strategy", SEN, published in 2017 and in the "Proposal of an Integrated National Plan for Energy and Climate" (PNIEC), published in December 2018) adopted to manage the change in the national energy system and, in particular, to enhance the electricity production from RES (30 % of Gross Final Energy Consumptions by 2030), with the target of reaching 50 GW of PV installed power by 2030.

In this framework, preliminary data [1] of the photovoltaic installations in Italy in 2018 indicate a value of about 400 MW, almost equal to the past two years' volume (409 MW in 2017 and 382 MW in 2016).

According to these preliminary data, yearly energy production from grid connected PV decreased (- 4,7 %) with respect to the 2017 value. Residential PV plants up to 10 kW, accounting for about 40 000 units, make up 40 % of the new installed capacity in 2018, thanks to tax break mechanisms; in the same period the installations of medium and large plants were still low, even if some utility scale plants (up to 30 MW) have been installed without any incentives; thus even further demonstrating that the "market parity" has been reached in Italian high-irradiation sites.

The PV off-grid sector for domestic and not-domestic applications confirmed the unchanged cumulative installed power which remains as a marginal sector.

On the whole, it can be preliminary estimated that a total cumulative PV capacity of around 20,1 GW was reached at the end of 2018 (Fig.1). In 2018, the preliminary estimated photovoltaic production [1] was near 22 900 GWh, 4,7 % less than 2017 and covering about 7 %

national electricity demand; moreover, with regard to the electricity production of the other RES, in the same year, the following was noted: Hydroelectric + 31,2 %, Geothermal -1,9 % and Wind -1,4 %.

NATIONAL PROGRAMME

The challenging target of National Energy Strategy (SEN) and the recent PNIEC, namely about 50 GW of cumulative installed PV power by 2030, is the opportunity to give new momentum to photovoltaics. The Italian PV market is waiting for new incentive mechanisms, expected in the announced Decree for Renewable Sources not yet adopted; comprising also new policies to support appropriate maintenance, repowering and revamping of existing plants and further measures to the benefit of prosumers. Nevertheless, some mechanisms to support PV installation are still in place covering the aspects of the valorisation of produced energy and support to the investments.

A) Valorisation of Produced Energy

Scambio Sul Posto (SSP)

This is a net billing scheme which deals with the market value of energy exchanged with the grid, allowing an economic compensation between the energy fed to the grid at a given time and the energy consumed at a different time. The mechanism can be applied to production plants of different size ($P < 20$ kW, $P < 200$ kW and $P < 500$ kW) depending on the year of operation starting (respectively 2007, 2014 and 2015).

Ritiro Dedicato (RID)

This mechanism, as an alternative to the free market, consists in the sale to the GSE (Gestore dei Servizi Energetici, state-owned company) of the electricity fed to the grid by some plant categories allowed to apply for this measure. This offers a trade with procedural simplicity and clear economic market conditions. Since 2015 the energy price offered by GSE is burdened by service charges reducing the appealing of the mechanism.

[1] Monthly report on Italian Electric System, published by TERNA

Sistemi Efficienti di Utenza (SEU)

According to the SEU model, it is defined by one or more production plants, operated by a single producer, directly connected, through a private transmission line, to a single end user. In this case the energy produced by the PV plant and billed to the final user is free from system charges.

B) Support to the Investments

Tax Breaks

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 by 50 % of the plant costs.

White Certificates (or Energy Efficiency Certificates)

Companies and public institution, carrying out structural energy efficiency measures (comprising also PV installations), are entitled of the White Certificates having a market value and a profitable trading, so helping the investment return time.

Over-amortization

This measure allows professionals, commercial bodies and companies to increase up to 130 % the fiscally recognized cost of new capital goods (including PV systems).

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, ENEL, several universities and other research institutes, including company's organizations.

ENEA is the most relevant research organization in the photovoltaic technology sector in Italy. In the field of PV devices the activities are focused on high efficiency tandem cells based on c-Si or heterojunction (a-Si/c-Si) rear cells and CZTS or perovskite single junction top cell. Some effort is also in place to combine PV materials with energy-efficient building materials. The research activities also include the analysis of LCA aspects and the development of technologies for the recovery of materials from discontinued photovoltaic modules.

For the advancement of PV systems and plants ENEA develops technologies and components for flat, concentrated (CPV), hybrid concentrated (PV-T) (Fig. 2) and BIPV systems. Moreover, it is involved in the development of "digital PV" by implementing systems, processes, components and models for maximization of producibility, storage, grid integration, automation of diagnostics and O&M.

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 (CPV), in the frame of the Italian electric system research programme RdS (Ricerca di Sistema) and European projects (the last one, CPV Match, concluded at the end of 2018). In particular, RSE is pursuing an original research path (for which the



Fig. 2 – Hybrid concentrated PV-T, 2-axis tracking system (c.f. 60X – 1,7 kW E-power – 4,0 kW T-power) under test at ENEA Portici Research Centre.

European Commission's Innovation Radar has identified RSE as "Key innovator"), concerning the MOVPE (Metalorganic Vapour-Phase Epitaxy) integration of the SiGeSn ternary material in III-V based structures for the realization of monolithic high efficiency – low cost four junction solar cells. RSE is also committed in the design of new optics and advanced solar tracking methods, as well as in the set-up of new methodologies for outdoor and indoor CPV module characterization.

Moreover, RSE is engaged in the development of new quaternary chalcogenides PV thin film cells made of chemical elements abundant on the earth's crust to ensure a potential large penetration of PV technology.

Furthermore, RSE carries out research and demonstration activities for enhancing the production of the existing Italian PV plants (i.e. by O&M strategies, based on advanced diagnostic techniques, and by repowering techniques) and for enhancing the RES penetration into the microgrids of small islands not connected to the national electric grid. These activities are carried out in the frame of EU projects (i.e. EU H2020 GOPV) and Italian government commitments.

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 from different climates worldwide. In the second area "BIPV field", EURAC is managing a database for BIPV products and BIPV case studies. The strong focus of the group is on giving support to early design of BIPV projects in various demo cases in Italy and around Europe. In the frame of the third area "PV grid integration", EURAC has access to large amount of data coming from more than 2 000 PV plants located in the region and it is investigating the impact of PV in the distribution grid by developing new algorithms for forecasting, by assessing the hosting capacity, and by analysing the impact of mitigation option such as storage. Finally, EURAC is a point of reference for O&M operators developing methodologies linked to "Industry 4.0" to assess the failure rate in the field and the relevant economic impact.

Enel is involved in R&D activities especially in its *Innovation Hub* located in Catania (Sicily), where research and innovation in the PV and RES sectors are being stimulated through a technology campus and an accelerator for startups.

INDUSTRY AND MARKET DEVELOPMENT

The production of photovoltaic modules in Italy during 2018 has been still characterized by a limited quantity, even if several manufactures have been producing new modules, which already reached a relevant quality and efficiency values.

An important industrial initiative is represented by 3SUN, formerly a company controlled by ENEL, which in April 2018 has become a unit of ENEL Green Power Group. Located in Catania, 3SUN continues to be the main Italian PV factory and one of the biggest in Europe. In 2018, 3SUN started the installation of new manufacturing lines based on innovative silicon heterojunction technology by converting its production lines from the double junction silicon thin-film modules, with annual capacity of 200 MW/y. Today it has almost completed the conversion process and has started to produce bifacial modules with glass-glass structure (Fig.3). The first phase of the project started in 2018 and consisted in implementing a module assembly line, with nominal capacity of 80 MW/year, by manufacturing bifacial modules, using bifacial PV cells purchased from external suppliers. This was a learning phase thought to better develop 2m² area bifacial modules with glass-glass and frameless structures, before expanding to bigger volumes of manufacturing of complex bifacial HJT cells. The manufacturing of such bifacial modules, having a conversion efficiency of about 18 % and a bifacial factor of 90 %, started in July 2018 and is ongoing. Subsequently, in June 2019, the lines will be switched to HJT bifacial cell and modules manufacturing with a nominal capacity of more than 200 MWp/year. The HJT modules will have an efficiency of 20 % with a very high bifacial factor, which will allow to achieve lower levelized costs of energy due to additional energy generation with respect to mainstream technologies, because of high bifacial behaviour and very good thermal stability.



Fig. 3 – EGP PV module factory: Cell stringing phase of module assembly line (started on Jul 2018) and HJT cell lines (will be completed on June 2019).

In the inverter sector, the Italian manufacturers confirmed their wide production and their ability to remain among the leading manufacturers around the world. Moreover, new initiatives on energy storage have been implemented and many installations happened in small PV plants connected to the grid.

Italian EPC contractors and system integrators have been involved in PV installations in Europe and in emerging market areas of South and Central America, South Africa and India. Among them, the biggest company is Enel Green Power, which is active especially in the field of utility scale plants. Other module manufactures have been able to join



Fig. 4 – 1 MW PV plant on the BAXI roofs in Bassano del Grappa, which uses monocrystalline FU270P modules (Photo: FuturaSun).

the improvement on module production with the installations of large PV plants. This is the case of FuturaSun which has filed the patent for an innovative Italian technology for the automatic stringing of 12 busbars cells (that triples the factory production capacity) and has installed in Italy about 50 MW PV plants in grid parity (Fig. 4) and others in foreign countries (i.e. Germany and Brazil).

Moreover, several Italian PV operators are focused on large size plant management and maintenance services in Italy. Generally, they aim at optimizing performances and reducing costs through integrating management, control and maintenance of big ground plants into single platforms.

In the field of concentrating photovoltaic (CPV), some Italian operators are active (Solergy, Beghelli Bechar and SUNGEN), with prototypes developed in EU funded projects, and are implementing systems both mirror and lens based, passively or actively cooled.

FUTURE OUTLOOK

The National Energy Strategy (SEN) is one of the main instrument of general programming and address of the Italian energy policy. In addition, more recently, the above mentioned PNIEC, presented to EU for evaluation, has raised the target of energy production from renewables from 28 % (SEN target) to 30 % by 2030. In consideration of these targets, the PV electricity production should reach a value of 75 TWh, more than three times the current value. To this aim, Italy needs to encourage the growth of PV in order to reach a value of about 50 GW of total installed power; that is an installation rate of about 2,5 GW per year (2019-2030), more than six times the current annual installation rate. Concrete actions to favour a development of PV market towards the aforementioned objectives are foreseen by the Decree for Renewable Sources (Decreto FER1), prepared and completed in 2018 but not yet formally issued.

The Decree puts in place incentives for:

- energy self-consumption;
- roof PV plants replacing asbestos roofing;
- PV plants for recharging stations of E-cars;
- PV plants realized in disused landfills;
- PV plants realized in remediated sites of national interest (SIN).

The incentives are focused on plant size above 20 kW, since the tax break for smaller plants is still in place. Below 1 MW the access to the incentives is allowed through a register inscription after public selection. Size above 1MW must participate in auction procedures.

For both categories, incentives are allowed also for repowering and revamping. Moreover, the possibility is provided that several plants will aggregate into a group to compete with the total power for the allocation of incentives.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

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

OSAMU IKKI, RTS CORPORATION



Fig. 1 - Road Surface PV System (Seven-Eleven Chiyoda Nibancho Store) (Chiyoda Ward, Tokyo). About 10,000 kWh/year for the installation of 100 m².

GENERAL FRAMEWORK

The Japanese government reviewed the Fourth Strategic Energy Plan, which was formulated in 2014 as the national energy policy, and the Fifth Strategic Energy Plan was approved by the Cabinet in July 2018. The Fifth Strategic Energy Plan focuses on ensuring realization of the 2030 energy mix and clearly states that it would position renewable energy as a mainstream power source, for the first time in the history of energy policy. Furthermore, the challenge toward energy transition and decarbonization, looking ahead to 2050, is described as the direction of Japan's long-term energy policy.

Following the formulation of the Fifth Strategic Energy Plan, the Ministry of Economy, Trade and Industry (METI) started to develop new rules, policy measures and guidelines toward making renewable energy a mainstream power source from the viewpoint of power generation cost and business environment, and toward establishing the next-generation network to support the large-volume introduction of renewable energy from the viewpoint of grid interconnection and dispatching ability. Specifically, improvement of the environment toward the large-volume introduction of renewable energy has been accelerated and strengthened by promoting acceleration of cost reduction and independence from the Feed-in Tariff (FIT) program, securement of long-term stable business operation, co-existence with community, implementation of the Japanese version Connect and Manage, reform of network costs, thorough disclosure of information, strengthening of industrial competitiveness and responses to FIT-approved projects which have not started operation.

The Ministry of the Environment (MoE) formulated the Program to promote the acceleration and maximization of renewable energy, and is making efforts to maximize dissemination of renewable energy with the leadership of companies and local governments, by promoting a combination of renewable energy, energy conservation and energy storage as a base.

Regarding the approved and the commissioned capacities of PV systems under the FIT program which took effect in July 2012, a total of 71,2 GWAC (as of the end of June 2018, including cancelled and revoked projects) of PV systems have been approved, of which

40,4 GWAC started operation. Japan's annual PV installed capacity in 2018 is estimated to be 7 GWDC, and its cumulative PV installed capacity is expected to reach the 56 GWDC level.

NATIONAL PROGRAM

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

METI is taking initiative in introducing PV systems under the FIT program. In FY 2018, the FIT levels for PV systems were set lower than those of the previous fiscal year. The tariff for PV systems with a capacity of 10 kW or more was set at 18 JPY/kWh (excl. tax) for the period of 20 years. For PV systems with a capacity of below 10 kW, the tariffs were set as follows, for the period of 10 years: 1) 28 JPY/kWh for FY 2018 (26 JPY/kWh for PV systems which are not required to be equipped with devices to respond to output curtailment) and 2) 26 JPY/kWh for FY 2019 (24 JPY/kWh for PV systems which are not required to be equipped with devices to respond to output curtailment). While the tariffs are planned to be set on a mid- to long-term basis, the tariff for FY 2020 has not been decided yet and it will be decided at an appropriate timing in the future. In the period from July 2012 when the FIT program started to the end of June 2018, total capacities of approved PV systems with a capacity of below 10 kW, between 10 kW and below 1 MW and 1 MW and more are 5,8 GWAC, 29,0 GWAC and 36,4 GWAC, respectively, amounting to 71,2 GWAC in total.

METI revised the Renewable Energy Act and enforced it from April 2017. Major points of the revision are transition of approval scheme from facility approval to PV project business plan approval, which examines business plans of PV projects, and the introduction of a tender scheme for PV systems with a capacity of 2 MWAC or more. In December 2018, METI decided new measures to address FIT-approved PV projects with a capacity of 10 kWAC or more which have not started operation, in order to curb the financial burden of the nation. METI will take measures such as the application of appropriate purchase price depending on the timing of start of operation, as well as setting a deadline for starting operation.

The total approved capacity as of the end of June 2018 decreased by more than 10 GWAC from 84,5 GWAC as of the end of March 2017, because the approval of PV projects for which connection contracts with electric utilities were not signed was cancelled, following the start of the new FIT scheme in April 2017. Mainly among large-scale PV projects, it takes time for many PV projects to start operation after they have obtained approval due to the issues of development permission and grid connection. Only 40,4 GWAC of FIT-approved PV systems started operation, of which approximately 2,6 GWAC started operation between January and June 2018, an 18,3 % decrease year on year. METI's data on commissioned capacity as of the end of June 2018 are the latest data available (as of January 25, 2019).

In and after April 2017, information on approval of a PV project business plan for PV systems with a capacity of 20 kW or more has been released. Although it takes time for examination, approval has steadily made progress. As of October 31, 2018, the capacity of approval of PV project business plan for PV systems with a capacity of 20 kW or more reached about 350 000 projects totaling 54,7 GWAC, including commissioned projects.

As for the tender scheme, the second and the third tenders were held for PV projects with a capacity of 2 MWAC or more. Similar to the first tender, the purchase price was decided by the pay-as-bid scheme, under which the bidding price is set as the purchase price. The tender target capacity for the second tender was 250 MWAC and the ceiling price was not disclosed. 19 PV projects totaling 393 MWAC applied for participating in the tender, of which 15 projects (334 MWAC) were qualified. However, out of the 15 projects, 9 projects (197 MWAC) actually participated in the tender. According to the tender results released, there was no bid winner, since all the bids exceeded the ceiling price of 15,5 JPY/kWh. Following the first tender, the bidding capacity fell below the tender capacity for two tenders in a row. The tender target capacity for the third tender was 197 MWAC and the ceiling price was not disclosed. 38 projects totaling 761 MWAC applied for participation, of which 32 projects (637 MWAC) were qualified, and 16 projects (307 MWAC) actually participated in the tender. 13 projects out of the 16 projects bid with the price below the ceiling price of 15,5 JPY/kWh, and 7 projects with the lowest bid prices, totaling up to the tender target capacity, won the bid. The highest bid was 15,45 JPY/kWh, and the project with the bid price same as the ceiling price lost the bidding. The lowest bid was 14,25 JPY/kWh and the weighted average winning bid was 15,17 JPY/kWh, which confirmed the effects of cost reduction through the introduction of the tender scheme. The Fifth Strategic Energy Plan, which was approved by the Cabinet in July 2018, showed the direction of making renewable energy a mainstream power source toward 2030, and the key issue is to accelerate further cost reduction.

Following the increase in installations of naturally variable renewable power sources such as PV and wind power generation systems, output curtailment was conducted on the dates and the hours when the power generation amount was forecasted to exceed the demand. In the mainland Kyushu region, the first output curtailment was

conducted on a weekend in the autumn, when the electricity demand decreased. The output curtailment was conducted 8 times in total in October and November 2018. Before that, Kyushu Electric reported at a METI council meeting on how they inform power producers of the output curtailment and the implementation procedures. In remote islands with isolated electric grids, output curtailment was conducted, similar to the previous year. It has been indicated that output curtailment is likely to be conducted in the future in the electric grids of the Shikoku region, etc. In case output curtailment is conducted, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) verifies it following the guidelines and the results of the verification are released.

In order to actualize the environmental value of renewable energy and the like, the non-fossil value trading market was established and the first tender was conducted in May 2018. Non-fossil certificates equivalent to FIT electricity generated between April and December 2017 are subject to the tender. 26 companies purchased the non-fossil certificates with a total contracted electricity amount of approximately 5,16 GWh. The weighted average price of the contracted amount was 1,30 JPY/kWh, which is the lowest bid price, and the income through the tender amounted to around 6,7 MJPY. The revenues gained through the trading of non-fossil certificates of FIT electricity will be used for reducing the financial burden of the nation. The non-fossil certificates bidden by and awarded to electricity retailers can be used for achieving the target of the Act on the Promotion of the Use of Nonfossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers and the Act on Promotion of Global Warming Countermeasures (ratio of non-fossil power source in 2030: 44 %, equivalent to 0,37 kg-CO₂/kWh), as well as for appealing to customers. In addition, considerations are underway to utilize non-fossil certificates for RE 100 and other corporate initiatives on the procurement of renewable energy-based electricity. The scheme regarding trading of non-FIT and non-fossil certificates has been designed for residential PV systems, for which surplus power has been purchased under the FIT program since November 2009 and the purchase period will expire from November 2019 onwards.

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

METI's budget related to resources and energy focuses on three pillars as follows: 1) Accelerated reconstruction of Fukushima Prefecture; 2) Low carbonization of energy utilization and 3) Enhancement of energy security. The amounts of budget regarding technology development and installation support of PV systems and related fields vary largely. There was only one new project, the "Project to develop technology to reduce amount of output curtailment of renewable energy," for which 4,6 BJPY including the FY 2017 supplementary budget was allocated. Among the major projects related to technology development and demonstration, 5,4 BJPY was allocated to the "Technology development project to reduce levelized cost of energy of PV power generation," 5,78 BJPY for the "R&D project to develop technology to address output fluctuations of electric grids," 4,1 BJPY for the "Demonstration projects to establish virtual power plants using consumer-side energy



Fig. 2 – Large-scale PV systems on farmland (Gotemba PV Power Plant No. 1 & No. 2) (Gotemba City, Shizuoka Prefecture). "SPLITMAX" PV modules using half-cut cells (by Trina Solar) (335 W).

resources," and 8,93 BJPY for the "Demonstration projects to establish supply chain of hydrogen derived from unused energy." As for support of dissemination, 7,0 BJPY was appropriated for "Projects to promote local production and local consumption of energy taking advantage of local characteristics" and 7,5 BJPY for "Projects to support promotion of renewable energy introduction in Fukushima Prefecture."

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

The **Ministry of the Environment (MoE)** appropriated 8,5 BJPY for a new project, the "Project to promote low-carbonization of houses by establishing net zero energy houses (ZEHs), etc. (in partnership with METI/ partly MLIT)." For this project, 7 799 applications were made in FY 2018, of which 7 100 applications were selected. Other new projects include the "Project to establish a stand-alone/ distributed energy system utilizing hydrogen" (1,0 BJPY), the "Project to establish information for environment-friendly introduction of renewable energy" (0,8 BJPY), the "Project to promote low-carbonization by utilizing green bonds and funds in communities" (0,95 BJPY), and the "FS project on low-carbon and resource-cycling 'creation of towns and living'" (0,2 BJPY). MoE decreased the budget amount for the "Project to promote self-sustainable dissemination of renewable energy-based electricity and thermal energy" from 8,0 BJPY to 5,4 BJPY. This project received 342 applications in FY 2018, of which 86 applications were made by local and public organizations. 166 projects were selected, and PV systems, etc., for self-consumption or local production for local consumption of electricity were introduced.

The **Ministry of Land, Infrastructure, Transport and Tourism (MLIT)** obliges the buildings to conform to the energy conservation standards, in response to the "Act on Improvement of Energy Consumption Performance of Buildings", the "Revised Act Concerning

the Rational Use of Energy (Energy Saving Act)" and so on. As a budget item to realize these efforts, the budget was continuously allocated to the "Green housing in local community" (11,5 BJPY), etc. Moreover, 9,148 BJPY was allocated for the "Enhancement of disaster prevention functions of governmental facilities which serve as disaster prevention bases," some amount (exact amount is unknown) 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. In order to secure safety of maritime transportation routes in case of disaster, the budget amount for "Disaster prevention measures for aids to navigation" was increased from 5,08 BJPY in FY 2017 to 8,33 BJPY in FY 2018.

The **Ministry of Agriculture, Forestry and Fisheries (MAFF)** is continuously implementing a subsidy program to support introduction of PV systems in facilities for agriculture, forestry and fisheries, in order to promote introduction of renewable energy to these industries. With the budget (included in 1,8 BJPY) for the "Introduction and utilization of renewable energy," MAFF is supporting efforts, etc. to utilize the advantages of the renewable energy projects for the development of regional agriculture, forestry and fisheries.

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 facilities. MEXT has been continuously committed to the "Realization of clean and economical energy system," which aims to promote R&D to overcome energy and global environmental issues. MEXT increased the budget for the "Project to create future society (promotion of high risk and high impact R&D)," which is designed to promote R&D on innovative energy technology from 0,4 BJPY to 0,68 BJPY.

Among **local authorities**, applications were invited for subsidy programs to support the introduction of residential PV systems and storage batteries, etc. Through partnerships with private enterprises, activities to promote local production and local consumption of electricity have been expanding further. Toward making renewable energy a mainstream power source, co-existence with community and long-term stable operation have become significant subjects, which has led to promoting the formulation of ordinances and guidelines for appropriate installation of PV systems. In addition, for sharing information among government ministries and agencies as well as municipalities, the "Liaison committee regarding sustainable introduction of renewable energy in local communities" was newly established.

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 five-year project on the "Development of high performance and reliable PV modules to reduce leveled cost of energy (FY 2015 to FY 2019)," which is designed to develop mainly PV device technology and technology to evaluate system reliability, aiming to reduce the cost of PV power generation. As accomplishments of this project, Toshiba developed the world's largest film-type perovskite PV module in 2018. Also, in order to strengthen R&D for commercialization of high-efficiency crystalline silicon (c-Si) PV cells and modules, projects by Panasonic and Kaneka were consigned to work on new development subjects, a device development project by Panasonic and a demonstration project on small-scale mass production by Kaneka. Furthermore, NEDO released its "Solar spectral irradiance database" with newly expanded functions. It is anticipated that this database will be utilized for high-accuracy evaluation of power generation amount as well as R&D on high-efficiency next-generation PV technology. Under the "Technological development project for improvement of PV system efficiency and operation and maintenance (O&M) (FY 2014 to FY 2018)," development of technology to increase the output of wall-mounted PV systems and technology to evaluate architectural functions of such systems by Kaneka was newly selected, to realize net zero energy building (ZEB). NEDO also conducts the "Development of Solar Power Recycling Technology" project (FY 2014 to FY 2018) and is promoting discussions on dissemination of PV power generation in the transport sector. In 2018, NEDO released an interim report and started activities within the framework of IEA PVPS Task 17 "PV and Transport." NEDO also conducts the "Project to support technology innovation of new and renewable energy by venture capital firms (from FY 2007)." In FY 2018, research themes on the next-generation power transmission and distribution technologies such as IoT systems and AC/DC conversion systems were selected as new research subjects on PV power generation.

JST supports research activities mainly through universities and research institutes. Under the "Advanced Low Carbon Technology Research and Development Program (ALCA)" of the "Strategic Creation Research Promotion Program", development on PV-related technology is continued, focusing on high quality silicon quantum dot PV, organic thin-film PV (OPV) and perovskite PV technologies. Under the ALCA project, R&D on the next-generation storage batteries is also underway as a specially-prioritized technology field. In the "Future Society Creation Project" which started in FY 2017, R&D on Pb-free perovskite PV and ultra-thin type c-Si triple junction PV has been promoted, with the aim of "Realizing low-carbon society with 'game-changing technology.'" Under this project, in 2018, development of low-cost grid system toward large-volume introduction of renewable energy-based power sources was selected, for the purpose of "realizing ultra-smart society." Furthermore, under the "Project to deploy R&D accomplishments," development of the next-generation PV technology using organic materials and new semiconductor materials, as well as development of high-performance wavelength conversion materials for solar cells, etc. has been supported. In 2018, development of ultra-flexible OPV was selected as a new subject of the public-private joint research.

Demonstration

Demonstration research is mainly promoted by NEDO. Under the "Technological development project for improvement of system efficiency and operation and maintenance (O&M) (FY 2014 to FY 2018)," NEDO conducts demonstration tests of building material-integrated PV modules, low-cost mounting structures most appropriate for long-life PV modules, as well as the next-generation long-life and high-efficiency inverters which have the design lifespan equivalent to 30 years. Aiming to increase safety and economic efficiency in addressing natural disasters and aging degradation, development and demonstration to assure safety of PV power generation facilities through snow load test, experiment on wind pressure resistance as well as a sink test are conducted. As to the accomplishments of these activities, NEDO formulated and released the PV system design guidelines in 2018.

Demonstration activities on technologies for utilization of PV system are conducted by METI and NEDO. These activities are conducted mainly overseas as part of the demonstration projects to improve storage technology and grid technology for dissemination of renewable energy, as well as technology to optimize electricity consumption (automated demand response (ADR), ICT technology), instead of working on PV technology alone. Under the "International demonstration project on technology and system to improve efficiency of energy consumption," NEDO continued a technology demonstration project on the use of large-scale PV system in an industrial complex and a green hospital demonstration project at a medical facility with the introduction of ICT and PV system in India in 2018. In addition, NEDO conducted a demonstration project on the power transmission and distribution operation of storage batteries designed to deal with surplus electricity from renewable energy, etc., in the USA and Germany, as well as a technology demonstration of ADR and energy



Fig. 3 – Ground-mounted PV System (Setouchi Kirei PV Power Plant) (Setouchi City, Okayama Prefecture). Approximately 235 MW multicrystalline silicon PV modules "TSM-260PC05A" (by Trina Solar) and PV modules (by Yingli Green Energy).

management technologies in Portugal, Slovenia, Poland and China, in order to expand introduction of renewable energy and promote energy conservation.

NEDO has also conducted a demonstration project on technology to address global warming since FY 2011 under the Joint Crediting Mechanism (JCM). In FY 2018, with the initiative of the private sector, a demonstration project including PV power generation was conducted in Indonesia. Under the JCM, an investigation on formation of demonstration projects was also conducted. In FY 2018, a feasibility study on the project to promote dissemination of desalination system using PV power generation was selected.

Furthermore, in Japan, demonstration projects on large-capacity storage battery systems are being 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. Supported by METI, a demonstration project on the establishment of virtual power plant (VPP) is also conducted in the form of a large-scale consortium. METI and MoE also conduct a demonstration project on ZEB and PV technologies which have been adopted for a large number of energy creation facilities. Discussion on the use of block chain technology has also started. MoE started a demonstration project to trade the portion of CO₂ emissions reduction by households through introduction of PV systems, etc. Electric utilities and energy service providers started discussion on the development of electricity trading service by using block chain technology and plans of demonstration tests were announced. Tokyo Electric Power Company (TEPCO) conducted a demonstration test on the "service to keep surplus PV electricity," in order to address the 2019 issue (in 2019 onwards, the FIT surplus power purchase period of residential PV systems will expire). NEDO started construction of the world's largest-scale hydrogen-based energy system using renewable energy in Fukushima Prefecture.

INDUSTRY STATUS AND MARKET DEVELOPMENT

In the PV cell/ module and PV system business in Japan, the presence of overseas manufacturers has been rapidly increasing. While the Japanese PV market itself is gradually shrinking, there are many cases where low-priced non-Japanese PV products are selected for both industrial and residential PV applications. Overseas PV manufacturers are strengthening their activities in Japan by expanding their local sales offices. A large number of manufacturers launched new products such as sc-Si PERC solar cells and new wiring technologies. Major Japanese manufacturers are proposing new products such as storage

batteries, high output PV cells and modules as well as building material integrated products, focusing on residential PV systems for self-consumption, while utilizing OEM products from abroad.

Following the deceleration of the domestic PV market, Japanese manufacturers are promoting business restructuring, through integration of their production bases, as well as selection and concentration of products for sale. Furthermore, they intend to shift their business models from the conventional business of selling PV cells and modules to offering proposals for installation including self-consumption type PPA models and O&M services, electricity trading and acceleration of overseas business development and so on.

In the area of PV inverters, new products have been launched one after another. Among large-capacity products, new products were released, with features such as high output, outdoor use, compact models, self-consumption and distributed type inverters, as well as those for low voltage and ground installations. For residential applications, new products such as hybrid storage systems were launched. Full-scale entries into overseas markets have started, and announcements were made on a plan to expand overseas sales activities, mainly in Southeast Asia. Tabuchi Electric, through Business Revitalization ADR (Alternative Dispute Resolution) procedures, is advancing its business reconstruction with the support of Diamond Electric.

In the area of mounting structures, float systems for floating PV systems and products for solar sharing (PV system installation on farmland while continuing agricultural activities) using greenhouses were released.

In the housing industry, companies, mainly homebuilders, are actively launching packaged products for net zero energy houses (ZEH). Proposals by companies affiliated with electric utilities and those dealing with housing facilities on PV system installation models with no initial cost are rapidly increasing. Among ZEH-related products, Sekisui Chemical and Misawa Homes sell ZEH as apartments for rent. Some manufacturers are proposing ZEH in combination with storage systems. As such, competitions are intensifying. In addition, Panasonic and Sekisui Chemical are developing a large-scale smart town, which will be equipped with a whole range of smart products. Efforts on the "Zero Yen PV installation model", under which PV systems are installed with no initial cost at consumers' sites and generated electricity is supplied to the consumers, were announced by several companies such as LIXIL TEPCO Smart Partners, TEPCO HomeTech, YKK AP/Huis

Ten Bosch/TEPCO HomeTech, NTT Smile Energy/Denka Shinki, Okinawa Co-op Energy, Home Equipment Assist/Shikoku Electric Power/STNet, TEPCO HomeTech/Solar Frontier, and CANAME. Installation models using lease programs by Looop and other companies are also on the rise.

In the area of electricity storage, demonstration projects are increasing, in addition to the launch of new products for PV systems. Announcements were made by manufacturers on the development and the releases of electricity storage systems with improved performances and safety for various applications such as residential, medium- and large-scale applications, those for VPP and those integrated with EV charging stations. Hybrid systems of storage batteries and inverters are also increasing and entries into overseas markets have started. As to demonstration projects, there were quite a few cases where manufacturers and trading companies introduced storage systems overseas for local production and local consumption of electricity through partnerships with local entities. In Japan, ELIY Power started a demonstration test to establish a large-scale VPP, in partnership with nine Japanese companies.

In the area of PV power generation business, construction and operation of a number of PV power plants are starting one after another, mainly large-scale PV power plants taking advantage of the FIT program. An approximately 235-MW PV power plant, one of the largest PV power plants in Japan, developed by Setouchi Future Creations LLC and Kuni Umi Asset Management started operation in Setouchi City, Okayama Prefecture. Furthermore, an increasing number of MW-scale floating PV power plants and those for solar sharing, as well as PV-wind hybrid systems started operation. Overseas project development has been promoted in full scale, and announcements were made on the projects in Vietnam (JGC, Sharp, etc.), Indonesia (Fujisaki Electric, etc.), Taiwan (Kyuden Mirai Energy, etc.), Saudi Arabia (SoftBank, etc.) and so on. Development of PV power plants without taking advantage of the FIT program has also been observed. In order to expand its supply capabilities, NTT Facilities started soliciting candidates for its development partner.

In the area of the PV power generation business support service, a variety of menus are being proposed following the expansion of PV installations. In addition to the activities to enhance remote monitoring services including remote monitoring of inverters, proposals on the service to forecast power generation amounts and electricity demands are advancing. Toward improving efficiency of inspection work on MW-scale PV power plants, automatic inspection and analysis services for PV systems using drones are increasing, while three-dimensional survey service for PV installations has emerged. Other announcements include the establishment of a mass production framework of PV module cleaning robots, packaged service of maintenance and power sales compensation of low-voltage PV systems and so on. In order to strengthen the business of reuse and recycle of PV modules, companies are establishing their bases to collect PV modules across Japan. Regarding the service to support

implementation of solar sharing, a service to match farmers and PV-related business operators was announced. Also, a service to support establishment of VPP has started.

In the area of PPS (power producer and supplier), announcements were made on proactive supply of renewable energy-based electricity taking into account of achieving the global initiative RE 100, as well as services to purchase PV electricity to address the 2019 issue, in addition to proposals for new entries and new menus. As for new entries, while major electric utilities are entering the PPS business through the establishment of venture businesses, entries by regional PPS in partnership with municipalities have continued. Investment in emerging companies by major businesses and their partnerships is also advancing, which is leading to establishing an infrastructure to trade renewable energy-based electricity, business for local production and local consumption of electricity in rural areas, and the P2P trading business among individuals. For the supply of renewable energy-based electricity, announcements were made on the combination of FIT electricity and green electricity certificates, utilization of non-fossil value certificates and J-Credits, as well as menus of supplying electricity with zero CO₂ emissions coefficient. Electricity trading with block chain technology is also making progress.

In preparation for the termination of the FIT surplus power purchase period of residential PV systems, major electric utilities and gas companies have already announced that they will purchase the surplus power, while PPS, who are leading this business field, as well as major PV system manufacturers also made announcements on their plans to purchase surplus power. Some companies disclosed their purchase prices. For example, Smart Tech announced that they will purchase PV electricity for 10 JPY/kWh as a limited time offer, up by 2 JPY/kWh from the regular price of 8 JPY/kWh.

As for the finance-related business, supply of funds for large-scale newly-built PV power plants both home and abroad as well as compound renewable energy systems is growing in particular. Financing options for users are increasing, including green bonds, infrastructure funds, syndicate loans, crowdfunding and loans for solar sharing. Operation of power generation facilities by lease companies is gaining momentum. An increasing number of companies are joining RE100 and providing information to ESG investment.

REPUBLIC OF KOREA

TECHNOLOGY STATUS AND PROSPECTS

DONGGUN LIM, KOREA NATIONAL UNIVERSITY OF TRANSPORTATION



Fig. 1 – Roof mounted PV system at National Museum of Korean Contemporary History, Seoul, Korea.

GENERAL FRAMEWORK AND IMPLEMENTATION

The Korean government announced the "Implementation Plan for Renewable Energy 3020" on 20 December 2017, which aims to increase the proportion of renewable energy generation from 7 % to 20 % by 2030. Its goal is to establish 63,8 GW of renewable source capacity by 2030. Currently, renewables can generate 15,1 GW. About 63 % of the new facilities will be in solar power and 34 % in wind. According to the plan, the Korean government will invest 110 trillion KRW (Korean Won, 1 100 KRW/USD) over the next decade to expand renewable energy infrastructure to ensure stable power supply instead of nuclear and coal-fired power generators.

The Korean government set the "8th Basic Plan for Long-term Electricity Supply and Demand" in 2017 that is based on an estimated forecast for power generation over the next 15 years until 2031. Under the new energy roadmap, natural gas and renewable energy sources will have a greater share in the generation mix in terms of installed capacity. Renewable energy would account for 33,7 % of the installed capacity in 2030 compared with the current 9,7 %.

The Korean government announced the modified version of GHG (Greenhouse Gas) reduction roadmap on 24 July 2018. The INDC (Intended Nationally Determined Contribution) target of Korea is 37 % reduction of GHG for the period of 2018~2030 on the BAU (Business As Usual) basis. Since the BAU-based GHG emission in Korea is estimated to be 850,8 Mton in 2030, the expected emission amount in 2030 after subtracting the reduction target will be 536,0 Mton which is 22,3 % reduced from the 2015 emission amount of 690,2 Mton. The GHG reduction roadmap reflected the "Implementation Plan for Renewable Energy 3020" and the "8th Basic Plan for Long-term Electricity Supply and Demand".

The Korean government announced its vision to create the "world's best renewable energy cluster" in Saemangeum and to spearhead it to the renewable energy industry on 30 October 2018. To create the renewable energy market, it is planned to construct the world's largest 3 GW solar power complex within the Saemangeum area, a GW-class offshore wind power complex in the waters near Gunsan, and offshore wind manufacturing industrial complex by establishing an offshore wind power port in order to promote transportation and attract manufacturing companies.

Since 2012, the Renewable Portfolio Standard (RPS) has been introduced as a main renewable energy program to replace FIT. Thanks to the new RPS scheme (with its PV set-aside requirement), the following has been installed: 295 MW in 2012, 531 MW in 2013, 926 MW in 2014, 1 134 MW in 2015, 909 MW in 2016, 1 362 MW in 2017, and 1 897 MW in 2018, respectively. At the end of 2018, the total installed capacity was 7 429 MW.

NATIONAL PROGRAMME

Korea has been making an effort to increase the renewable energy portion of national energy mix. In the 2nd Energy Master Plan, Korea's renewable energy share of primary energy supply will account for 11 % in 2030. This goal was announced in 2014. That is same as the target of the 1st Energy Master Plan which was announced in 2008. Currently, renewable energy is estimated to account for 5,1 % of total primary energy supply in 2017.

(1) RPS Programme

The RPS is a system that enforces power producers to supply a certain amount of the total power generation by NRE (New and Renewable

Energy). The RPS replaced the FIT Scheme from 2012. In Korea, 21 (in 2018) obligators (electricity utility companies with electricity generation capacity exceeding the 500 MW) are required to supply 10% of their electricity from NRE sources by 2023; up from 2 % in 2012. In 2018, 1 897 MW was installed under this programme. The RPS is expected to be the major driving force for PV installations in the next few years in Korea with improved details such as boosting the small scale installations (less than 100 kW) by adjusting the REC and multipliers, and unifying the PV and non-PV markets. To further enhance the predictability of profit (to attract project financing entities), the Ministry of Trade, Industry and Energy (MOTIE) launched a new long-term (20 years) fixed price (SMP+REC) RPS scheme in 2017. This scheme has an advantage of guaranteeing the long-term power purchase with a fixed price which is determined by the market-following system including competitive bidding. MOTIE also launched 15 of 29 projects in a new REC multiplier scheme, in which there is a maximum 20 % increase in the REC multiplier when community residents are involved in the projects. Grid connection of PV systems is guaranteed up to 1 MW by the Government since 2017. The newly adjusted REC multiplier scheme based on five evaluation criteria (economic feasibility, environmental effect, potential, industry promotion effect, and policy priority) is summarized below.

TABLE 1 – REC MULTIPLIERS IN RPS

MULTIPLIER	ELIGIBLE ENERGY SOURCE	
	Installation Type	Details
1,2	On land	Less than 100 kW
1,0		100 kW ~ 3 000 kW
0,7		More than 3 000 kW
	On forestland	Regardless of capacities
1,5	On building or existing facilities	Less than or equal to 3 000 kW
1,0		More than 3 000 kW
1,5	Floating on the water surface	

(2) Home Subsidy Programme

This programme was launched in 2004 that merged the existing 100 000 Solar-Roof Installation Programme. Although the 100 000 solar-roof deployment project was to install PV system in residential houses, the One Million Green Homes Plan focuses on a variety of resources such as PV, solar thermal, geo-thermal, and small wind. In general, detached and apartment houses can benefit from this programme. The Government provides 60 % of the initial PV system cost for single-family and private multi-family houses, and 100 % for public multi-family rent houses. The maximum PV capacity allowed is 3 kW. In 2018, 78,1 MW was installed under this programme.



Fig. 2. Zero-energy house, Seoul, Korea.

(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. In addition, the government supports maximum 80 % of initial cost for special purpose demonstration and pre-planned systems in order to help the developed technologies and systems to diffuse into the market. Various grid-connected PV systems were installed in schools, public facilities, welfare facilities as well as universities. In 2018, 16,9 MW was installed under this programme.

(4) Regional Deployment Subsidy Programme

In an effort to improve the energy supply & demand condition and to promote the development of regional economies by supplying region-specific PV systems that are friendly to the environment, the government has been promoting the regional deployment subsidy programme designed to support various projects carried out by local government. The government supports up to 50 % of the installation costs for NRE (including PV) systems owned and operated by local authorities. In 2018, 17,9 MW was installed under this programme.

(5) Convergence and Integration Subsidy Programme for NRE

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 2018, 25,6 MW was installed under this programme.

(6) PV Rental Programme

Household owners who use more than 350 kWh of electricity can apply for this programme. Owners pay PV system rental fee (maximum monthly 70 000 KRW which, on the average, is 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 PV rental fees and selling REP (Renewable Energy Point) having no multiplier. In 2018, 21,1 MW was installed under this programme.



Fig. 3 – Gwangjin Bridge, Seoul, Korea.

(7) Public Building Obligation Programme

New buildings of public institutions, of which the floor area exceeds 1 000 square meters, are obliged by law to use more than 21% (in 2017) 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 2018, 68,6 MW was installed under this programme.

R&D, D

The KETEP (Korea Institute of Energy Technology Evaluation and Planning) controls the biggest portion of the MOTIE-led national PV R&D budget and managed a total of 67 BKRW in 2018. The PV R&D budget was about 61 % for c-Si area and about 36 % for next-generation thin film area.

INDUSTRY AND MARKET DEVELOPMENT

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

TABLE 2 – CAPACITY OF PV PRODUCTION CHAIN IN 2018

POLY-SI (TON)	INGOT (MW)	WAFERS (MW)	CELLS (MW)	MODULES (MW)
82 000	3 250	2 000	6 505	8 690

Production of Feedstock and Wafers: OCI achieved its total production capacity of poly-silicon feedstock up to 52 000 tons. Woongjin Energy has reached capacity of ingot of 1 500 MW and wafer of 2 000 MW.

Production of Photovoltaic Cells and Modules:

Hanwha Q Cells has 3 700 MW in both c-Si solar cells and modules. LG Electronics has a capacity of 1 500 MW in both c-Si solar cells and modules. Hyundai Heavy Industry Green Energy has a capacity of 600 MW in both c-Si solar cells and modules. Shinsung E&G has a capacity of 500 MW and 200 MW in the c-Si solar cells and modules, respectively.

The RPS scheme was the main driver for PV installation in 2018, and a remarkable size of 2 057 MW was recorded. At the end of 2018, the total installed PV capacity was about 7 429 MW; among them, the PV installations that were made under RPS scheme accounted for 84,9 % of the total cumulative amount.

MALAYSIA

IR. DR. SANJAYAN VELAUTHAM, CEO, SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY, MALAYSIA

WEI-NEE CHEN, CHIEF CORPORATE OFFICER, SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY, MALAYSIA



Fig. 1 – 30 MW Large-scale solar (LSS) plant by Gading Kencana Development Sdn Bhd in Bidor, Perak.

GENERAL FRAMEWORK AND IMPLEMENTATION

In 2018, PV market growth was driven by the feed-in tariff (FiT), Large Scale Solar (LSS) and Net Energy Metering (NEM) programmes. The FiT and NEM are implemented by Sustainable Energy Development Authority (SEDA) Malaysia and LSS by the Energy Commission (EC) of Malaysia. As at end of 2018, cumulative installed capacity of PV from FiT was 382,9614 MW, LSS 401,488 MW and NEM 9,0073 MW. In 2018, the total new PV capacity added was 397,2975 MW. The main actors involved in the FiT, LSS and NEM are the Ministry of Energy, Science, Technology, Environment and Climate Change, SEDA, the EC, the distribution licensees, PV developers and 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: The FiT scheme began in December 2011 and is funded by a surcharge imposed on electricity bills of 1,6 %. By 2017, available quota for PV under FiT was reduced due to constraint in the Renewable Energy (RE) Fund. As at 31 December 2018, a cumulative installed capacity of 382,9614 MW of PV projects were operational of which the 81,9172 MW was for the individuals, 7,8062 MW was for the community, 292,242 MW was for the non-individual PV projects and 0,996 was for the MySuria project. This translated to 8 862 individuals,

356 communities, 580 non-individuals and 332 Group B40 [1] from MySuria feed-in approval holders. More information on PV quota, FiT rates and operational capacity can be viewed at www.seda.gov.my. In 2018, the new PV capacity added under FiT scheme was 2,9345 MW.

LSS Update: The LSS was implemented in 2016 as an organic progression of the FiT scheme. The cumulative quota awarded under the LSS as aof end of 2017 was 1 207,88 MW_{ac} [2]. of which 250 MW_{ac} was granted directly and awarded under fast track programme while the rest was based on competitive bidding held in two tranches; 400,90 MW in 2016 and 556,98 MW in 2017. As of the end of 2018, the total capacity achieving commercial operation was 401,488 MW. The remaining capacity is expected to achieve commercial operation between 2019 and 2020. In 2018, the new PV capacity added under LSS projects was 387,136 MW.

NEM Update: The NEM has been implemented since November 2016. While the FiT and LSS have faced much success in terms of application submission, the NEM take-up rate has been slow. The key reasons for the low take-up rate are due to low electricity tariff rates (at the point of self-consumption) as the tariffs are still being subsidized and the low prevailing Displaced Cost (at the point of sale to the grid as a result of surplus). A total of 100 MW per year has been allocated from 2016 – 2020, making a total of 500 MW. As at end of 2018, the cumulative total number of applications approved was 468 of which 302 were from domestic, 105 from commercial and 61 from the industrial sector. The cumulative capacity approved was only 23,527 MW of which 2,139 MW was from domestic, 7,615 MW from commercial and 13,773 MW from industrial sector. In order to incentive the take-up rate of the NEM, in October 2018 MESTEC

[1] Malaysians are categorised into three different income groups:

Top 20 % (T20), Middle 40 % (M40), and Bottom 40 % (B40). B40 group has median income of 3 000 MYR per month.

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

announced the enhanced NEM which will allow surplus to the grid to be compensated on a one-to-one basis with the retail rate. This enhanced NEM will commence 1st January 2019. In 2018 alone, the new operational capacity under the NEM was 7,227 MW.

INDUSTRY DEVELOPMENT

On the PV manufacturing front, Malaysia remains a significant PV producer (after China and Taiwan). It was estimated that over 90 % of the PV products were exported to Europe, US and Asia.

In 2018, the total metallurgical grade silicon (MGS) and polysilicon manufacturing nameplate capacity remained at 20 kilotons

with employment of 536. For ingot, wafer, solar cells and PV modules manufacturing, the total estimated nameplate capacity was 14 187,4 MW with employment of 21 404. Figure 2 shows the major PV manufacturing statistics in Malaysia classified under four categories for 2018 and 2019 (estimate): Metallurgical and Poly Silicon, Ingot and Wafer, Solar Cells, and PV Modules.

Within the PV industry, there were 108 PV service providers active in the market in 2018. The list of these registered PV service providers for 2018 can be found in www.seda.gov.my.

METAL SI & POLY SI		2018		2019 (ESTIMATE)	
No.	Company Name	Capacity (kilo ton)	Employment	Capacity (kilo ton)	Employment
1	OCIM Sdn Bhd (Poly-Si)	20	536	27	558
	Total	20	536	27	558
INGOT/WAFER		2018		2019 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
1	LONGi (Kuching) Sdn Bhd (ingot)	1 100	212	500	212
2	LONGi (Kuching) Sdn Bhd (wafer, P-type mono)	1 000	175	1 000	175
	Total	2 100	387	1 500	387
CELL		2018		2019 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
1	SunPower (N-type Mono-Si)	760	1 590	820,9	1 593
2	Hanwha Q-Cells (P-type Multi-Si)	1 800	2 000	2 000	2 000
3	Hanwha Q CELLS (P-type Mono-Si)	N/A	N/A	2 000	2 000
4	Jinko Solar (Multi-Si)	2 200	2 416	3 400	2 461
5	LONGi (Kuching) Sdn Bhd	800	608	880	600
6	LONGi Technology (Kuching) Sdn Bhd (established since 29 Aug 2018)	0	0	1 200	810
7	JA Solar (Multi-Si)	1 100	1 500	1 200	1 550
	Total	6 660,4	8 114	11 500,9	11 014
MODULE		2018		2019 (ESTIMATE)	
No.	Company Name	Capacity (MW)	Employment	Capacity (MW)	Employment
1	First Solar (CdTe thin film)	2 227	3 300	2 989	3 300
2	Flextronics (OEM for crystalline)	450	3 813	200	3 763
3	Panasonic (HIT N-type mono crystalline)	450	862	550	901
4	LONGi (Kuching) Sdn Bhd	900	782	900	782
5	Jinko Solar (Multi-crystalline)	1 400	4 146	2 400	3 518
	Total	5 427	12 903	7 039	12 264

Fig. 2 - Major PV Manufacturing Statistics in Malaysia.

MOROCCO

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

BADR IKKEN, GENERAL MANAGER, IRESEN

AHMED BENLARABI, RESPONSIBLE FOR PV SYSTEMS, IRESEN

GENERAL FRAMEWORK AND IMPLEMENTATION

The energy sector in Morocco is marked by the sustained increase in energy demand and strong energy dependence from the outside, with a predominance of petroleum products in the energy balance. Therefore, an energy strategy plan has been set up in 2009, with an initial target of reaching 42 % of installed capacity by 2020 and reaching 52 % by 2030, with a share of solar energy of 14 % [1]. This strategy aims to secure the energy supply, provide it access with reasonable prices, manage its different aspects (production, transport, pricing, etc.), and protect the environment. Yet, with the fast development of different programs, those targets are expected to be exceeded as shown in the figure below, especially since the current share in 2018 has already achieved 39 % [2]. The new repartition of the electrical capacity share planned to be reached by 2020 is as follows:

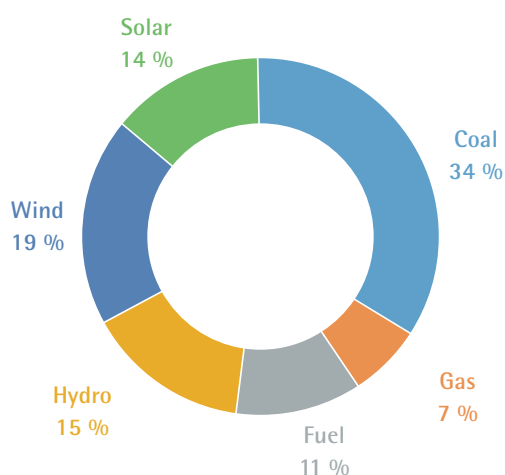


Fig.1 - Planned capacity distribution by 2020 [3].

The energy policy is primarily the responsibility of the Ministry of Energy, Mines and Sustainable Development (MEMSD) and is supported by the following institutions:

- Masen (Moroccan Agency for Sustainable Energy);
- ONEE (Office National de l'Electricité et de l'Eau Potable/ Branche électricité);
- IRESEN (Institut de Recherche en Energie Solaire et Energies Nouvelles);
- AMEE (Agence Marocaine de l'Efficacité Energétique);
- SIE (Société d'Investissements Energétiques).

NATIONAL PROGRAM

Different programs have been launched by the government and are piloted by ONEE and MASEN, expecting to set up an additional capacity of 6 000 MW [4] in terms of renewable energy by 2020. In 2018, the solar capacity installed was 827 MW [5].

TABLE 1 - PV PROGRAMS LAUNCHED IN THE FRAMEWORK OF THE MOROCCAN NATIONAL STRATEGY

PROGRAM	LOCATION	CAPACITY	STATUS
Noor PV I	Lâayoune, Boujdour, Ouarzazate	170 MW	Installed, commissioning phase
Noor PV II	Lâayoune, Boujdour, Taroudant, Kalâat Sraghna, Bejaâd, Guercif, El Hajeb	800 MW	Call for Bids will be launched in 2019
Noor Midelt	20 km North-East to the city of Midelt	CSP/PV = 825 MW PV = 525 MW	Selection of developer, construction starts in 2019
Noor Tafilalt	Erfoud, Missour, Zagora	120 MW	Constructions started in 2018, operation of the plant expected in first quarter of 2019
Noor Atlas	Tata, Tan Tan, Outat El Haj, Ain Beni Mathar, Boudnib, Bouanane, and Enjil	200 MW	Selection of EPC, construction are expected to start in 2019
Noor Argana	Taliouine, Walidia, Alnif, Boulmane, Imintanout, and Rich	200 MW	Call for bid expected to be launched in mid-2019. Operation expected in 2020

The National Authority for Regulation of Electricity (ANRE) has been set up under the aegis of the MEMSD and is composed of different players in the Moroccan energy sector. Its main goal is to optimize the legal and regulation framework for the renewable energy sector, in particular the development of PV power plants [6], by modifying the law 13-09 to allow access for the private developers and different IPPs to the middle voltage grid.

Concerning the transport infrastructures, many intergovernmental negotiations are ongoing to reinforce the existing ones with Spain and Algeria, but also to setup new ones with Mauritania and Portugal. Finally, from a quality check perspective, the label "TaQa Pro" for the qualification of PV plant installers and technicians has been launched

[1] PAREMA, Les énergies renouvelables et l'efficacité énergétique au Maroc, September 2017, GIZ Maroc

[2] <https://www.usinenouvelle.com/article/plan-solaire-2020-du-maroc-39-deja-en-developpement-selon-l-agence-publique-masen.N357893>

[3] PAREMA, Les énergies renouvelables et l'efficacité énergétique au Maroc, September 2017, GIZ Maroc

[4] <https://www.medias24.com/MAROC/Quoi-de-neuf/182319-Solaire-les-premiers-appels-d-offres-du-projet-Noor-PV-II-lances-dans-quelques-mois-Bloombreg.html>

[5] <https://www.medias24.com/MAROC/ECONOMIE/ECONOMIE/180565-Bakkoury-En-2020-nos-objectifs-seront-depasses.html>

[6] Ministry of Energy, Mines, and Sustainable Development

on 4 December 2018, and a certification laboratory for the qualification of PV modules is being accredited and finalized in the Green Energy Park platform.

R&D, DEVELOPMENT [7]

Created in 2011, the Research Institute of Solar Energy and New Energies (IRESEN) is at the heart of the national energy strategy in the Kingdom of Morocco, by its positioning in the fields of applied research and innovation. IRESEN has an ambitious strategy to develop research infrastructure for innovation and researchers, and to create a large network of shared infrastructures dedicated to research. Its Funding Agency works to meet the priorities identified within the framework of the national energy strategy. IRESEN has since 2012, invested 40 MEUR in 56 ongoing R&D projects, and financed 540 researchers and PhD students. It also has setup 12 laboratories across the Kingdom bridging the gap between the academic and the industry world. So far, IRESEN has published more than 60 scientific articles and communication per year since its creation. It also launched in 2018 the first edition of the Green Inno Boost call for project to support start-ups.

IRESEN is also a research institute through the setup of mutualized infrastructures dedicated to R&D. It has therefore set up the Green Energy Platform, unique model of its kind in Africa that allows on the one hand the creation of synergies and the mutualization of infrastructures of several Moroccan research institutions in order to create a critical mass and achieve excellence. Alternatively, it supports the local players in the acquisition of knowledge and know-how by the various partner universities as well as Moroccan industries. Among its activities, the photovoltaic thematic revolves around the following 3 axes:

- Identification of the most suited PV technologies for Moroccan conditions;
- Development of a new generation of PV technologies for extreme climates (deserts);
- Securing of the market through certification and quality check.

IRESEN is also setting up a new platform, the Green and Smart Building Park, dedicated to smart-grids, energy efficiency, and green mobility. Among the different research projects, the integration of renewable technologies in buildings, especially BIPV, and the study of impact of different micro-grid interacting between each other will



Fig. 2 - 2 MW power plant of the Atlantic Industrial Free Zone of Kenitra.

be undertaken. Furthermore, the integration of photovoltaic charging infrastructure for electrical mobility will be carried out. The platform is expected to be operational by the last quarter of 2019.

INDUSTRY AND MARKET DEVELOPMENT

So far, 4 PV module manufacturers have set up their facilities in Morocco as photovoltaic module assembly lines. The biggest production line capacity being held by Almaden Morocco with a 250 MW, the largest production line in North Africa [8]. In 2016, Jet Contractors, with an initial production line capacity of 30 MW, announced the creation of a Joint Venture with Hareon Solar to extend the current production line to 160 MW [9]. Nonetheless, many other leading PV module producers are willing to set up their production line in the Kingdom. Moreover, all other related industries dedicated for the Balance of System (BoS), the solar cabling sector, electrical components (DC breaker, fuses, etc.), PV modules structures, as well as engineering expertise are already well developed.

Concerning the installed capacities in terms of photovoltaic plants, there are many installations already operational and developed by the government such as the pilot PV Plant of Assa-Zag owned by ONEE with a capacity of 800 kW that has started operation in 2014, but also by the private sector such as the 2 MW PV plant of the Atlantic Free Zone in Kenitra. The photovoltaic installation owned by private entities (industries or tertiary sector) are connected in a self-consumption configuration. Additionally, concerning the solar pumping and the off-grid plant, the sector is well developed and assessment studies are currently ongoing to obtain the results and trends of development for these programs.

The following graph shows the importations of PV modules in terms of investment during the period from 1998 up to 2016 [10]:

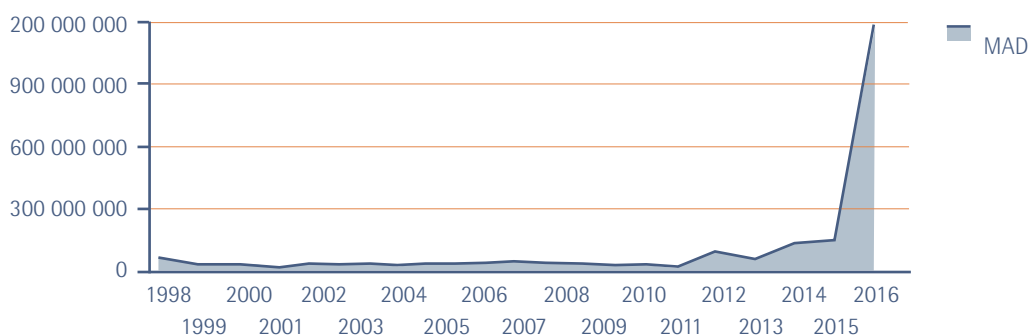


Fig. 3 - Graph of importation of PV modules from 1998 to 2016.

[7] www.iresen.org

[8] <https://renewablesnow.com/news/to-the-point-almaden-morocco-to-commission-250-mw-pv-production-line-629574/>

[9] PV Status Report 2018, JRC Science for Policy Report, 2018

[10] <http://www.douane.gov.ma/adil/>

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS

OTTO BERNSEN & SAQIB BUTT, NETHERLANDS ENTERPRISE AGENCY RVO, ENERGY INNOVATION



Fig. 1 - Renewable Energy in the Netherlands (Photo: RVO Image Database).

GENERAL FRAMEWORK

In 2018 the Dutch PV market continued its growth with an estimated 1 400 MWp installed capacity according to CBS (1st of March 2019). The Netherlands have established themselves over the last few years as one of the fastest growing markets for solar panels in Europe both for rooftop systems and larger ground mounted systems.

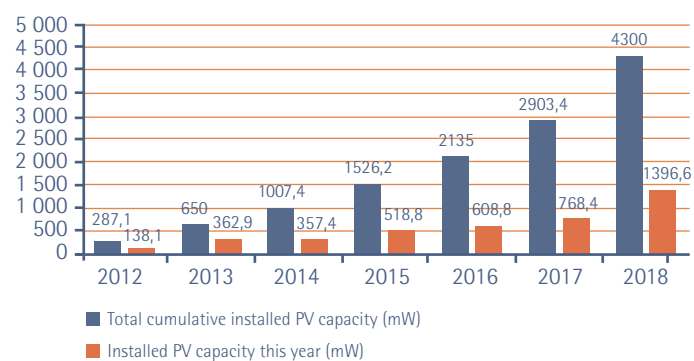
However, given the high population density of the Netherlands the focus has shifted from the market incentives towards the limiting factors for incorporating large amounts of solar energy. These topics being foremost grid integration and the usage of the limited available surface in the Low Countries. The result of this dynamic is a highly innovative market with attention for the integration of solar panels in buildings, the landscape, the infrastructure, the waterways and transportation systems.

Ongoing attention exist for the monitoring of the performance and maintenance of the solar systems to bring down operational costs and investments risks.

The national Climate Goals are set at 16 % renewable energy sources (RES) in 2023 and almost no emissions in 2050. The Netherlands are on target to achieve these goals. In 2018, concrete measures were taken to replace natural gas as the main energy source in the Netherlands and increased electrification will be a major part of this trajectory.

TABLE 1 – INSTALLED CAPACITY MWP/YEAR AND ACCUMULATED IN THE NETHERLANDS

Dutch Installed Capacity mWp/y and Accumulated Capacity



NATIONAL PROGRAMMES

In 2018, the national efforts in renewable energy were redefined in missions with a clear focus for solar and the implementation on land and sea, the integration into the grid and the social acceptability of large amounts of solar panels in the environment. The innovation is led by the Top consortium for Knowledge and Innovation (TKI) for Solar under the flag of Urban Energy (see <http://topsectorenergie.nl/urban-energy/>).

Supporting schemes for the implementation of solar power are varied and complementary. For small rooftop systems, a net metering scheme exists and for larger systems over 15 kWp the SDE+ scheme is available, which is basically a reversed auction system. For collective PV systems, a tax reduction system is in place called the "Postcodezoos", covering members with a similar postal codes. An energy label is mandatory (the EPC) for newly built houses coming onto the market, which stimulates the installation of rooftop PV panels. As of 2020 all new buildings will need to be almost "energy neutral". Several provinces and municipalities offer additional local subsidies for solar panels.

The renewable energy subsidy (HE), with 50 MEUR budget a year, is a generic innovation scheme for all renewable energy sources, including combinations with storage for example, targeting the Dutch Climate goals for 2030 and technologies that save on the SDE+ expenses in future years. The goal is the accelerated introduction of new products to the market in order to reach the national climate goals with lower expenses.

RESEARCH AND DEVELOPMENT ACTIVITIES

In 2018, much as in previous years, a R&D budget of around 7,5 MEUR for solar divided over the two program lines of the TKI Urban energy "solar technologies" and "multifunctional building parts" exists. In addition, there are separate programs for fundamental research (NWO and STW), for renewable energy and technical innovation in general and specific programs for SMEs. The granted R&D project can be found in the publication below. https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/publicaties/Projectcatalogus/Projectcatalogus_UE_projecten_2018.11.30.pdf

Research into solar technologies, production and applications is dispersed in the Netherlands over many universities including Utrecht, Leiden, Amsterdam, Delft, Nijmegen, Groningen, Eindhoven, Twente. More fundamental research is conducted also at the institutes AMOLF in various groups, such as Nanoscale Solar Cells, Photonic Materials and Hybrid Solar Cells; see their website at <http://www.amolf.nl/research/nanoscale-solar-cells/> and DIFFER <https://www.differ.nl/research/solar-fuels>.

INDUSTRY STATUS

The Dutch solar sector is varied and complementary with an established international market position and new start-ups every year. New technologies are developed and introduced and in 2018, the test site for bifacial solar modules which has been completed at the headquarters of Tempres in Vaassen deserves special mention. The site is used to monitor the outdoor performance of bifacial PV module technologies and compare this with their monofacial counterparts. It is a joint effort with Yingli and other partners, and the bifacial modules are expected to improve module performance by over 30 %.

A general introduction into the solar sector can be found on the website of Holland Invest <https://www.hollandtradeandinvest.com/dutch-solutions/clean-energy/the-innovative-power-of-the-dutch-solar-pv-sector>.

DEMONSTRATION PROJECTS

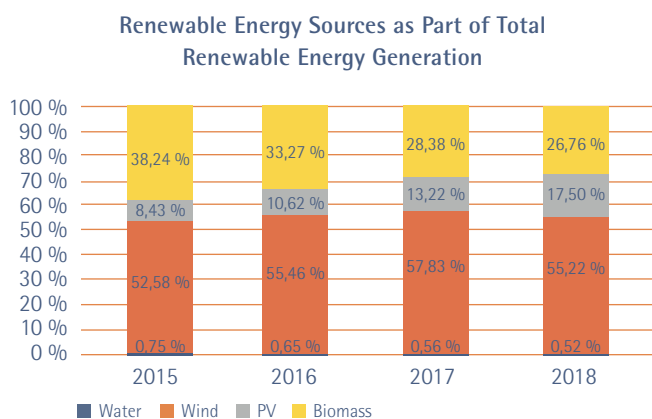
New market segments are being explored notably the integration of solar panels in buildings, infrastructure, including floating, and vehicles. For these specific niche markets, dedicated platforms are formed by industry and the universities together. The latest is the platform for floating solar panels, on the sea, as well as on the river and lakes <https://www.zonopwater.nl/>.

IMPLEMENTATION AND MARKET DEVELOPMENT

The PV market showed sustained growth and a continued acceleration in 2018 with an estimated added amount of 1 400 MWp installed capacity (CBS). The percentage of RES has risen from 14 % to an estimated 15 % in 2018 of total electricity production. The share of PV has risen from 13,22 % to 17,50 % of the total amount of RES (see Table 2).

The expectations for 2019 are that these amounts will still increase and that more social organisations will become involved in the implementations, such as waterships, municipalities and housing cooperatives. At the same time, measures and incentives are being discussed for specific niche markets that have potential to grow, but which are still facing specific barriers.

TABLE 2 – SOLAR POWER AS A % OF TOTAL RES



Source: CBS.

NORWAY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TROND INGE WESTGAARD, THE RESEARCH COUNCIL OF NORWAY



Fig. 1 - This supermarket in Trondheim has a combination of building integrated PV panels in the façade, standard solar panels on the roof, battery storage, and energy wells. The project received support from ENOVA SF due to its innovative combination of energy efficient technologies (Photo: Geir Fikke, Solenergi FUSen AS).



Fig. 2 - Wall of a supermarket in the Oslo area, where the façade is a combination of building integrated PV panels and wood materials. This project also received support from ENOVA SF. In addition to combining energy efficient technologies, this project made extensive use of wood materials in the building design (Photo: Trygve Mongstad, Solenergi FUSen 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. In 2018, hydropower generated 95 % of the total electricity production of 147 TWh, while the gross domestic electricity consumption was 137 TWh. The generation from wind power is increasing from year to year due to increased installed capacity, and it is now 2,6 % of the total electricity generation. The hydropower generator capacity can, under normal circumstances, satisfy peak demand at any time.

Norway and Sweden operate a common electricity certificate market 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 is only relevant for hydropower, wind power, and PV installations on commercial rooftops. To compensate for this, the public agency Enova SF subsidizes up to 35 % of the installation costs for grid connected residential PV systems at a rate of 10 000 NOK per

installation and 1 250 NOK per installed kW maximum capacity up to 15 kW. This programme is now extended to also incorporate leisure homes with grid connection.

Surplus electricity from small, privately operated PV systems can be transferred to the grid at net electricity retail rates (i.e. excluding grid costs, taxes and fees). Small suppliers are exempt from specific grid connection fees that are generally charged from electricity suppliers. Such installations are not allowed to exceed a limit of 100 kW electric power feed-in to the grid.

Enova SF has a programme that supports energy efficiency projects for commercial buildings and residential apartment buildings. This programme has e.g. supported construction of supermarkets that have combined PV panels with other innovative energy saving technologies (Figure 1 & Figure 2).

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 83 MNOK (10 MUSD) for 2018. 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.

Leading national research groups and industrial partners in PV technology participate in the Research Center for Sustainable Solar Cell Technology (<http://www.susoltech.no>), which is funded by RCN and Norwegian industry partners. The research activities are within silicon production, mono- and multi-crystalline silicon ingots and wafers, solar cell and solar panel technology, and use of PV systems in northern European climate conditions. The total center budget is 240 MNOK (31 MUSD) over its duration (2017–2025).

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 two labs – a characterization laboratory and a polysilicon production laboratory, 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: Focus on production and characterization of solar grade silicon.
- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterization.
- 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. 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 Solar Norway (formerly 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, REC Solar Norway produces multicrystalline silicon blocks at Herøya in eastern Norway for the Singapore based company REC Solar Pte. Ltd. and for external customers.

NorSun manufactures high performance monocrystalline silicon ingots and wafers at its plant in Årdal in western Norway. Annual ingot production capacity exceeds the equivalent of 400 MW of solar panel capacity. Most of the ingots are 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 400 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 approximately 600 MW, consisting of power plants in Europe, Africa, Asia and South America. Large projects are under construction in Malaysia, Argentina, South Africa, and Egypt.

IMPLEMENTATION

The Norwegian PV market is small on an international scale. In total, approximately 23 MW of PV capacity was installed in 2018, which resulted in an accumulated PV generation capacity of approximately 68 MW. Reduced installation costs for both commercial and residential rooftop installations are the main market driver.

Installation rates of PV systems depend on how financially attractive such investments are for companies and for home owners. The combination of moderate and very season dependent solar resources in Northern Europe, relatively low electricity prices, and moderate financial support is important in this aspect.

The Norwegian Water Resources and Energy Directorate (NVE) has proposed new rules for grid connection tariffs. This proposal aims at what is claimed to be a fairer distribution of grid costs compared to the existing tariffs. NVE's proposal would have had negative consequences for PV installations where the owner also requires relatively high peak power from the conventional grid. On the other side PV installations that reduce peak power demand will potentially benefit from the new tariffs. The proposal was met with criticism for being unpredictable for consumers, and a review of a proposal with minor revisions takes place in 2019.

PORTUGAL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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ISABEL CABRITA, DGEG (DIRECAO GERAL DE ENERGIA E GEOLOGIA)

JOSE MEDEIROS PINTO, APREN (ASSOCIACAO PORTUGUESA DE ENERGIAS RENOVAVEIS)



Fig. 1 – 4,1 MW CSF MONTES NOVOS PV plant at Estremoz (Photo: Edgar Santos).

GENERAL FRAMEWORK AND IMPLEMENTATION

The Portuguese National Renewable Energy Action Plan 2013/2020 (NREAP) is reaching its end. So, the development of new strategies for renewable policies for the decade 2021/2030 are now being discussed under the umbrella of the Clean Energy Package for All Europeans issued by the European Commission and seeking the climate goal agreed in the 2015 Paris Agreement.

In December 2018, preliminary results of the Portuguese National Carbon Neutrality Roadmap for 2050 (RNC2050) were presented, setting the targets from 2030 to 2050, which underline the government ambition to reach carbon neutrality in 2050, supported by well-defined trajectories for the different economy sectors. In January 2019, the preliminary report of the National Energy and Climate Plan (NECP) was presented that covers the measures and activities for 2030, setting a challenging target of 47 % RES share in final energy consumption.

At the end of 2018, Portugal had an accumulated PV installed capacity of 673 MW. The location of the PV installations is mainly in the south of the country and, since 2014, 11 concentration photovoltaic power plants have been in operation, totalizing a capacity of 14 MW. It should be noted that in recent years and because of the public policies adopted, Portugal maintains PV as one of the priority technologies in terms of its mix of renewable electricity production. Decentralization of production has been strengthened, maintaining the policy in promoting units of Self Production.

Table 1 presents the major targets of NECP 2030 and RNC2050:

TABLE 1 – TARGETS OF DECARBONIZATION UNTIL 2050

	2030	2040	2050
GHGs Reduction (without LULUCF) (% relative to 2005)	-45 % to -55 %	-65 % to -75 %	-85 % to -90 %
Renewable energy sources (RES)	47 %	70 % to 80 %	85 % to 90 %
RES – Electricity	80 %	90 %	100 %
RES – Transports (without aviation and navigation)	20 %	64 % to 69 %	100 %
RES – Heating and Cooling	38 %	58 % to 61 %	69 % to 72 %
Energy Efficiency	35 %	n.d.	n.d.

Source: NECP 2030 and RNC 2050

According to provisional data of the Directorate General of Energy and Geology (DGEG), the increase in installed capacity was in 2018 of 88 MW:

- Self-Production legislation (Decree-Law 153/2014 of 20 October) was responsible for 37 MW, namely Self Production Units (UPAC) with 29 MW, and Small Production Units (UPP), up to 250 kW, with 8 MW;
- New utility scale power plants with a total capacity of 51 MW, with 46 MW coming from a single utility scale PV power plant.

reaching in terms of PV energy produced, 1 017 GWh, which represents 1,7 % of the total electricity production in Portugal.

Solar energy is expected to have an important role in the increase of decentralized power production.

NATIONAL PROGRAMME

The NREAP still in place defines a target of 31 % for renewable energy sources in the final energy consumption by 2020, implying a share of renewable electricity of around 59,6 % in the gross electricity consumption. Portugal is making its final effort for reaching those targets, for which the Solar PV contribution is of paramount relevance. Excepting the self-consumption regime, all licencing for new installations are issued according to Decree-Law DL215-B/2012 and since 2016 the Feed in Tariff regime was suspended and all installations from that time on go through a Market process.

The current regulatory framework for self-consumption regime (Decree-Law DL153/2014 of 20 October) displays efficient rules for small-scale RES generation either UPPs (small scale production units up to 250 kW) with a FiT regime applied to total electricity injected into the grid or UPACs (self-consumption units) that can inject to the grid the surplus of production at 90 % of the wholesale average market price. This regulation has been a great asset for small scale PV development and public awareness.

The electricity scenario of the new NECP 2030 presents an increasing evolution of solar PV capacity, reaching around 8,1 GW to 9,9 GW in 2030, which implies a well-defined strategy to boost the high amount of installed capacity supported by grid reinforcement, both regarding the infrastructural system and smart management.

In the future, concerning the decarbonization of the economy and the targets set for both 2020 and 2030, the promotion of renewable energy sources, namely PV, is one of the purposes of national energy policy. The ambitious targets that have been established, are expected to lead to a significant contribution of RES in final energy consumption by 2030, and solar is expected to play a major role in pursuing those objectives.

R&D, D

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

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

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, Cu₂O, Cu(In,Ga)Se₂ solar cell devices and materials, quantum dot solar cells, thin film Si, encapsulation barrier, and Si-NW solar cells.

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

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

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.

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

University of Lisbon (Instituto Superior Técnico) working on organic cells.

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 the development of conversion technologies, such as perovskites, kesterites (CZTS) and CTS, for tandem cells, on new PV/T modules, on BIPV, and on Prosumers concepts.

DGEG – Directorate-General of Energy and Geology working on modeling the contribution of PV technologies for the national energy system up to 2030, namely supporting the National Energy-Climate Plan (NECP).

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

INDUSTRY AND MARKET DEVELOPMENT

Provisional data for 2018 registered an incorporation rate for renewable energy sources (RES) into the electricity production mix of about 51,7 % (30,8 TWh), within an annual total electricity production of 59,5 TWh. The remaining 48,3 % (28,7 TWh) were produced by fossil fuels.

Solar PV accounted for 1,7 % of the total generation.

March 2018 was a remarkable key point for RES electricity, as its generation registered 103,6 % of the mainland electricity demand for the whole month. This event showed the capability and flexibility of the system to integrate high levels of RES, illustrating how the system will work in the future with a high share of variable RES, revealing the importance of the interconnection capacity between countries and the role of the hydro balancing pumping facilities.

The annual average for MIBEL's daily market prices in Portugal was 57,5 EUR/MWh, which reflected a 9,6 % increase over last year. In fact, in 2018, some technical/economic factors were identified as enablers for high electricity prices, such as:

- the increase of electricity demand (2,5 % over 2017 value) in mainland Portugal (1,7 % when considering corrections on temperature and number of working days);
- the increase of CO₂ emission allowances price within the European market by 2,7 times compared to 2017, with a 2018's annual average of 15,9 EUR/tCO₂;
- the increase of commodity prices over 2017 values: 34 % for natural gas and 15 % for coal;
- the outage of nuclear power plants in Spain and other European markets, leading to an increase in electricity prices throughout Europe.
- Figure 3 shows the monthly electricity market prices for the last two years in Portugal; reflecting the positive impact of renewables for the same period. It is worth noting March 2018, mainly the high RES share already mentioned and the lowest value for the monthly electricity market price (39,75 EUR/MWh).

Also, this figure shows the opportunity to increase solar PV contribution, that will compensate the lack of hydro resource in summer months.

In the last three years there was a great interest in developing solar PV projects under the current market wholesale conditions. Since 2016, there were submitted to DGEG more than 2 GW of solar PV projects

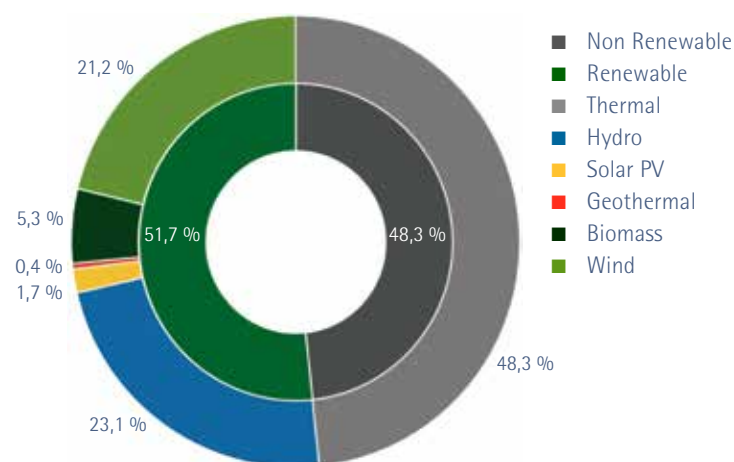


Fig. 2 - Electricity generation by energy source in Portugal 2018, DGGE data (provisional).

for licensing, but until the end of 2018 with little concretization rate, as only about 50 MW of solar PV plants were entered into service, establishing PPAs contracts with retail energy traders. The main topic about these projects is that they have a high investment risk as the market price is very volatile. Furthermore, as there is no figure of last resort market aggregator in Portugal, these few power plants, even if they have established a PPA, are subjected to high balancing costs. A final note to highlight a huge drawback occurred in 2018, related with the news coming from ACCIONA confirming the definitive closure of its solar panel assembling plant in Moura, Portugal, as its economic viability is impossible in a competitive market environment dominated by Chinese manufacturers. In December, seven days after the EU decided to eliminate tariffs on the import of panels from China – Jinko announced the end of their activity in Moura and transferred its production to factories in Asia. Throughout 2018, Acciona tried to negotiate the entry of a third-party, without any result.

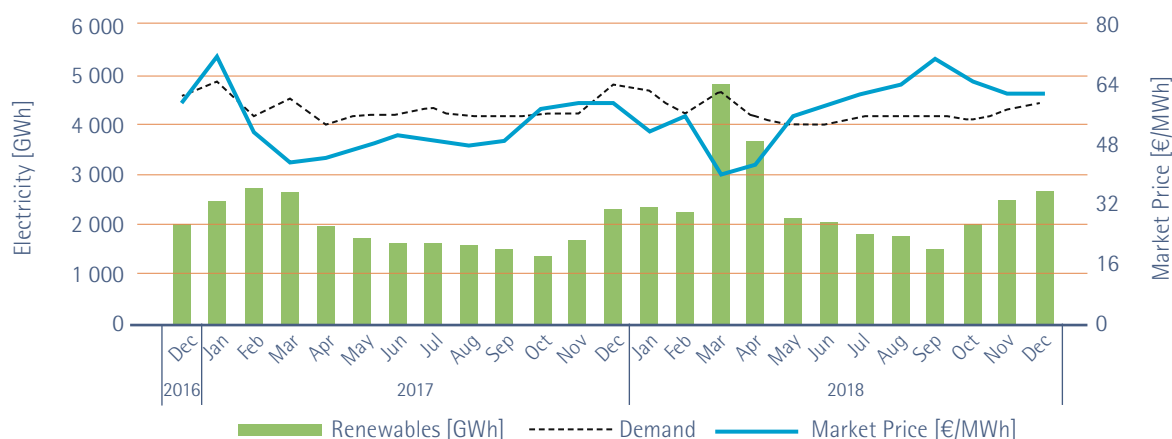


Fig. 3 - Renewable Electricity Production and Iberian Wholesale Electricity Price (December 2016 to December 2018) (Source: OMIE, REN; APREN's analysis).

SOLARPOWER EUROPE

SOLARPOWER EUROPE'S ACTIVITIES

AURELIE BEAUVAIS, POLICY DIRECTOR, SOLARPOWER EUROPE



Fig. 1 - SolarPower Europe's Digital Solar & Storage event took place on 4 and 5 December 2018 at BMW World in Munich (Photo: Fiona Castiñeira).

SolarPower Europe is a member-led association representing organisations active along the whole solar value chain.

SolarPower Europe's aim is to shape the regulatory environment and enhance business opportunities for solar power in Europe. It envisions a future where solar energy is the leading contributor to the European energy system.

2018 was a crucial year for the energy sector in Europe. The finalisation of the "Clean Energy for All Europeans" package sets the scene for a new era of growth for renewables in Europe, and proposes important adaptations to the power market rules.

Through constant interaction with policymakers over the last two years, SolarPower Europe is proud to have contributed to the shaping and adoption of forward-looking reforms paving the way towards a sustainable, renewable-based European energy system:

- A 32 % EU binding RES target by 2030 in the European energy mix, on top of the guarantee that member states will not fall short on their 2020 RES targets
- A proactive European framework for self-generation and consumption
- An obligation for EU countries to provide visibility on national support schemes for at least five years ahead by publishing a long-term schedule
- An "anti-retroactivity clause" to ensure the stability of financial support to renewables

- Simpler and faster administrative procedures for projects of all sizes
- Minimum shares of renewables in all new buildings and buildings undergoing major renovation
- The guarantee that small-scale projects will benefit from priority dispatch and balancing responsibilities exemptions after 2020
- A restrictive framework for capacity mechanisms including an emissions target to avoid coal generation qualifying under such schemes
- An enabling framework for solar and storage applications
- An adaptation of market rules (day-ahead, intraday, balancing) to make them fit for variable solar electricity

SolarPower Europe has been a driving force in coalition building at EU level, leading highly successful political campaigns; Make Power Clean, Small is Beautiful, and the RE-Source Platform.

In addition to the above-mentioned highlights, SolarPower Europe increased its advocacy efforts to remove the trade measures on solar panels from Asia. In September 2018, the EU removed the solar trade measures, a historic move that was welcomed by a broad group of European policymakers, NGOs and EU solar companies – making solar even more affordable for European citizens.

In parallel, SolarPower Europe's Industrial Strategy task force has been working at full speed in 2018, to provide EU policymakers with the solar industry's key recommendations for the implementation of a practical supply-side industrial policy in Europe. These



Fig. 2 - SolarPower Europe wins European Association Award 2018 for 'Best Provision of Industry Information and Intelligence.'

recommendations were launched at the SolarPower Summit in March 2018. Finally, SolarPower Europe has been actively committed to the recast of the Ecodesign regulation covering PV systems, promoting the ever-increasing sustainability and quality of PV installations. In 2018, SolarPower Europe's activities on ecodesign and sustainability standards were extended to EV and stationary batteries.

SolarPower Europe has maintained a high-level of interaction with existing coalitions gathering utilities, system operators, sectoral industry associations, NGOs and other relevant stakeholders. It chaired the "Energy Union working group" of the e-mobility platform - promoting the electrification of the transport sector, and created a platform dedicated to the promotion of renewable-based mobility - solar mobility. It also maintained its contribution to the Electrification Alliance, gathering more than 50 organisations to promote the significant potential of electricity on the EU's path towards decarbonisation. In 2018, SolarPower Europe became an associated member to the Covenant of Mayors, which brings together thousands of local governments voluntarily committed to implementing EU climate and energy objectives.

SolarPower Europe also increased substantially its presence in the media and organised several successful events:

- 120 % increase in media mentions from 2017 to 2018, including coverage in Financial Times, Bloomberg, the Guardian, Forbes, Reuters.
- 33 % increase in followers across our social media channels (Twitter, Facebook, LinkedIn, YouTube and Instagram) from 2017 numbers.
- The SolarPower Summit in March 2018, which gathered over 300 high-level industry representatives and policymakers including the participation of Maroš Šefčovič, Vice-President of the European Commission in charge of the Energy Union, Miguel Arias Cañete, Commissioner for Energy and Climate, and Brussels Energy Minister Celine Fremault.
- Midsummer Celebration on the 4th of July, with the launch of SolarPower Europe's communications campaign: Generation Solar – We Are All Generation Solar.
- A high-level workshop on solar mobility, organized on 19th of September with the participation of Brussels Mobility Minister Pascal Smet and DG ENERGY Director General Dominique Ristori.

- The RE-Source event on 20th and 21st of November 2018, with over 800 attendees and high-level European policymakers. This event was acknowledged as second "Best Association Networking Event" at the 2018 European Association Awards.
- The Digital Solar and Storage event hosted on 4th and 5th of December in Munich, with over 400 experts and business leaders from the solar sector.
- The Solar Operation & Asset Management conference, organised in collaboration with the Solar Trade Association and hosted on 6th of December in London. A successful event, now in its third year running, gathering over 150 industry representatives and experts from the solar industry.

Throughout the year, SolarPower Europe pursued and reinforced a strong service-oriented approach towards its members by delivering high-quality deliverables on:

- Operation and Maintenance (O&M), with the publication of industry-led best practices guidelines.
- Environmental Footprint task force, which delivered high-level recommendations on the European solar sector ahead of the ecodesign/ecolabel legislation recast.
- Solar and storage, which developed 10 policy priorities for the deployment of such combined solutions as well as a "Solar & Storage" mini report.
- Digitalisation, which will look inter alia at how to make solar accessible to all consumers and created a new report on digital-friendly energy regulation "When solar policy went digital".
- Emerging markets, with the delivery of SolarPower Europe's first emerging markets report on Mozambique, and a financing matrix for project developers.
- A "Grid Intelligent Solar" report, highlighting the contribution of utility-scale solar installations to the electricity system's reliability.

Finally, SolarPower Europe's policy and business objectives were again supported in 2018 by thought-leading research in fields such as solar PV market forecasts, financing, and electricity market design. In March 2018, SolarPower Europe received a European Association Award for "Best Provision of Industry Information and Intelligence" for the 2018 edition of its Global Market Outlook.

SOUTH AFRICA

PV TECHNOLOGY STATUS AND PROSPECTS

GAOSHITWE LEKOLOANE, JARRAD WRIGHT, KITTESSA RORO, CSIR ENERGY CENTRE, COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

TSHEPO MALEFETSE, THEMBAKAZI MALI, SOUTH AFRICAN NATIONAL ENERGY DEVELOPMENT INSTITUTE

GENERAL FRAMEWORK AND IMPLEMENTATION

The National Development Plan (NDP) envisages that South Africa will have an energy sector that promotes economic growth and development through adequate investment in energy infrastructure. This means that by 2030 South Africa will have an adequate supply of electricity to ensure that economic activity and welfare are not disrupted and that at least 95 % of the population will have access to electricity. The NDP [1] 2030 proposes clear objectives for the energy sector which will promote:

- Economic growth and development through adequate investment in energy infrastructure
- Social Equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households
- Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change

The Integrated Resource Plan 2018 (IRP) [2] proposes that gas and other renewable resources like wind, solar and hydroelectricity will be viable alternatives to coal. The IRP 2018 includes the following additional capacity by 2030:

- 1 000 MW of generation from Coal,
- 2 500 MW from Hydro,
- 5 670 MW from PV,
- 8 100 MW from Wind and
- 8 100 MW from Gas.

The resultant installed capacity mix in year 2030 consists of:

- Coal with 34 000 MW which is 46 % of total installed capacity,
- Nuclear with 1 860 MW which is 2,5 %,
- Hydro with 4 696 MW which is 6 %,
- Pump Storage with 2 912 MW which is 4 %,
- PV with 7958 MW which is 10 %,
- Wind with 11 442 MW which is 15 %,
- CSP with 600 MW which is 1 %,
- Gas with 11 930 MW which is 16 %

It must be noted that while the coal installed capacity will be lower than current installed base, it will still contribute more than 65 % of the energy volumes with nuclear contributing about 4 %.

Other recommendations in the NDP include diversifying power sources and ownership in the electricity sector, supporting cleaner coal technologies, and investing in human and physical capital in the 12 largest electricity distributors. Energy security is at the core of current and future industrial and technological advancement. The Department of Energy [3] (DoE) is mandated to ensure the secure and sustainable provision of energy for socio-economic development. This is achieved by developing an integrated energy plan, regulating the energy industries, and promoting investment in accordance with the integrated resource plan. The department's strategic goals, among others, are to ensure that the energy supply is secure and demand is well managed, and that there is an efficient and diverse energy mix for

universal access within a transformed energy sector, and to implement policies that adapt to and mitigate the effects of climate change. The DoE places emphasis on broadening electricity supply technologies to include gas and imports, as well as nuclear, biomass and renewable energy resources (wind, solar and hydro), to meet the country's future electricity needs and reduce its carbon dioxide emissions. Goals beyond 2020 include contracting more than 20 000 megawatts (MW) of renewable energy, including an increasing share from regional hydro-electricity. South Africa has committed to attain substantial reductions in carbon dioxide emissions by 2025. The country supports research, technology development and special measures aimed at environmentally sustainable economic growth.

With the growth of small scale embedded generation in the country, a PV GreenCard [4] was formed for safety certification, quality assurance standard and training for solar PV installers. Quality and safety are assured via the specialized education and training provided to solar PV installers prior to them being certified and registered on the PV GreenCard database. This certification means that these installers are proficient and compliant with all of the relevant national and municipal electrical regulations. The SSEG in the country is estimated that close to 60 000 solar PV installation have been undertaken in the residential, commercial and industrial market segments, whereas the unofficial installed capacity of rooftop solar PV installation amounts to more than 300 MW with only 38 MW been officially registered with appropriate municipalities. The PV GreenCard registry process will provide up to date data on installed capacity for better planning and investment decision making.

NATIONAL PROGRAMME

In 2010, the Department of Energy (DoE), the Treasury and the Development Bank of Southern Africa collaborated to set up the Independent Power Producer (IPP) office and designed the Renewable Energy Independent Power Producers Procurement Programme [5] (REIPPPP). At the heart of the programme was the provision that Eskom enter into Power Purchase Agreements (PPAs), ensuring that investors could forecast accurately their profits and bankability – which is enhanced by having payment risk mitigated by government guarantee.

The programme's primary mandate is to secure electrical energy from the private sector for renewable and non-renewable energy sources. The programme is designed to reduce the country's reliance on fossil fuels, stimulate an indigenous renewable energy industry and contribute to socio-economic development and environmentally sustainable growth. The IPP office has been designed not only to procure energy, but has also been structured to contribute to the broader national development objectives of job creation, social upliftment and broadening of economic ownership. The programme contributes to security of energy supply in South Africa and ensures a diversified energy mix through the procurement of additional

[1] National Development Plan 2030

[2] DoE Integrated Resource Plan 2018_ South Africa

[3] Department of Energy

[4] PV GreenCard <https://www.pvgreencard.co.za/>

[5] Renewable Energy Independent Power Producers Procurement Programme (REIPPPP)

renewable energy, coal, gas and cogeneration capacity from the private sector. The IPP office provides the following services for ensuring a proper rollout

- Professional advisory services
- Procurement management services
- Monitoring evaluation and contract management services

Since 2013 the IPP increased the country's installed and operational renewable energy capacity to more than 3GW. As from June 2018, 97 % of IPP's scheduled to be operational have started commercial operations.

Actual average
tariffs in R/kWh
(Apr-2017-R)

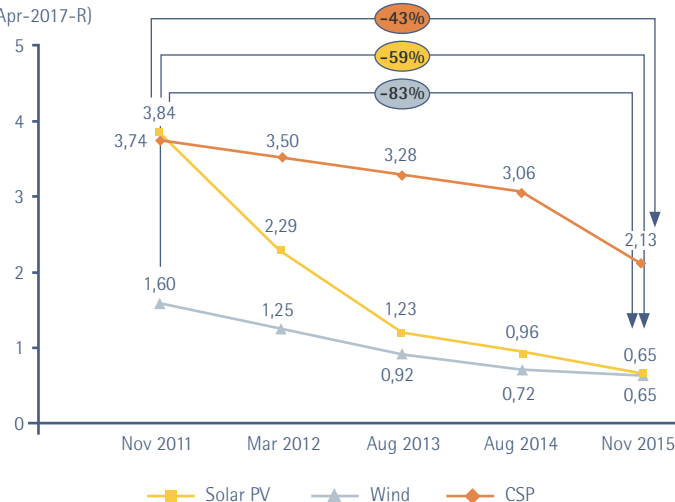


Fig. 1 – Average tariff cost reductions achieved in South African REIPPPP [6].

Sources: [Department of Energy \[7\]](#); [South African Independent Power Producers Association \[8\]](#); [StatsSA](#); [CSIR analysis](#)

Through a competitive bidding process the IPP effectively leveraged rapid, global technology development and price trends, buying clean energy at lower and lower rates with every bid window, resulting in the country getting the benefit of renewable energy at progressively lower tariffs. Cost for all technologies under the REIPPPP has continued to drop consistently as shown in Figure 1 and this is expected to drop further on future bid window rounds.

The total foreign equity and financing invested in REIPPPP's reached R48.7 billion by June 2018. The 27 recently signed projects which were signed April 2018 will provide foreign investment to the total of R17.9 billion, domestic investment of R36.9 billion and total investment of R55.9 billion.

RESEARCH & DEVELOPMENT

The Department of Science and Technology [9] (DST) has appointed the South African National Energy Development Institute [10] (SANEDI) to implement the research and development initiatives identified in the component of the Draft Solar Technology Roadmap. This has been undertaken in the past four years as part of its mandate to promote energy research and technology innovation and also to advise the Minister of DST on research in the field of energy technology. The mandate allows SANEDI to promote relevant energy research through cooperation with any other entities, institutions or individuals equipped with the relevant skills and expertise within and outside South Africa. Moreover, the mandate will also open up areas of possible collaborations with any entity, in line with providing for training and development in the field of energy research and technology development, establishment and expansion of industries; and commercialisation of energy.

Furthermore, the DST has funded Solar Technology Research, Development and Innovation (RDI) programme, with SANEDI appointed by DST to among other things, implement the Programme by establishing the Programme Management Office (PMU), developing criteria for funding of proposals for development of solar technologies and undertaking of solar related studies, issuing Calls for Proposals and funding of successful RDI projects. Projects such as the Energy Research Programme (ERP) review and Solar Technology Development projects have been undertaken.

The DST-funded Energy Research Programme (ERP) is mainly focused on basic and applied research and is meant to ensure that South Africa stays abreast with regard to the latest technologies and research. The ERP is additionally used for the implementation of the Energy Grand Challenge to realize the objectives of human capital development and develop alternative energy technologies. The specific objectives of the ERP are to strengthen South African technological capability, improve the coordination of energy research areas, create international linkages and increase human capital development (HCD) in the field of renewable energy. Therefore, the ERP demonstrates the willingness by the South African government to improve energy access by researching and developing green technologies that contribute towards improving energy access while at the same time addressing other pressing issues related to poverty alleviation and unemployment.

The Council for Scientific and Industrial Research (CSIR) is a world-class African research and development organisation established through an Act of Parliament in 1945 and the organisation's executive authority is the Minister of Science and Technology. The CSIR fosters partnerships with a network of clients and partner organisations, regionally and abroad, as part of a global sphere of influence on matters of technology. The expertise from diverse research fields to provide integrated solutions and interventions to support a broad range of national development

[6] CSIR Analysis: Statistics of utility-scale solar PV, wind and CSP in South Africa in 2017

[7] Department of Energy: State of Renewable Energy in South Africa Report 2016

[8] South African Independent Power Producers Association

[9] Department of Science and Technology

[10] SANEDI <https://www.sanedi.org.za/>

programmes, as set out in the NDP. With South Africa having high level of Renewable Energy potential and in line with the national commitment to transition to a low carbon economy, the CSIR has established an integrated Solar PV Research and Testing Facility [11] to provide support for the photovoltaic (PV) industry in the Southern Africa by providing qualitative reliability evaluation of PV modules, pre-qualification testing, outdoor performance modelling, and performance monitoring of PV modules and systems. The indoor environmental chambers, mechanical load tester and sun simulator provide a testing laboratory to perform accelerated stress testing and provide quantitative data to compare the relative reliability of various PV modules in the market. The laboratory is the first in sub-Saharan Africa to offer indoor accelerated stress testing for PV modules and energy rating measurements across a broad range of temperature and irradiance levels.

Indoor testing and measurement services include the following:

- Performance measurements under standard test conditions
- Accelerated stress and extended reliability testing
- Temperature coefficient determination for current, voltage, and power output
- Performance rating across a range of irradiance and temperature
- Electrical safety tests: wet and dry insulation
- Fault diagnosis: Electroluminescence and Infrared imaging
- Pre-qualification testing for locally developed modules and components

Outdoor testing and measurement services include the following:

- Feasibility studies for PV installations
- Light induced degradation measurements
- Light soaking, stabilization, soiling and long-term degradation studies
- Performance modelling and validation
- Hotspot endurance stress testing
- Provision of high resolution meteorological data



Fig. 2 - PV Testing Facility at CSIR, located in Pretoria.



Fig. 3 - CSIR Indoor sun simulator located in Pretoria.

INDUSTRY AND MARKET DEVELOPMENT

South Africa has a clear drive to deliver on its commitment to reduce carbon emissions and a clear way to deliver on this is to reduce carbon emissions through a robust renewable energy programme like the REIPPPP. A total of 6,3 GW approved and 4 GW of renewables (mainly from wind and PV) from IPPs already online as an outcome of the REIPPPP (Figure 4). The acceleration and roll-out of capacity under the REIPPPP has given South Africa a strong foundation to continue market development in future. As of 31 December 2018, 2078 MW of wind, 1479 MW of utility-scale solar PV and 400 MW of CSP was operational in South Africa thereby adding 100 MW of CSP in 2018 [12].

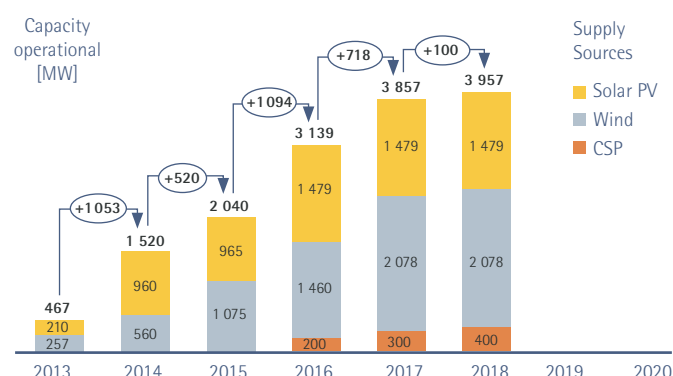


Fig. 4 - Installed capacity of dominant utility-scale renewable energy in South Africa (2013-2018) [13].

Notes: RSA = Republic of South Africa. Solar PV capacity = capacity at point of common coupling. Wind includes Eskom's Sere wind farm (100 MW).

Sources: Eskom; DoE IPP Office

[11] <https://www.csir.co.za/csir-energy-centre>

[12] G. Lekoloane, JG Wright, and C Carter-Brown "Municipal energy transition: Opportunities for new business models and revenue streams

[13] Joanne Calitz and JD Wright "Statistics of utility-scale solar PV, wind and CSP in South Africa in 2018

SPAIN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

GENERAL FRAMEWORK

There has been a clear tendency change in 2018 for PV installations in Spain. However, the capacity awarded on tenders in 2017 following compromise with the European Union concerning electricity generation by Renewable Energies, has not yet been installed. The summary of those tenders totals 3,9 GW for different PV plants and a similar quantity for wind.

The effect of those tenders has also tractioned some other private initiatives for big PV plants installation. On the other side, concerning self-consumption, the situation has also been unblocked during second half of the year due to the modifications of the law regulating it. Two of the most important modifications are the elimination of the sun tax and the permission for collective self-consumption.

In summary and due to non-materialization of awarded grid connected plants, the total installed capacity for the year has been only 261,7 MW, out of which 235,7 MW is for self-consumption.

With these numbers and as the electricity coming out of self-consumption cannot be easily estimated, the contribution of PV to the electricity demand coverage in the country during 2018 has not

been changed from the previous year. Figure 1 shows the evolution of electricity coverage by RREE since 2008 but only considering the grid connected generation.

As can be seen in Figure 1, total demand coverage by grid connected RREE in 2018 had an increase from 2017, up to a total of 37,4 %. The main difference has been originated in the amount of electricity generated from hydroelectric (going up to 13,7 %), while as practically no new capacity has been installed in RREE (1,5 % more from wind), the other energies remain almost constant. Wind, as always, is the winner among all with a 19 % of total demand coverage, 3 % corresponds to PV and 1,7 % from solar thermal. In summary, 7,4 % points more than prior year for the total demand coverage coming from RREE during 2018, approaching again the 40 % total.

Information presented corresponds to consolidated values up to 2017, reported by grid operator REE (Red Eléctrica de España). For 2018 data are estimations as of December for both peninsular and extra-peninsular territories. Final information for the year will appear in the July 2019 timeframe. Off grid and self-consumption capacity has not been considered at all in the graph.

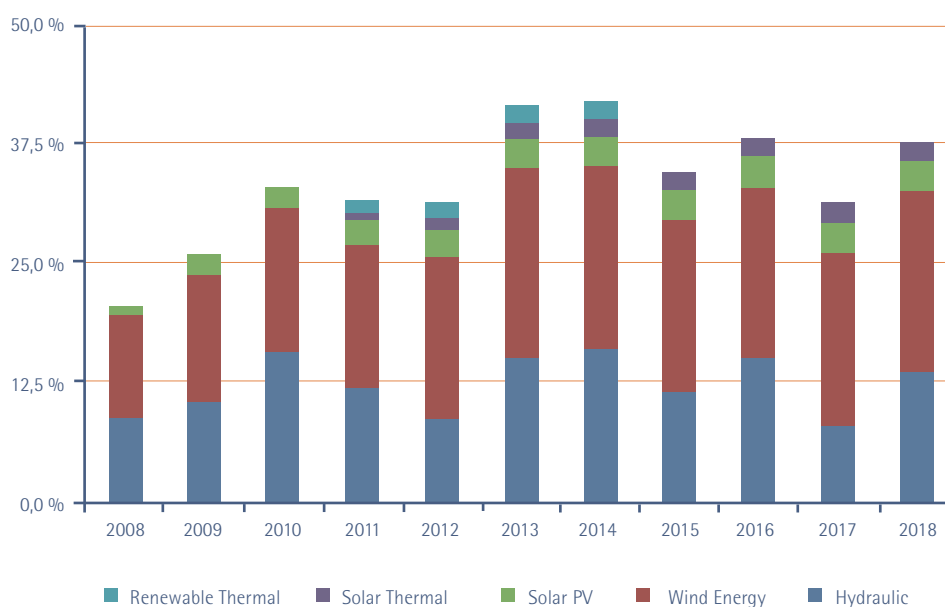


Fig. 1 – Percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 -2018, REE).

In absolute numbers, the total electricity demand out of the grid for the country is close to 262 TWh and the increase in hydraulic generation, and at a lower level in wind, compensates in part the decreases last year on generation due to coal, combined cycle and slightly lower nuclear (Figure 2).

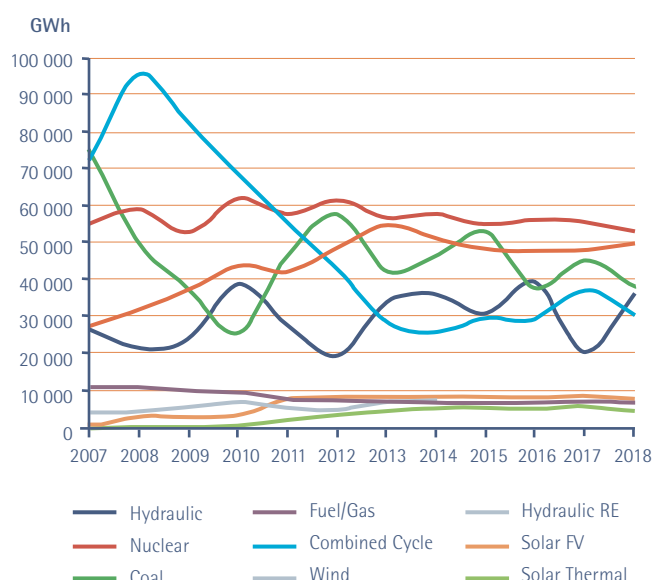


Fig. 2 - Evolution of electricity generation (all sources).

NATIONAL PROGRAMME

There is no specific novelty in the National Programme, apart from the tenders in 2017. However, modifications on some regulatory laws are going to support important PV development. Actual prices of components and solar irradiation characteristics in the country make the LCOE value attractive for investors and new big PV plants are being announced. Also, cooperative self-consumption, provides electricity prices below the ones of the traditional energies and that, together with the change in mentality to support a greener society are going to be drivers for more PV deployment. Increase in PV could also be seen on the very sunny islands starting slowly in the Balearic Islands (mostly self-consumption) and not so much in the Canary Islands yet, as priority has been given to wind there.

In summary, Figure 3 shows the evolution of installed capacity, both grid connected and off-grid, with specific separation of self-consumption. Provisions are that 2019 will have at least 3,9 GW grid connected coming from the tenders, and should be added to that the capacity installed by private initiatives and a big amount of smaller and medium size PV for self-consumption.

R&D, D

New R&D projects awarded during 2018 to Spanish institutions are related to various fields. For the big plants, the need is seen on the optimization of the O&M activities that must change the paradigm when speaking about tenths or even hundreds of MW. The inspections

Evolution of installed PV

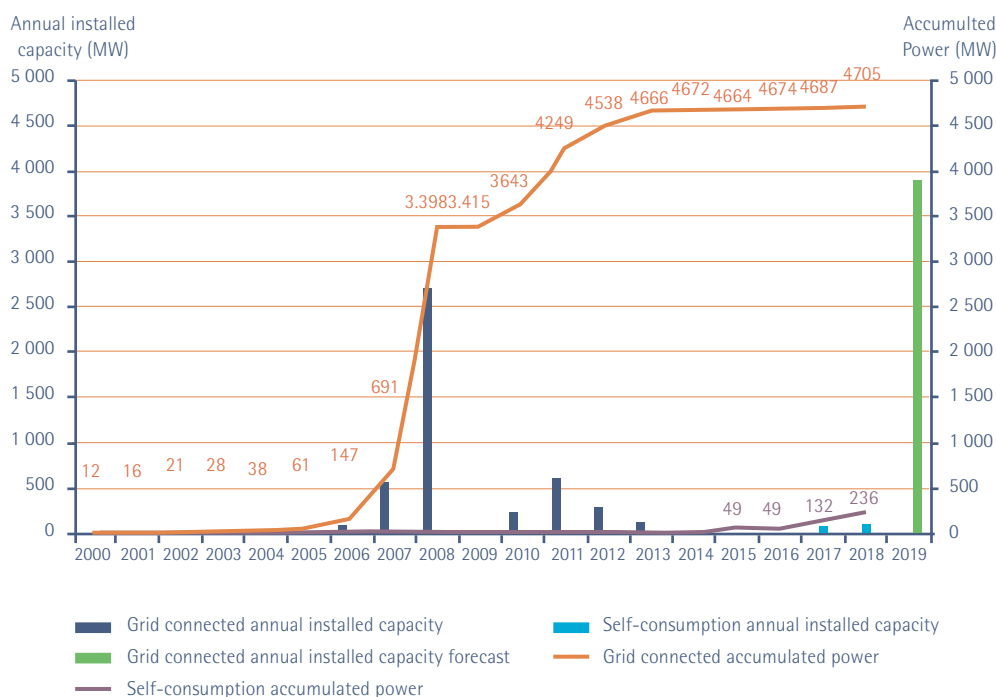


Fig. 3 - Evolution of installed PV 2000 - 2018 with expected minimum grid connected value for 2019.



Fig. 4 - PV plant under construction with Soltec's horizontal 1-axis PV trackers.



Fig. 5 - New Power Electronics factory in Valencia.

are made from the air through the use of drones and in general, tele-detection and diagnosis appear as the most effective tools. The DOCTOR-PV project awarded by national call and involving an important consortium of Spanish companies and R&D centers is dealing with it. Another point to optimize performance of the big plants is related to the study of soiling and its varieties; depending on the meteorological conditions as is the case with the INVIVO project from ERA-NET-MED with CIEMAT's participation or the Marie Curie Project on a similar subject from Jaen University. Tools or methodologies in order to take the optimum cleaning decision or the means to avoid soiling as much as possible are two of the subjects driving activities in some other R&D projects. Also, as part of the support to the optimum generation of PV plants is the research on activation energies of defects driving to degradation modes of PV modules that is being done on the SOLAR-TRAIN project (ITN-Marie Curie) with the CENER's participation.

Concerning other PV applications, such as BIPV, it is important to mention the BIPVBOOST project from H2020 with participation of TECNALIA and ISFOC, dedicated to standardizing and lowering the cost of BIPV products, or the CEFABID from H2020 ERA-NET for obtaining clean energy from road acoustic barriers infrastructure development. Another aspect that is noteworthy is the GRECO Project (www.greco-project.eu) from the SWAFS-H2020 call led by Instituto de Energía Solar of Polytechnic University of Madrid (IES-UPM) in order to demonstrate strategies for open science on PV R&D. The study of new materials (organics or hybrid materials) and new cell concepts remains as an important activity, but it's still far from the full device integration and module fabrication.

Finally, as in prior years, effort on R&D is also dedicated to the hybridization of PV with other technologies for massive generation and given the modularity and easy integration of PV technology, its participation in the new schemes of microgrids that support the concept of smart buildings and smart cities.

INDUSTRY STATUS

Industrial development in the country for the specific PV business is low. Activity in PV modules is residual; however there are some Spanish companies active in manufacturing other PV components of the new mega plants, which have also an important deployment and implantation worldwide. This is the case of POWER ELECTRONICS and INGLETEAM on the side of PV inverters, or SOLTEC (the third largest manufacturer in the world), STI NORLAND, NCLAVE, etc., in the case of horizontal one axis tracking systems. The successful activity of



Fig. 6 - Construction work from ONYX SOLAR for the installation of BIPV in DEWA's building for R&D (Dubai).

EVASA, the only company active in encapsulant production in Europe during last years, has been interrupted as they went bankrupt in 2018. Still there are low volume manufacturing companies working on that topic (NOVOGENIO). Also, with activity that initiates in R&D and together with optimum design and manufacturing goes up to real BIPV installations, ONYX SOLAR continues its trajectory, having finished impressive buildings in Dubai, among other places, during last year.

The lower level of manufacturing concerning PV modules technology is not only a problem affecting Spain; it is the same all over Europe. Therefore, efforts exist for returning to more production capacity or finding the niche product that could justify it.

The summary of 2018 with respect to PV technology in Spain is positive due to the trend change and the hope of having imminently more generation capacity out of PV in the country.

SWEDEN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TOBIAS WALLA, SWEDISH ENERGY AGENCY

PIERRE-JEAN RIGOLE, SWEDISH ENERGY AGENCY



Fig.1 – RISE – RISE EMC-lab "Awitar" in Borås – 82 kWp – Yearly production 48 MWh (Photo: Anna Åberg, Welcome eventbyrå).

GENERAL FRAMEWORK AND IMPLEMENTATION

According to the EU burden-sharing agreement, Sweden is required to achieve a renewable energy share of 49 % by 2020. However, Sweden has increased this goal to a renewable energy share of at least 50 % of the total energy use.

In 2016, the government, the Moderate Party, the Centre Party, and the Christian Democrats reached an agreement on Sweden's long-term energy policy. This agreement consists of a common roadmap for a controlled transition to an entirely renewable electricity system, with target as follows:

- By 2040, Sweden should achieve 100 % renewable electricity production. This target is not a deadline for banning nuclear power, nor does it mean closing nuclear power plants through political decisions.
- By 2045, Sweden is to have no net emissions of greenhouse gases into the atmosphere and should thereafter achieve negative emissions.
- By 2030 an energy-efficiency target of 50 % more efficient energy use compared with 2005. The target is expressed in terms of energy relatively to GDP.

Incentives for renewables

Sweden has a technology-neutral market-based support system for renewable electricity production called the electricity certificate. Sweden and Norway have shared a common electricity certificates market since 2012, wherein certificates may be traded between borders.

The objective of the common certificates market is to increase the production of renewable electricity by 28,4 TWh by 2020, compared to 2012. This corresponds to approximately 10 % of total electricity

production in both countries—achieved principally through hydro, bio-power and wind power. PV still accounts for less than 0,15 % of the Swedish electricity production. In the Swedish energy policy agreement signed in 2016, the electricity certificate support scheme was extended to 2030 with an added ambition of 18 TWh.

Subsidy for PV installations

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 30 % to enterprises and 20 % to individual person in 2014. The subsidy was increased to 30 % to individual starting from beginning of 2018. The subsidy has become popular and the volume of applications is occasionally greater than the available funds. Though, after the election to the parliament in 2018, the budget for the subsidy was decreased from 93 MEUR to 42 MEUR per year for 2019. 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 EUR 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.

Besides the support systems there are ongoing efforts from Swedish authorities to simplify the process of procuring a PV system, for example the National Board of Housing, Building and Planning has submitted a proposal to simplify and clarify the process of obtaining a building permit for PV installations. The Swedish Energy Agency



Fig. 2 – Solvåg – Piteå – 117 double-sided solar panels from Prism Solar (USA) – 36 kWp – Yearly production 45 MWh (Photo: Warm in the Winter The facility is both a research project and an open green park and social meeting place. It contains 117 double sided solar panels that capture sunlight on the front and reflect light on the back. These are located against different point of the compass and with different angles of inclination towards the sun).

has ongoing information and knowledge dissemination efforts, for example through a national project where local energy advisors are trained in PV regulations and applications.

Public perception

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 [1].

NATIONAL PROGRAMME

The Swedish Energy Agency is the governmental authority responsible for most energy-related issues including implementation of governmental policies and decisions related to incentive in the energy sector, information on energy system and climate change, providing the government and the public with statistics, analyses and forecasts, and founding of research and innovation.

In 2016, the agency developed a proposal for the first national strategy in order to promote solar electricity. It suggests that a yearly production of 7-14 TWh electricity from PV can be feasible in Sweden in 2040 (note that this figure is not an official national target). This yearly production would be equivalent to 5-10 % of the electricity consumption if electricity usage is the same 2040 as today.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research, development and demonstration is supported through several national research funding agencies, universities and private institutions in Sweden. However, among the national research funding agencies, the Swedish Energy Agency is specifically responsible for the national research related to energy. With an annual budget of 140 MEUR, some 55 programmes and 900 projects running is therefore the main funding source for research and innovation projects within PV.

In 2016, the Swedish Energy Agency has published its strategy defining priorities within PV and solar thermal electricity (STE). Prioritized research areas are: Grid integration, Innovative and flexible solar cell and BIPV, high efficiency solar cell, competitive solar

thermal electricity, resource efficiency, ecological environment and sustainability, prosument perspective, and integration in attractive and sustainable cities.

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. The programme includes both national and international research and innovation project, innovation procurement and expert studies. International projects are conducted in the EU collaboration SOLAR-ERA.NET Cofund. In addition to the research program, the Swedish Energy Agency also provides funding to PV companies though dedicated project supporting their technology development.

Highlights

There are strong academic groups 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 techniques to improve production cost and performance of conventional silicon solar cells.

Comprehensive research in CIGS and CZTS thin film solar cells is performed at the Ångström Solar Center at Uppsala University. The objectives of the group are to achieve high performing cells while utilizing processes and materials that minimize the production cost and the impact on the environment. The Center collaborates with the spin-off company Solibro Research AB (a company of Hanergy), and Midsummer AB.

At Lund University, the division of Energy & Building Design studies energy-efficient buildings and how to integrate PV and solar thermal into those buildings. There is research at the same university on nanowire for solar cells and an innovative production technique called Aerotaxy. The research is performed in collaboration with the company Sol Voltaics AB. Based on the GaAs nanowire, Sol Voltaics is developing a product called Solfilm, which can be used a single junction solar cell or in combination with existing crystalline silicon to form a tandem solar cell.

[1] Svenska folkets åsikter om olika energikällor - https://som.gu.se/digitalAssets/1656/1656970_svenska-folkets---sikter-om-oilka-energik-llor-1999-2016.pdf



Fig. 3 - Derome Plusshus's warehouse and logistic center in Varberg - 600 kWp. (Photo: Derome Plusshus).



Fig. 4 - Solevi - Göteborg Energi - 5,5 MWp - Sweden's largest utility-scale solar plant (Photo: Göteborg Energi - Jeanette Larsson).

An ongoing collaboration between Linköping University, Chalmers University of Technology and Lund University, under the name Center of Organic Electronics, carries out research on organic and polymer solar cells. Different areas of use are being investigated, such as sunshade curtains with integrated solar cell. In 2017, the spin-off company Epishine was created to commercialize the technology.

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. Two Swedish start-up companies, Exeger and Dyenamo, are developing and commercializing the product based on this technology.

The company Swedish Algae Factory cultivate algae (diatoms) to use their shell material of to enhance the efficiency of solar panels. The company collaborate with Chalmers university and was awarded a project within the Horizon 2020 action LIFE. The project aims to build up a larger pilot facility for production of this innovative algae material.

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

INDUSTRY AND MARKET DEVELOPMENT

The cumulative installed grid-connected power has grown from only 250 kW in 2005 to 307,4 MW in 2017. The market for solar cell in Sweden grew by 50 % to 117,6 MW installed capacity compared to 78,6 MW in 2016. However, PV still accounts for only about 0,15 % of the Swedish electricity production (160,5 TWh under 2017), 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.

The Swedish PV market is dominated by customers who buy and own the PV systems. Past years some companies have also started to offer third-party financing as a method of realizing a PV installation.

A fast-growing number of small to medium-sized enterprises exist, that design, sell and installed 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

specifically for this market segment. Some utilities are selling turn-key PV systems, often with assistance from PV installation companies.

Sun Renewable Energy AB is the only remaining solar cell factory for silicon PV modules in Sweden. The company overtook the business after the bankruptcy of SweModule AB. There are also a few companies exploring other types of solar cells. Midsummer AB offers both thin-film CIGS cells as well as equipment to manufacture CIGS cells. Exeger AB is offering dye sensitised solar cells that can harness the energy of ambient light for powering consumer electronics and have their own manufacturing plant in Sweden.

Notably, several companies are now offering roof integrated PV products. In 2018, Midsummer AB started the production in Sweden of a solar roof product, where their CIGS based solar panels are mounted on a standing seam steel roof. Soltech Energy Sweden AB, Nyedal Solenergi AB, Monier AB, and S:t ERIKS AB are selling a PV integrated roof tile designed and constructed to replace traditional roof tiles.

Other Swedish companies that can be highlighted are PPAM Solkraft AB which develops different niche products such as bifacial PV modules; Ferroamp AB and Checkwatt AB developing balance-of-system equipment such as smart inverters, power meters, or energy hubs; and Trine AB that provides services for people to invest in solar energy in growing markets offering them to earn a profit while making social and environmental impact.

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS

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



Fig. 1 – Installing photovoltaic panels in high mountains could reduce the power deficit experienced in winter, according to a recent study by the WSL Institute for Snow and Avalanche Research SLF and EPFL (Annelen Kahl, Jérôme Dujardin, and Michael Lehning, PNAS January 22, 2019 116 (4) 1162-1167) (Photo: © ZHAW Wädenswil).

GENERAL FRAMEWORK AND IMPLEMENTATION

The transformation of the Swiss energy system aimed at with the "Energy Strategy 2050" is a long-term project. The Swiss electorate accepted a revised Federal Energy Act in 2017 in a popular referendum. This new legislation entered into force on 1 January 2018. The aims are to reduce energy consumption, increase energy efficiency and promote the use of renewable energy (www.energystrategy2050.ch). In addition, the revised act prohibits the construction of new nuclear power plants. As an additional element of the "Energy Strategy 2050" the Federal Council (Swiss government) decided to establish new framework conditions for the Swiss electricity market and submitted a revised Electricity Supply Act (Stromversorgungsgesetz) at the end of 2018, for consultation until end of January 2019. The focus lies on security of supply, an efficient and fully open electricity market, as well as new network regulations designed to support the expansion of decentralized, renewable power production. In the context of climate policy and with respect to the reduction of fossil fuel consumption, the next stage of Swiss climate policy is under current discussion in the Parliament (revision of the CO₂-act).

Electricity production from photovoltaics is one of the key pillars in the strategy for the future Swiss electricity supply and should contribute – according to the official scenarios – with roughly half (11,1 TWh) of the net addition in renewable electricity production until 2050 (24,2 TWh). In 2017, the national power production was 61,5 TWh. A monitoring report of the "Energy Strategy 2050" in 2018 – sketching the situation until end of 2017, actually before the coming into force of the new legal measures – shows, that the increase in renewable power production in Switzerland is at the moment on track and the benchmark for 2020 with 4,4 TWh should be within reach (see Figure 4). The contribution from photovoltaics is thereby above the long-term scenarios. This fact will be considered in the revision of the official scenarios for the "Energy Strategy 2050" starting in 2019. The entry in force of the new Energy Act in 2018 had specific impacts on the development of photovoltaics in Switzerland. The surcharge on electricity consumption from the grid for the support of renewable energy and other measures has increased from 0,015 CHF per kWh to 0,023 CHF. The feed-in-tariff scheme established in 2009 is now time limited and new installations will be considered only until to 2022. Due

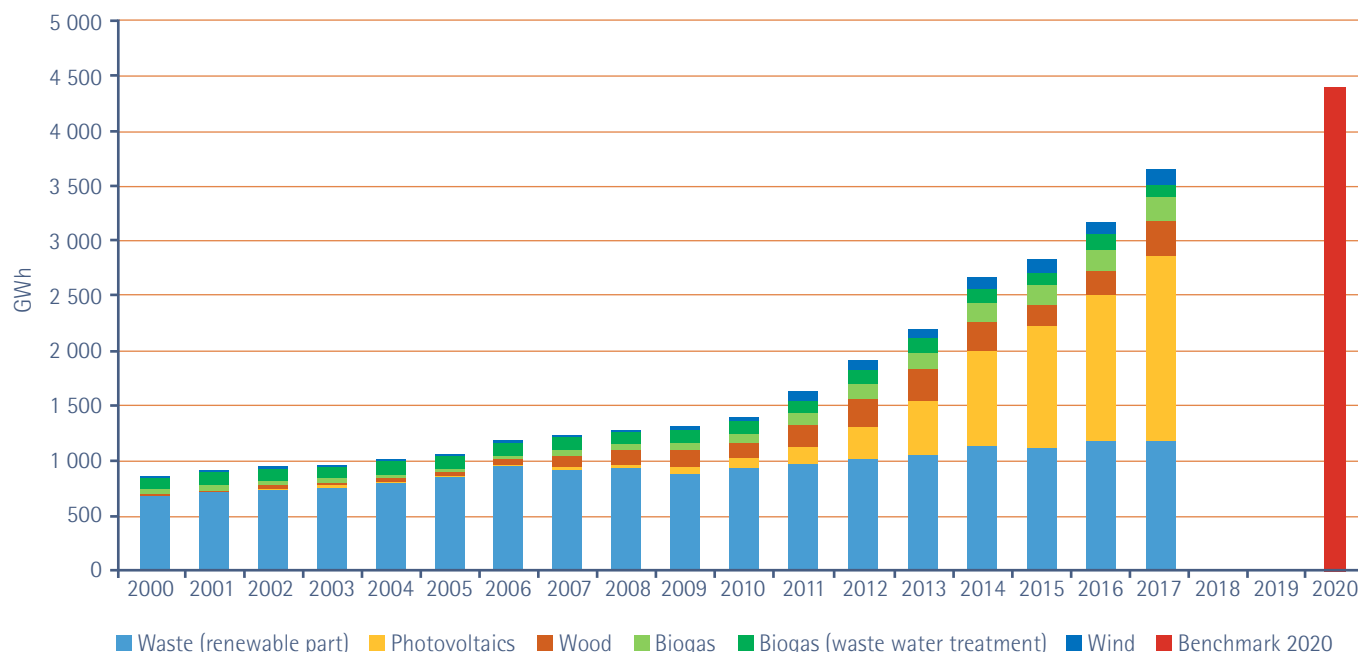


Fig. 2 – Evolution of the power production from renewables in Switzerland without hydropower. The increase in production from photovoltaics has mainly contributed to the fact that Switzerland is currently on track to reach its benchmark for 2020 of 4,4 TWh (Source: SFOE).

to an existing long waiting list, no new photovoltaics installation will enter into the feed-in-tariff scheme. Installations of a certain capacity within the feed-in-tariff scheme will have to sell their production directly in the market from 2020 on and are remunerated with a tariff closer to market requirements. Installations with capacity smaller than 100 kW only receive a onetime investment subsidy of 30 % of the costs of a reference installation. The onetime investment subsidy is available for all systems with capacities from 2 kW to 50 MW. At the end of 2018, the Swiss Federal Office of Energy announced a strong increase of the quotas for onetime investment subsidy for photovoltaic installations. With this measure, a large part (260 MW) of smaller installations (<100 kW) can be supported until end of 2019 with a total subsidy of 100 MCHF. Also, larger installations (150 kW to 50 MW) with pending subsidy requests and a total capacity of 502 MW will receive a guarantee for subsidies within 2019 with a total volume of 150 MCHF. While providing for financial security for partly already built PV systems, these changes in the regulatory framework should also bring an additional boost to the Swiss PV market in the coming years.

This, together with additional new opportunities such as the collective grid connection of various end consumers to increase self-consumption and flexibility, should give a push to the yearly market development of photovoltaics in Switzerland, which has been stagnating around 250 MW in the last years.

NATIONAL PROGRAMME

The Swiss Federal Office of Energy (SFOE) runs a dedicated national photovoltaic RTD programme that involves a broad range of stakeholders. The programme is part of the long-standing coordinative activities by the SFOE to support research and development of energy technologies in Switzerland, where funds deployed in a subsidiary manner aim to fill gaps in Switzerland's research funding landscape. Grants are given to private entities, the domain of the Swiss Federal Institutes of Technology (ETH), universities of applied sciences, and universities.

The focus of the photovoltaics programme lies on R&D in a system and market oriented approach, from basic research, over applied research, product development, pilot and demonstration projects. On average, the volume of the SFOE PV RTD programme (including pilot and demonstration) is in the order of 10 % of the total public support for photovoltaics research in Switzerland, which is in the order of 36 MCHF per year (including roughly 30 % from European projects). The programme supports research and pilot & demonstration projects in different areas of photovoltaic cell technologies (c-Si, CIGS and others), in the field of photovoltaic modules and building integration of photovoltaics, as well as in the topics of system aspects of photovoltaics such as grid integration, quality assurance of modules and inverters or battery storage technology. Other themes are life



Fig. 3 - High efficiency pilot PV system by Insolight which uses a unique module design: The panel's protective glass embeds a grid of lenses which concentrate the direct sunlight on an underneath array of high-performance space-grade solar cells. An integrated tracking system keeps each cell in focus regardless of the sun's position without active tracking of the modules. Efficiencies of 29 % have been demonstrated (Photo: © Insolight).

cycle analysis, solar forecasting, as well as performance monitoring. International co-operation on all levels, 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 is another key element of the SFOE photovoltaics programme.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

There are many Swiss research laboratories dealing with all kinds of different aspects of photovoltaics (see Figure 4 for an overview). In the field of solar cells, the focus lies on high-efficiency crystalline silicon solar cells (heterojunction technology, PERC, passivating contacts) and

on various thin-film solar cell technologies, in particular CIGS cells. Perovskite solar cells and especially the topic of tandem cells (c-Si with perovskite or III/V, CIGS with perovskite) gain increasingly attention. The development of new module architectures, especially for building integration applications, is another large field of research with a lot of ongoing activities. This includes new approaches and solutions for coloured, light-weight and flexible modules, as well as customized modules with various shapes applying different types of techniques. Grid integration of photovoltaics, photovoltaics in combination with heat pumps and different storage technologies (batteries and thermal storage), photovoltaics and electro-mobility (bidirectional charging) are further themes with ongoing and increased activities.



Fig. 4 - Swiss photovoltaics technology landscape. Circles denote research institutions, squares industrial activities (Source: SFOE).



Fig. 5 - dhp has realized the world's first solar folding roof across a sewage infrastructure, a consistent double use of already sealed land for solar power generation in urban infrastructures and with 100% self-consumption. Following a pilot plant with the HORIZON solar folding roof, the system was extended to a capacity of 643 kW in 2018 (Photo: © dhp technology).

R&D Highlight 2018: Fully Textured Monolithic Perovskite/Silicon Tandem Solar Cells

The optics in different layers of a monolithic two-terminal perovskite/silicon tandem solar cell is of key importance to achieve high efficiency. In 2018, the photovoltaics laboratory at CSEM and EPFL Neuchâtel presented a top cell (perovskite) deposition process that enables the conformal growth of multiple compounds with controlled optoelectronic properties directly on the micrometer sized pyramids of textured monocrystalline silicon. With this technique, a perovskite/silicon tandem solar cell with 25,2 % power conversion efficiency could be demonstrated (Florent Sahli et al., Nature Materials, 17, 820-826 (2018)).

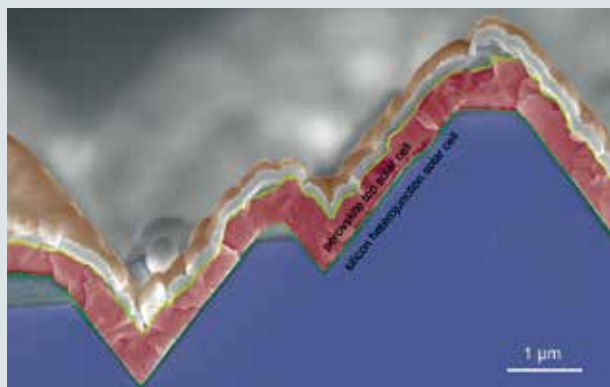


Fig. 6 - Monolithic perovskite/silicon tandem solar cell (Photo: © CSEM/EPFL-IMT).

Several universities of applied sciences are investigating the system performance of photovoltaics, some of them for many decades, such as the Berner Fachhochschule (BFH) and the University of Applied Sciences of Southern Switzerland (SUPSI) with the long-term monitoring of photovoltaic installations. In 2018, a new group with experts from SUPSI, BFH and other institutions has been formed which collectively contributes to the ongoing activities in IEA PVPS Task 13 on Performance and Reliability of Photovoltaic Systems.

NEWS FROM INDUSTRY

Swiss industrial players are grouped along the entire photovoltaics 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, including recycling (see Figure 4 for an overview). A broad range of competitive technologies, products and services are offered to the growing photovoltaic market, both domestically and abroad.

Meyer Burger, one of the largest equipment suppliers for complete module manufacturing lines and advanced module technologies, communicated a successful return to profitability at net earnings level for the first half of 2018. The main focus today is on photovoltaic cell coating and module connection technologies. Also in 2018, the solar system business from Meyer Burger, taken over from the company 3S in 2010, was sold and transferred to 3S Solar Plus AG (<https://3s-solarplus.ch/>), a newly created company, that focuses on the Swiss market with its MegaSlate product.

Apart from larger players, an increasing number of new industrial players can be observed during the last years, some with very revolutionary approaches. The EPFL start-up company Insolight (<https://insolight.ch/>) (see Figure 3) with its concentrating technology using plastic magnifying lenses in order to boost the efficiency of a standard solar panel towards 30 % is one example. Another one is the company dhp-technology (<http://www.dhp-technology.ch/>) (see Figure 5) with its photovoltaic folding roof technology for the double use of industrial areas such as waste-water treatment plants.

THAILAND

PV TECHNOLOGY STATUS AND PROSPECTS

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MR YONGYUTH SAWATDISAWANEE, DEPUTY DIRECTOR GENERAL, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY

MR SUREE JAROONSAK, DIRECTOR OF SOLAR ENERGY DEVELOPMENT DIVISION, DEPARTMENT OF ALTERNATIVE ENERGY DEVELOPMENT AND EFFICIENCY



Fig. 1 – The 75 kW PV rooftop project installed over the parking building of the Department of Alternative Energy Development and Efficiency, Ministry of Energy of Thailand. The project aims to introduce demand-side management program to increase renewable energy consumption in the building using Building Energy Management System (BEMS) to balance between generated power and electricity demand, and to cut peak demand of building electricity need (Photo: DEDE).

GENERAL FRAMEWORK AND IMPLEMENTATION

Thailand has constantly promoted PV system installation for a long time. In 2018, Thailand PV system installed capacity officially reached 2 812 MW of total electricity production, a nearly half-way through the target of 6 000 MW by 2036 according to the Alternative Energy Development Plan (AEDP). Thailand PV schemes can be generally divided into on-grid and off-grid PV systems, which consist of ground mounted systems and the rooftop systems. The majority of PV systems in Thailand are the small power producers (SPPs), those who can incorporate renewable energy generation with a generating capacity of more than 10 MW but not exceeding 90 MW, and the very small power producers (VSPPs), those who can produce 1 MW to 10 MW, totaling the installed capacity of ground mounted PV systems of 2 700 MW. The second phase solar incentive program for government agencies and agricultural cooperatives using ground-mounted systems was carried out in 2018, which was responsible for 171,52 MW.

NATIONAL PROGRAM

Currently, Thailand is now under major revision of all energy plans, including the Power Development Plan (PDP) 2015 and AEDP 2015 to intensify the country ambitious goal in renewable energy targets. The new PDP plan was undergone public hearing on December 2018 and

was expected to be approved by the National Energy Policy Council early 2019, with the target of solar energy likely to be increased to reflect the continually cost reduction of solar PV systems.

The first phase of solar incentive program for government agencies and agricultural cooperatives attracted 64 participants with the total proposed agreement of 271,82 MW while the second phase was scheduled COD December 2018. The target of the second phase was to incorporate 171,52 MW electricity from PV in government buildings (52,52 MW) and agricultural cooperatives (119 MW) into the grid. The FiT for the program was 4,12 baht/kWh, a slight reduction in incentives due to cost reduction of PV modules.

Next year, the solar rooftop incentives legislations are expected to be finalized and would play crucial role in directing the future of Thailand solar PV market.

R&D, D

Thailand has made progresses in various PV research. In 2018, research projects of PV reliability of PV power plants in term of the effect of dust to PV performance of power plants and the degradation of



Fig. 2 - 5 MW Tap Sa Kae Solar Power Plant operated by EGAT combines 4 different solar PV technologies. The plant was integrated with learning and research center in the field of solar PV efficiency, energy-efficient building design, and edutainment center that welcome students and interested person to visit and immerse themselves in renewable energy in the Lower Central Region of Thailand.

PV module in the operating conditions of rooftop PV systems and PV power plants were carried out by King Mongkut's University of Technology Thonburi (KMUTT), together with the Electricity Generation Authority of Thailand (EGAT) and Thailand Research Fund (TRF). Moreover, the National Electronics and Computer Technology Center (NECTEC) has also studied PV system performance of different PV systems in the similar area such as Concentrator Photovoltaic System (CPV), fixed PV system and PV system with solar tracking. The collaborating model and forecast research led by NECTEC and Chulalongkorn University also studied the forecast of PV output using Weather Research and Forecast (WRF) model and solar power forecast with weather classification using self-organized map.

For the demonstration of PV systems, the Department of Alternative Energy Development and Efficiency (DEDE) has installed 75 kW PV rooftop on its parking lot to increase the efficiency of utilizing renewable energy in the building as well as to integrate building energy management system (BEMS) measures to balance energy supply and demand for the building. The Provincial Electricity Authority (PEA) has 250 kW of PV rooftop system on the head office building in the same basis.

DEDE has also studied the potential surface analysis in managing solar PV wastes and residues along with the feasibility study of the establishment of the first solar PV recycle center in Thailand.

Electric vehicle (EV) promotion in Thailand is one of the primary strategies to reduce fossil fuel dependency and energy use in transport sector. To support this, EGAT, PEA and the Metropolitan Electricity Authority (MEA) have provided a number of charging stations, some of them have incorporated PV rooftop systems as power sources.

INDUSTRY AND MARKET DEVELOPMENT

PV systems were expected to continue to flourish in the upcoming future since the cost of PV electricity production now becoming more competitive with the conventional electricity production.

In the next year, the project of PV rooftop systems for the household will be implemented. The initial target of the project is to install the total 100 of MW PV from household rooftop and connect to the grid.

Thailand aims to extend the market of solar power trading from traditional power distribution power system with large scale power producers towards decentralized power distribution system. Solar PV owners will be able to either utilize their own power for self-consumption, enter private PPA for energy trading, or connect to the grid to sell electricity to state utilities.

Solar floating platform and viable battery storage systems are the area in which Thailand has interested to develop and extend its reach.

TURKEY

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK AND IMPLEMENTATION

Turkey, located in Southeastern Europe and Southwestern Asia, has an area of about 780 580 km². The total population was approximately 82 million in 2018, and the population growth rate has been 1 % per year for last fifteen years [1]. With its geographical location and weather, Turkey has great potentials of hydraulic, wind, solar and geothermal energy sources. In addition, Turkey is a livestock and agriculture country and this makes it suitable for power generation from biomass energy. However, Turkey's total energy demand has been increasing rapidly and imported fossil fuels dominate Turkey's total primary energy consumption by the rate of 75 % [2]. Turkey's energy import bill in 2018 increased by nearly 15,6 percent compared to 2017. Turkey paid 42,99 Billion USD (BUSD) for its energy imports last year compared to 37,20 BUSD in 2017. Turkey's total import bill in 2018 showed a 4,6 percent decrease and amounted to 223 BUSD, out of which energy accounted for 19,2 percent [3,4]. Electricity consumption increased by 0,75 percent in 2018 compared to 2017. The country's power consumption was 292,17 TWh in 2018 compared to 289,97 TWh in 2017. Turkey produced 293,78 GWh of electricity in 2018 - a production increase of 1,11 percent, up from 290,55 GWh in 2017. The amount of electricity imported last year reached nearly 1,38 TWh, compared to 1,66 TWh in 2017. Turkey bought electricity from five countries - Greece, the Czech Republic, Bulgaria, Georgia and Azerbaijan, out of which Bulgaria held the biggest share of electricity exports to Turkey. Turkey bought nearly 1,01 TWh of electricity from Bulgaria, paying 42,20 MUSD to its neighbor [5].

According to the study of Ministry of Energy and Natural Resources (ETKB), with high demand scenario in 2023, Turkey's energy demand will increase approximately 7,5 % per year, and will reach 538 TWh. Based on a low demand scenario in 2023, it is expected to reach 480 TWh with an annual increase rate of 6,7 %. Similarly, for the year of 2030, Turkey's energy demand will reach 757 TWh in a high demand scenario and 610 TWh in a low demand scenario, respectively [6-8]. As seen in Table 1, Turkey had 88,55 GW installed capacity of electricity by the end of 2018. The breakdown of installed capacity of electricity by sources is as follows: 52,97 % fossil fuels (natural gas, coals, liquid fuels etc.), 31,95 % hydro, 7,91 % wind, 5,72 % solar and 1,45 % geothermal [2]. Nearly all of natural gas and around 40 % of coal were imported from abroad. Therefore, Turkey boosts up its self-sufficiency by handling its rich potential of renewable energy sources (RES).

Compared to the additional installed capacity of 6 207,7 MW in 2017, added power capacity slowed down to 3 350,8 MW in 2018. Only renewables caused an increase in installed capacity of Turkey during 2018: solar PV (1 642,2 MW), hydroelectric power (1 018,3 MW), wind (489,2 MW) and geothermal (218,8 MW).

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 79,1 % in 2018 [9]. Turkey's power distribution network is completely in private sector hands. The liberalization and privatization of electricity generation and distribution increased the amount of private investments and results with increase of generation capacity and energy access security.

Turkey announced its National Energy Efficiency Action Plan for the 2017-2023 period ("Action Plan") which was published in Official Gazette number 30289 on January 2, 2018 [9]. The Action Plan outlines 55 actions involving buildings and services, energy, transport, industry and technology, agriculture and other issues for horizontal sectors. It examines energy and natural resources, aiming to encourage Turkey's prosperity in the most efficient and environmentally conscious manner possible. The Action Plan aims to save 23,9 MTOE from Turkey's primary energy consumption with the reduction by 14 %, via a strategy which includes 10,9 BUSD of planned investment by 2023 [9-10]. In the Action Plan, it is stated that expanding the use of renewable energy and cogeneration systems in buildings will be encouraged. Also, cogeneration and district heating/cooling systems are planned to become compulsory in new community buildings. To support renewable energy use, related administrative processes will be expedited for existing buildings.

A recent issue has emerged from the economic problems resulting from the sharp devaluation of the Turkish Lira in 2018, and wiped almost a third of the value off the Turkish Lira. Since the beginning of 2018, Turkey's natural gas prices have increased by 29,5 % and 54 % respectively for residential and commercial/industrial consumers. The economic situation and currency volatility will be likely to continue the next few years, and will affect all energy sector as well as solar PV investments.

TABLE 1 – BREAKDOWN OF INSTALLED CAPACITY OF ELECTRICITY BY ENERGY RESOURCES IN 2017 AND 2018

ENERGY RESOURCES	INSTALLED CAPACITY (MW) (2017)	INSTALLED CAPACITY (MW) (2018)	ADDED CAPACITY (MW) (2017-2018)	INCREASE OR DECREASE (%) (2017-2018)
Fossil fuels based thermal power plants	46 926,5	46 908,8	-17,7	-0,04
Hydroelectric	27 273,1	28 291,4	1 018,3	3,73
Wind	6 516,2	7 005,4	489,2	7,51
Solar PV	3 420,7	5 062,9	1 642,2	48,01
Geothermal	1 063,7	1 282,5	218,8	20,57
Total	85 200,2	88 551,0	3 350,8	3,93

NATIONAL PROGRAMME AND LEGISLATION

Solar energy is the most important renewable energy source, which is still untapped in Turkey with a potential of 500 GW minimum. Turkey's renewable energy investment totaled 2,2 BUSD in 2018, down 5 % on 2017 [11]. At the end of 2018, cumulative installed PV power in Turkey has reached about 5 062,9 MW and increased very rapidly with a 48 % growth compared to the previous year's data, 3 420,7 MW [2]. The photovoltaic installations started to take off in 2014 with 40 MW installed capacity. In 2018, newly added PV power systems have about 1 642,2 MW capacity (Table 2).

Table 2 shows that the majority of the PV system installations was in the period of the first half of the year. Approximately 1 300 MW of new capacity was added during this period while only 340 MW was installed in the second half of the year. This is mainly the result of the economic problems raised in the year of 2018. The government thinks that solar PV will boost up after the stabilization in economy in very near future. Therefore, it is planned to develop around 10 GW additional capacity each in solar and wind energy for the next 10 years compared to the 2018 baseline [12].

TABLE 2 – MONTHLY FIGURES FOR PV POWER PLANTS INSTALLED IN 2018 [2].

MONTH	TOTAL INSTALLED (MW)		
	LICENSED	UNLICENSED	TOTAL INSTALLED
January	22,9	3 455,8	3 478,7
February	22,9	3 919,2	3 942,1
March	22,9	4 567,4	4 590,3
April	22,9	4 605,0	4 627,9
May	22,9	4 680,0	4 702,9
June	22,9	4 703,0	4 725,9
July	22,9	4 721,0	4 743,9
August	31,9	4 761,0	4 792,9
September	49,8	4 768,0	4 817,8
October	81,7	4 842,0	4 923,7
November	81,7	4 920,8	5 002,5
December	81,7	4 981,2	5 062,9

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. The Law 6446 introduces some important changes in the current electricity market system, including amendments to license types, framing its provisions around each type of market activity, specific provisions for certain license types (generation, transmission, distribution, wholesale, retail, auto-producer and auto-producer group), the introduction of a preliminary licensing mechanism and investment incentives, such as extended deadlines and

grace periods for environmental compliance. The Law 6094 introduces significant amendments to improve the incentive mechanism under the Renewable Energy Law (Law No: 5346) and encourage renewable energy investment opportunities [7]. According to the Law 6094, a purchase guarantee of 13,3 USDcents/kWh is given for solar electric energy production for ten years. The incentives are available for the PV power plants for 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 (+05 USDcents/kWh).

Turkey aims to increase the share of renewable energy in its production mix. In line with this goal, the Energy and Natural Resources Ministry is continuing with its Renewable Energy Designated Area (YEKA) projects. YEKAs are defined under a separate regulation issued in the 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 facility, (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 Regulation's objectives 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 [13].

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 [14]. The first bidding was held in Karapınar, Konya with an allocated capacity of 1 GW on March 20, 2017. A consortium consisting of Hanwha Q CELLS and Kalyon Enerji Yatirimlari A.S. was awarded by submitting the lowest bid, 6,99 USDcent/kWh, to construct the largest PV power plant with an installed capacity of 1 GW (AC) in Turkey. The purchase guarantee price will be valid for 15 years. As part of the award criteria, the consortium has to build a fully integrated solar cell and module factory with a capacity of 500 MW within the next 21 months. The new facility will consist of integrate ingot, wafer,

cell and module processes. In addition to the manufacturing facility, the consortium will establish on-site research and development (R&D) centre with 100 permanent employees. The Karapınar YEKA-1 Solar Power Plant tender was the first practice in the energy sector to be based on the condition of localization and YEKA-based price determination [14-17].

The second bidding within the framework of YEKA was intended to be realized by the end of 2018 with a total capacity of 1 000 MW for three sites/locations divided into three tenders. 500 MW to be allocated would be assigned to the Sanlıurfa-Viransehir site in the southeast of the country, 200 MW to the Hatay-Erzin site, in the same region, and 300 MW to the Nigde-Bor site, in central Anatolia, for which a 30 MW/90 MWh (AC) Li-ion battery storage project would also be tendered. The sites were identified by the Turkish government in April 2018. The Turkish government had stipulated selected projects must incorporate a minimum 60 % of PV panels manufactured in Turkey. In addition, a minimum cell efficiency of 21 % and module efficiency of 18 % had been set as minimum standards. Selected projects would have to start commercial operation by January 2024. However, the bidding for three sites was cancelled due to economic situation of the country. Now, the government is reconstructing the details of the tender and is expected to re-announce it within 2019 [18].

New regulations were offered by the Energy Market Regulatory Authority in January 2018 to make it easier for the development of household scale (10 kW or less) rooftop solar in Turkey, including a net-metering style provision that would allow such facilities to sell back excess electricity to the grid at 13,3 USDcent/kWh. This was shortly followed by an amendment to tax statutes, also exempting the excess electricity sales of these small-scale solar facilities from income taxes. These are welcome sources of support for a rooftop solar sector [19].

In terms of research and development, Turkey's capacity has been increasing in the recent years. In addition to the General Directorate on Renewable Energy, the Marmara Research Center of the Technological and Scientific Research Center of Turkey also carries on solar energy related research projects along with a number of universities. Ege University, Muğla University, Middle East Technical University, İstanbul Technical University, Kocaeli University, Harran University and Firat University can be counted among the chief academic institutions in the country that are involved with solar energy research. Solar photovoltaic science and engineering is also gaining ground in the curriculum of related undergraduate and graduate programs in such institutions. Surely the proliferation of such programs and research will help in meeting the countries need for expertise in the area [20].

INDUSTRY AND MARKET DEVELOPMENT

By the end of 2018, there were 5 868 PV power plants (5 062,9 MW in total) in operation, of only nine (81,7 MW in total) are in the licensed segment. The legislation defines the unlicensed electricity power limit as max. 1 MW. Until the beginning of 2016, some investors had preferred to install MW scaled PV power plants in total by covering

a few unlicensed plants, but it is now prohibited by the changed amendments made to the Unlicensed Electricity Generation Regulation on 23 March 2016.



Fig. 1 - One of the largest rooftop PV power systems consisting of thin-film PV modules in Osmaniye (10 MW) [21].

Regarding PV manufacturing activities, currently there are not any manufacturers of feedstock, ingots and wafers in Turkey. Currently, there are 30 PV module manufacturers in Turkey with a production capacity of more than 3 500 MW annually. There are also a few PV module constituents (glass, frame etc.) manufacturers in Turkey. The majority of fabricators are undergoing simple construction, cabling, framing work, whereas 85 % of total PV investments was imported. The import reached to 9,7 BUSD cumulatively since 2014 [22]. The solar energy sector currently employs around 20 000 workers.



Fig. 2 - Commercial rooftop PV power system at Tiryaki Agro Company in Mersin (4.24 MW) [23].

Turkey's PV market is being accelerated and development is seen in all dimensions from production to installation with the support of raising awareness in all levels of society. The Turkish Solar Energy Associations continued their endeavors to facilitate information flow for a healthy market development. One of the events organized by GÜNDER and UFTP entitled "SOLARTR 2018 Conference and Exhibition" was concluded in İstanbul on November 29-30, 2018, in addition to several

meetings and workshops organized for capacity building and removing the barriers along the whole year. The conference was 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.



Fig. 3 - SOLARTR 2018 Conference and Exhibition, November 2018 [22].

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- [5] <https://www.dailysabah.com/energy/2019/02/05/turkeys-electricity-import-bill-down-33-percent-in-2018>
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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 often vary in form and magnitude. To date, a national-level deployment mandate has not been implemented, however individual state mandates have been successfully implemented, with 2018 bringing several very notable new mandates. Existing policy at the national and state level and rapidly declining technology costs have enabled PV to continue to grow rapidly in the U.S. By the end of 2018, the U.S. was expected to reach 62,4 GW_{DC} [1] of cumulative installed capacity, an increase from 51,8 GW_{DC} in 2017, and 50,0 GW_{DC} in 2016 [2].

State-level policy and financing mechanisms, such as low-cost loan programs, continue to encourage further solar market expansion. 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, although the trend towards third-party ownership has slowed this year, loans and cash purchases of systems continue to increase in popularity due to both the declining cost of solar and new loan products entering the market. Nationally, third-party ownership stood at 32 % at the end of the 3rd quarter of 2018 [3] Companies have also issued innovative financing mechanisms to raise cheaper sources of capital through public markets.

U.S. Annual PV Installations

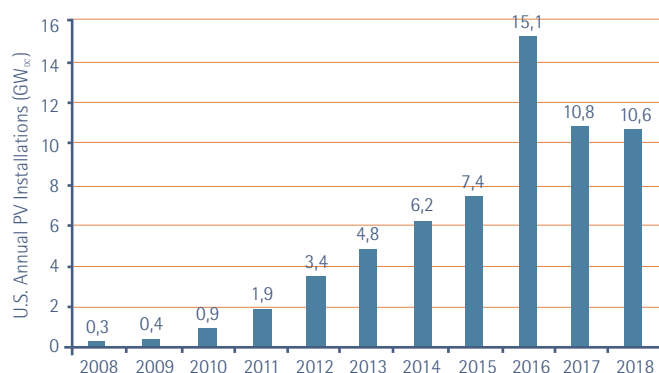


Fig. 1 – U.S. Annual PV Installations. Source: GTM/SEIA, U.S. Solar Market Insight Report 4Q18. December, 2018.

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). The 30 % ITC runs until 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 [4]. In June 2018, the Internal Revenue Service issued guidance that clarified the extension of the ITC for developers who can qualify their project under one of two tests [5]. Known as "Commence Construction" rules, the guidance allows a developer to lock themselves into the current ITC rate provided they finish building their system within four years. Under the prior law, a project must have been placed into service to qualify for the credit. The 5-year tax depreciation changed under the tax law passed in 2017, which became effective in 2018, and now allows project owners to depreciate 100 % of their capital expenses during the first year of system operation through 2022; starting in 2023, the percentage of capital equipment that can be expensed immediately drops 20 % per year (e.g., 80 % in 2023 and 60 % in 2024) until the provision drops to 0 % in 2027.

State incentives in the U.S. have been driven in large part by 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 vary considerably, RPS policies typically enforce compliance through penalties, and many include the trading of renewable energy certificates (RECs). Alternatively, a clean energy standard (CES) is similar to an RPS, but allows a broader range of electricity generation (E.g., nuclear) resources to qualify for the target. As of October 2018, twenty-nine states, three territories, and Washington D.C., had RPS policies with specific solar or customer-sited provisions [6]. A number of states have recently adopted increasingly aggressive RPS and carbon-free generation goals. In September 2018, California enacted legislation [7] increasing its RPS to 60 % of electricity retail sales by 2030 and requiring all generation in the state

[1] GTM Research SEIA: Solar Market Insight Report 2018 Year In Review. March 2019.

[2] GTM Research SEIA, Q4 2018: U.S. Solar Market Insight. December 2018.

[3] Id.

[4] 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 %.

[5] Tests to qualify under the Commence Construction rule include the Five Percent Safe Harbor test, which can be met by incurring five percent or more of the total project cost in the year that construction begins, and the Physical Work Test, which can be met by starting work of a physical nature (E.g., construction, landscaping).

[6] North Carolina Clean Energy Technology Center. Renewable Portfolio Standard Policies. Accessed January, 2019. <http://www.dsireusa.org/resources/detailed-summary-maps/>

[7] https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100

to be carbon-free, or a 100 % CES, by 2045. California, the U.S. solar market leader, now joins Hawaii in having established 100 % renewable or carbon-free generation goals. In December 2018, Washington, D.C. passed similar legislation, requiring 100 % renewable generation by 2032. New York [8], New Jersey [9], Washington state [10], and a growing number of cities are poised to implement similar standards. While these RPS and CES markets are expected to increase installations to meet new requirements, in 2018 over two thirds of utility-scale procurements were voluntary, occurring outside of RPS structures [11]. In addition to RPS and CES, 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. State net metering participation is declining, as some states, including California, have begun to transition to new, value-based compensation mechanisms for customer-connected PV systems.

The U.S. government also supports the advancement of PV through its work at the National Science Foundation, the Department of Defense, the National Aeronautics and Space Administration, and the Department of Energy's (DOE) Office of Science, Advanced Research Projects Agency - Energy (ARPA-E), and the Solar Energy Technologies Office (SETO). DOE further supports the demonstration of PV and other renewable technologies through the DOE Loan Program Office's Loan Guarantee Program [12]. In addition to the U.S. government, states such as California, New York, Florida and Hawaii, as well as public and private companies also fund solar R&D.

RESEARCH, DEVELOPMENT & DEMONSTRATION

The DOE is one of the primary bodies that supports 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 SETO, Office of Science, and ARPA-E collaborated to support efforts by national laboratories, academia, and private companies to drive down the cost of utility-scale solar electricity to about 6 USD cents per kilowatt-hour by the year 2020. In 2017, DOE announced that it had met its utility-scale 2020 goal and updated its SunShot goal to further reduce the installed cost of solar energy to 3 USD cents per kWh by 2030, while enabling greater adoption by addressing grid integration challenges and market barriers [13].

By funding a portfolio of complementary RD&D concepts, SETO promotes a transformation in the ways the U.S. generates, stores, and utilizes solar energy. These research and development activities fall into five broad categories, which in fiscal year 2018, were funded at the levels found in Table 1:

[8] <https://www.nyserda.ny.gov/About/Newsroom/2018-Announcements/2018-12-17-Governor-Cuomo-Unveils-Agenda-for-First-100-Days>

[9] <https://nj.gov/governor/news/news/562018/approved/20180523a-cleanEnergy.shtml>

[10] <https://www.governor.wa.gov/sites/default/files/climate-change-package-overview-policy-brief.pdf>



Fig. 2 - Workers install PV panels on Natatorium in Atlanta, Georgia; Georgia Institute of Technology.

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 power 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.

[11] GTM Research SEIA, Q4 2018: U.S. Solar Market Insight. December 2018

[12] A full list of projects funded with DOE loan guarantees is available at: <https://energy.gov/lpo/loan-programs-office/>

[13] Since solar energy does not match demand at higher penetrations, even lower prices are needed to spur development. More information on the SunShot 2030 Goal of 3 ¢/kWh can be found here: <https://www.energy.gov/eere/solar/sunshot-2030>



Fig. 3 – Dangling Rope Marina, Lake Powell, Utah; Glen Canyon National Recreation Area.

TABLE 1 – BREAKDOWN OF SOLAR ENERGY TECHNOLOGIES PROGRAM FY 18 ENACTED FUNDING

Photovoltaic Research & Development	70,0 MUSD
Concentrating Solar Power	55,0 MUSD
Systems Integration	71,2 MUSD
Balance of Systems Soft Cost Reduction	11,0 MUSD
Innovations in Manufacturing Competitiveness	34,4 MUSD
Total	241,6 MUSD

INDUSTRY AND MARKET DEVELOPMENT

The U.S. market, in terms of annual installed capacity, experienced a minor decrease from roughly 10,8 GW in 2017 to 10,6 in 2018. The unprecedented increase in installed capacity seen in 2016 was largely due to expectations from developers and utilities that the ITC would expire. Many planned installations were accelerated to meet the expected deadline, which contributed to an apparent lull in 2017. Viewed as a single period, installed capacity from 2016 – 2018 tracked close to its ten-year average growth rate.

In January 2018 the President of the United States placed a tariff [14] for a period of four years on imported cells and modules. The tariff is set at 30 % in the first year, and will be reduced by five percent in each of the next three years. The first 2,5 GW of cells imported each year are excluded. Additionally, in 2018, the U.S. Federal Reserve raised interest rates four times, increasing rates from 1,5 % at the beginning of the year to 2,5 % by the year end [15]. While U.S. interest rates are still historically low, increasing capital costs could impact the rate of new installations.

Several solar market segment trends changed in 2018. Supported by strong performance in Q4 2018, the residential installation market grew by 7 %. Non-residential sector, or commercial, installations decreased by 8 %, mainly due to policy shifts in the leading markets

of California and Massachusetts; California is shifting away from a solar-friendly time-of-use rate structure, and Massachusetts is transitioning to the Solar Massachusetts Renewable Target (SMART) program – the successor to its Solar Renewable Energy Certificate (SREC) program. The non-residential sector has been otherwise supported by a growing community solar market, which comprised ~ 20 % of non-residential installed capacity in 2018. Over half of community solar's capacity increases this year have been in Minnesota, attributable to support from community solar-specific feed-in tariffs [16]. An increasing amount of residential and non-residential installations are expected to contain storage as lithium-ion battery prices continue to fall, net metering gets reduced or eliminated, and time-of-use rates increase in popularity. In 2018, an estimated 3 % of residential and 2 % of non-residential installations contained storage [17].

The utility sector's decrease in installations in the first part of the year has been attributed to delays related to uncertainty around the effects of import tariffs [18]. Utility sector installations and procurements were expected to pick up in late 2018 due to a sharp decrease in global panel prices that occurred mid-year.

U.S. PV module manufacturing production, after a contraction in 2017, increased from 223 MWp in Q4 2017 to 316 by Q3 2018, an average of 12,5 % quarter over quarter (60 % Compound Annual Growth Rate) [19]. A number of manufacturers have also announced plans to increase U.S. capacity within the next few years. The U.S. has a significant presence in other parts of the PV manufacturing value chain, including polysilicon, encapsulants, wiring, and fasteners. The manufacturing sector employed 33 700 people in 2018, a 9 % decrease from 2017 [20].

Industry-wide, approximately 149 000 jobs relating to solar were added from 2010 to 2018, and the industry has grown to a total of over 242 000 employed in 2018 [21]. 2018 saw a decline of approximately 8 000 jobs from 2017.

[14] Tariffs resulted from a case brought by two U.S. based PV manufacturers to the U.S. International Trade Commission under Section 201, Trade Act of 1974, accusing foreign governments of implementing policies supporting their domestic manufacturing in violation of WTO rules and the GATT agreement.

[15] <https://www.federalreserve.gov/monetarypolicy/openmarket.htm>

[16] GTM Research SEIA: Solar Market Insight Report 2018 Year In Review. March 2019.

[17] GTM Research/SEIA, Q4 2018: U.S. Solar Market Insight. December 2018.

[18] Id.

[19] Id.

[20] Id.

[21] Solar Foundation. (2019). National Solar Jobs Census 2018. Washington, DC: The Solar Foundation.

[22] Id.

IEA PVPS COMPLETED TASKS

DELIVERABLES – WHERE TO GET THEM?

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

TASK 2 – PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS (1995–2007)

Task 2 Reports & Database

1. Analysis of Photovoltaic Systems, T2-01:2000
2. IEA PVPS Database Task 2, T2-02:2001
3. Operational Performance, Reliability and Promotion of Photovoltaic Systems, T2-03:2002
4. The Availability of Irradiation Data, T2-04:2004
5. Country Reports on PV System Performance, T2-05:2008
6. Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies, T2-06:2007
7. Performance Prediction of Grid-Connected Photovoltaic Systems Using Remote Sensing, T2-07:2008

TASK 3 – USE OF PHOTOVOLTAIC POWER SYSTEMS IN STAND ALONE AND ISLAND APPLICATIONS (1993–2004)

Task 3 Reports

1. Recommended Practices for Charge Controllers, T3-04:1998
2. Stand Alone PV Systems in Developing Countries, T3-05:1999
3. Lead-acid Battery Guide for Stand-alone Photovoltaic Systems, T3-06:1999,
4. Survey of National and International Standards, Guidelines and QA Procedures for Stand-Alone PV Systems, T3-07:2000
5. Recommended Practices for Charge Controllers, T3-08:2000
6. Use of appliances in stand-alone PV power supply systems: problems and solutions, T3-09:2002
7. Management of Lead-Acid Batteries used in Stand-Alone Photovoltaic Power Systems, T3-10:2002
8. Testing of Lead-Acid Batteries used in Stand-Alone PV Power Systems – Guidelines, T3-11:2002
9. Selecting Stand-Alone Photovoltaic Systems – Guidelines, T3-12:2002
10. Monitoring Stand-Alone Photovoltaic Systems: Methodology and Equipment – Recommended Practices, T3-13:2003
11. Protection against the Effects of Lightning on Stand-Alone Photovoltaic Systems – Common Practices, T3-14:2003
12. Managing the Quality of Stand-Alone Photovoltaic Systems – Recommended Practices, T3-15:2003
13. Demand Side Management for Stand-Alone Photovoltaic Systems, T3-16:2003
14. Selecting Lead-Acid Batteries Used in Stand-Alone Photovoltaic Power Systems – Guidelines, T3-17:2004
15. Alternative to Lead-Acid Batteries in Stand-Alone Photovoltaic Systems, T3-18:2004

TASK 5 – GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC SYSTEMS (1993–2003)

Task 5 Reports

1. Utility Aspects of Grid Interconnected PV Systems, T5-01:1998
2. Demonstration Tests of Grid Connected Photovoltaic Power Systems, T5-02:1999
3. Grid-connected Photovoltaic Power Systems: Summary of Task 5 Activities from 1993 to 1998, T5-03:1999

4. PV System Installation and Grid-interconnection Guideline in Selected IEA Countries, T5-04: 2001
5. Grid-connected Photovoltaic Power Systems: Survey of Inverter and Related Protection Equipment, T5-05: 2002
6. International Guideline for the Certification of PV System Components and Grid-connected Systems, T5-06:2002
7. Probability of Islanding in Utility Networks due to Grid Connected Photovoltaic Power Systems, T5-07: 2002
8. Risk Analysis of Islanding of Photovoltaic Power Systems within Low Voltage Distribution Networks, T5-08: 2002
9. Evaluation of Islanding Detection Methods for Photovoltaic Utility-interactive Power Systems, T5-09: 2002
10. Impacts of Power Penetration from Photovoltaic Power Systems in Distribution Networks, T5-10: 2002
11. Grid-connected Photovoltaic Power Systems: Power Value and Capacity Value of PV Systems, T5-11: 2002

TASK 6 – DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION (1993–1998)

Task 6 Reports, Papers & Documents

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"
8. The "Review of Medium to Large Scale Modular PV Plants Worldwide"
9. Proceedings of the Madrid Workshop

TASK 7 – PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT (1997–2001)

Task 7 Reports

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, T7-01:1999
2. PV in Non-Building Structures – A Design Guide, T7-02:2001
3. Potential for Building Integrated Photovoltaics, T7-04:2001
4. Guidelines for the Economic Evaluation of Building Integrated Photovoltaics, T7-05:2002
5. Market Deployment Strategies for Photovoltaics in the Built Environment, T7-06:2002
6. Innovative electric concepts, T7-07:2002
7. Reliability of Photovoltaic Systems, T7-08:2002
8. Book: "Designing with Solar Power – A Source Book for Building Integrated Photovoltaics (BIPV)", Edited By Deo Prasad and Mark Snow, Images Publishing, 2005 (ISBN 9781844071470)

TASK 8 – STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM (1999-2014)

Task 8 Reports

1. Book: "Energy from the Desert: Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems", James and James, 2003 (ISBN 1 902916 417)
2. Report: "Summary – Energy from the Desert: Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems", 2003
3. Report: "Summary – Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems", 2006
4. Book: "Energy from the Desert: Practical Proposals for Very Large Scale Photovoltaic Systems", Earthscan, 2007 (ISBN 978-1-84407-363-4)
5. 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)
6. Report: "Summary – Energy from the Desert: Very Large Scale Photovoltaic Systems, Socio-Economic, Financial, Technical and Environmental Aspects", 2009
7. 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))
8. Report: "Summary – Energy from the Desert: Very Large Scale Photovoltaic Power – State-of-the-Art and into the Future", 2013
9. Report: "Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future", 2015 (ISBN 978-3-906042-29-9)
10. Report: "Summary – Energy from the Desert: Very Large Scale PV Power Plants for Shifting to Renewable Energy Future", 2015
11. Brochure: "Energy from the Desert: Fact sheets and the Summary of the Research", 2015

TASK 9 – DEPLOYMENT PV SERVICES FOR REGIONAL DEVELOPMENT (1998-2018)

Task 9 Reports

1. Financing Mechanisms for SHS in Developing Countries, T9-01:2002
2. Summary of Models for the Implementation of Photovoltaic SHS in Developing Countries, T9-02:2003
3. PV for Rural Electrification in Developing Countries – A Guide to Capacity Building Requirements, T9-03:2003
4. The Role of Quality Management Hardware Certification and Accredited Training in PV Programmes in Developing Countries: Recommended Practices, T9-04:2003
5. PV for Rural Electrification in Developing Countries –Programme Design, Planning and Implementation, T9-05:2003
6. Institutional Framework and Financial Instruments for PV Deployment in Developing Countries, T9-06:2003
7. 16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries, T9-07:2003
8. Sources of Financing for PV-Based Rural Electrification in Developing Countries, T9-08: 2004
9. Renewable Energy Services for Developing Countries, in support of the Millennium Development Goals: Recommended Practice and Key Lessons, T9-09:2008

10. Task 9 Flyer: PV Injection in Isolated Diesel Grids, T9-10:2008
11. Policy Recommendations to Improve the Sustainability of Rural Water Supply Systems, T9-11: 2011
12. Pico Solar PV Systems for Remote Homes, T9-12:2012
13. Rural Electrification with PV Hybrid Systems – 2013 (En), T9-13:2013
14. Mini-réseaux hybrides PV-diesel pour l'électrification rurale – 2013 (Fr), T9-13 :2013
15. Innovative Business Models and Financing Mechanisms for PV Deployment in Emerging Regions, T9-14:2014
16. PV Systems for Rural Health Facilities in Developing Areas, T9-15:2014
17. A User Guide to Simple Monitoring and Sustainable Operation of PV-diesel Hybrid Systems, T9-16:2015
18. Guideline to Introducing Quality Renewable Energy Technician Training Programs, T9-17:2017
19. PV Development via Prosumers. Challenges Associated with Producing and Self-consuming Electricity from Grid-tied, Small PV Plants in Developing Countries, T9-18:2018

TASK 10 – URBAN SCALE PV APPLICATIONS (2004-2009)

Task 10 Reports

1. Compared Assessment of Selected Environmental Indicators of PV Electricity in OECD Cities, T10-01:2006
2. Analysis of PV System's Values Beyond Energy –by country, by stakeholder, T10-02:2006
3. Urban BIPV in the New Residential Construction Industry T10-03:2008
4. Community Scale Solar Photovoltaics: Housing and Public Development Examples T10-04:2008
5. Promotional Drivers for Grid Connected PV, T10-05:2009
6. Overcoming PV Grid Issues in Urban Areas, T10-06:2009
7. Urban PV Electricity Policies, T10-07:2009
8. Book: Photovoltaics in the Urban Environment, Routledge, ISBN 9781844077717

TASK 11 – HYBRID SYSTEMS WITHIN MINI-GRIDS (2006-2012)

Task 11 Reports

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

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