Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

PVPS

# ANNUAL REPORT 2019

PHOTOVOLTAIC POWER SYSTEMS TECHNOLOGY COLLABORATION PROGRAMME

Cover photo

**THE INTERNATIONAL OLYMPIC COMMITTEE'S (IOC) NEW HEADQUARTERS' PV ROOFTOP, BUILT BY SOLSTIS, LAUSANNE SWITZERLAND**

One of the most sustainable buildings in the world, featuring a PV rooftop system built by Solstis, Lausanne, Switzerland.

At the time of its certification in June 2019, the new IOC Headquarters in Lausanne, Switzerland, received the highest rating of any of the LEED v4-certified new construction project. This was only possible thanks to the PV system consisting of 614 mono-Si modules, amounting to 179 kWp and covering 999 $m^2$ of the roof's surface. The approximately 200 MWh solar power generated per year are used in-house for heat pumps, HVAC systems, lighting and general building operations.

Photo: Solstis © IOC/Adam Mork


**COLOPHON**

**Cover Photograph**
Solstis © IOC/Adam Mork
**Task Status Reports**
PVPS Operating Agents
**National Status Reports**
PVPS Executive Committee Members and Task 1 Experts
**Editor**
Mary Jo Brunisholz
**Layout**
Autrement dit
**Background Pages**
Normaset Puro blanc naturel
**Type set in**
Colaborate
**ISBN**
978-3-906042-95-4

# PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

# ANNUAL REPORT 2019

# CHAIRMAN'S MESSAGE

A warm welcome to the 2019 annual report of the International Energy Agency Photovoltaic Power Systems Technology Collaboration Programme, the IEA PVPS TCP! We are pleased to provide you with highlights and the latest results from our global collaborative work, as well as relevant developments in PV research and technology, applications and markets in our growing number of member countries and organizations worldwide.

2019 has – again – confirmed the strong development of the global photovoltaic (PV) market of previous years and the continuous increase in competitiveness of solar photovoltaic power systems. Due to this development, PV is increasingly becoming a strategic pillar of the energy policy in many of our member countries and of the decarbonization of the energy system. Achieving levelized costs of electricity from PV well below 2 USDcents/kWh in utility scale systems under favourable conditions, diversifying PV applications and markets, 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.

Compared to 2018, our market analysis for 2019 estimates an increase of 12%, or approximately 115 GW, installed worldwide, raising the cumulative installed capacity to well above 620 GW. China, the USA, India and Japan represented the largest markets in 2019, accounting for more than 50% of the additional installed capacity in these four countries alone. Nine countries had more than 10 GW of cumulative PV systems capacity at the end of 2019, 39 countries had at least 1 GW cumulative capacity and 18 countries installed at least 1 GW in 2019. Meanwhile, in 22 countries, PV contributes with 3% or more to the annual electricity supply. With the total installed capacity by the end of 2019, PV can now contribute to roughly 3% 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 TCP. In 2019, IEA PVPS continued its focus on the integration of PV in the energy system. The IEA PVPS TCP thereby broadens 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, building and vehicle 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. In 2019, IEA PVPS renewed its activities towards off-grid and edge-of-grid PV systems through a new Task 18, with emphasis on applications in developing and transition countries.

As PV matures with a growing number of countries, stakeholders and organizations involved, 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. Bringing the best added value to our members and target audiences is the goal that we pursue together. Besides fostering an increased cooperation within the IEA technology network, stronger ties are being built with other international organizations such as IRENA, the IEC and the International Solar Alliance ISA.

Interest and outreach for new membership within IEA PVPS continued in 2019, namely with India, Singapore and Argentina. 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.

Our work would not be possible without a dedicated 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 devoted efforts for a unique and truly global cooperation!

This IEA PVPS TCP annual report is published in a time when the world is experiencing unprecedented challenges in coping with the global Covid-19 pandemic. While we are just about to understand how deeply and how long many of our habits and our way of life will be affected, both professionally and privately, we can also observe a unique creativity to overcome this difficult situation. I am convinced that we may all learn from these new experiences, including for other challenges such as global climate change. I wish all of you the very best, stay healthy and committed!

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 ninerenewable 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 2019, eighteen Tasks were established within the PVPS programme, of which eight 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.

## 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 orga-nisations and agencies;

54th IEA PVPS Executive Committee Meeting, Santiago, Chile, November 2019.

- 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.

## 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 $CO_2$ 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 of Photovoltaic Systems. 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.
- Task 18. Off-Grid and Edge of Grid Photovoltaic Systems. Begun in 2019.

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 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,

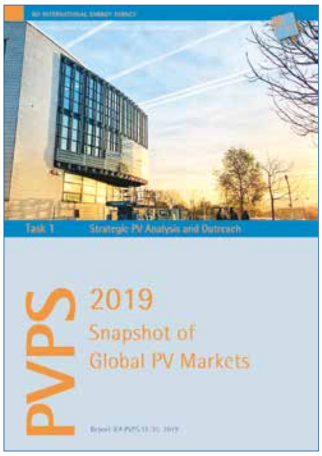


Fig. 1 – PVPS Report: A Snapshot of Global PV Markets; Report IEA PVPS T1-35:2019.


Fig. 2 – PVPS Report: Trends in Photovoltaic Applications – Survey Report of Selected IEA Countries between 1992-2018; Report IEA PVPS T1-36:2019.

prices, economic benefits, new initiatives including financing and electricity utility interests.

### 24th Edition of the Trends in Photovoltaic Applications Report

Each year the printed report, *Trends in Photovoltaic Applications*, is compiled from the National Survey Reports (NSRs) produced annually by all countries participating in the IEA PVPS Programme, and additional information provided by a network of market and industry experts. The *Trends* report presents a broader view of the current status and trends relating to the development of PV globally. The report aims at providing the most accurate information on the evolution of the PV market, the industry value chain, 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-four issues of *Trends* have been published. They are all available on the IEA PVPS website.

### A Snapshot of Global PV Markets Report

Since 2013, an additional report, *A Snapshot of Global PV Markets, 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

Fig. 3 – IEA PVPS Task 1 Experts Meeting, in Montreux, Switzerland, April 2019.

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, first published in 2016 will be updated in 2020. It analyzes and compares policies supporting the local self-consumption of PV electricity. It accompanies the most recent developments in regulatory updates in key countries allowing PV system owners to become real prosumers. It provides an independent, fair and accurate analysis on the policy evolutions currently ongoing in several countries, highlighting the technical, economic and regulatory challenges associated to the development of PV for prosumers.

## SUBTASK 1.2: THINK TANK ACTIVITIES

Task 1 aims at serving as the PVPS programme' s Think Tank, while providing the Executive Committee and dedicated PVPS Tasks with ideas and suggestions on how to improve the research content of the PVPS programme. In that respect, Task 1 has identified from 2013 to 2019 several subjects that led to specific activities:

- *Self-consumption Policies:* with the phase-out of financial incentives, distributed PV development requires ad hoc policies. Known under various names from "Net-metering" to "net-billing", self-consumption policies are evolving towards decentralized self-consumption, new grid financing schemes and access to electricity markets for prosumers. This subject was summarized in a specific report in 2016 with numerous workshops held and will continue to be a subject of focus in the coming 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 a continuous interest. In 2019 as well, Task 1's work was focused on studying emerging models through dedicated workshops and conferences.
- *PV for Transport:* the electrification of transport is one of the key elements to decarbonize that sector. Furthermore, 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. On this topic, Task 1 continues to support Task 17 PV & Transport.
- *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 has organized several workshops where utilities and PV experts exchanged information and visions about the role of utilities. The 5th IEA PVPS Utility Workshop, "Peer2Peer Electricity Trade," will be held as a virtual online meeting on 20 April 2020. IEA PVPS Task 1 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.
- *PV as an Enabler of the Energy Transition:* Climate change policies and integrated energy policies have been heavily discussed and researched to better understand the potential and limitations of PV.
- *Recommendations and Analysis:* the fast development of PV in all continents required from regulators and authorities to perfectly understand the key features of the PV technology development. IEA PVPS Task 1 will provide a set of recommendations in various fields, to disseminate the vast experience acquired by its experts over the last years.

## SUBTASK 1.3: COMMUNICATION ACTIVITIES

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

Fig. 4 – IEA PVPS Task 1 Workshop on Self-consumption, in Montreux, Switzerland, April 2019.

Fig. 5 – IEA PVPS Task 1 Workshop on Innovative Self-consumption, at the EU-PVSEC-36, Marseille, France, September 2019.

*Events:* Task 1 organizes or participates to events during energy or PV-related conferences and fairs. Workshops are organized on various subjects, sometimes in cooperation with other tasks of the PVPS program or external stakeholders. In 2019, the following workshops were organized in several locations around the world:

- Montreux, Switzerland: In conjunction to the Task 1 meeting, a workshop dedicated to self-consumption innovative projects and policies was organized.
- Chicago, Illinois, USA: A joint Task 1 and Task 17 workshop on grid costs and barriers in addition to PV for transport was organized during the 46th IEEE-PVSC conference. The 1st session focused on PV and transport and the 2nd session titled "Grid cost, barriers or drivers" dealt with grid cost impacts for further penetration of PV in international cases.
- Marseille, France: During EU-PVSEC-36, a workshop was organized within the conference program focusing on innovative applications for heating and cooling, but also for innovative self-consumption projects, in cooperation with the European SET-Plan Action 4 group and the European Horizon2020 PVP4GRID project. Task 1 also coordinated the organization of the events of Task 12, Task 13, Task 15 and Task 16.
- Xi'an, China: The "Eco-PV" workshop at the 29th PVSEC was co-organized with the Chinese Academy of Sciences and the PVSEC organizers. It covered PV recycling and PV market and industry development.
- In addition, IEA PVPS was partner at several events in 2019. Task 1 speakers represented the program in several conferences throughout the world.

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

*Publications:* The publications of Task 1 have been described in the previous paragraph: they aim at providing the most accurate level of information regarding PV development.

*Website and Social Networks:* Task 1 manages the website of the IEA PVPS TCP. IEA PVPS is present on ResearchGate, Twitter and LinkedIn.

*PV Power Newsletter:* Three issues were published in 2019. Task 1's ambition is to provide accurate and complete information in the newsletter about the IEA PVPS TCP at least twice a year.

### IEA PVPS in the Media

New publications are disseminated by press releases to around 500 contacts from medias and national PV associations. The contact list has been expanded to include more media from Asian, African and Latin American countries in a progressive way. Translations of Task 1 press releases are made 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 IEA PVPS TCP.
This cooperation takes places with:

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

## SUMMARY OF TASK 1 ACTIVITIES AND DELIVERABLES PLANNED FOR 2020

Task 1 activities will continue to focus on development of quality information products and effective communication mechanisms in support of the PVPS strategy. Furthermore, Task 1 will continue to analyse PV support policies and provide adequate and accurate information to policy makers and others stakeholders. In addition to the recurrent market and industry analysis, Task 1 will continue to study the evolution of business models, as well as 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 2020 on the IEA PVPS website.
The target date for publication of the 7th issue of the *Snapshot of Global PV* report is the beginning of Q2 2020.

Fig. 6 – IEA PVPS Task 1 Eco PV Workshop, at PVSEC-29, Xian, China, November 2019.

The target date for publication of the 25th issue of the *Trends in Photovoltaic Applications* report is the Q4 2020.

A joint report with Task 14 on registration of PV systems is foreseen.

An update of the self-consumption policies report is foreseen.

### SUBTASK 1.2: THINK TANK ACTIVITIES

The main subjects to be developed in 2020 within the Task 1's Think Tank activities can be described as follow:

- 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.
- Social aspects of PV development is now part of the general analysis of policies.
- 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 TCP.

### SUBTASK 1.3: COMMUNICATION ACTIVITIES

Task 1 will continue its communication activities in 2020. 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 TCP.

### SUBTASK 1.4: COOPERATION ACTIVITIES

Task 1 will continue to cooperate with adequate stakeholders in 2020. 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, a special focus could be put on subjects such as heating & cooling in buildings, clean mobility and hydrogen.

## 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 (2019 AND PLANNED 2020)

**The 52nd Task 1 Experts Meeting** was held in Montreux, Switzerland, in April 2019.
**The 53rd Task 1 Experts Meeting** was held in Xian, China, in November 2019.
**The 54th Task 1 Experts Meeting** took place as a virtual meeting via teleconference, in March 2020.
**The 55th Task 1 Experts Meeting** will be held in Jeju, Korea, in November 2019, together with the PVSEC-30.

### TASK 1 PARTICIPANTS IN 2020 AND THEIR ORGANIZATIONS

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

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Australia | Mr. Warwick Johnston | SUNWIZ |
| | Ms. Linda Koshier | UNSW |
| Austria | Mr. Hubert Fechner | Austrian Technology Platform Photovoltaics |
| | Mr. Peter Illich | Technikum Vienna ENERGYbase |
| Belgium | Mr. Benjamin Wilkin | APERe |
| Canada | Mr. Christopher Baldus-Jeursen | NRCAN/RNCAN |
| Chile | Ms. Ana Maria Ruz Frías | CORFO |
| China | Ms. Lyu Fang | Electrical Engineering Institute, Chinese Academy of Science |
| | Mr. Li Zheng Guo | LONGI |

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Copper Alliance | Mr. Angelo Baggini | ECD |
| Denmark | Mr. Peter Ahm | PA Energy AS |
| European Commission | Mr. Arnulf Jäger-Waldau | European Commission, Directorate General for Joint Research Centre |
| Finland | Mr. Jero Ahola | Lappeenranta University of Technology |
| | Mr. Christian Breyer | |
| France | Mr. Tristan Carrere | ADEME |
| | Mr. Daniel Mugnier | TECSOL SA |
| | Mr. Jean-Yves Quinette | |
| Germany | Dr. Georg Altenhöfer-Pflaum | Forschungszentrum Jülich |
| Israel | Mr. Honi Kabalo | PUA |
| | Ms. Yael Harman | Ministry Of Energy |
| Italy | Ms. Francesca Tilli | GSE S.p.A. |
| | Ms. Luisa Calleri | Elettricità Futura |
| | Mr. Andrea Zaghi | |
| | Mr. Giosuè Maugeri | RSE S.p.A. |
| | Dr. Franco Roca | ENEA |
| Japan | Ms. Izumi Kaizuka | RTS Corporation |
| | Mr. Osamu Ikki | |
| | Mr. Masanori Ishimura | NEDO |
| Korea | Mr. Chinho Park | Yeugnam University |
| Malaysia | Ms. Wei Nee Chen | SEDA |
| Mexico | N/A | |
| Morocco | Mr. Ahmed Benlarabbi | IRESEN |
| Norway | Mr. Øystein Holm | Multiconsult |
| Portugal | Mr. Pedro Paes | EDP |
| SEIA | N/A | SEIA |
| SEPA | N/A | SEPA |
| EPIA/SolarPowerEurope | N/A | SolarPowerEurope |
| South Africa | Stephen Koopman | CSIR |
| Spain | Mr. José Donoso | UNEF |
| Sweden | Mr. Johan Lindahl | Becquerel Institute Sweden |
| Switzerland | Mr. Lionel Perret | PLANAIR |
| | Mr. Léo Heiniger | |
| Thailand | Mr. Itthichai Chadthianchai | Department of Alternative Energy Development and Efficiency |
| | Mr. Arkorn Soikaew | |
| The Netherlands | Mr. Otto Bernsen | Agentschap NL |
| Turkey | Dr. Kemal Gani Bayraktar | TTMD |
| | Prof. Dr. Bulent Yesilata | Gunder |
| | Dr. Ahmet Yilanci | Ege University |
| USA | Mr. Christopher Anderson | US DoE |
| | Mr. David Feldman | NREL |

# TASK 12

PV SUSTAINABILITY ACTIVITIES

## 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. 2019 marks the third 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 – 2019 saw the completion 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, the goal of Task 12 is to foster international collaboration and knowledge creation in PV environmental sustainability and safety, as crucial elements for the sustainable growth of PV as a major contributor to global energy supply and emission reductions of the member countries and the world. 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.

The objectives of Task 12 are to:

1. Quantify the environmental profile of PV in comparison to other energy technologies;
2. Investigate end of life management options for PV systems as deployment increases and older systems are decommissioned;
3. Define and address environmental health & safety and other sustainability issues that are important for market growth.

The *first objective* of this Task is well served by life cycle assessments (LCAs) that describe the energy, material, and emission flows in all the stages of the life of PV.

The *second objective* is addressed through the analysis of recycling and other circular economy pathways.

For the *third objective*, Task 12 develops methods to quantify risks and opportunities on topics of stakeholder interest.

## OUTREACH

Task 12 aims to facilitate a common understanding of PV Sustainability, with a focus on Environment Health and Safety (EH&S), among the various country-members and disseminate the Task's outcomes and knowledge to stakeholders, energy and environmental policy decision makers, and the general public.

Task 12 is operated jointly by the National Renewable Energy Laboratory (NREL) and University of New South Wales (UNSW). Support from the United States' Department of Energy (DOE) and UNSW are gratefully acknowledged.

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 PVPS TCP'S TASK 12

### SUBTASK 1: END OF LIFE MANAGEMENT

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


Fig. 1 – IEA PVPS Task 12 experts with Chinese recycling experts at the Task 12 Experts Meeting, in Xi'an, China, hosted by Longi, 30 October 2019.

(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). In 2019, Task 12 contributed a survey of the status of crystalline silicon PV module recycling in selected world regions to the **IEA PVPS Trends Report** (IEA PVPS T1-36 : 2019), including Europe, Japan and the USA. This status survey will carry forward to future years in a new activity, whereby the status in additional countries can be contributed by Task 12 members and regularly updated to observe trends over time in the development of this new market.

As an example of an integration of Subtask 1 and Subtask 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 2020 include environmental and economic assessment of re-use potential for PV system components, development of design for recycling guidelines for PV as well as an update to the global status of recycling in select countries.

## SUBTASK 2: LIFE CYCLE ASSESSMENT (LCA)

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 have been applied in the 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. 2019 saw the extension of this leadership standard to cover inverters as well, hence providing a sustainability metric for the most important components of a PV System. (The standard is available here: https://www.techstreet.com/standards/nsf-457-2019?product_id=2091842.)

The planned update of Life Cycle Inventory data for the supply chains of c-Si PV technologies, which was foreseen for 2019, has been postponed to 2020 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. 2020 will also see another update to Task 12's flagship **LCA Methodological Guidelines**. Extending further the topics on which Task 12 conducts LCA, in 2020, Task 12 intends to complete the development and application of a new LCA metric on primary mineral resource intensity of PV, an LCA of PV plus storage, as well as a fact sheet covering many of the LCA metrics in one, easy-to-read sheet.

## SUBTASK 3: OTHER SUSTAINABILITY TOPICS

With the publication of the second part of the Human Health Risk Assessment Methods for Photovoltaics (**Human Health Risk Assessment Methods for Photovoltaics - Part 2: Breakage Risks, T12:15-2019**), 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 PV modules left broken in the field and leaching of metals within the module to rainwater. To evaluate these concerns, screening-level risk assessment methods are presented that can estimate emissions that may occur when broken PV modules are exposed to rainwater, estimate the associated chemical concentrations in soil, groundwater and air, and finally compare these exposure-point concentrations to health-protective screening levels. The screening-level methods can be used to decide whether further evaluation of potential health risks is warranted. A few example scenarios demonstrate application of the methods. Specifically, this report presents an analysis of potential human health impacts associated with rainwater leaching from broken modules for two PV technologies, focusing on release of the highest-prioritized chemical element for each: lead (Pb) content in crystalline-silicon (c-Si) PV modules and cadmium (Cd) content in thin film cadmium telluride (CdTe) PV modules.

This series of reports will be completed in 2020 with a report on leaching in module disposal scenarios (Part 3).

## ACTIVITIES IN 2019

2019 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 – Italy – and the identification of new or additional experts from existing member countries and organizations – France, PV Cycle – 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 2019 in Sweden, China hosted the Autumn Task 12 Experts Meeting in Xi'an in November 2019.

## GOVERNANCE, DISSEMINATION AND NEXT MEETINGS

### Membership:

Total membership stands now at 13 countries and 2 industry associations, with ~20 active experts. Italy and new experts from France, PV Cycle, and Belgium have joined most recently.

### Next Meetings:

Next to continuation of the regular cadence of expert meetings – the Spring meeting is being hosted by The Netherlands in March 2020, and South Korea has invited Task 12 for an IEA PVPS Joint Tasks Meeting adjacent to the Asia PVSEC in Autumn 2020.

## PUBLICATIONS

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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. https://onlinelibrary.wiley.com/doi/full/10.1002/pip.2841

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

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

**TABLE 1 - TASK 12 PARTICIPANTS**

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| Italy | Lucio Sannino | ENEA |
| | Pierpaolo Girardi | RSE (Ricerca sul Sistema Energetico) |
| | Andrea Danelli | |
| Japan | Satoru Shimada | NEDO (New Energy and Industrial Technology Development Organization) |
| | 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 Comerc Internacional) and Oxford Brookes University |
| | Carmen Alonso-Garcia | CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) |
| Sweden | Linda Kaneryd | Swedish Energy Agency |
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| Switzerland (alternate) | Philippe Stolz | Treeze |
| The Netherlands | Mariska de Wild-Scholten | SmartGreenScans |
| | Frank Lenzmann | 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

### INTRODUCTION

Within the framework of PVPS, Task 13 aims to provide support to market actors working to improve the operation, the reliability and the quality of PV components and systems. Operational data from PV systems in different climate zones compiled within the project will help provide the basis for estimates of the current situation regarding PV reliability and performance. 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, 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 change, both in magnitude with a near-doubling of global capacity every three to four 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 system 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 had started its 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, reliability and lifetime of PV systems in a wide variety of environments and applications. By working together across national boundaries we can all take 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 and continue to provide competitive return on investment.

Specifically we aim 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, Asian-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. However, new technologies also present challenges to current practices and standards.

The objectives of Subtask 1 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 focuses on four specific activities. ST1.1 investigates 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 focuses 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 focuses 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 focuses 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 is exploring 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, metal-wrap-through (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.

Bifacial cells and modules are rapidly making their way into the PV market. Subtask 1's work in this area is focused on collecting data and modelling methods and results from international bifacial research groups. In 2019, Subtask 1 collected bifacial performance results collected from seven different research groups and obtained commitments for participation in a model comparison study from a similar number of labs. Subtask 1 is beginning to 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. One of the complicating factors that concerns bifacial performance is "edge effects" which result in modules near the end of rows or near the edges of arrays receiving more light than more interior modules. Figure 1 illustrates two examples based on detailed 3-D ray tracing calculations that shows the need to be up to 10 modules in from the edge of the row before these effects are eliminated. This is important because nearly all the available field research on bifacial PV systems has been done on systems that are small relative to this edge effect and therefore many of the published studies that rely on performance comparisons from such systems likely overestimate the advantages of bifacial PV in larger systems.

Additionally, progress is being made in collecting information from members about unique characterization challenges for new PV system designs and configurations, including, PV with integrated energy storage, AC modules with integrated inverters, agricultural photovoltaics, floating PV and other novel PV system applications. Each of these applications have features that differ from traditional PV systems, which require new ways to characterize their performance. For example, dual-use applications incorporate PV for the purpose of generating electricity as well as another valuable use, such as altering the local environment for agriculture, or increasing self-consumption (via energy storage). We are also examining alternate PV system designs that allow for PV modules to be folded away during bad weather. By avoiding exposure to high winds, lightweight mounting structures can be used, opening up new application possibilities.

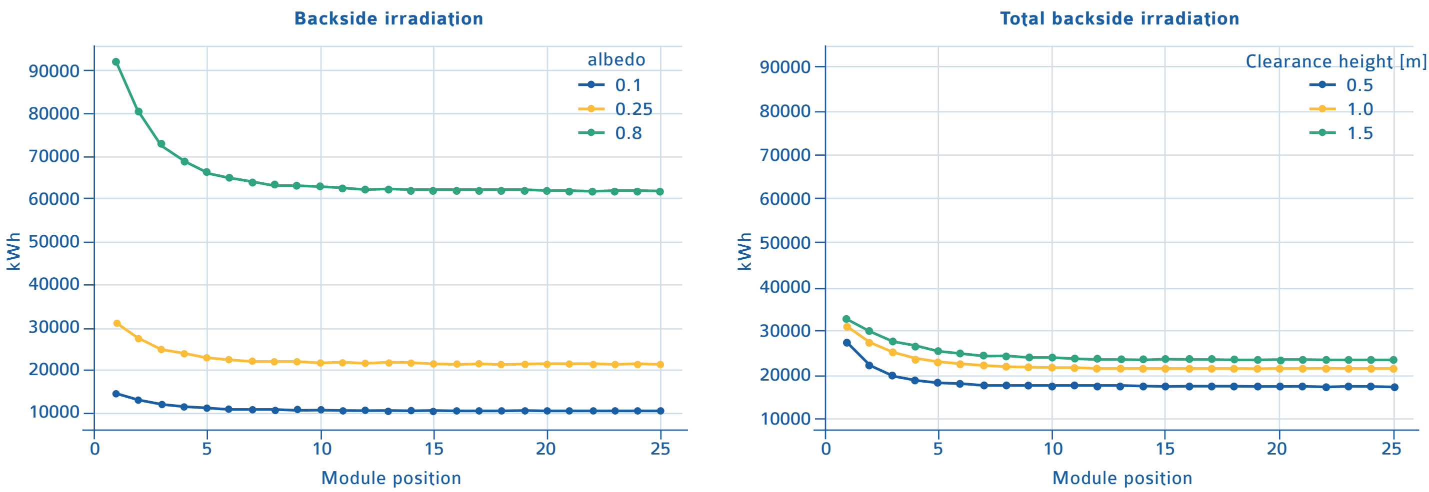


Fig. 1 – Simulated bifacial PV performance showing edge effects at various albedos (left) and module clearance heights (right) (Source: J. Stein, SANDIA).

Fig. 2 – Task 13 Expert Meeting at Atamostec, Chile, 25 October, 2019 (Photo: Elias Urrejola, Atamostec).

## SUBTASK 2: PERFORMANCE OF PHOTOVOLTAIC SYSTEMS

The objectives of Subtask 2 are to study the uncertainty related to the main parameters affecting yield assessment and long-term yield prediction. 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.

In 2019, the focus in gathering content to carry out the analysis needed to populate the various reports and to check if the timelines set at the beginning are still valid.

Two yield assessment benchmarking exercises were carried out in two locations, a PV site located in the mountainous environment of Bolzano, Italy and one PV site located in the arid environment of Alice Springs, Australia. The results showed high variability in terms of P50 values due to the choice of irradiance database and model used for the yield assessment and in terms of P50/P90 values due to the assumptions used in the uncertainty calculation. The results of the yield assessments were compared with real data measured from the two chosen sites.

The impact of climate on energy yield of PV modules was further investigated within a dedicated activity with the final aim of providing a guidance in energy rating of different PV module technologies in different climates. A questionnaire was created to identify and specify available datasets to be used for separating and quantifying meteorological impact factors on the energy yield to compare different PV module types in various climates. The data available can be separated into indoor and outdoor energy rating data, as well as meteorological data (climate). The report will provide status and good practice methods for energy rating measurements of PV modules, provide typical data sets for PV modules performance for different operating conditions, facilitate a comparison and assessment between different energy rating approaches, energy yield simulation by software tools and measured data from the field.

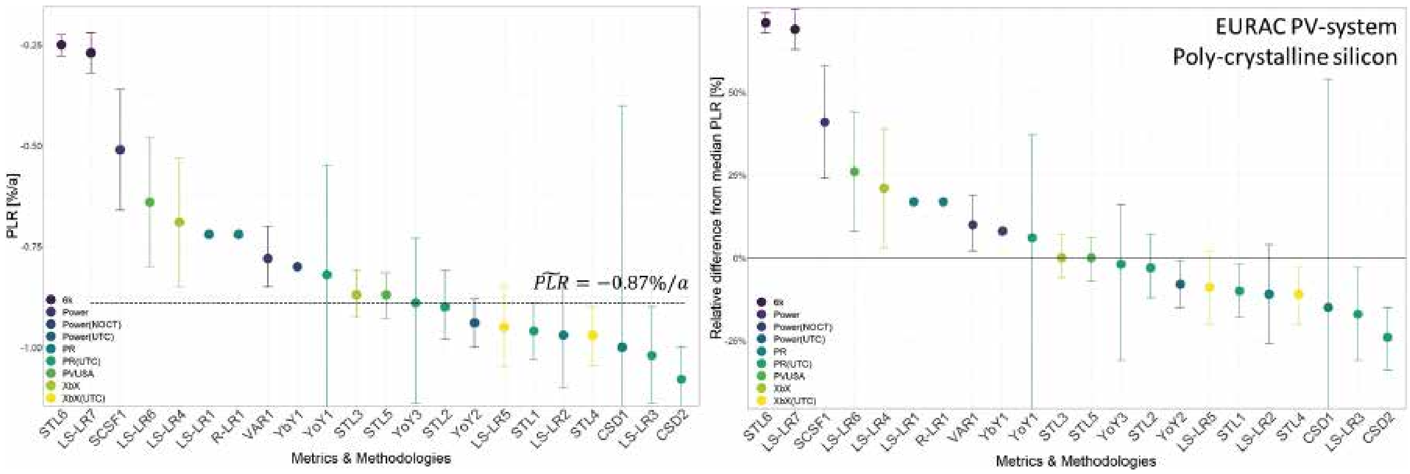


Fig. 3 – Results for the Performance Loss Rates (PLR) exercise showing the values for a polycrystalline system located in Bolzano (dataset provided by EURAC) calculated using different combinations of metrics and methodologies. On the left side, the absolute values, on the right side the relative difference from the resulting median PLR.

One of the parameters affecting yield assessments and performance is soiling. In Subtask 2, a dedicated activity investigates the physical principles related to soiling and the impact of soiling on PV performance and reliability. The work was focused in collecting information about available sensors for soiling and snow, in estimating energy losses of utility-scale systems, in listing available models, and in providing mitigation measures. Specific examples were provided for snow losses in Sweden and in Canada and experiences in PV module cleaning.

The activity focused on the assessment of Performance Loss Rates (PLR) continued with a large international participation in the benchmarking exercise using several datasets from different climates and technologies, including datasets generated from digital power plant models where the PLR value is known. Each participant to the exercise was asked to apply the preferred filtering, metric and methodology showing high variability in the final outcome (see Figure 3). The results were presented during the EUPVSEC in Marseille, France. The PVPS Task 13 performance database was also used for the calculation of the PLR (more than 140 systems) where the PLR was correlated with climate. The results were presented during the IEEE PVSC conference in Chicago, Illinois, USA, in June 2019.

## 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 & snow. Task 13 aims at contributing with the O&M guidelines to its objectives and to improve the communication among the different stakeholders.

The PV risk analysis serves to identify and reduce the risks associated with investments in PV projects. The key challenge in reacting to or preventing failures at a reasonable cost is the ability to quantify and manage the different risks. Within IEA PVPS Task 13, an international group of experts aims to increase the knowledge of methodologies to assess technical risks and mitigation measures in terms of economic impact and effectiveness. The developed outline provides a reproducible and transparent technique to deal with the complexity of risk analysis and processing in order to establish a common practice for professional risk assessment.

After a first research of scientific literature and technical reports, the common practices for quantifying the impact of technical risks were compared, limitations and challenges compiled and selection criteria defined. The second part deals with the systematical approach to identify the main technical risks, define the most important risk parameters and collect these failure, loss and occurrence data from real case studies or previous IEA PVPS Task 13 reports. These statistics serve as the basis for risk models, such as the CPN method, which are used to assess the associated risk and the economic impact over the project-lifetime of a PV plant. In addition to the knowledge of the individual risks, the economic impact of these risks are the driving factors for further analysis and decisions. In a final step, tailored to the identified risks and the status of the PV plant, a list of recommended mitigation measures and the related costs is composed. The costs of mitigation measures are included in a cost-benefit analysis in order to derive the best strategy from a technical and financial perspective. These results will be published in a conference paper in 2020 and in the technical report on professional risk assessment for PV investments in 2020/2021.

Subtask 3 will provide good practice on methods for portable devices to qualify PV power plants. This Subtask has also started to collect and share other participants' 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 was compiled.

The mobile measurement devices and inspection methods in the field including I-V curve data, dark I-V data, electroluminescence (EL) images, infra-red (IR) images, UV fluorescence (FL) images, spectroscopic methods and photoluminescence (PL) measurements are being discussed and assessed regarding different quality levels and involved costs. We 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. We 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.

Task 13 will collect contributions and experiences on O&M procedures in 15 different countries and climates from 25 collaborating experts. We aim to collect O&M recommendations to face in different scenarios where nature and climate set out the rules and the operator tries to work out the best practices. The moderate climate O&M guideline will cover the basic or most common aspects and situations that can be shared in different climates or regions. This topic will be elaborated further where extreme climates present diverse particularities and may require greater attention to O&M operators and strategies.

The existing O&M guidelines on national and international levels will be summarized highlighting the similarities and differences. Subtask 3 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 will provide recommendations for the assessment and mitigation of revenue losses due to soiling and snow losses. This Subtask will also 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

Subtask 4 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 Intersolar Europe Conference 2019 took place in Munich, Germany from 13-15 May 2019 and has provided the opportunity to hold two conference sessions including focused Task 13 presentations and a moderated panel discussion with external panellists from different sectors. Both workshops, "PV Systems - Performance & Reliability" and "PV Systems - Operation and Maintenance", took place at the conference centre in Munich on 14 May 2019. The first event addressed the uncertainty surrounding the main parameters affecting yield assessment and long-term yield prediction, as well as their impact on LCOE and selected business models. Degradation factors were also considered in analysing performance loss rates in large quantities of both high and low-quality data. The second workshop focussed on new methodologies, which are introduced to assess technical risks and mitigation measures in terms of economic impact and effectiveness during operation. These processes will place particular emphasis on providing information on available inspection technologies and best practice to qualify PV modules in the field.

The first workshop attracted more than 80 international visitors, the second workshop included 120 visitors from around the world (Figure 4a).

Fig. 4a – Intersolar Europe Conference 2019, Munich, Germany.

The EU PVSEC-36 took place on 9-13 September 2019, in Marseille, France. Task 13 organized a PVPS Task 13 Workshop as one of the parallel events during this conference. The topics of this Task 13 Workshop were focussed on “Innovations in Photovoltaic Materials”. Task 13 experts and invited external speakers presented ideas, concepts and results from a global set of researchers aiming to both reduce cost and improve the performance and reliability of PV modules and systems by using new materials in front of an international audience (Figure 4b).

Fig. 4b – EU PVSEC 2019, Marseille, France.


Fig. 4c –13th PV Performance Modelling and Monitoring Workshop in Kunshan, China.

Sandia National Laboratories, Fraunhofer ISE on behalf of Task 13 and the Harbin Institute of Technology hosted the 13th PV Performance Modelling and Monitoring Workshop 9-10 December 2019, in Kunshan, China. At the workshop, experts from industry and research presented on various topics related to PV simulation, data analysis and monitoring. In panel discussions on each topic, the approximately 250 participants had the opportunity to discuss open questions with the experts (Figure 4c).

Furthermore, Task 13 experts participated in the following events in 2019:

- PV Module Technology Forum, Cologne, Germany, 12-13 February 2019.
- NREL Reliability Workshop, Denver, CO, USA, 26-28 February 2019.
- 17. Nationale Photovoltaik-Tagung, Bern, Switzerland, 26-27 March 2019.
- Intersolar Europe, Munich, Germany, 14-16 May 2019.
- 2019 PV Systems Symposium, Albuquerque, NM, USA, 14-16 May 2019: https://www.regonline.com/builder/site/?eventid=2553450.
- 9th SOPHIA Workshop PV-Module Reliability, Graz, Austria, 28-29 May 2019.
- SNEC PV Power Expo, Shanghai, 4-6 June 2019.
- 46th IEEE Photovoltaic Specialist Conference (PVSC 46, Chicago, IL, USA, 16-21 June 2019.
- 36th European PVSEC, Marseille, France, 09-13 September 2019, IEA PVPS Task 13 Workshops on 11 September 2019.
- Bifi PV Workshop, Amsterdam, The Netherlands, 16-17 September 2019: Task 13 presentations and organization: https://www.bifipv-workshop.com/2019amsterdamproceedings.
- Seminar of COST Action PEARL PV of the topic of PV Reliability and Durability, Malta, 14 October 2019: Three presentations by Task 13 experts.
- Training School of COST Action PEARL PV of the topic of EVALUATION OF THE PERFORMANCE DEGRADATION OF PV-SYSTEMS, Malta, 15-18 October 2019: Five presentations on results of IEA PVPS Task 13 activities.
- International PV Soiling Workshop, IRESEN, Morocco, 28-30 October 2019.
- PVSEC-29, Xi'an, China, 04-08 November, 2019, with presentation by IEA PVPS Task 13 expert.
- SAYURI-PV 2019, Tsukuba (Ibaraki), Japan, 18-19 November 2019: Presentation on inspection methods for fielded PV modules to quantify module degradation (Task 13 expert).
- 2019 Asia-Pacific Solar Research Conference, Canberra, Australia, 03-05 December 2019.
- Smart Solar PV Forum in Berlin, Germany, 04-05 December 2019, with presentation on Data-Driven Risk Analysis by IEA PVPS Task 13 expert.
- NIST/UL Workshop on Photovoltaic Materials Durability, Gaithersburg, USA, 12-13 December 2019.
- 13th PV Performance Modelling and Monitoring Workshop in Kunshan, China, 9-10 December, 2019 - Presentation on IEA PVPS Task 13 activities.

## MEETING SCHEDULE (2019 AND PLANNED 2020)

The 21st **PVPS Task 13 Experts Meeting** took place in Utrecht, Netherlands, 02-04 April, 2019.
The 22nd **PVPS Task 13 Experts Meeting** was held in Santiago, Chile, 22-25 October, 2019.
The 23rd **PVPS Task 13 Experts Meeting** will take place in Piteå, Sweden, 24-26 March, 2020.
The 24th **PVPS Task 13 Experts Meeting** will take place in Jeju Island, South Korea, 8-10 November, 2020.

## TABLE 1 - TASK 13 PARTICIPANTS IN 2019 AND THEIR ORGANIZATIONS

| COUNTRY | ORGANIZATION |
|---|---|
| Australia | Ekistica |
| | Murdoch University |
| | The University of New South Wales (UNSW) |
| Austria | Austrian Institute of Technology (AIT) |
| | Österreichisches Forschungsinstitut für Chemie und Technik (OFI) |
| | Polymer Competence Center Leoben (PCCL) GmbH |
| Belgium | 3E nv/sa |
| | Interuniversity Microelectronics Centre (imec) |
| | KU Leuven |
| | Laborelec |
| | Tractebel – Engie |
| Canada | CANMET Energy Technology Centre |
| Chile | Atacama Module System Technology Consortium (AtaMoS-TeC) |
| China | Institute of Electrical Engineering, Chinese Academy of Sciences (CAS) |
| Denmark | SiCon • Silicon and PV Consulting |
| Finland | Turku University of Applied Sciences |
| France | Electricité de France (EDF R&D) |
| Germany | Fraunhofer Institute for Solar Energy Systeme (ISE) |
| | Institute for Solar Energy Research Hamelin (ISFH) |
| | TÜV Rheinland Energy GmbH (TRE) |
| Israel | M.G.Lightning Electrical Engineering |
| Italy | European Academy Bozen/Bolzano (EURAC) |
| | Gestore dei Servizi Energetici - GSE S.p.A. |
| Japan | National Institute of Advanced Industrial Science and Technology (AIST) |
| | New Energy and Industrial Technology Development Organization (NEDO) |
| Netherlands | Utrecht University, Copernicus Institute |
| Norway | Institutt for Energieteknikk (IFE) |
| Spain | National Renewable Energy Centre (CENER) |
| | University of Jaén |
| Sweden | EMULSIONEN EKONOMISK FORENING |
| | Mälardalens Högskola (Mälardalen University) |
| | Paradisenergi AB |
| | PPAM Solkraft |
| | Research Institutes of Sweden (RISE) |
| Switzerland | 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 | King Mongkut University of Technology Thonburi (KMUTT) |
| USA | 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


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

### INTRODUCTION

Pursuing 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, the integration of growing shares of variable renewables into the power systems has become a truly global issue 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 a 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 and 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, while allowing PV to be fully integrated into the power system; from serving local loads to serving as grid resources for the interconnected transmission, distribution and generation system.

### OVERALL OBJECTIVES

As part of the IEA PVPS TCP, Task 14's main objective in its Phase 3, which started in 2019, 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 widearea 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


Fig. 2 – IEA PVPS Task 14 Experts at their Meeting at TBEA SunOasis, Xi'an, China in November 2019 (Photo: IEA PVPS Task 14).

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 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, Task 14 Phase 3's work programme 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 Task 14's title 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.

Task 14's work programme addresses the 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 technical topics include Transmission – Distribution Grid Planning and Operation with high penetration RES, stability and transient response for wide-area as well as insular grids, 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 grids complements the research in Task 14. To ensure that PV grid integration solutions are well-aligned with such comprehensive requirements it is also indispensable to analyse 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 analysed, aiming at formulating recommendations about PV communication and control concepts to optimize PV integration into smart grids within different kinds of infrastructures.

## PROGRESS AND ACHIEVEMENTS

In 2019, the main activities focused on the implementation of the Task 14 Phase 3's work programme.

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

- In November 2019, the New Energy Development Organization (NEDO) of Japan, together with Task 14 organized a Grid Code and Requirements for Generators Workshop, which took place at the Tokyo University of Science, Kagurazaka campus, Tokyo, Japan.
- At the event, experts from Task 14 together with local Japanese stakeholders shared their experiences and viewpoints with respect to grid codes and regulatory frameworks, which are of fundamental importance for the sustainable integration of Solar PV in the electricity systems.
- In November 2019, Task 14 contributed to the PVPS session "PV in Future City" at the PVSEC-29 conference in Xi'an, China. In addition, Task 14 experts contributed two invited talks at the PVSEC-29 conference, sharing latest results and case studies, highlighting the importance of an integrated view on RES integration to the electricity system.

Task 14's workshop presentations are publicly available for download from the Workshops section on the IEA PVPS website.

## INDUSTRY INVOLVEMENT

In addition, a number of PV industry and utility representatives also participate in the Task 14 group.

Based on the results achieved thus far within 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.

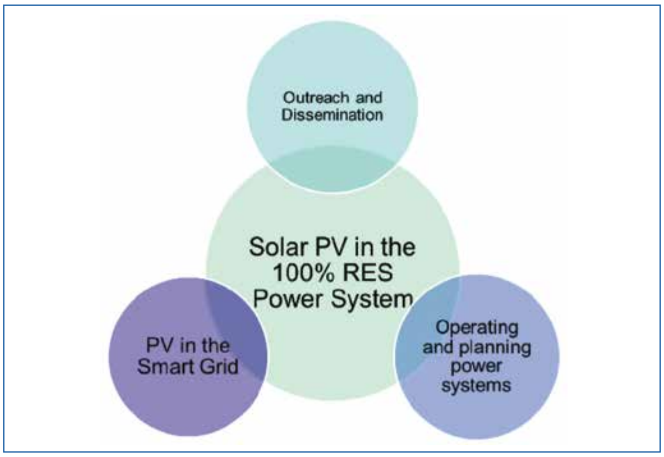


Fig. 3 – IEA PVPS Task 14 Organization in Phase 3 2018-2022.

Fig. 4 – TBEA control room for technical operation of 1,5 GW PV and Wind energy systems in China (Photo: Gerd Heilscher, Task14 meeting at TBEA, Xian China).

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.

In 2019, Task 14 also intensified the collaboration with national and international standardization bodies, technical committees and working groups.

Currently Task 14 experts are actively involved in the following groups:

- IEC TC 8 (System aspects of electrical energy supply); JWG 10 (Distributed energy resources connection with the grid): Liaison Christof Bucher, Switzerland;
- CENELEC TC8X (System aspects of electrical energy supply) WG03 (Requirements for connection of generators to distribution networks). Liaison Roland Bründlinger, Austria;
- CENELEC TC82 (Solar photovoltaic systems); WG 2 BOS components and systems, Liaison Roland Bründlinger, Austria;
- IEEE Committee SASB/SCC21 – SCC21 (Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage). Liaison Tom Key, USA;
- Relevant national committees: Austria, Germany, Denmark, Switzerland, USA, Japan, Spain, Italy.

## 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.

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:

- Conference Future Energy Networks, Berlin, Germany, January 2019
  - Oral presentation "DSO-TSO communication and related standardization", Falko Ebe, T14, Germany
- PV Symposium Bad Staffelstein, Germany, March 2019
  - Oral presentation "International communication standards for Solar PV and electricity grids", Gerd Heilscher, T14 OA, Germany
- IEEE PVSC 46, June 2019, Chicago, USA
  - Oral presentation "Integration of Photovoltaic Systems into Smart Grids", Christoph Kondzialka, T14, Germany
  - Poster presentation "Electricity produced from photovoltaic systems in apartment buildings and self-consumption - Comparison of the situation in various IEA PVPS countries", Chicago, USA, Arnulf Jäger-Waldau et al, T14, European Commission
- 7. Praxis Forum Information Security Management in critical infrastructures, April 19, Würzburg, Germany
  - Invited presentation "IT-security for decentralised energy systems", Gerd Heilscher, T14 OA, Germany
- IEEE PES General Meeting, Atlanta, USA, August 2019
  - Presentation "Possible System Security Impacts of Distributed Photovoltaics Behavior During Voltage Disturbances", Naomi Stringer et al, T14, Australia
  - Presentation "The impact of DC/AC ratio on short-term variability of utility-scale PV plants", Kanyawee Keeratimahat et al, T14 Australia
  - Presentation "Renewable energy auctions versus Green Certificate Schemes – lower prices but greater integration costs?", Iain McGill et al, T14 Australia
- Solar Integration Workshop 2019, Dublin, Ireland,
  - Presentation, „PV Forecasting in Distribution System Operation – Requirements and Applications", M. Kraiczy et al, T14 Germany
- PVSEC29, Xi'an, China, November 2019
  - Oral Presentation "Data driven estimation of aggregate distribution PV systems output in the Australian states", Navid Haghdadi, T14 Australia
  - Oral Presentation "Integrating High PV Penetrations into Restructured Electricity Industries", Iain McGill, T14 Australia
  - Invited presentation "Integration of Photovoltaics into the Smart Grid", Gerd Heilscher, T14 OA, Germany
  - Invited presentation "An Overview of Global Grid Codes for the Integration of High Penetration of Solar PV systems", Roland Bründlinger, T14 OA, Austria

Presentations of all Task 14 events organised thus far are publicly available for download from the Archive section of the IEA PVPS website: https://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 2020, 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: https://www.iea-pvps.org/index.php?id=212

## MEETING SCHEDULE (2019 AND PLANNED 2020)

### 2019 Meetings

- The 19th **Task 14 Experts Meeting** was held at El-Hierro, Spain, 24-25 March 2019, hosted by University La Laguna and the government of El-Hierro.
- The 20th **Task 14 Experts Meeting** was held in Xian, China, 5-6 November 2019 during the week of the PVSEC29 conference. The meeting was jointly hosted by the Institute for Electrical Engineering, Chinese Academy of Sciences and TBEA XinJiang SunOasis Co., Ltd.

### 2020 Meetings (tentative)

- The 21st **Task 14 Experts Meeting** will be held as a web meeting, 22-23 June 2020. The meeting will be hosted by the Technische Hochschule Ulm, University of Applied Science.
- The 22nd **Task 14 Experts Meeting** is tentatively planned to be held on Je-ju-do, Korea, in November 2020.

**TABLE 1 – LIST OF TASK 14 PARTICIPANTS 2019 (INCLUDING OBSERVERS)**

| 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 | Kenenergy |
| EC | Arnulf Jàger-Waldau | European Commission |
| Germany | Gunter Arnold | Fraunhofer IEE |
| | Martin Braun | |
| | Markus Kraiczy | |
| | Ebe Falko | Technische Hochschule Ulm |
| | Gerd Heilscher | |
| Italy | Giorgio Graditi | ENEA-Portici Research Centre |
| | Adriano Iaria | RSE – Ricerca Sistema Eletrico |
| Japan | Takeshi Maeno | NEDO |
| | Yuzuru Ueda | The University of Tokyo |
| Malaysia | Koh Keng Sen | SEDA |
| Spain | Ricardo Guerrero Lemus | University of La Laguna |
| Switzerland | Christof Bucher | Basler & Hofmann AG |
| | Lionel Perret | Planair SA, Switzerland |
| | Marine Cauz | |
| | Florent Jacqim | |
| 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 building sector is responsible for 36% of global end-use energy consumption and nearly 40% of total direct and indirect $CO_2$ emissions. Goals and specific targets have been set up globally to reduce the environmental impact of the built environment. Political statements and directives have been moving further towards zero-energy buildings, communities and cities. PV systems play a significant role in this development and future renewable energy systems will require large areas for PV. Building envelope areas can contribute significantly to this. At buildings, renewable energy generation is closely located to the consumer, avoiding transportation losses. With the massive price decrease of photovoltaic technology in the previous years, the integration of PV in construction products also becomes economically attractive. 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 still has a small market, but huge potential. To fully grasp this potential, a transition in the built environment has to be realized, in which regulatory barriers, economic barriers, environmental barriers, technical barriers and communicational barriers have to be overcome.

### OBJECTIVE

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

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.

In the first phase of Task 15 (2015-2019) the following main thresholds were defined on the track of BIPV roll out; 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, and a transfer gap between product and application.

Task 15's extended work is expected to be undertaken over the next four years (2020-2023) and is divided into 5 subtasks addressing existing issues and barriers for the widespread implementation of BIPV by exchanging research, knowledge and experience, and offering the possibility to close gaps between all BIPV stakeholders, creating an enabling framework to accelerate the implementation of BIPV. Thus, the second phase of Task 15 aims at further helping stakeholders from the building sector, energy sector, the public, government and financial sector to overcome technical and non-technical barriers in the implementation of BIPV by the development of processes, methods and tools that assist them.

### APPROACH

To reach the objective, in phase 1, an approach based on 5 Subtasks had been developed, focused on growth from prototypes to large-scale producible and applicable products. The Subtasks with their target audiences were:

- 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 were identified and breached. By the end of 2019, the first phase of this Task was finished and, based on input from the PVPS Executive Committee and Task 15 experts, the Task will continue in a second phase (2020-2023).

In the second phase, Task 15 continues to create an enabling framework to accelerate the penetration of BIPV taking into account especially economic, technological, legal, aesthetic, reliability and normative issues. To address these topics, the experts have developed the following Subtasks:

- A: Technological Innovation System (TIS) Analysis for BIPV
- B: Cross-sectional Analysis: Learning from Existing BIPV Installations
- C: BIPV Guidelines
- D: Digitalization for BIPV
- E: Pre-normative International Research on BIPV Characterisation Methods

Thus, phase 2 of Task 15 contributes to the ambition of realizing zero-energy buildings and built environments. Starting from the status quo in 2019, there is still a number of issues and Task 15's Subtasks are tailored to make a major contribution to overcome these issues and accelerate the whole BIPV market towards the future vision: The widespread knowledge about BIPV enables all stakeholders to realize architectonically appealing BIPV systems that are economically rewarding, well planned, constructed

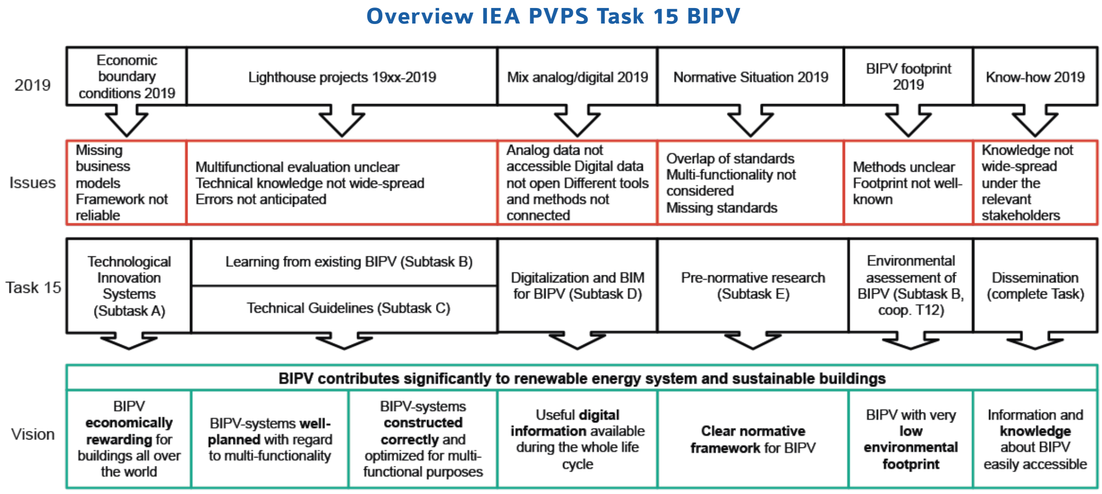


Fig. 1 – From status quo (2019) towards Task 15's vision. In between, there are several challenges and issues. Task 15 addresses the main issues in its different Subtasks on an international level and wants to accelerate the BIPV market towards its vision.

and operated with support of digital methods, based on a clear normative framework and thus strongly contribute to a renewable energy system and buildings with a small environmental footprint.

## ACTIVITIES OF IEA PVPS TASK 15 IN 2019

### SUBTASK A: BIPV PROJECT DATABASE

The aim of this Subtask is to create awareness through an information portal and informative digital publication 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 BIPV projects that are representative for their country and suitable for international comparison and dissemination. In total, over 145 projects have been received.

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.

The 25 projects are published on the information portal, hosted by Italy, and the final version of the digital publication is expected by Q1 2020.

### SUBTASK B: TRANSITION TOWARDS SOUND BIPV BUSINESS MODELS

The aim of this Subtask 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.

Subtask B is further sub-divided in the following 4 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 was focused on how this expected transition affects the deployment of BIPV solutions in particular. The report B.1/B.2 "Inventory on Existing Business Models, Opportunities and Issues for BIPV" is available on the IEA PVPS website.

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

This is the core activity of the Subtask. It performs an in-depth analysis on the definition of the true economic value of BIPV. It analyzes how new business models can be derived to fully exploit the values of BIPV and the possible need for new ad hoc financial instruments.

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

Fig. 2 – Task 15 Experts' visit to a NZEB library, Montreal, Canada, June 2019.

Fig. 3 – BIPV at the Solar Decathlon Africa, Marrakech, Morocco, September 2019.

Fig. 4 – BIPV project downtown Montreal, Canada, June 2019.

- The B.3 report is in final reviewing and publication is expected in Q1 2020. The report 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.
- 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 five activities, indicated below.

About 15 – 20 persons from 12 countries have regularly participated as authors or reviewers to the various reports that Subtask C prepared this year. The work on BIPV standardisation in Subtask C, particularly in Activity C2, continues to benefit the work within the IEC/TC 82 Project Team, PT 63092. The fifth, partially face-to-face meeting of PT 63092 on 04.06.2019 in Montreal, Canada, immediately before the Task 15 meeting, where the joint response to the comments of National Committees on the CD was finalised. Revised versions of PT 63092-1 and PT 63092-2, taking the responses to all national committee comments into account, were prepared and subsequently submitted for voting as an IS (international standard) to IEC/TC 82, WG2. Voting on CDVs IEC 63092, Parts 1 and 2, took place in January 2020 and was positive. The next step is the preparation of an FDIS, taking the comments of the National Committees into account.

### 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" available on the IEA PVPS website.

C.2 BIPV technical requirements overview – final report entitled "Analysis of requirements, specifications and regulation of BIPV" available on the IEA PVPS website.

C.3 Multifunctional BIPV evaluation – Two questionnaires formulated and distributed; first responses received.

C.4 Suggest topics for exchange between different standardization activities at the international level – report C4/C3 entitled "Multifunctional Characterisation of BIPV - Proposed Topics for Future International Standardisation Activities" is undergoing final reviewing and publication is expected in Q1 2020.

## SUBTASK D: ENVIRONMENTAL ASPECTS OF BIPV

The aim of this Subtask 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 8 countries (Austria, Switzerland, Sweden, Denmark, Korea, Netherlands, Norway, Spain, Italy) are active in this Subtask, led by France. The work is divided into two main activities; state of the art on LCA of BIPV and a case study report. The state of the art report (report D.1) is completed but is still being revised. 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.

The case study report is completed and in final revision by both IEA PVPS Task 15 experts and IEA PVPS Task 12 experts.

## SUBTASK E: APPLIED RESEARCH AND DEVELOPMENT FOR THE IMPLEMENTATION OF BIPV.

The aim of this Subtask 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.

This Subtask's work 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 5 activities. Each activity leader has identified and leads his or her working group, and collects contributions for the reports.

### 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 University of Applied Sciences Technikum Vienna. A second version of the E.1 report is finished and available on the IEA PVPS website.

#### E.2 - Comparison Fields and Reliability tTests

This action is led by OFI and University of Applied Sciences Technikum Vienna, and brings together the work carried out 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 2020 after analysis of the monitoring results.

#### 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 be 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 University of Applied Sciences Technikum Vienna, 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 final version of the report is available on the IEA PVPS website.

#### E.5 - BIPV Design and Simulation

This action is led by POLIMI, which collects the state of the art of the present software solutions and suggests 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 strength and weakness 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. The final report is available on the IEA PVPS website.

## SELECTION OF OUTREACH EVENTS – 2019

- June 7th 2019: BIPV Outreach Event, Montreal, Canada
- June 23rd 2019: INTERSOLAR BIPV Parallel Event, Munich, Germany
- September 2019: EU PVSEC BIPV Task 15 End Event, Marseille, France
- September 2019: Solar Decathlon BIPV Event, Marrakesh, Morocco

## SUMMARY OF TASK 15 ACTIVITIES PLANNED FOR 2020

The activities planned for the Subtasks are the following:

- Publication of PFD book Subtask A and finalizing Task 15 BIPV online database.
- Publication of report B3.
- Publication of report C4/C3.
- Publication of report on D1 - D3.
- Publication of report E2.2 and E3.
- Kick-Off Meeting of IEA PVPS Task 15.2 in Freiburg, Germany
- Task 15.2 Meeting and PVPS Joint Meetings in Jeju, S. Korea

## PUBLICATIONS AND DELIVERABLES

- Report C1, "Compilation and Analysis of User Needs for BIPV and its Functions"
- Report C2, "Analysis of requirements, specifications and regulation of BIPV"
- Report E4, "COLOURED BIPV - Market, Research and Development"
- Report E5, "BIPV Design and Performance Modelling: Tools and Methods"

## MEETING SCHEDULE (2019 AND PLANNED 2020)

The **10th Task 15 Experts Meeting** was held in Montreal, Canada, 4-7 June 2019.

The **Task 15 Phase 2 Definition Workshop** was held in Montreal, Canada, 7 June 2019.

The **11th Task 15 Experts Meeting** is planned in Freiburg, Germany, 11th-13th March 2020.

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

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Australia | Rebecca Yang | RMIT University |
| Austria | Peter Illich | University of Applied Sciences Technikum Vienna |
| | Karl Berger | AIT |
| | Gabriele Eder | OFI - Austrian Institute for Chemistry and Technology |
| | Lukas Gaisberger | University of Applied Sciences Upper Austria |
| | Michael Grobbauer | University of Applied Sciences Salzburg |
| | Dieter Moor | ERTEX Solar GmbH |
| | Andreas Kornherr | |
| | Lutz Dorsch | FH Salzburg |
| | Hildegund Figl | IBO |
| | Markus Karnutsch | FH Salzburg |
| | Christoph Mayr | AIT |
| Belgium | Patrick Hendrick | Université libre de Brusseles |
| | Jonathan Leloux | Lucisun |
| | Philippe Macé | Becquerel Institute |
| | Jens Moschner | KU Leuven / Energyville |
| | Jorne Carolus | |
| Canada | Veronique Delisle | Natural Resources Canada |
| | Costa Kapsis | Canadian Solar Industries Association |
| | Andreas Athienitis | Concordia University |
| | Hua Ge | |
| China | Xiaolei Ju | China Architecture Design and Research Group |
| | Limin Liu | China Renewable Energy Society |
| | Duo Luo | Zhuhai Singyes Co. |
| | Meng Xiajie | Longi |
| | Xiaobo Xi | |
| | Jinqing Peng | Hunan University |
| Denmark | Karen Kappel | Solar City Denmark |
| | Kenn Frederiksen | Kenergy |
| | Nebosja Jakica | SDU |
| Germany | Helen Rose Wilson | Fraunhofer ISE |
| | Johannes Eisenlohr | |
| France | Simon Boddaert | CSTB |
| | Jerome Payet | Cycleco |
| | Francoise Burgun | CEA/INES |
| Italy | Francesca Tilli | GSE |
| | Alessandra Scognamiglio | ENEA Research Center Portici |
| | Laura Maturi | EURAC |
| | Stefano Avesani | |
| | Jennifer Adami | |
| Japan | Hiroko Saito | PVTEC |
| | Hisashi Ishii | LIXIL |
| | Seiji Inoue | AGC |
| | Michio Kondo | AIST |
| | Keiji Kusuhara | NEDO |

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Korea | Jun-Tae Kim | Kongju National University |
| | Jae-Yong Eom | Eagon Windows & Doors Co. |
| The Netherlands | Michiel Ritzen | Zuyd University of Applied Sciences |
| | John van Oorschot | |
| | Zeger Vroon | |
| | Tjerk Reijenga | bear-ID |
| | Otto Bernsen | RVO |
| | Mariska de Wild-Scholten | SmartGreenScans |
| | Roel Loonen | Eindhoven University of Technology |
| | Roland Valckenborg | TNO/SEAC |
| | Huib van den Heuvel | Solarge |
| | Wilfried van Sark | University Utrecht |
| Norway | Anne Gerd Imenes | Teknova |
| | Anna Fedorova | NTNU |
| | Reidun Dahl Schlanbusch | SINTEF |
| | Tore Kolaa | |
| | Jens Hanson | UiO |
| | Gaylord Kabongo Booto | IFE |
| | Gaute Otnes | |
| Spain | Nuria Martin Chivelet | CIEMAT |
| | Estefania Caamano | Technical University of Madrid |
| | Javier Neila Gonzales | |
| | Francesca Olivieri | |
| | Román Eduardo | Tecnalia |
| | Asier Sanz | |
| | Jose Maria Vega | |
| | Ana Belen Cueli Orradre | CENER |
| | Ana Rosa Luganas | |
| | Elena Rico | Onyx |
| | Juan Manuel Espeche | R2M |
| | Teodosio Del Cano | Onyx |
| Sweden | Bengt Stridh | Mälardalen University |
| | Peter Kovacs | RISE |
| | Rickard Nygren | White arkitekter |
| | Jessica Benso | |
| | David Larson | RISE |
| | Solkompaniet | |
| | Kersti Karltorp | |
| | Anna Svensson | Soltech Energy |
| Switzerland | Francisco Frontini | SUPSI |
| | Pierluigi Bonomo | |
| | Fabio Parolini | |
| | Erika Saretta | |
| | Peter Roethlisberger | Solaxess |
| | Karl Viridén | Viridén + Partner |
| Lithuania* | Juras Ulbikas | PVTP Mirror group national representative |
| Singapore* | Veronika Shabunko | SERIS |

# 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 most recent Task, IEA SHC Task 46 "Solar resource assessment and forecasting" ended in December 2016. The current solar resource Task was started mid 2017 in the TCP of IEA PVPS and runs till June 2020. The extension till 2023 was confirmed in November 2019.

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.

Task 16 is a joint Task with the TCP SolarPACES (Task V). It collaborates also with the Solar Heating and Cooling (SHC) – the third TCP regarding solar topics. Meteotest leads the Task as OA on behalf of the PVPS TCP with support of Swiss Federal Office of Energy (SFOE). Manuel Silva of University of Sevilla, Spain leads the Task V on behalf of SolarPACES.

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

However the work of the new Task will be 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 fore-casting techniques
- Subtask 4: Dissemination and Outreach

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

### APPROACH

The work programme of the proposed Task 16 addresses on one side scientific meteorological and climatological issues to high penetration and large scale PV in electricity networks, but 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 paper 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 commercial level (companies). In the current Task IEA SHC 46 this involvement was achieved. All big partners are willing to extend their work in the new Task and many new are interested.

The work plan is also focused on work that can only be done by international collaboration like 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 up to now.

The work programme is organized into three main technical subtasks (subtasks 1 – 3) and one dissemination subtask (subtask 4), including three to four activities (Tables 1 and 2):

### TABLE 1 - SUBTASKS AND ACTIVITIES OF TASK 16

| SUBTASK | ACTIVITY |
|---|---|
| Subtask 1: Evaluation of current and emerging resource assessment methodologies | 1.1 Ground based methods |
| | 1.2 Numerical Weather models |
| | 1.3 Satellite-based methods |
| | 1.4 Benchmarking Framework |
| 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.

Fig. 1 – Group photo during Expert Task Meeting at Utrecht, NLD (April 2019).

### TABLE 2 - SCOPE OF 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 focusses on different aspects of forecast evaluation and comparison. In particular we will address 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. |

Depending of 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 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 (52) and countries (20).
In 2019 two Expert meetings (Utrecht, NLD – Fig. 1 - and Santiago de Chile, CHE and three workshops have been organized. One report has been written and is currently in internal review. The final result – the update of the solar resource handbook – has been initiated (Version 2017 was published at NREL: https://www.nrel.gov/docs/fy18osti/68886.pdf).

## SUBTASK 1: EVALUATION OF CURRENT AND EMERGING RESOURCE ASSESSMENT METHODOLOGIES.

### Workshop on best practices for automatic and expert based quality control procedures and gap filling method

The workshop was held at the 5th International Conference on Energy-Meteorology (ICEM) on June 25th in Lyngby, DNK (http://www.wemcouncil.org)

It was chaired by P. Blanc (Mines Paristech, FRA) and Jan Remund (Meteotest, CHE).

About 40 persons attended the workshop. The presentations can be downloaded (when logged in – which is free) at WEMC homepage.

After introduction of J. Remund, P. Blanc gave a first review of automatic quality control procedures (QCPs), including the emerging ones based on cross-comparison with surrounding in-situ measurements, models of clear sky irradiance and satellite based estimations is given. The second part of the workshop is dedicated to gap filling methods to cope with data gaps in pyranometric and meteorological time series (missing data or detected as incorrect by the QCP), notably for time aggregation procedure. He showed also the power of visual controls (Fig. 2).

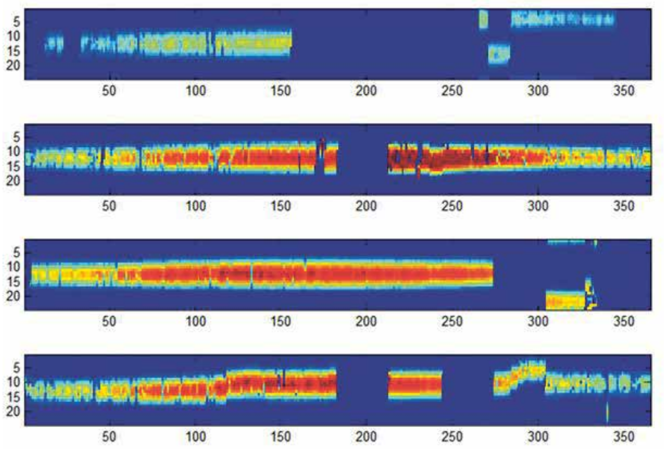


Fig 2 – Visual controls of GHI time series

M. Sengupta (NREL, USA) presented the data quality assessment methods employed by NREL for both measured and modelled solar resource data using NREL's SERI-QC software package will be presented.

A. Jensen (DTU, DNK) presented different methods, ranging in complexity and accuracy. In order to determine the most suitable method and the impact of each method, the long-term solar irradiance time series from DTU is gap-filled using a range of different gap fillings methods. The results of each method are compared.

Finally the QC method based on satellite data developed by JRC will be given by P. Blanc. (on behalf of Ana Gracia).

## SUBTASK 2: ENHANCED DATA & BANKABLE PRODUCTS

### Workshop and paper on site adaptation methods

Solar radiation components with very high accuracy are needed in almost every solar energy project for making the project bankable. Long-term time series of solar irradiance can be supplied by satellite-derived imagery or by reanalysis models with very different uncertainty associated to the specific approaches taken and quality of boundary conditions information. In order to improve the reliability of solar radiation modeled datasets the comparison with short-term ground measurements can be used for correcting some aspects, bias mainly, of the modeled data by using different methodologies denoted as site adaptation. Therefore a benchmarking of different site adaptation methods was proposed within the Task 16 IEA-PVPS activities. In this work more than ten different methods have been used for assessing the improvement capabilities of ten different datasets covering both satellite and reanalysis derived solar radiation data. The improvement capabilities of these methods are not universal and homogeneous among the different methods but in general it can be state that significant improvement can be achieved eventually in most of sites and datasets.

Additionally a workshop was organised at SWC 2019 conference in Santiago (November 5th 2019) with Jesus Polo (Ciemat), Armando Castillejo (Pont. Univ. Cat. de Chile), Jan Remund (Meteotest) and Mathieu David (Univ. La Reunion) presenting their adaptation methods. Presentations can be found here: http://www.iea-pvps.org/index.php?id=513

## SUBTASK 3: EVALUATION OF CURRENT AND EMERGING SOLAR FORECASTING TECHNIQUES

### Workshop on probabilistic forecast

This workshop was prepared by Nicolas Schmutz (Reuniwatt, FRA) and Jan Remund (Meteotest, CHE). It was held at EU PVSEC 2019 (Marseille, Sept. 9-13).

### About 30 persons attended the meeting.

Philippe Lauret (Univ. La Reunion, FRA) introduced the topic, Olivier Liandrat (Reuniwatt, FRA) showed as use case of probabilistic forecasts for a hybrid PV-Diesel system, Elke Lorenz (Fraunhofer ISE, DEU) presented the ECMWF IFS-ensemble for the energy management of a PV-battery system and Manajit Sengputa (NREL, USA) showed how WRF-Solar is updated with a probabilistic toolset.
Presentations can be found here: http://www.iea-pvps.org/index.php?id=513

### Report on benchmarking of spatial aggregation methods

In the IEA Activity 3.2 Report (R3.2.1) different PV power forecasting methods at regional level are evaluated and compared both for Italy and the province of Utrecht, NLD.

For Italy, results have been collected both at regional level up to 3 days ahead and for the overall PV power generation over Italy. For the PV power forecasts at the zonal levels of Italy, the benchmark model achieves a skill score between 20% and 36%

and a mean bias error (MBE) between -0,4% and 1,5% for all forecast horizons (i.e., 1-3 days ahead) (Fig. 3). It should be noted that the forecasts and measurements are normalized with respect to the installed capacity in the area throughout this report. Considering instead the 24h ahead forecasts of the entire PV fleet of Italy the benchmarks achieve a skill score between 28% and 47%, while the MBE lies between 0,1% and 1,9%. In addition to the benchmarks, blends of the benchmarks are also applied to this dataset, which improves the skill score from 47% (the best model) to 51% using a nonlinear blending technique.

Finally, the benchmark models achieve skill scores between 31% and 39% on the PV power production forecasts over the province of Utrecht, the Netherlands, while the MBE lies between 0,3% and 1,9%.

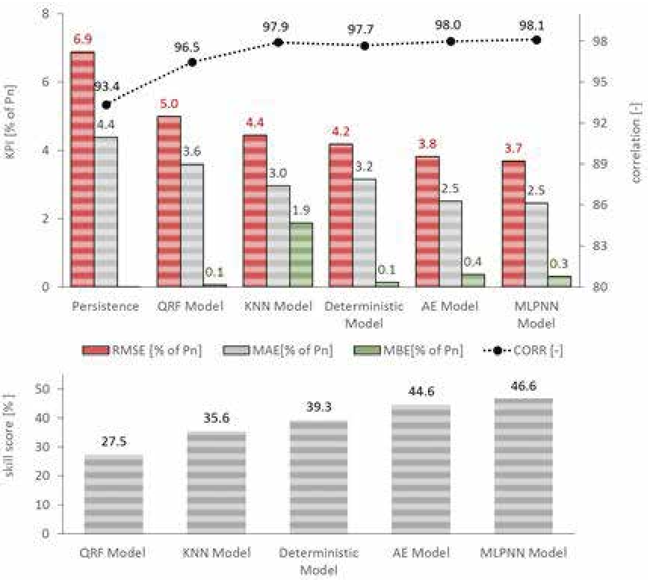


Fig. 3 – The figure summarizes the values of the main KPIs of the forecasting methods participating to the benchmarking (QRF: Uppsala University, KNN: i-EM, Deterministic Model: UNIROMA2/EURAC, AE Model: RSE, MLPNN: UNIROMA2/EURAC)

The improvement of the forecasts with respect to the persistence prediction ranges from **27,5%** to **46,6%**. Non-Linear blending improves the skill score from **47%** (the best model MLPNN) up to **51%** (not shown)

### Sky-imager forecasting benchmark

The benchmark of solar power forecast method based on the use of any sky camera system is organised by Stefan Wilbert and Andreas Kazantzidis.

Fig. 4 – All sky cameras mounted on the common test site at PSA.

The objectives of this benchmark are:

- Qualify the current short-term forecasting solutions based on the use of all-sky cameras
- Provide to users a guidance of existing solutions and their accuracy
- Generate high values observations for researchers

The observation campaign have been held at PSA Almeria (during August – November 2019). The current short-term forecasting solutions based on the use of an all-sky camera (additional measurements or cameras are allowed) are qualified.

The benchmarking will include the results of an integrated forecasting solution (hardware + software). Forecasts can be produced either in real-time or in backtest.

The following metrics were used in the benchmark:

- Root-mean-square deviation (RMSD), mean-absolute deviation (MAD), (mean and median) Bias, Coefficient correlation
- Rampscore according
- Performance (skill score) against «smart persistence» (based on reference algorithm provided by NREL )
- Interquartile Range (IQR= p75 – p25¬) and outliers

Univ. Patras (which is independent as they don't have a camera in the comparison) leads the work on the analysis of the benchmark. Results will be presented in 2020 at several conferences and in a scientific paper.

## SUBTASK 4: DISSEMINATION AND OUTREACH

The Task 16 has been presented at the following occasions:

- ICEM 2019, June, Lyngby, Denmark
- IEA Wind Task 36 (forecasts), June, Task meeting, Lyngby, Denmark
- EUPVSEC 2019, Marseille, September, France
- SolarPACES 2019, Daegu, October, Korea
- SWC 2019, Santiago de Chile, November, Chile

Two Expert Task meetings have been organized:

- 4th Task meeting at Univ. Utrecht, NLD, April 2nd – 4th 2019
- 5th Task meeting at Pontificia Universidad Católica de Chile, Santiago de Chile, CLD, November 11th - 12th 2019

## GOVERNANCE AND NEXT MEETINGS

### Membership

Total membership stands now at 20 countries with 52 active participating organizations.

### Publications

The following list includes only a part of the papers published by the team members. As part of the scientific work many additional papers have been published.

Papers about the state of the Task:

Remund, J., Renné, D., Silva-Pérez, M. A., Sengupta, M., Wilbert, S., & Polo, J., 2019: IEA PVPS Task 16 SolarPACES Task V Solar resource for high penetration and large scale applications. Solar World Congress 2019, Santiago de Chile, 1(Table 1), 4–9.

General papers involving several partners:

Alarcon, D., Balenzategui, J. L., Bayram, I. S., Cabrera, A., Dominguez, J., Fabero, F., ... Wilbert, S., 2019: Solar Resources Mapping (J. Polo, L. Martín-Pomares, & A. Sanfilippo, eds.). Springer Nature. ISBN 978-3-319-97483-5.

Gueymard, C.A., V. Lara-Fanego, M. Sengupta, and Y. Xie, 2019: Surface albedo and reflectance: Review of definitions, angular and spectral effects, and intercomparison of major data sources in support of advanced solar irradiance modeling over the Americas. Solar Energy 182 (2019) 194-212.

Larrañeta, M., Fernandez-Peruchena, C., Silva-Pérez, M.A., Lillo-bravo, I., Grantham, A., Boland, J., 2019: Generation of synthetic solar datasets for risk analysis (2019). Solar Energy, 187, pp. 212-225

Nouri, Bijan, Stefan Wilbert, Pascal Kuhn, Natalie Hanrieder, Marion Schroedter-Homscheidt, Andreas Kazantzidis, Luis Zarzalejo, Philippe Blanc, Sharad Kumar, Neeraj Goswami, Ravi Shankar, Roman Affolter, and Robert Pitz-Paal., 2019: Real-Time Uncertainty Specification of All Sky Imager Derived Irradiance Nowcasts. Remote Sensing no. 11 (9):1059.
Nouri, B, P Kuhn, S Wilbert, N Hanrieder, C Prahl, L Zarzalejo, A Kazantzidis, Philippe Blanc, and R Pitz-Paal., 2019: "Cloud height and tracking accuracy of three all sky imager systems for individual clouds." Solar Energy no. 177:213-228.

Perez R., M. Perez, M. Pierro, J. Schlemmer, S. Kivalov, J. Dise, P. Keelin, M. Grammatico, A. Swierc, J. Ferreira, A. Foster, M. Putnam and T. Hoff, 2019: Perfect Operational Solar Forecasts – a scalable strategy toward firm power generation. Solar World Congress (Keynote), Santiago, Chile

Pierro M., R. Perez, M. Perez, D. Moser, M. Giacomo & Cristina Cornaro, 2019: Italian protocol for massive solar integration (part1): imbalance mitigation strategies, (under peer review)

Sengupta, M., A. Habte, Y. Xie, A. Lopez, and C. A. Gueymard, 2019: The National Solar Radiation Data Base (NSRDB) for CSP Applications. AIP Conference Proceedings 2126, 190015 (2019); https://doi.org/10.1063/1.5117712.

## PLANS FOR 2020

The Task 16 will continue the work in 2020. A second phase starts in July 2020 and will end in June 2023. During 2020 the final result of the first phase – the updated solar resouce handbook will be written. Additionally a report about regional aggregation methods will be published.

The extension will include the following new topics:
- solar energy at urban scales (e.g. solar cadastres)
- data and model for bifacial modules (mainly albedo information)
- All sky imagers forecasts (description, benchmarking)
- Firm PV power
- Public library of code

One workshop is planned:
- Workshop on Solar Resource Products: An Overview; planned June 2020 at Intersolar 2020 exhibition; lead: Birk Kraas, CSP services, Germany.

### Meeting schedule 2020

In 2019 two Task meetings are planned:
the first one in Rome, Italy March 25-27th 2020 (organized by Univ. Tor Vergata) and the second in Jeju, South Korea, 6-7th 2020, in the framework of the all Task meeting.

# TASK 17

## PV AND TRANSPORT

Fig. 1 – Participants at the 2nd Task 17 Expert Meeting in Munich, Germany, 13-14 May 2019.

## OVERALL OBJECTIVES

The main goal of Task 17 is to deploy PV in the transport sector, which will contribute to reducing $CO_2$ 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 contribute to clarifying the potential of utilization of PV in transport and proposals on how to proceed toward realizing the concepts.

Task 17's scope includes PV-powered vehicles such as PLDVs (passenger light duty vehicles), LCVs (light commercial vehicles), HDVs (heavy duty vehicles) and other vehicles, as well as PV applications for electric systems and infrastructures such as charging infrastructures with PV, battery and 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 2019

### 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 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: PV-powered Commercial Vehicles

Activity 1.1 investigates the current status of PV-powered vehicles including PLDVs, LCVs, HDVs and other type of vehicles by reviewing academic papers, technical presentations, and public announcements. The amount of technical information on PV-powered vehicles has been increasing rapidly in recent years. The key issues are: the introduction of EVs into the global market is rapidly advancing; the movement for market introduction of PV-powered vehicles are becoming active; and, on the other hand, the benefits of PV-powered vehicles for general customers are not clear at this moment. Furthermore, from the viewpoint of vehicles' visualisation, present technology regarding design of PV cell/modules integrated into vehicles and their likely evolution and ultimate potential in terms of costs and performance are reviewed.


Fig. 2 – Examples of PV-powered vehicles (left: Lightyear One, right: Demonstration Car by Toyota Motor Corporation, Sharp Corporation and NEDO).

In order to make clear the expected/possible benefits and the requirements for PV and other components, Activity 1.2 conducts 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. A model to evaluate the energy flows and SOC of batteries of EVs in relation to the local irradiance climate, daily drive distance, charging patterns, financial conditions and environmental impacts, is developed. Important items to analyse energy balance of PV power generation and vehicle energy requirement and to identify the benefits for factors of vehicles and sunshine are: measurement of solar radiation on vehicles under various conditions; identification of representative vehicle usage pattern of driving and parking; and an energy flow model considering radiation on the vehicle.

Based on the energy flow model developed, Activity 1.3 analyses expected $CO_2$ reduction by PV-powered vehicles. In addition to energy and environmental benefits, possible benefits for customers, industries and society will be clarified; such as less-charging, portable power source for the no grid power area and for emergency, industrial activation, and comfortable transportation systems.

Activity 1.4 is focusing on aspects that are specific for the on-board application of PV in electrically powered commercial vehicles. A case study and an analysis of the energy balance will be performed. Requirements, barriers and solutions for PV powered commercial vehicles will be identified. Currently, light commercial vehicles, cooling trucks and heavy duty vehicles are being discussed, and a more comprehensive assessment of PV-powered commercial vehicles will be carried out.

## 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 charging.

Subtask 2 consists of following activities:

- Activity 2.1: PV-powered Infrastructure for Vehicles
- Activity 2.2: PV-powered Applications for Electric Systems

As a fully conceptual designing of a PV-powered EV charging system, a preliminary design of (an) artefact(s), and technical, financial, user and aesthetic requirements are being discussed. Also, a modelling of PV charging stations for EVs is discussed. An academic paper regarding a feasibility study on solar PV powered electric cars using an interdisciplinary modelling approach for the electricity balance, $CO_2$ emissions and economic aspects will be published.

New services realized by PV-powered applications such as V2H and V2G are proposed as new topics. Technical characterization of new services, possible contributions and benefits of new business models, as well as social impact and social acceptance of new associated services will be discussed.

## SUBTASK 3: POTENTIAL CONTRIBUTION OF PV IN TRANSPORT

In order to reduce $CO_2$ emissions from transport, changing energy sources from conventional to renewable energy, especially PV which have a good track record in supplying electricity at utility-scale, should be accelerated. Also, new social models by innovative '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 discussing 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.

Additionally, R&D and deployment scenarios, possible global contribution and benefits will be discussed and proposed.

### SUBTASK 4: DISSEMINATION

A considerable amount of new knowledge is expected to be developed under 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 the PV industry and the transport industry which includes the automobile industry, the battery industry, and energy service providers.

Task 17 carried out following dissemination activities in 2019:

- Technical session at the InterSolar Europe 2019 in Munich, Germany on 14 May 2019;
- Workshop at the 46th IEEE-PVSC in Chicago, USA on 18 June 2019;
- Solar Mobility Forum, a side event of the 36th EU-PVSEC in Marseille, France on 11 September 2019, as well as technical sessions at the 36th EU-PVSEC.

Furthermore, Task 17 contributed to the IEA PVPS workshop at the 29th PVSEC in Xi'an, China on 4 November 2019.

## ACTIVITIES PLANNED FOR 2020

Task 17 will continue to discuss detail activities for accomplishment of objectives of PV and Transport, and will start taking actions for technical reports. As well, dissemination activities at the international conferences and communication with stakeholders will be organized.

## MEETING SCHEDULE (2019 AND PLANNED 2020)

A **Regional Task 17 Meeting** was held in Kawasaki, Japan, 5 March 2019.
The 2nd **Task 17 Experts Meeting** was held in Munich, Germany, 13-14 May 2019.
The 3rd **Task 17 Experts Meeting** was held in Xi'an, China, 2-3 November 2019.
The virtual **4th Task 17 Experts Meeting** will be held by teleconferencing, 18 - 20 May 2020.
The **5th Task 17 Experts Meeting** will be held in Jeju, Korea, 7-9 November 2020.

## EXPECTED DELIVERABLE

The first Task 17 technical report focusing on PV-powered vehicles will be drafted in 2020.

## DISSEMINATION ACTIVITY

A Task 17 International Workshop will be held at the 47th IEEE-PVSC in Calgary, Canada, June 2020 (tbd).

### TABLE 1 – LIST OF TASK 17 PARTICIPANTS

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Australia | N.J. Ekins-Daukes | University of New South Wales |
| | Julia McDonald | IT Power Australia |
| Austria | Maximilian Rosner | DAS Energy |
| China | Zilong Yang | Institute of Electrical Engineering Chinese Academy of Sciences (IEE-CAS) |
| | Fang Lv | IEE-CAS |
| | Jian Ding | Hanergy Thin Film Power Group |
| France | Manuela Sechilariu | Université de Technologie de Compiègne |
| | Fabrice Locment | |
| | Fabien Chabuel | CEA |
| | Sylvain Guillmin | |
| | Benjamin Commault | |
| | Stephane Guillerez | |
| | Fathia Karoui | |
| | Anthony Bier | |
| | Nouha Gazbour | |
| | Julien Gaume | |
| | Gregory Bertrand | ENEDIS |
| | Frank Ambrosino | |
| | Anne-Sophie Cochelin | |
| | Alain Gaggero | |
| | Daniel Mugnier | TECSOL |
| | Alexandra Batlle | |
| | Nicolas Peiffer | |
| | Gerald Seiler | SAP LABS France |
| | Serge Fabiano | |
| | Jerome Benoit | |
| | Pierre Sixou | POLYMAGE SARL |
| | Anthony Galvez | |
| Germany | Robby Peibst | Institut fur Solarenergieforschung GmbH (ISFH) |
| | Kaining Ding | Forschungszentrum Jülich GmbH |
| Japan | Toshio Hirota | Waseda University |
| | Keiichi Komoto | Mizuho Information & Research Institute, Inc. |
| | Kenji Araki | Toyota Technological Institute |
| Morocco | Zakaria Naimi | Green Energy Park |
| The Netherlands | Anna J. Carr | TNO Energy Transition |
| | Bonna K. Newman | |
| | Angele Reinders | University of Twente |
| Switzerland | Urs Muntwyler | Bern University of Applied Sciences |
| | David Zurflüh | |
| Spain | José María Vega de Seoane | TECNALIA |

# TASK 18

## OFF-GRID AND EDGE-OF-GRID PHOTOVOLTAIC SYSTEMS

Fig. 1 – Task 18 Kick-Off Meeting, Task 18 Experts, Delft, The Netherlands, February 2020.

## OVERALL OBJECTIVES

Within the framework of PVPS, Task 18 aims to foster international collaboration in the area of off-grid and edge-of-grid PV system technologies. Building on the knowledge amassed through Task 3 – Use of Photovoltaic Power Systems in Stand-Alone and Island Applications (Finished 2004), Task 9 – Large-Scale Deployment of PV in Emerging and Developing Regions (Finished in 2018) and Task 11 – PV Hybrid Systems within Mini-grids (Finished 2011), Task 18 will dedicate the majority of its efforts to exploring the new technologies, systems, markets and environments within which these types of systems are being developed. The overall objective of Task 18 is to:

1. Get a snapshot of the technical innovations in off-grid and edge-of-grid systems. As the industry has moved substantially since the last technically focused off-grid task was closed, Task 18 will assess the cutting-edge technologies, systems and financial instruments that are being employed around the globe and will assess possible disruptors which may influence this segment going forward.
2. Understand how hybrid off-grid systems are financially optimised to suit the needs of all stakeholders.
3. Analyse the "Operations and Maintenance" activities and challenges, both social and technical, that are associated with "Remote Area Power Systems".

## SUMMARY OF TASK 18 ACTIVITIES FOR 2019/2020

Task 18 was approved at the 53rd IEA PVPS ExCo meeting in Helsinki, Finland on April, 2019. Since then, Task 18 has had several teleconferences, mostly focused on the creation of its Workplan, as well as its Kick-Off meeting in February, 2020 at the Technical University of Delft, in Delft, the Netherlands. At this meeting, the Task 18 Workplan was discussed and updated, and assignments were made for activities which were deemed the Task's first priority.

### SUBTASK 1: TECHNICAL INNOVATIONS IN OFF-GRID AND EDGE-OF-GRID PV SYSTEMS

It was agreed that it is important to understand how off-grid and edge-of-grid systems and systems technology have evolved since Task 3 and Task 11 have finished. As systems become more sophisticated and technology matures, Task 18 determined it was prudent to take a snapshot of various aspects of the off-grid and edge-of-grid sectors.

Activities planned under Subtask 1 are as follows:

- Activity 1.1 – Lithium Ion Batteries in Off-Grid and Edge-of-Grid Applications
- Activity 1.2 – Compatibility of Off-Grid systems as they grow and consider interconnection
- Activity 1.3 – Technology used in 100% Renewable Energy fed Microgrids
- Activity 1.4 – Digitisation in Off-Grid PV Systems
- Activity 1.5 – Innovative Mobility in Off-Grid PV Systems

Subtask 1 and Activity 1.1 will be led by Michael Mueller from Germany and all participants will support Activity 1.1. Activity 1.1 will begin by collecting global case studies of off-grid and edge-of-grid PV systems which utilise lithium ion energy storage systems.

Dr. Pavol Bauer and Laura M. Ramirez Elizondo from the Netherlands, will also begin work on Activity 1.4 which will take a cross section of design tools and optimisation models used for off-grid PV systems.

### SUBTASK 2: FINANCIAL OPTIMISATION IN HYBRID OFF-GRID SYSTEMS

Subtask 2 will specifically look at the financial optimisation of hybrid Off-Grid systems (Hybrid being generator set combined with renewables). This Subtask will provide an in-depth analysis of the constraints and variables required to create a model and will also review currently available modelling software against these predefined constraints in variables in order to conduct a gaps analysis.

Subtask 2 will continue by specifying which of these gaps provide the greatest opportunity for Task 18 to add industry value. Task 18 will then address this identified gap by creating a program specification that can be used with or in conjunction with off-the-shelf modelling tools to provide greater accuracy.

This Subtask will also write a best practice guide for conducting project feasibility where the project approval criteria addresses social, environmental and economic factors. This guide to triple bottom line analysis could be used by NGOs and equity holders who require government and community engagement.

### SUBTASK 3: OPERATIONS AND MAINTENANCE OF REMOTE AREA POWER SYSTEMS

Subtask 3 will review the mixture of preventative maintenance, corrective maintenance and condition-based maintenance as it is related to the site-specific parameters of a remote area power system. These parameters might include local skill sets, weather conditions, logistics difficulties, environmental constraints/hazards, telecom quality/availably, etc.

This Subtask will result in a best practice guide for the approach that might be taken for remote area power systems based on their unique parameters.

Subtask 3 will also address sustainable training programmes for remote area power systems as, at some level, community ownership/responsibilities will always be required.  In particular, the more remote communities tend to require a higher level of local engagement and as such it is imperative that these systems have an O&M regime which includes the sustainable transfer of skills to onsite personnel.

### SUBTASK 4: COOPERATION AND DISSEMINATION

Task 18 plans to cooperate with other tasks, the Alliance for Rural Electrification, the International Renewable Energy Agency, and Mission Innovation Challenge #2.

## ACTIVITIES PLANNED FOR 2020

Task 18 will continue to develop detailed activities within the existing Workplan and seek to assign responsibilities and deadlines to these activities.  Task 18 will also seek to add resources to the Task in order to reach a critical mass necessary to achieve the Workplan set forth in the given timeline

## MEETING SCHEDULE (2020)

The 1$^{st}$ Task 18 Meeting (Kick-off Meeting) was held at TU Delft, Delft, the Netherlands in February, 2020.
The 2$^{nd}$ Task 18 Meeting will be held in August, 2020 in a location TBD.

## DISSEMINATION ACTIVITY SCHEDULE IN 2020

A Dissemination plan will be formulated in due course

**Expected Deliverables**

Activity 1.1 - Lithium Ion Batteries in Off-Grid and Edge-of-Grid Applications Part 1:  Case Studies - August 2020
Activity 1.4 - Digitisation in Off-Grid PV Systems
Part 1: Market analysis of existing design tools and optimisation models: December 2020

### TABLE 1 – TASK 18 PARTICIPANTS

| COUNTRY | PARTICIPANT | ORGANISATION |
|---|---|---|
| Australia | Chris Martell | GSES Pty Ltd |
| | Geoff Stapleton | |
| | Dow Airen | Northern Territory Power and Water Company |
| | Lachlan McLeod | Ekistica Pty Ltd |
| Canada | Dr. Michael Ross | Yukon Research Centre |
| Germany | Michael Mueller | Steca |
| Malaysia | Dr. Chen Shiun | Sarawak Energy Berhad |
| Morocco | Ahmed Benlarabi | IRESEN |
| | Zakaria Naimi | |
| The Netherlands | Otto Bernsen | De Rijksdienst voor Ondernemend Nederland (RVO) |
| | Dr. Pavol Bauer | TU Delft |
| | Laura M. Ramirez Elizondo | |
| Spain | Xavier Vallve | Trama TecnoAmbiental |
| | Pablo Diaz Villar | University of Alcala |

# AUSTRALIA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

RENATE EGAN, UNIVERSITY OF NEW SOUTH WALES
IAIN MAGILL, UNIVERSITY OF NEW SOUTH WALES
LINDA KOSCHIER, IEA PVPS TASK 1 EXPERT AUSTRALIA

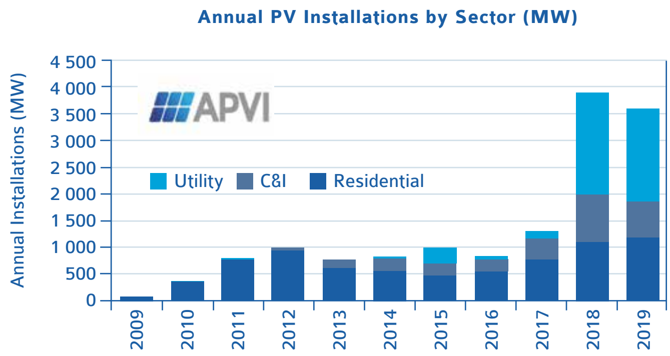


Fig. 1 – Historic trends in annual PV installations in Australia by sector.

## GENERAL FRAMEWORK AND IMPLEMENTATION

Australia has remained in the top ten PV markets in the world for over ten years, and 2019 looks like it will come close to matching the 2018 record year for capacity additions. Final numbers are not yet in, but projections are for a total 3,6 GW commissioned in 2019, with record capacity additions driven by continued strong growth in utility scale solar, with over 1,6 GW added in that sector alone over the calendar year. Residential solar and commercial and industrial markets remain strong – providing a combined total for rooftop solar of close to 2GW.

Over 2,2 million Australian homes and businesses now have a rooftop PV system – over 220 000 of which were added in 2019. Residential penetration levels are now at 25% of free-standing homes and reach over 70% in some urban areas. Over 650 MW of commercial and industrial PV was added in 2019, with many shopping centre owners rolling out MW-scale solar across their entire portfolio (data from https://pv-map.apvi.org.au/)

Deployment has been driven by high electricity prices, a continued reduction in PV system prices, an increasing awareness of the benefits of PV to businesses, large corporate PPA market, plus solar farm deployments to meet the final targets of the long-running Renewable Energy Target (RET) and various State and Territory government schemes.

With the closing of the RET scheme in 2020, Federal Government support for solar installations over 100 kW ends in 2020. Smaller installations, up to 100 kW will continue to be supported through to 2030, with the level of support declining each year. Some additional State based incentives exist for utility, business and particularly household solar and batteries.

Energy policy is the subject of much discussion, yielding little in the way of national direction since late 2013. Forward thinking policies continue to be reshaped, de-scoped and discarded, leaving the energy industry with insufficient certainty to make long-term decisions. Technical and market hurdles erode investor confidence further, with large scale connection requiring in some cases the addition of synchronous condensers to contribute to system strength, and some existing plants being constrained in their output due to stability issues, network congestion, or in response to periods of negative pricing in the wholesale market. Negative pricing events are now regular occurrences, with some coal-fired plant offering at 1 000 AUD/MWh to remain dispatched in during peak solar (and wind) periods. In these periods, a growing number of the solar plants have power purchase contracts that specify they curtail. Another issue is the NEM's use of Marginal Loss Factors (MLF) to reflect average losses (and increasingly curtailment) associated with additional load and generation in

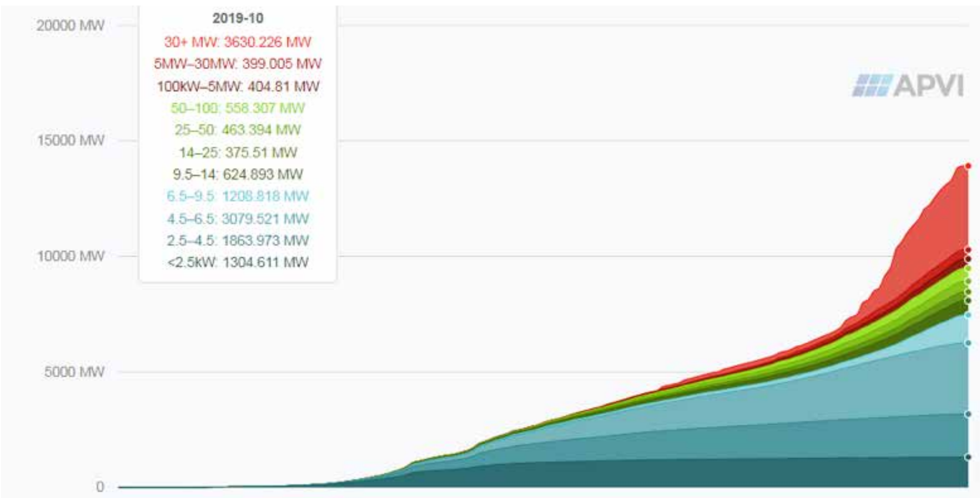


Fig. 2 – Cumulative installed capacity by system size to October 2019.

different parts of the network. The addition of large solar plants can markedly change these MLFs which then impact on the price received by these plants. The MLF is recalculated every year and presents a risk to existing investment as new generation is added in particular parts of the network, and loads change.

The Australian rooftop solar market is widely expected to remain stable in 2020, with enthusiasm for solar remaining from households and businesses becoming increasingly aware of the competiveness and benefits of investment. For large scale solar, there is a project pipeline for a further 2,4 GW of utility scale solar projects with a decline in forward commitments beyond that due to policy and market uncertainty and the associated risks around connection costs and performance requirements.

Fig. 3 – Flexible, light-weight PV Module installation on the Sydney Maritime Museum. Modules by Sunman (Photo: Energus Pty Ltd.).

## NATIONAL PROGRAMME

With solar increasingly competitive in Australia, National Programmes are drawing to a close. The Large Scale RET target of 33 000 GWh of renewable electricity annually over 2020-30 has now been met by existing renewables plant and won't drive additional renewable capacity over the coming decade. Support for small-scale systems (up to 100kWp) will, unless changed, continue through to end 2030, with an uncapped Small-scale Renewable Energy Scheme (SRES) that are able to claim certificates (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 the Clean Energy Finance Corporation (CEFC), a statutory authority established by the Australian Government, that works to increase the flow of finance into the clean energy sector by investing to lead the market, to build investor confidence and to accelerate solutions to difficult problems. CEFC investments in new generation in 2018-19 declined compared to earlier years, reflecting broader market conditions, including grid and transmission constraints and the build out of the Renewable Energy Target. New CEFC commitments in 2018–19 included 190 MAUD in projects targeting energy generation from solar, delivering a portfolio with 1,1 BAUD invested in over 1,6 GW in their solar portfolio (CEFC Annual Report, 2019).

Additionally, the Australian Renewable Energy Agency (ARENA) was established by the Australian Government to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia. ARENA holds a portfolio of 654 MAUD solar projects (ARENA Annual Report, 2019).

## RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2019, research was funded by the Australian Research Council, Co-operative Research Centres and ARENA.

ARENA is the largest funder of photovoltaics research in Australia. In 2018-19, ARENA committed $AUD 2m for accelerating solar PV innovation and, significantly, a further 38 MAUD to extend the Australian Centre for Advanced Photovoltaics to continue world-leading research in solar PV R&D (ARENA Annual Report, 2019).

## INDUSTRY AND MARKET DEVELOPMENT

2019 saw a stabilisation of the PV market, after significant growth in 2019. Average system sizes in the sub-100kW market grew further to 7,3 kW/system, reflecting both the growth in commercial installations, and growth in the typical size of residential systems as householders prepare their homes for future addition of batteries and electric vehicles.

Average residential solar PV system prices continued to decline in 2019, to 1,12 AUD per Watt including STCs, or 1,65 AUD/Watt without STC support (https://www.solarchoice.net.au/blog/solar-power-system-prices).

The Australian storage market remained strong in 2019, but data on total installs remains inaccurate. Estimates are that a further 20 000 batteries were installed in 2019, matching 2018 numbers. 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.

2020 is expected to see stability in rooftop solar – with continued growth in commercial and industrial installations, but a decline in utility scale solar. 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 2020. 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 30 GW of PV projects searching for an alternative pathway towards commercialisation. Though a policy gap may occur, there is acceptance amonst 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 – TECHNOLOGY PLATTFORM PHOTOVOLTAIK ÖSTERREICH


Fig. 1 – Carport with curved glass and built-in coloured LED strip in the middle. PV modules by Module ertex-solar. (Photo: © Energiewelle Wr. Neudorf Community Wiener Neudorf).

## GENERAL FRAMEWORK AND NATIONAL PROGRAMME

Austria, as member of the European Community, is committed to the European Climate targets. There was a change in national policy in 2019 towards a conservative green government, which backed the existing official governmental target of reaching 100% renewable electricity in 2030 which is significant; this time expanded by the target to make Austria $CO_2$ neutral until 2040. For electricity, the target shall be reached by a new energy law, which sees photovoltaic followed by wind as leading technologies for further increase since the potential in hydro is limited mainly due to environmental restrictions.

In the electricity sector, about 75% is generated by renewable energy sources, but with no significant increase in percentage since many years. This means the capacity of the new built photovoltaic and wind power with altogether nearly 5 GW in the last 20 years, just matched with the increase in electricity demand. Traditionally, hydropower at about 60%, is the backbone of the Austrian electricity supply. Meanwhile, wind energy plays a significant role at approximately 11%; with about 5% of bio-electricity completing the renewable portfolio together with photovoltaics which has achieved nearly 2% in 2019. Austria has never produced electricity from nuclear energy and has a clear policy against nuclear.

Targeting another 11 TWh of PV generation in 2030 means that the installation rate would face a need to be increased by a factor of nearly 10, compared to current installation rates.

Moreover, the electricity demand in general is predicted to rise significantly due to electric vehicles, an increased cooling demand and a change in heating systems from fossil driven to electricity supported facilities, mainly heat pump driven. Furthermore, some more electricity need for the communication sector is expected, due to the growth of the digitalisation.

Quite 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 and which barriers needs to be dismantled.

A total of approximately 1,7 GW of PV power had been installed in Austria by the end of 2019, mainly as roof top systems on buildings with more than 90% of the total installed capacity. Large PV power plants are not yet established, although one 16 MW plant (on two sites close by in the east of Austria) was announced in July 2019, by both the leading Austrian companies in electricity and oil and gas, and is still in the design phase. It will be the first PV system exceeding the 5 MW category in Austria.

Besides some possible simplifications in legal framework conditions and bureaucratic measures, Austria's support schemes are essential for the installation rates; including some regional support mechanisms, two quite complex federal support schemes are still dominating:

- The feed-in-tariff system is designed only for systems between 5 and 200 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 of guaranteed feed-in-tariffs. 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 2019, the tariff was set at 7,67 EURcent/kWh for PV at buildings and no incentive for PV on open landscape; an additional 250 EUR subsidy per kWp (max. 30% of total invest cost) was offered. This support scheme was capped at 8 MEUR.
- A Federal investment support was introduced for systems up to 500 kWp. For these systems, a support for storage systems was included in the range of a minimum of 0,5 kWh/kWp to a maximum of 10 kWh/kWp. For PV, the support was in the range of 250 EUR/kWp for systems below 200 kWp in total, and 200 EUR for larger systems up to 500 kWp. Systems beyond 500 kWp did not obtain any support, which might be the reason for not having many MW systems in Austria. Another 15 MEUR was available for the second federal support scheme.

About 9,4 MEUR were dedicated to PV investment support for small systems up to 5 kWp in 2019 by the Austrian "Climate and Energy Fund". This additional support scheme has existed since

2008 and is well-co-ordinated with the feed-in scheme. With 275 EUR per kWp for roof-top systems and 375 EUR per kWp for building integrated systems, the support per kWp was the same as in 2018. This support has led to about 8 100 new PV systems with a total capacity of 47 MWp in 2019.

For the fifth 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 might have led to approximately 10,0 MWp installed in 2019. Regions that participate in the "Climate and Energy Pilot Regions" Programme are eligible to receive funding for PV installations that are in special "public interest". In 2019, 134 PV installations were funded with 1,59 MEUR. In total, 4,4 MWp were submitted."

The mean system price for private systems went further slowly down to 1 587 EUR/kWp (excluding VAT) for a 5 kW system according to the Austrian PV market report for 2018.

## RESEARCH AND DEVELOPMENT

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 2019; initially supported by the Ministry of Climate Action, this 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 the latest scientific results to the industry by innovation workshops, trainee programmes and conferences, joint national and international research projects, and other similar activities are part of the work programme, besides the needed awareness raising aimed at further improving the frame conditions for manufacturing, research and innovation in Austria at the relevant decision makers level. In November 2019, the PV Platform launched the second "Austrian Innovation Award for Building integrated PV" and the winners will receive the awards from the Federal Minister of Climate Action in March 2020. 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. This award will face its continuation on a biannual basis.

The research organisations and industrial companies are participating in various national and European projects as well as in different tasks of the IEA PVPS Technology Collaboration Programme. The national Energy Research Programme from the Austrian Climate and Energy Fund, as well as the "City of Tomorrow" Programme from the Ministry of Climate Action cover quite broad research items on energy technologies, including PV.

The total expenditures of the public sector for energy research in Austria was about 144 MEUR in 2018, dominated by energy efficiency projects with a total of 67 MEUR; and about 22,4 MEUR was dedicated to renewable energy, with a share of 8,5 MEUR for photovoltaics.

Fig. 2 – Thalheim: Green hydrogen from solar energy. The modular system combines production, refueling, storage and reconversion of solar hydrogen and the efficient use of waste heat (Photo: Fronius International).

Within IEA PVPS TCP, Austria is leading Task 14 "Solar PV in a Future 100% RES Based Power System", as well as Task 15 "Enabling Framework for the Acceleration of BIPV", both together with German experts. Moreover, Austria is actively participating in Task 1, 12, 13, 16 and 17.

The national RTD in photovoltaics is focusing on materials research, system integration, as well as much more 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 & MARKET DEVELOPMENT

Self-Consumption is generally a further additional driver of PV development. However, this strategy is increasingly criticized, since it leads to the fact that the available roofs are covered only partly with PV, in order not to exceed owners' electricity needs.

The self-consumption tax, which was introduced in 2014 for annual production, which exceeds 25.000 kWh, was abolished in 2019. Photovoltaics in multifamily buildings, which were legally enabled in 2018, still face a tedious time, with only a few systems realized so far, mainly due to complex contract structures along with low financial benefits for the users. Local energy communities are widely discussed in Austria in order to implement the EU Renewable Energy directive RED-II. However, the legal framework for local energy communities is not yet provided. Peer2Peer electricity trade is just about to emerge in Austria with some companies offering services to buy electricity directly from the – mainly private – owners of renewable systems. This market might increase in the years to come significantly driven, but not exclusively, by more and more photovoltaic and wind systems falling out of the 13 year feed-in-tariff period.

The main PV applications in Austria are still grid connected distributed systems, representing much more than 95% 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. One million PV roofs are a target of the new government; showing the willingness to put a focus on the building-applied PV.

## MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria is a non-governmental interest group of the solar energy and storage industry. The association promotes solar PV at the national and international level and acts as an informant and intermediary between business and the political and public sectors. Its focus lies on improving the general conditions for photovoltaic and storage system in Austria and on securing suitable framework conditions for stable growth and investment security. Benefiting from its strong public relations experience, PV-Austria builds networks, disseminates key information on the PV industry to the broader public, and organizes press conferences and workshops. By the end of 2019, the association counted 226 companies and persons involved in the PV and storage industry as its members. Over the next decade, Austrian electricity is to be covered exclusively from renewable energies. Photovoltaics will play a major role in the renewable energy system and will have to make the largest additions by 2030.

Austria's two-day 17$^{th}$ Annual National Photovoltaic Conference took place in Vienna again in 2019. This event was jointly organised by the Photovoltaic Technology Platform and the Federal PV Association, as well as 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 500 PV stakeholders in industry, research and administration.

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

## FUTURE OUTLOOK

$CO_2$ neutrality in Austria, the official political target, can only be achieved with huge expansion rates in the area of renewable energy systems. The number of wind turbines would have to increase 25-fold, and for photovoltaics, even if all of the roofs available throughout Austria were equipped with solar systems, additional areas on the open landscape would have to be used. It's both the increase in consumption and the replacement of fossil driven energy which would create this tremendous need for renewable energy systems. Therefore, the national policy has a strong focus on energy efficiency, which is shown by the dominance of this sector in the Federal research budget, but needs to be accompanied by an engaged change in relevant laws and the regulation.

Thermal insulation in private and commercial use, waste heat use and the search for ways to better store renewable energies are priorities in the national energy policy. Building renovation on a grand scale seems to be crucial, since the building sector is responsible for over 10% of greenhouse gas emissions. "Photovoltaic Building 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 the further deployment of PV. Meanwhile, the much lower cost of PV systems and the ambition to optimise systems for self-consumption purposes might open new opportunities for private as well as for small and medium enterprises and for the industry.

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.

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

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

Electric cars are subsidised in Austria since March 2017 with up to 5 000 EUR per vehicle. More than 30 000 fully electric cars were registered in Austria by the end of 2019. A further strong growing E-vehicle sector might have a significant influence on the PV development; moreover, since the decision for obtaining subsidy depends on a 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.

# BELGIUM

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

BENJAMIN WILKIN, APERE ASBL, BRUSSELS

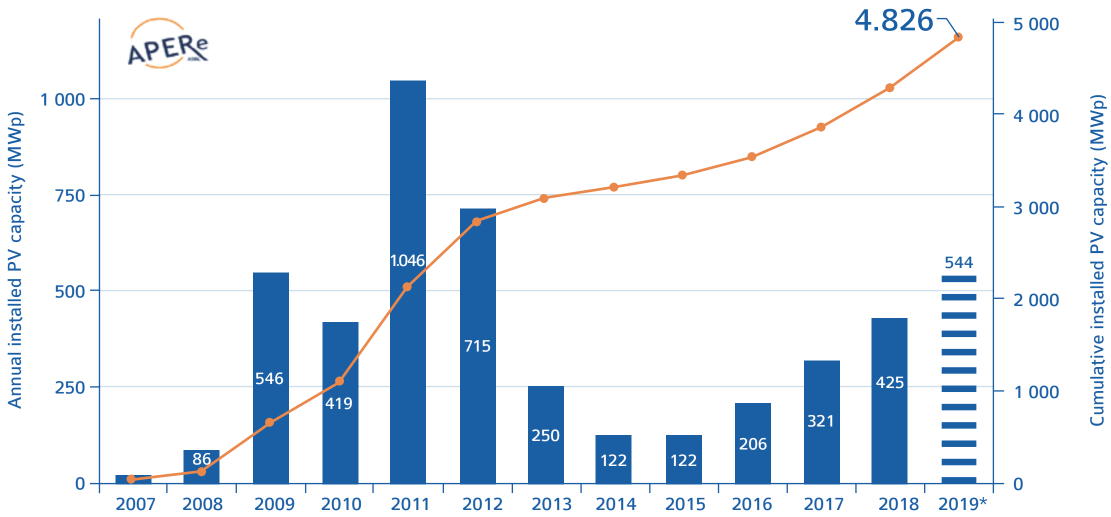


Fig. 1 – Belgium's Annual Installed PV Capacity and Cumulative Installed PV Capacity (MWp).

## GENERAL FRAMEWORK

Belgium reached a cumulative installed PV capacity of approximatively 4,850 GWp at the end of December 2019, according to the latest – and still provisional - figures from the three regional authorities.

The country added around 550 MWp in 2019, which is a significant rise compared to 2018 (425 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 425 Wp per inhabitant in 2019.
In Flanders, the market for small systems (< 10 kWp) was slightly smaller than in 2018 (-6%).

But the market for the industrial segment (> 250 kWp) exploded with 156 MWp installed in 2019. This improvement is mainly due to one utility-scale ground mounted system of 100 MWp. These systems are not subject to a net-metering or prosumer fee, but they benefit from a green certificate (GC) support scheme to ensure that investors have an Internal Rate of Return (IRR) of 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 420 MWh in 2019 (280 MWp in 2018). The installation of small systems (< 10 kW) represents 58% of the installed capacity. The large plants (> 250 kW) and the commercial segments (10-250 kW) represent respectively 18% and 24% of the total installed capacity.

In Wallonia, there was no more incentive but a net metering system from July 1, 2018. A controversy has arisen regarding the application of the partial end of the net metering system, the new government suggesting that the small PV systems (≤ 10 kW) commissioned before July 1, 2019 will still keep a full net metering benefit. As a consequence, the first 6 months of 2019 showed a similar increase in installations, compared to 2018. At any rate, the suggestion from the government was not followed by the regulator.

All the other segments seemed to be in diminution of 40 to 45% in 2019 compared to 2018.

In terms of installed capacity, Wallonia installed about 104 MWp in 2019, going up to 1,26 GWp. The installation of small systems (< 10 kW) represents 76% of the installed capacity. The large plants (> 250 kW) and the commercial segment (10-250 kW) represent respectively 9,5% and 14,5% of the total installed capacity.

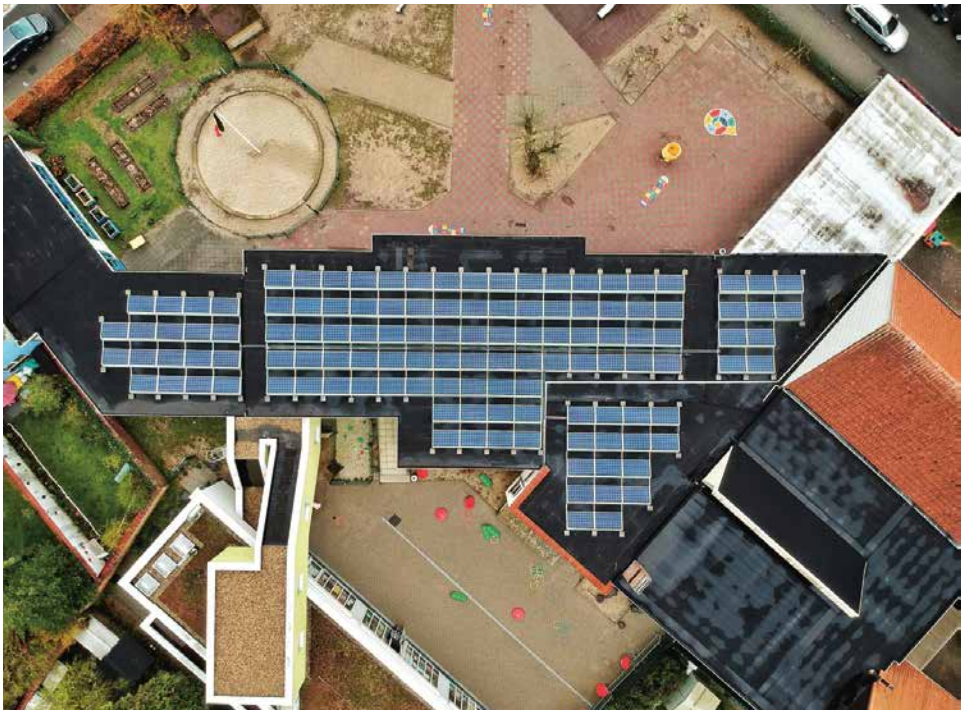

Fig. 2 – PV project in a pilot Renewable Energy Community in Brussels: Installation from a school rooftop, excess of production is sold to the neighbours through a collective self-consumption operation.

Brussels is the last region where green certificate support remains operational, also for small PV systems (< 10 kW), and its installation market increased since 2017. 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 has been postponed to at least mid-2021. Nevertheless, 2019 was the last year of a total net-metering application. Since January 2020, as an intermediary step, the net-metering system is applied only for the commodity part of the bill. Regulated tariffs must be paid, when electricity consumed is taken from the grid.

In 2019, the amount of installed capacity stayed high and stable compared to 2018 with around 23 MWp installed compared to 23,6 MWp in 2018. The cumulative capacity is reaching approximately 113 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 55% and 34% 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.

In December 2019, Belgium introduced the definitive version of its Climate-Energy National Plan to the European Commission for approval, after having organized a large public consultation on the provisional version. The new objectives for photovoltaic included in this plan aim for an annual PV energy production of 4 500 GWh (5 GWp) for 2020, and 9 735 GWh (11 GWp) in 2030. To reach these targets, the annual installation rate should be around 600 MW/year between 2020 and 2030, considering that the new 2020 goal will be reached.

In Flanders, this would mean 3 200 GWh (3,6 GWp) in 2020 and 6 250 GWh (6,7 GWp) by the end of 2030. In order to reach such targets, the annual growth should be around 280 GWh, which means 310 MWp/year between 2021 and 2030, considering that the new 2020 goal will be reached.

In Wallonia, this would mean 1 200 GWh (1,3 GWp) in 2020 and 3 300 GWh (3,7 GWp) by the end of 2030. In order to reach such targets, the annual growth should be around 240 MWp/year between 2021 and 2030, considering that the new 2020 goal will be reached.

In Brussels, this would mean 117 GWh (0,13 GWp) by the end of 2020 and 185 GWh or (0,21 GWp) by the end of 2030. In order to reach such targets, the annual growth should be around 8 MWp/year between 2021 and 2030, considering that the new 2020 goal will be reached.

## 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 being done on Smart PV modules that would embed additional functionalities, such 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 European Clean Energy Package has been adopted, which includes several directives that must be transposed in regional law. Consequently, every region has started to prepare the revision of the legislation about electricity market and renewable energy. Furthermore, in April 2019, the Walloon Government adopted a decree about new local renewable electricity market (including solar PV generation), and a "Collective virtual self-consumption market". This regulation has still to be completed with bylaws and adapted according to the content of the new directives mentioned above.

## INDUSTRY

Issol, with a new owner, is a company active in the "tailor-made" PV systems. There is another producer of modules (classic size and shape): Evocells. Soltech and Reynaers, are the two main companies focusing on BIPV applications. Derbigum is specialized in amorphous silicon.

Apart from these four 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

As mentioned above, new business models are coming through the emergence of energy communities and collective self-consumption. However, their development is still at too early stages to impact substantially the market. However, their influence should grow in the coming years.

Small-scale projects (< 10 kW) account for 62% of the cumulative installed capacity with around 581 000 installations, which represents one household out of 10. The other 38% power capacity includes about 9 500 large-scale projects.

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

| YEAR | ANNUAL GROWTH (MWP) | CUMULATIVE (MWP) |
|---|---|---|
| 2007 | 20 | 24 |
| 2008 | 86 | 110 |
| 2009 | 546 | 656 |
| 2010 | 419 | 1 075 |
| 2011 | 1 046 | 2 122 |
| 2012 | 715 | 2 837 |
| 2013 | 250 | 3 087 |
| 2014 | 122 | 3 208 |
| 2015 | 122 | 3 329 |
| 2016 | 206 | 3 536 |
| 2017 | 321 | 3 857 |
| 2018 | 425 | 4 282 |
| 2019* | 544 | 4 826 |

# CANADA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 – Fenlands Banff Recreation Centre's 280 kW photovoltaic array in Banff, Alberta (Photo: SkyFire Energy solar power systems).

## GENERAL FRAMEWORK

This report was prepared by CanmetENERGY in Varennes and the Canadian Solar Industries Association (CanSIA). CanmetENERGY-Varennes is a Natural Resources Canada research centre 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 has developed the Pan-Canadian Framework on Clean Growth and Climate Change (PCF). Released in December 2016, the PCF includes greenhouse gas (GHG) reduction targets of 30% below 2005 levels by 2030 [1]. Progress on the PCF is assessed in annual reports, the most recent of which was published in December 2018 [2]. Examples of specific investments made so far over the 12-year period (2016-2028) of the "Investing in Canada Infrastructure Program" include 9,2 BCAD for green infrastructure projects and 20,1 BCAD in funding for 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. Nevertheless, 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].

## NATIONAL PROGRAMME

In Canada, energy development is a provincial/territorial jurisdiction and consequently each province/territory employs a different mix of PV support policies. Common programs include net metering and rebate programs for home renovations and energy efficiency upgrades. National annual installation of new PV systems peaked at 675 MWDC in 2015 (compared to 163 MWDC in 2018), spurred almost exclusively by Ontario's policy supports for solar, wind, bioenergy, and hydroelectricity projects (these supports were reduced in 2016 and discontinued in 2018). The largest of Ontario's solar support policies were the Feed-in Tariff (FIT) and microFIT programs, both launched in 2009. Both FIT programmes provided 20-year contract periods for PV, and fixed prices for renewable electricity sold to the province. For example, for a ground-mounted array between 10 kW and 500 kW, electricity prices ranged from 44,3 CADcents/kWh in September 2009 to 19,2 CADcents/kWh in January 2017. Other Ontario 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).

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

Through scientific research, 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 pursues research on the performance and quality of PV systems and components, as well as their integration into


Fig. 2 – This graph shows installed photovoltaic capacity (in megawatt DC) and the number of utility interconnected systems as of December 31, 2018, for all provinces and territories. The Northwest Territories did not provide updated capacity data for 2018 and so 2017 figures were used.

buildings and electricity grids. CanmetENERGY also conducts research in grid integration of PV in the Arctic, particularly in remote communities in Nunavut, Yukon, and the Northwest Territories. The aim of these programmes in northern communities is to reduce dependence on fossil fuels, and evaluate performance, cost, and durability of PV in these harsh climates.

Several national programs announced by the Federal Government in 2017 will support solar PV demonstration projects. This includes the 500 MCAD Low Carbon Economy Challenge Fund, the 220 MCAD Clean Energy for Rural and Remote Communities and the 100 MCAD Smart Grid Programme [4].

## INDUSTRY AND MARKET DEVELOPMENT

The total cumulative PV capacity in Canada as of December 31, 2018, was around 3,1 GWDC. Approximately 96% of grid-connected PV installations were in Ontario. A map of cumulative PV capacity across the country is given in Figure 1. Estimation of the value of the Canadian PV industry to the country's economy in 2018 is approximately 406 MCAD. The number of estimated manufacturing, installation, electric utility, and research work in this sector was around 5 500 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 Stace and Morgan Solar [5]. Turnkey PV system prices varied from 1,46 CAD/W to 2,93 CAD/W depending on size and location. This translates into solar electricity production costs ranging from 8 CADcents/kWh to 12 CADcents/kWh on average [5].

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# CHILE

## PV TECHNOLOGY STATUS AND PROSPECTS

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### GENERAL FRAMEWORK AND IMPLEMENTATION

Since 2015, Chile has had a Long-Term Energy Policy, built through an open consensus process involving different private and public players and supported with updated technological knowledge, an also participative process is currently updating this policy.

During 2019 a process of public consultation for the new Climate Change Law was carried out, which allowed to start its legislative approval process by submitting it to the Congress at the beginning of year 2020. The main elements of this bill are: to establish a new mitigation goal for the country, to create the Agency and the instruments of climate change management, the incorporation of climate change into other policies and last, but not least, its financing, economic instruments and information systems. If all goes well, Chile would be the first developing country establishing by law its carbon neutrality by 2050.

Simultaneously, on June 2019, the President and his Energy Minister jointly announced a de-carbonization plan for Chile. The commitments of the voluntary program of coal plants decommissioning was a private-public agreement between the utilities and the government. Mainly, as it was communicated on December 2019 at COP 25, the first phase of the program is the decommissioning, before 2024, of ten coal units by a total capacity of 1,4 GW (25%), three of them were just closed during 2019. The second phase take account of the remaining eighteen coal units totalizing 4,2 GW (75%) of the total coal generation capacity, those will be decommissioned before the year 2040.

Two laws were enforced during the year 2019. The first one is Law No.21194, reducing the profitability of energy distribution companies from the 10% to a value between 6% and 8% after taxes. Given the financial scenario, it was clear that distribution companies' risks amounted less than the figure agreed in the old contracts and the new procedures would provide greater transparency.

The second Law No.21185, creates a transitional mechanism to stabilize energy prices for those customers subject to regulated prices. It established a Regulated Customer Stabilized Price, setting that the values in force during the first half of 2019 that will remain fixed until January 1st, 2021. Therefore, the 9,2% energy price increase that had entered into force on October 10, 2019 was rendered ineffective. In this way, the government was answering to the large social demands started on October 18, 2019. This was possible because based on prices obtained during the last bidding processes for supplying energy to regulated customers in the next 5 years up to 2026; they ensured a considerable reduction in the generating component of the price of energy. For this reason, the law also established that the delay in the payment of the balances to generating companies will not have a financial cost for the citizens, no interest will accrue, unless by 2026 still outstanding balances are maintained, in which case the acquired commitments will be financially adjusted.

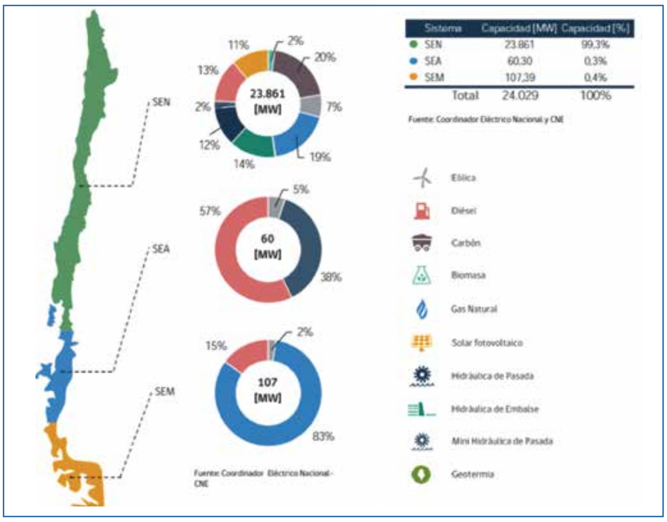


Fig. 1 – Total net installed capacity by technology, 2019 (Source: Ministry of Energy).

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

In 2008, Chile passed a law requiring generating companies to produce at least 5% of their electricity from non-conventional renewable energy (NCRE) sources, with the target rising gradually by 0,5% per year, to reach 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 yearly incremental targets). It is interesting to note that by December 2019, 23,3% of the total installed generating capacity was NCRE and it supplied 19,4% of the total power generation that year, Particularly, 47,2% NCRE´s hourly maximum participation was reached at 16:00 on December 25, 2019 (58% solar and 30% wind). So, the country would reach the 20% NCRE target during 2020; five years before the planned dates.

Total installed capacity of photovoltaic solar power plants as of December 2019 was 2,7 GW corresponding to 147 installations, 70% of the capacity was located in the northern regions and 30% in the Metropolitan region of Santiago. The total solar PV energy generation during 2019 was 6,37 TWh equivalent to 9% of total generation in the National Electricity System, 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 respectively, do not have reported solar energy generation, although they only account for 0,7% of the total installed capacity in the country. See Figure 1.

An increasing number of Solar Photovoltaic (PV) distributed generation facilities have been registered between 2015 and 2019; currently reaching a total accumulated of 42 MW, corresponding to more than 5,500 installations of less than 100kWp with 73% of facilities located in central regions (Metropolitan, Valparaíso, O´Higgins and Maule). See Figure 2. In January 2018, a series of modifications to distributed generation law were passed. The most important being: a) to raise the capacity limit of generators from 100 kW to 300 kW. This, in order to support the development of a bigger self-consumption project for benefitting productive activities, and b) aiming 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.

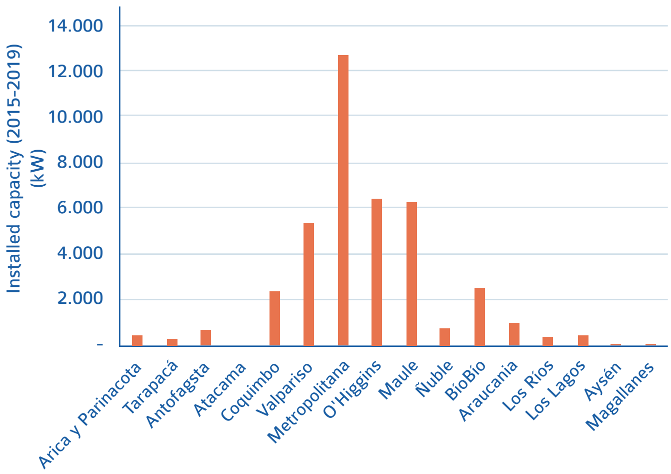


Fig. 2 – Declared distributed generation with power less than 300 kW (2015-2019) (Source: Solar and Energy Innovation Committee from Energía Abierta Database, Minister of Energy).

## 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 Ministry of Energy's Forecasting and Regulatory Impact Analysis Division 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 by law reviewed every five years for different energy scenarios of expansion of generation and consumption projected for thirty years. Because of these scenarios are considered in the planning of the electricity transmission systems carried out by the National Energy Commission, and renewable energy and storage costs fast decreasing has been necessary to have an annual update of the Long Term Planning, The results of the updated Long-Term Energy Planning delivered in December 2019 projected a massive entry of solar generation systems, up to 20 GW of photovoltaic systems, and around 10 GW of solar power concentration systems by 2050 in some scenarios. Other responsibility of this Division is to support the Ministry of Environment for defining, evaluating, implementing and monitoring the way to the Carbon Neutrality, during 2019 the jointly efforts delivered the Chilean NDC mitigation proposal [1].

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 the 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 2018 were considered very successful, as they received multiple bids resulting in considerably lower energy prices, mainly thanks to the development of the solar and wind industry in the country. The 2019 annual bidding process was postponed until 2020, mostly because of decreasing regulated energy demand 0,5% and the increasing "free" clients demand of more than 7% [2].

## R&D, D

Since 2013, the Solar Energy Research Centre (SERC Chile) is the most relevant among solar R&D organizations in Chile. It is financed by the Research and Development National Agency, in its second administrative cycle of five years (2018 -2022), bringing together six universities and Fraunhofer CSET Chile. The Centre's productivity has been increasing year by year reaching in 2019 a total of 101 ISI publications and 401 since its creation, as well as the publication of 10 books during 2019, reaching a total of 36 since 2013.

The International Solar Energy Society Solar World Congress 2019 together with the IEA Solar Heating and Cooling Programme International Conference on Solar Heating and Cooling for Buildings and Industry were held in Santiago, in November 2019, jointly with the 9th Edition of the International Conference on Solar Air Conditioning. Also, the IEA PVPS TCP's Executive Committee and PVPS Task 13's and Task 16's Experts Meetings were held in Santiago.

[1] https://mma.gob.cl/wp-content/uploads/2020/03/Mitigation_NDC_White_Paper.pdf

[2] http://generadoras.cl/documentos/boletines/boletin-mercado-electrico-sector-generacion-enero-2020

SWC/SHC 2019 was organized locally by SERC Chile and the Solar and Energy Innovation Committee Corfo, with more than 500 participants from 48 countries and included technical visits to solar PV and CSP plants in Antofagasta and Santiago.

Fig. 3 – Technical visit of SWC/SHC 2019 participants to Atacama Desert Solar Platform (PSDA) November 2019.

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. During 2019, the first version of the Atacama Module (ATAMO) in vertical, fix-tilt and horizontal axis tracking systems was installed. Its data monitoring is in beta phase of calibration; data acquisition and errors measurement from April 2020, with continuous data capture is planned.

## INDUSTRY AND MARKET DEVELOPMENT

With the highest solar generating 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 from electric mobility devices, the hydrogen-based economy and the low-emission copper production techniques. 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 long-term provider of mineral materials such as battery grade lithium carbonate and hydroxide, as well as the challenge 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 should be replaced.

In October 2019, to address these challenges, CORFO launched a call for proposal for the largest Clean Technology Institute [3] ever created in the country, which will have a strong industrial focus on development, scaling and adoption of technological solutions in solar energy, solar fuels, low emission mining and advanced materials of lithium and other minerals. The call will be open until 30th March 2020 and the award proposal is expected by the middle of May 2020.

Fig. 4 – First version of Atacama module (ATAMO) installed at the Antofagasta Solar Testing Platform developed by ATAMOSTEC Consortium and CEA-INES and ISC Konstanz technology partners.

[3] https://www.corfo.cl/sites/cpp/convocatorias/instituto_de_tecnologias_limpias_fase_rfp

# CHINA

## PV TECHNOLOGY AND PROSPECTS

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## GENERAL FRAMEWORK

### The Influence of the 5.31 New Policy

After abruptly issuing the "**5.31 new policy**" that put an end to its pre-existing feed-in tariff scheme from May 2018, the Chinese government launched a series of policies on PV applications on January 7, April 30, May 7, May 17, May 22, and May 31 of 2019, respectively. The general goal of these policies is to reduce the subsidy gradually and finally remove the subsidy; guiding the rapid realization of grid-parity by a "price-bidding" mechanism, and ensuring the smooth landing of the PV industry.

These policies have exerted great influence on the Chinese PV market and PV industry. The total PV installation in China in 2019 was 30,1 GW, which suffered a 32% decrease compared with that of 2018, but China still remains the biggest PV market in the world. The rapid decline of Chinese PV installations brings great pressure on the Chinese PV industry, which in turn pushes the price of the overall supply chain of PV industry to decrease dramatically. The PV module price has decreased 22-25% during 2019, in the China market. The decrease of PV module prices promotes the growth of the emerging PV market. According to CPIA, the PV export value reached 16,22 BUSD by the end of September 2019; surpassing the total PV export value of 2018. The export amount of PV modules reached 53 GW by the end of September 2019; indicating 41,8% of growth over that of 2018.

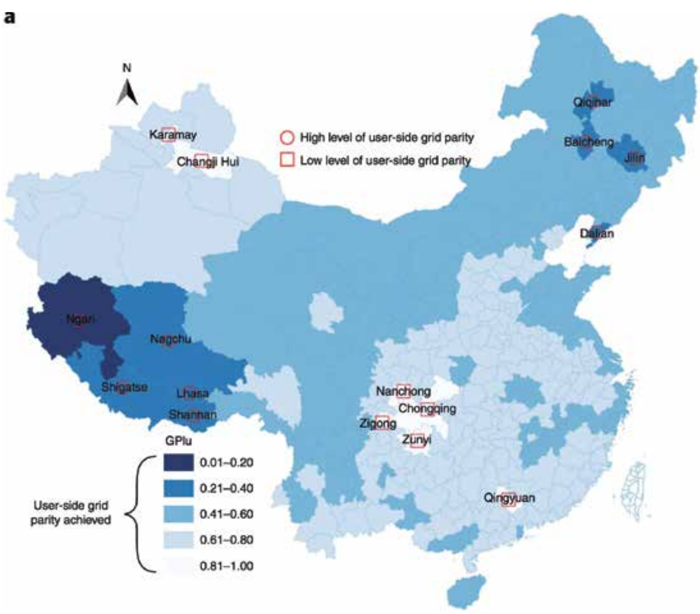


Fig. 1 – The Grid-parity Map of Chinese cities (Source: Nature Energy 4, 709-717, 2019. Produced with permission. Copyright 2019, Springer Nature/ Nature Energy).

### "Grid Parity" Arrives

A combination of technological advances, cost declines and government support has helped make grid parity a reality in China without subsidy today, as shown in Figure 1.

On January 7, 2019, NDRC issued the policy for PV and wind "grid-parity" projects (projects without needing subsidies). Such projects will obtain favourable privileges in land fees, grid connections, loans, etc.

By the end of April 2019, NEA received PV grid-parity project applications from 16 provinces and approved 168 projects with the capacity of 14,78 GW in total. Among them, 4 694 MW were to be finished in 2019 and the remaining 10 087 MW will be completed in 2020.

All of the grid-parity projects approved have 100% electricity feed into the grid with the FIT of coal-fired power plants (around 0,35 CNY/ kWh). No self-consumption projects were approved.

In 2019, the lowest bidding price for the Top Runner Plan project in Dalate of Inner Mongolia reached 0,26 CNY/kWh, which is lower than local FIT of coal fired power (0,2829 CNY/kWh), without subsidy.

## NATIONAL PROGRAM

### New FIT and Bidding Rule

According to the NDRC document issued on April 30, 2019 (NDRC [2019] No.761), PV FIT for 2019 is shown in Table 1:

TABLE 1 – PV FIT IN 2019 (CNY/KWH)

| RESOURCES ZONE | FIT* | SUBSIDYFOR SELF-CONSUMPTION |
|---|---|---|
| I | 0,40 (0,65) | 0,1 (0,18 for PVHS) |
| II | 0,45 (0,75) | |
| III | 0,55 (0,85) | |

FIT: feed-in tariff, PVHS: PV home systems
*: FIT in bracket is for poverty alleviation projects

It is of interest to note that except for PV home systems and PV poverty alleviation projects, all other projects must obtain FIT or fixed subsidy through bidding. The FIT and subsidy level shown in Table 1 just provide the upper limit value. PV home systems benefit from the fixed subsidy of 0,18 CNY/kWh; with either "self-consumption" or "selling the entire PV electricity to grid", while the subsidy level is the same.

Fig. 2 – PV Poverty Alleviation, Qinghai (Photo: LONGi. Ltd.).

By the end of June 2019, NEA received application projects from 22 provinces, with total application capacity at 24,56 GW and finally approved at 22,79 GW. This situation is presented in Table 2:

**TABLE 2 – APPROVED BIDDING PROJECTS (MW)**

| DISTRIBUTED PV 100% FEED-IN GRID | | DISTRIBUTED PV SELF-CONSUMPTION | |
|---|---|---|---|
| Project | Capacity | Project | Capacity |
| 473 | 564,859 | 3 082 | 4 100,467 |
| **CENTRALIZED PV PLANTS** | | **TOTAL** | |
| Project | Capacity | Project | Capacity |
| 366 | 18 123,32 | 3 921 | 22 788,642 |

### Mandatary Share of Renewable Energy and Non-Hydro Renewable Energy Power

On May 15, 2019, the Chinese government officially issued the regulation of "Mandatary Share of Renewable Energy Power" (MSREP), which establishes a mechanism for the use of renewable energy.

MSREP, which is the same as RPS in western countries, is an effective policy to promote renewable energy power distribution by forcing local governments to undertake the obligation of consuming renewable energy power in a certain amount. This regulation assigns the obligation of renewable energy power and non-hydro renewable energy power, mainly from wind and PV, to all provinces.

The mandatary 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 the total power consumption in China by 2020, accordingly.

Fig. 3 – Top Runner Project, TBEA (Photo: Solarbe).

MSREP has been in effect since January 1, 2020. This policy plays an important role in solving the grid-connection of PV power plants and improving the utilization of PV generated electricity without subsidy. This "Responsibility weighting mechanism for renewable energy utilization" guarantees the utilization of renewable energy by setting restrictive assessment indicators, which is widely supported by renewable enterprises. It provides an alternative way to solve the gap of subsidy funding, in addition, relieve the financial pressure of enterprise.

### 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:

- **PV Poverty Alleviation:** The government will build around 5kW PV for each poor family and the family can receive 3 000 CYN each year by selling PV electricity to grid. This project will help 2,8 million poor families and 15,5 GW of PV has already been approved.
- **Top Runner Plan:** The 'PV Top Runner Plan' is to encourage PV companies to upgrade technologies through innovation. The Top Runner Plan started in 2015, with a total installed PV capacity for the 1st and 2nd phases at 6,5 GW. The capacity of the 3rd phase is 6,5 GW (5 GW for Top-Runner and 1,5 GW for Super Top-Runner).

## RESEARCH & DEVELOPMENT (R&D)

### 2019 Solar Cell Best-Efficiency Table of China

CPVS has been publishing the Solar Cell Best-Efficiency Table of China since 2017. On November 5, 2019, at the PVSEC-29 conference, CPVS published the 2019 Solar Cell Best-Efficiency Table of China:

#### TABLE 3 – LABORATORY LEVEL HIGHEST CELL EFFICIENCY

| NO. | TECHNOLOGY | CELL EFFICIENCY (%) | AREA ($cm^2$) |
|---|---|---|---|
| 1 | HIT | 24,85 ± 0,35 | 244,54 (t) |
| 2 | TOPCon (bifacial) | 24,58 ± 0,34 | 244,62 (t) |
| 3 | PERC | 24,03 ± 0,34 | 244,59 (t) |
| 4 | PERC | 22,8 ± 0,32 | 246,66 (t) |
| 5 | GaAs (single junction) | 29,1 ± 0,58 | 0,9980 (da) |
| 6 | CIGS (on glass) | 22,92 ± 0,33 | 0,9856 (da) |
| 7 | CIGS (flexible) | 20,56 ± 0,13 | 0,8657 (ap) |
| 8 | Perovskite (cell) | 23,7 ± 0,76 | 0,0739 (ap) |
| 9 | Perovskite (cell) | 22,2 ± 0,1 | 1,146 (da) |
| 10 | Perovskite (minimodule) | 17,25 ± 0,55 | 19,277 (da) |
| 11 | Perovskite (submodule) | 14,30 ± 0,35 | 300,74 (da) |
| 12 | Organic Solar Cell | 16,48 | 0,04137 |

1. Hanergy 2. Trina Solar 3. LONGi 4. Canadian Solar 5. Hanergy 6. Hanergy 7. Hanergy 8. Institute of Semiconductor, CAS 9.NJU 10. Microquanta 11. Microquanta 12. SCUT

Source: CPVS

### The 13th Five-Year National Science and Technology Plan

China's Ministry of Science and Technology has supported a number of PV R&D projects:

- Design, preparation and mechanism study of laminated solar cells with perovskite/crystalline silicon;
- Complete research and development of flexible copper indium gallium selenide thin film solar cells and modules;
- Key technologies for high-efficiency P-type polysilicon battery industrialization;
- Controlled attenuation of N-type polysilicon battery industrialization key technology;
- High-efficiency homojunction N-type single crystal silicon double-sided power generation solar cell industrialization key technology research and production line demonstration;
- Crystalline silicon photovoltaic module recycling processing technology and equipment;
- New photovoltaic medium voltage power generation unit modular technology and equipment;
- New photovoltaic medium voltage power generation unit modular technology and equipment;
- Key technologies for empirical research and testing of photovoltaic systems under typical climatic conditions;
- Research on Key Basic Problems of Supercritical $CO_2$ Solar Thermal Power Generation.

## 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 whole manufacture chain in 2019 are shown in Table 4:

#### TABLE 4 - PV PRODUCTION AND CHINA'S SHARE IN 2019

| SECTORS | WORLD | CHINA | SHARE (%) |
|---|---|---|---|
| Poly-Silicon (103Ton) | 508,0 | 342,0 | 67,3 |
| Silicon Wafer (GW) | 138,3 | 134,7 | 97,4 |
| PV Cells(GW) | 140,1 | 110,3 | 78,7 |
| PV Modules (GW) | 138,2 | 98,6 | 71,3 |

Source: CPIA

### PV Market Development

By the end of 2019, installations reached 30,1 GW. Among these, the distributed PV was 12,19 GW, shared 40,5%.

#### TABLE 5 – PV INSTALLATION BY SECTORS IN 2019

| MARKET SECTOR | ANNUAL (MWp) | CUMULATIVE (MWp) | SHARE (%) |
|---|---|---|---|
| Distributed | 12 190 | 63 440 | 40,5 |
| Power Plant | 17 910 | 141 640 | 59,5 |
| Total | 30 100 | 205 080 | 100 |

Source: CPIA

### Energy Transition Target and Future Forecast

2020 is the last year of "The 13th Five-Year National Science and Technology Plan"; moreover, it is the first year of "The 14th Five-Year National Science and Technology Plan". After experiencing the abrupt "5.31 new policy" in 2018, and undergoing the adjustment by 2019, the cost of PV will further decline and the price will be more closely reaching parity. It was learned at NDRC and NEA meeting, at beginning of 2020, that the Chinese government will keep the price policy stable and change as little as possible and as soon as possible, as to the project's timely preparation and construction. The installation is estimated to be at least 40 GW.

### 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

FERNANDO NUÑO, PROJECT MANAGER, COPPER ALLIANCE

Fig. 1 – 1 600 kVA transformer. The transformer is a key element in utility-scale PV installations. Special attention should be paid to its efficiency performance (Photo: Copper Alliance).

The Copper Alliance® represents a network of regional copper centres and their industry-leading members, led by the International Copper Association (ICA). ICA is a nonprofit organization that brings together the copper industry and its partners to make a positive contribution to the UN Sustainable Development Goals and to support markets for copper. Considering the strong linkages between carbon reduction and copper use, the Copper Alliance aims to accelerate the energy transition.

## SUSTAINABLE ENERGY

The Copper Alliance carries out campaigns to develop energy sustainability in key areas such as building automation and controls, high-efficiency motor systems, electric mobility, renewable energy systems and demand-side management.

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

- Development of energy efficiency standards for motors and transformers;
- Study of avenues for electrification of industrial processes that 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

The Copper Alliance supports PV development through various streams:

- Policy advocacy;
- Regular and active involvement in standardisation activities at IEC level;
- Training engineers and policymakers on facilitating, designing, installing and operating PV systems.

## COPPER ALLIANCE INVOLVEMENT IN IEA PVPS TCP ACTIVITIES

The Copper Alliance actively participates in the IEA PVPS TCP's ExCo meetings and Task 1 activities. In addition to the publication of IEA PVPS reports and summaries, the Copper Alliance successfully held the PVPS Trends 2019 Report Webinar in December 2019.

## ABOUT COPPER ALLIANCE

The Copper Alliance® is a network of regional copper centers and their industry-leading members. It is responsible for guiding policy and strategy and for funding international initiatives and promotional activities. Headquartered in Washington, D.C., the organization has offices in three primary regions: Europe, Asia and North America. The Copper Alliance has partnerships and programs in more than 100 countries.

# DENMARK

## PV TECHNOLOGY STATUS AND PROSPECTS

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PETER AM, PA ENERGY LTD., DENMARK

Fig. 1 – Prinsessegade, Copenhagen, Denmark. An architectural integration of solar panels in new build. JUAL SOLAR Console System used on roof with 42 kWp capacity. Installed by JUAL SOLAR A/S, SolarOpti Aps and Free Energy ApS.

### GENERAL FRAMEWORK

A new energy plan covering 2020 – 2030 has been politically negotiated since mid-2018, and is now confirmed. It inter alia confirms the principle of technology neutral auctions over the 10-year period. Furthermore coal will be phased out, at least three large scale off-shore wind farms will be established; however, no targets have been set for PV.

The very first Danish "climate law" has been decided upon as well, with the overall target of limiting GHG emissions by 70% by 2030. Furthermore, all new laws, regulations and other public rules are supposed to undergo an environmental impact assessment as a standard procedure.

Renewable energy is very much a present and considerable element in the energy supply: by end of 2019 more than 50% of the national electricity consumption was generated by renewable energy sources including incineration of waste; if biomass is included the RE share of power production was more than 70%. During 2019, PV provided 3% 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 after previous reductions so far only modest increases. Renewable energy technologies, in particular wind, play an important role with PV still seen as a minor option suffering from previous go-stop political interventions preventing a stable market development despite a proven growing degree of competitiveness. However, the above 2020-2030 plan with technology neutral auction scheme may provide a more firm base for a future PV market, and the technology neutral auction round in 2019 exhibited for PV (and wind) a negligible need for a price adder on top of the electricity market price.

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

### NATIONAL PROGRAMME AND IMPLEMENTATION

Denmark has no unified national PV programme, but during 2019 a number of R.D.D. projects supported mainly by the Danish Energy Agency'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. The number of commercial PV projects – with no public support but based on PPAs – is increasing both in number and volume, and several commercial PV developers are impacting the PV deployment across the EU and internationally.

Fig. 2 – 31 kW Ennogie Solar Roof on Automobile Shop. The sales and display area of the company has large window areas and heat from the sun is a problem in the summer. To accommodate this, the owner has several air conditioning units installed which use a lot of electricity. Since the AC is needed when the sun is shining, it matches the production from the roof very well. With the Ennogie Solar Roof, the AC basically runs for free and saves the customer expensive grid electricity. ROI is less than 4 years.

Net-metering for privately owned and institutional PV systems was established mid 1998, and is still in existence, however with consequent limitations and restrictions.

The previous Danish market uncertainties still had impact on the PV market 2019; about 104 MWDC installed capacity was added leading to a total installed capacity of more than 1,1 GW by the end of 2019. The amount of PV installations not applying for the additional support but operating in the economic attractive "self consumption mode" or based on selling electricity on the commercial market appears to be growing, but not firm data is available yet.

The main potential for deployment of photovoltaics in Denmark has traditionally been identified as building applied or integrated systems. However, since 2016 the number of ground based centralised PV systems in the range of 50 to 100 MW - or more - has been growing mostly based on commercial PPA's or providing power to the actual market price (Nordpool). The government's technology neutral auction scheme can be expected to stimulate this trend, although public concerns regarding large scale ground mounted PV parks are rising.

In 2015, the Danish Energy Agency commissioned a revision of the national PV Strategy. The revision, which has been carried out in consultation with a broad range of stakeholders including the Danish PV Association, was completed in the first half of 2016 and can be found (in Danish) 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. The national TSO, Energinet.dk, has informed, that about 7-8 GW of PV can be grid connected in Denmark without serious network problems. 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 some interest as well.

Penetration and high penetration of PV in grid systems are as a limited effort being researched and verified by small demonstrations and network codes are reported to be under revision to accommodate a high penetration of inverter-based decentral generation and to conform to the EU wide harmonisation under development in Entso-E/EC. As mentioned above, the Danish TSO has published a study indicating that about 7,5 GW PV can be accommodated in the national grid system without serious network 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 since 2016, although future increases have been indicated.

## INDUSTRY AND MARKET DEVELOPMENT

A Danish PV Association (Dansk Solcelle Forening) was established in late 2008. With now some 80 members, the association has provided the emerging PV industry with a single voice and is introducing ethical guidelines for its members. The association originally formulated a strategy aiming at 15% of the electricity coming from PV by 2035, and has continuously revised this target, but is 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 initiated a national PV/solar energy conference held in January 2018, in the Danish parliament, 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 photovoltaics, mainly for stand-alone systems for the remote-professional market sector such as telecoms, navigational aids, vaccine refrigeration and telemetry.

A growing number of companies are acting as PV system developers or integrators designing, developing and implementing PV systems to the home market and increasingly internationally. Danish investors have entered the international PV scene on a rising scale, acting as holding companies, e.g. for cell/module

Fig. 3 – 4,8 kW Ennogie Solar Roof on Private Two - Family House: The solar roof can easily be combined with alternative roof material – as in this case, the roof tiles. Many houses built in the 1960s and 1970s need new roofs. In many cases, the houses are originally gas-heated and the owners choose to modernize with a heat pump. Additionally, many add a battery pack to the Ennogie roof. The combination of a solar roof from Ennogie and a heat pump reduces the heating costs considerably. On a yearly basis, approximately 70% of the family house's energy needs are covered by the solar roof.

manufacturing in China and the EU and increasingly acting as international PV developers/owners of large scale PV farms.

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

The total PV business volume in 2019 is very difficult to estimate with any degree of accuracy due to the relative small market of around 100 MWDC and to the commercial secrecy of the PV sector, both domestically and internationally. The cumulative installed PV capacity in Denmark (including Greenland) was estimated at just above 1,1 GW, by the end of 2019.

## FUTURE OUTLOOK

The present social democratic government, which came into power by mid-2019, announced both a general "climate law" including environmental impact assessment of all future laws and regulations, and the target of a GHG emission reduction of 70% by 2030. However, it is too early to say how this will be minted out in terms of real life strategies and action plans.

The now growing market sector of PV installations for self consumption and commercial applications appears to be firming up. However the development of politically determined market conditions, including various taxes, are uncertain.

# EUROPEAN COMMISSION

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

MARIA GETSIOU, EUROPEAN COMMISSION, DIRECTORATE-GENERAL FOR RESEARCH AND INNOVATION
PIETRO MENNA, EUROPEAN COMMISSION, DIRECTORATE-GENERAL FOR ENERGY

### THE EUROPEAN ENERGY POLICY FRAMEWORK

The EU has agreed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy and to deliver on the EU's Paris Agreement commitments for reducing greenhouse gas emissions. The completion of this new energy rulebook –the Clean energy for all Europeans package - marks a significant step towards the implementation of the energy union strategy, adopted in 2015. The Clean energy for all Europeans package consists of eight legislative acts. After political agreement by the Council and the European Parliament in 2018 and early 2019, enabling all of the new rules to be in force by mid-2019, EU countries have 1-2 years to transpose the new directives into national law.

The changes will bring considerable benefits from a consumer perspective, from an environmental perspective, and from an economic perspective. It also underlines EU leadership in tackling global warming and provides an important contribution to the EU's long-term strategy of achieving carbon neutrality by 2050 [1].

The Clean Energy package includes a revised Energy Efficiency Directive, a recasted Renewable Energy Directive, the Energy Performance in Buildings Directive, a new Electricity Regulation and Electricity Directive, as well as 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]. It empowers European consumers to become fully active players in the energy transition and fixes two new targets for the EU at the time horizon 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. 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).

The newly appointed European Commission for the period 2019-2024 launched the European Green Deal, for making Europe climate-neutral and protecting our natural habitat. The European Green Deal is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use [3].

### DEPLOYMENT

A total of 131,9 GW are estimated as installed cumulated capacity in the EU by the end of 2019, a 14% increase over the 115,2 GW operating the year before. In 2019, Spain has an estimated addition of 4,7 GW, Germany of 4 GW, the Netherlands of 2,5 GW, and France of 1,1 GW [4].

The consolidated figures on the cumulated PV capacity installed in some EU Member States by the end of the year 2018 are reported in Figure 1.

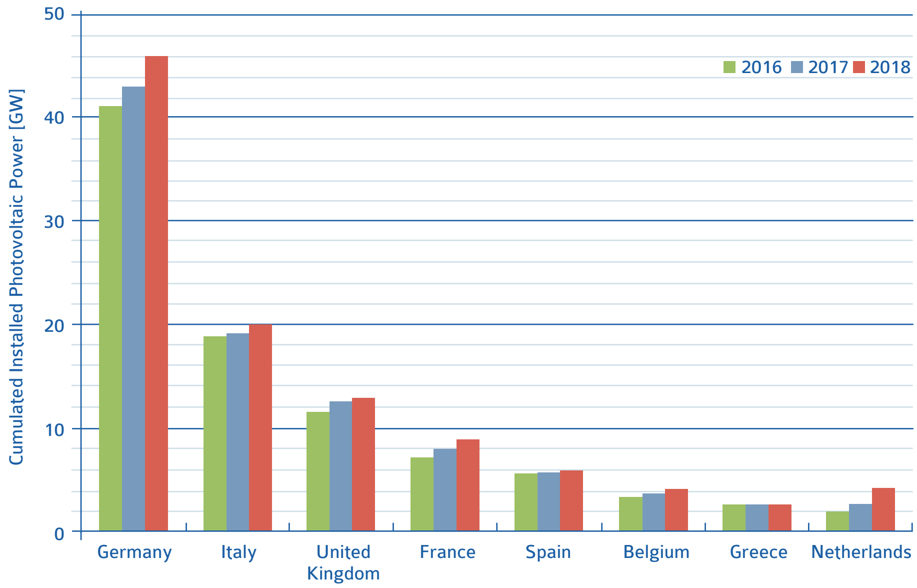


Fig. 1 – Cumulative installed photovoltaic capacity in some EU countries [4].

## 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.

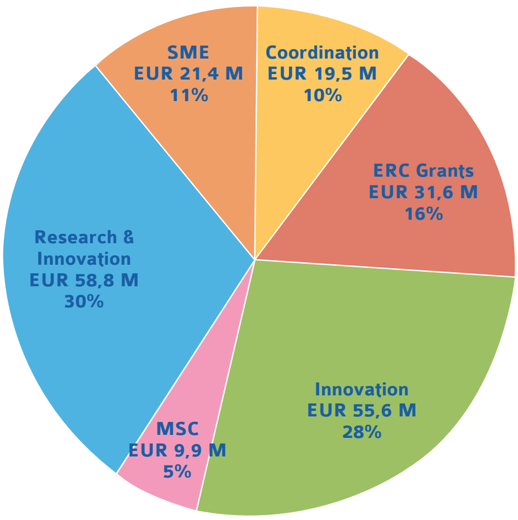


Fig. 2 – Photovoltaic activities funded under Horizon 2020.

A total EU financial contribution of about 196,8 MEUR is being invested, under H2020, on activities which are related to photovoltaics. This contribution is mostly spent for research and innovation actions (30%), innovation actions (28%) and grants to researchers provided by the European Research Council (16%). Fellowships, provided under the Marie Skłodowska-Curie programme, absorb 5% while actions for SME are at 11% of the overall investment. Coordination actions, such as ERA-NET, represent 10% 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 delivery 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 the 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 six 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, and 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, known as the denominated PV Implementation Working Group (IWG), became operational in May 2018. Its membership comprises nine 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 facilitates this process through a Coordination and Support Action (CSA) PV Impact (Grant agreement ID: 842547) which aims tackling the task of increasing PV research, development and innovation across the European Union. The project will track progress in the sector altogether, collecting data on public and private spending as well as technology improvements and check if they are meeting expectations [8].

The project's 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 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.

## REFERENCES


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[3] The European Green Deal, COM(2019) 640 final

[4] EU MARKET OUTLOOK For Solar Power /2019 – 2023, SolarPower Europe

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# FINLAND

## PV TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 – IEA PVPS TCP Executive Committee's Technical Tour at the Suvilahti Solar PV plant, in Helen Oy, May 2019 in Finland (Photo: Jero Ahola).

### GENERAL FRAMEWORK AND IMPLEMENTATION

Finland has an objective to become a greenhouse gas neutral society by 2035. In the energy sector, the challenge of transformation is particularly great. Approximately three-quarters of all greenhouse gas emissions in Finland come from heating, power generation, and direct fossil fuel consumption, when energy use in transportation is included. One of the main solutions to achieve the objective is direct and indirect electrification of energy use with emission-free electricity. In addition, actions to increase the amount of negative $CO_2$-emissions by forest-based carbon sinks are considered.

### NATIONAL PROGRAMME

There is no specific national strategy nor objectives for photovoltaic power generation in Finland. Instead, the solar PV is mainly considered an energy technology that can be used to enhance the energy efficiency of buildings by producing electricity for self-consumption. However, it is becoming widely accepted that wind power and solar PV are currently the least cost options for the electric power generation in Finland. To support PV installations, the Ministry of Employment and the Economy and Business Finland grant investment subsidies to renewable energy production. In 2019, a total of 13,2 MEUR investment subsidies for around 500 PV installations were granted. The support is only intended for companies, communities and public organizations, and it is provisioned based on applications. The subsidy level has been 20% 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 40% of the total work cost including taxes resulting up about 10 to 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-Lahti University of Technology and Tampere University, as well as at the Metropolia, Satakunta and Turku Universities of Applied Sciences. There is also active research on silicon solar cells at Aalto University, on high-efficiency multi-junction solar cells based on III-V semiconductors at Tampere University, 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 perovskite solar cells, 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 programmes for solar energy R&D&I, but PV is funded as a part of open energy research programmes. In 2019, Business Finland's public research and development funding for solar electricity was around 7,8 MEUR. In addition, the Academy of Finland granted 4,2 MEUR for basic research.

### INDUSTRY AND MARKET DEVELOPMENT

For a long time, the Finnish PV market was 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 6 MW, was built in Finland during years 2017-2019 in Nurmo. By the end of 2019, the installed grid-connected PV capacity was estimated to be approximately 200 MW, with PV plants numbering more than 20 000.

# FRANCE

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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DAMIEN SALEL AND FREDERIC DELPIT, HESPUL

Fig. 1 – 221 kWp photovoltaic power plant located on Hélianthe Building (Eiffage's head office), located in the Confluence district, Lyon, France. Architect: Atelier de la Rize (Photo: © Aerofilms for Lyon Confluence - 2019).

## GENERAL FRAMEWORK AND IMPLEMENTATION

The regulatory framework of photovoltaic did not go through significant modifications in 2019. Nevertheless, laws such as PACTE (Action Plan for Growth and Transformation of Enterprise) and Energy – Climate have redefined the perimeter of collective self-consumption operations along with slight changes concerning organizational aspects. Moreover, individually self-consumed electricity from a photovoltaic installation including third party investment has been officially exempted from taxes.

The trend of assets concentration has been confirmed in the photovoltaic market. Indeed, the total installed capacity under control of the ten biggest producers increased from 29% in 2018 to 34% in 2019.

Over the last 8 years (including 2019), the rhythm of installation of new capacities has stalled at an average level between 600 MW/year to 1 GW/year. In order to reach the national goals of the future PPE (multi-year energy planning), the capacity installed should amount to 3,5 GW/year on average over the ten coming years. The number of projects being instructed (projects that have applied for grid connection but are not yet connected to the network) is increasing: from around 2,5 GW early 2017, it is now approaching 7 GW in 2019. When this stock of projects will effectively be connected to the grid within the next 3 years, the rhythm of annual installed capacity should take off.

The public opinion is rather favorable to the development of photovoltaics for producing electricity with a score of almost 80%. Opinion survey [1] ranked photovoltaics in third position behind thermal solar and heat pumps to the question: "which energy source should be encouraged to produce heat and electricity?"

National photovoltaic capacity grew by 966 MW in 2019, compared to 876 MW in 2018, for a cumulative capacity of 9 904 MW.

## NATIONAL PROGRAMME

The Energy-Climate law has been published in November 2019. It includes a target of 40% of renewable energies of the electric production mix in 2030. The current PPE (Multiannual Energy Program Decree) defines a target of installed photovoltaic capacity between 18,2 GW and 20,2 GW in 2023. Meanwhile, total capacities connected to the grid reached almost 10 GW by the end of 2019. The revised PPE was to be presented in 2019. Public consultation on the text started January 20th 2020 and will last until mi-February 2020. The 2023 objective remains around 20 GW for photovoltaic installed capacity. A new objective was set between 35,1 GW and 44 GW of installed photovoltaic capacities for late 2028.

[1] Opinion Way Survey for Qualit'ENR – 2019 Edition

These targets appear to be ambitious, considering the actual total volume of approximately 17 GW combining commissioned and under instruction (grid connection queue) projects. The PPE maintains and strengthens the priority given to the development of less costly ground based photovoltaic, preferably on urbanized land or degraded areas and of parking canopy systems, ensuring that projects respect biodiversity and farming lands.

The peak power target for 2028 is respectively of 20,6 to 25 GWp for ground based and parking canopy systems and of 14,5 GWp to 19 GWp for buildings.

The principal tool of the development policy of photovoltaic in 2019 remains the mechanism of call for tenders. More than 80% of the peak power of new projects under instruction is supported through this mechanism. There were 8 national calls for tenders in 2019, with results published for six, including the Innovation and Fessenheim tenders, and one cancelled.

The innovation call for tenders is related to innovative photovoltaic installations. It is split in 2 families:

- Ground mounted installation, peak power between 500 kWp to 5 MWp, including floating PV
- Buildings, agricultural hangar, parking canopy and agri-voltaism, peak power between 100 kWp and 3 MWp

The call for tenders of Fessenheim territory (Alsace region - in the northeast of France) aims to develop ground, building, greenhouse, agricultural hangar and parking canopies photovoltaic installations within the Haut-Rhin department. However, the main target in terms of peak power of this call for tender are ground based photovoltaic systems. It is related to the shutdown of the Fessenheim nuclear power plant (programmed for 2020 for reactor 1 and 2022 for reactor 2).

The second policy tool is the Feed-in tariff, supporting more than 20% of the cumulative peak power of new projects under instruction. It is dedicated to building mounted systems and parking canopies for under 100 kWp. The feed-in tariff of the 0-36 kWp category remained stable with a variation lower than 1%. The category 36-100 kWp has undergone a significant drop of 4%.

The feed-in tariff revision mechanism is based on the volume of grid connection requests and general inflation – a low variation indicates low grid connection request volumes.

### TABLE 1 – COMPETITIVE TENDERS – VOLUMES, 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 | ENERGY TRANSITION OF FESSENHEIM TERRITORY |
|---|---|---|---|---|---|---|
| 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 | 500 kW – 6 MW family 1 100 kW – 3 MW family 2 | 100 kW to 30 MW |
| SUPPORT MECHANISM | Call for Tenders 2017–2020 | Call for Tenders 2017–2020 | Call for Tenders 2017–2020 | Call for Tenders** 2017–2020 | Call for Tenders 2017–2020 | Call for Tenders 2019-2020 |
| VOLUME | 1 175 MW in 10 calls of 75 MW to 150 MW | 1 200 MW in 10 calls of 75 MW to 150 MW | 5,62 GW in 8 calls of 500 MW to 850 MW | 350 MW in 12 calls of 25 to 50 MW | 350 MW in 3 calls of 70/140/140 MW | 300 MW in 3 call of 60 to 120 MW |
| REMUNERATION TYPE | PPA*** | FIP**** | FIP | Self-consumption + bonus on self-consumption + FIP | FIP | FIP |
| AVERAGE TENDERED PRICE (OR BONUS FOR SELF-CONSUMPTION) | 8th call: 97,5 EUR/MWh | 8th call: 86,5 EUR/MWh | 6th call: 64 EUR/MWh | 6th call: 17,7 EUR/MWh | 1st call: 80,7 EUR/MWh | 1st call: **Family 1** (Ground based) : 57,06 EUR/MWh **Family 2** (Building mounted above) 500 kWc: 94,77 EUR/MWh |

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

*** PPA = Power Purchase Agreement at tendered rate. Contract with an obliged purchaser, the PPA being guaranteed by the French government.

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

**TABLE 2 – PV FEED-IN TARIFFS FOR THE 4TH QUARTER OF 2019 (EUR/Kwh)**

| TA (NO SELF-CONSUMPTION) TARIFF Q4 2019 | POWER OF PV INSTALLATION (kW) | PA (PARTIAL SELF-CONSUMPTION) TARIFF Q4 2019 |
|---|---|---|
| 0,1857 EUR/kWh | ≤3 kW | 0,10 EUR/kWh (+0,39 EUR/W installed) |
| 0,1579 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 (+0,18 EUR/W installed) |
| 0,1076 EUR/kWh | 36 kW to 100 kW | 0,06 EUR/kWh (+0,09 EUR/W installed) |
| Average selling price (EUR/AverakWh) 0,0919 (8th Call) | Call for Tenders 100 kW to 500 kW | Average selling price (EUR/AverakWh) 0,0919 (8th Call) |

The average tariff of the call for tenders related to buildings increased by 20% in 2019 compared to 2018. This evolution may be related to an under-subscription to the call for tenders leading to an insufficiently competitive environment.

The call for tenders related to self-consumption suffered the same difficulty. Step 5 was cancelled and the target of step 6 has been lowered in order to avoid another sub-subscription.

Average tariffs of the call for tenders for ground installations have also been increasing by 10% compared to 2018 while the price of equipment was decreasing. Even if this call for tenders is not under-subscribed, the competition is relatively weak with one project granted for 1,3 projects submitted.

Even if the Fessenheim territory gets lower irradiation than French mean values, the average prices noted on family 1 (ground photovoltaics) are lower than the ones proposed on the national ground photovoltaics call for tenders. This could be explained by a more efficient competition on this call for tenders.

PPA (Power Purchase Agreements) at market prices have appeared on the French market. In 2019, such agreements have been contracted for 176 MW. The average duration of contracted PPA's is 25 years.

## R&D

Research and Development for photovoltaics in France ranges from fundamental materials science, to pre-market development and process optimization, and 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 organizations, 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 amount of France's public financing dedicated to Research and Development for photovoltaics was M€ 44 in 2018 compared to M€ 47 in 2017.

The two major centers for collaboration on photovoltaics, the "Institut Photovoltaïque d'Ile-de-France" (IPVf) and the "Institut National de l'Énergie Solaire" (INES) are equipped with significant industrial research platforms, working with a number of laboratories and industry companies across France. In 2019, INES and IPVF joined the European Perovskite Initiative consortium. The consortium aims at publishing a European white paper on perovskites.

INES works with industrial partners on subjects ranging from building integration components to grid integration and storage technologies, as well as fundamental research on silicon and cell technologies.

In 2019, INES succeeded in producing at industrial scale heterojunctions cells reaching 24% efficiency.

The principal state agencies that are financing research are:

- the National Research Agency (ANR), which finances projects through topic-specific and generic calls and also through tax credits for internal company research. Projects awarded or that have started in 2019 through ANR calls include both fundamental materials research and photovoltaics-specific research (such as thin films, light harvesting antenna, micro-grid...).
- 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 French state's 3rd "Investments for the future" programme (Investissements d'Avenir) that is financing innovative pre-industrial technologies (on ecological transition topics).
  In 2019, ADEME ran three 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 Renewable Energy Systems) and reducing the environmental footprint of Renewable Energy Systems, with a strong focus on replicable actions. Other eligible subjects included innovative solutions for off-grid sustainable energy access.

The major events on photovoltaics research in France were the EU PVSEC (European Photovoltaic Solar Energy Conference and Exhibition) held in Marseille in September, the National PV Days (JNPV) in early December at the initiative of the Fed-PV, (CNRS PV research federation) and IPVf and Energaïa forum organized in Montpellier in December by Occitanie region.

One call for tender is dedicated to innovative installations. This mainly includes agrivoltaism and floating photovoltaics.

2019 saw the inauguration of the biggest floating photovoltaic installation in Europe, located in Piolenc – southeast of France - with a peak power of 17 MWp.

## INDUSTRY AND MARKET DEVELOPMENT

The year 2019 saw an increased concentration of the photovoltaic energy production market with over 34% of the commissioned capacity in the hands of 10 companies (compared to 29% in 2018). However, the tendency for concentration (through mergers and acquisitions) was less important than in 2018. EDF Renewables completed in 2019 the acquisition of Luxel Group, an independent solar energy actor in France. The top 25 include 9 foreign companies controlling around 16% of the total installed peak power.

The Joint Research Center, the European Commission's science and knowledge department, completed in December a preparatory study on sustainable product policy instruments that could be applied to solar photovoltaic. The development of this study has been subject to a broad consultation of stakeholders, among them French representatives. This process resulted in the publication of policy recommendations related to an Ecodesign, an Energy Label, an EU Ecolabel and some EU Green Public Procurement criteria for PV modules, inverters and/or systems.

Future energy regulation for buildings, awaited for 2020, has been extensively discussed with building sector representatives, based on E+C- (Energy+ / Carbon-) experimentation label results. E+C- experimentation label was launched in 2016 with the aim to experiment building construction including not only energy consumption criteria but also greenhouse gas emission criteria. The results of this experimentation are expected to be used for the future energy regulation for buildings, called RE2020. The future regulation should include a new set of criteria on energy and carbon, also applied to photovoltaic equipment.

French national tenders call for a different calculation method of the laminate (PV module without frame) carbon content. The average value of selected projects is lower than 350 kg eq. $CO_2$/kWp, as published by the French energy regulator early 2019.

E+C- experimentation carbon content evaluation criteria is based on Type III environmental declarations as defined in ISO 14025 standard and takes into account the whole PV module. The French national tenders methodology has been developed by DGEC (General Direction for Energy and Climate – French government) based on default values provided in tabular form, taking into consideration the PV module without its frame and including a maximum threshold.

PVCycle France, the accredited eco-organization for PV module waste in France, proposed participatory workshops on take-back and recycling schemes. 4 workshops were held in 2019, with participants from the whole photovoltaic sector, the majority being PV modules producers.

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 – Technical Advice) before being accepted as viable solutions by most insurance companies. Obtaining certification is a lengthy process, and return on investment is far from obvious since the market is small. Once the quality of the product is demonstrated to the satisfaction of the AQC (Quality Construction Agency), it is put on a Green List and thus no more under observation. Some roof mounting kits were certified in 2019, giving installers the possibility to install this kind of systems, but some manufacturers still struggle to have their products certified. One of the consequences is that installers have difficulty to qualify for the 10-year building liability warranty, especially those arriving in the market. The AQC published a study on the detection of electrical risks, which follows the one made last year on the description of electrical risks.

The French Building Federation's photovoltaics branch (GMPV) has pushed further its assistance to installers and building professionals, with a number of working groups and workshops, for example on installation techniques and insurability.

Total annual installed capacity increased slightly in 2019. Growth concentrates mainly on the commercial segment of systems from 9 kWp to 100 kWp (+ 53% compared to 2018), other segments varying less 15%. Overall grid connected volumes grew by an estimated 945 MW in 2019 as compared to 876 MW in 2018 and 888 MW in 2017. Commercial and industrial systems continue to dominate grid connections, with 55 % of new capacity (535 MW).

### TABLE 3 – GRID CONNECTED CAPACITY AT THE END OF DECEMBER 2019 (PROVISIONAL)

| POWER CATEGORY | CUMULATIVE POWER (MW) | CUMULATIVE NUMBER OF SYSTEMS (NUMBER) |
|---|---|---|
| Up to 9 kW (Ta FiT) | 1 435 (15%) | 408 284 (90%) |
| 9 kW to 100 kW (Tb FiT) | 1 919 (19%) | 37 301 (8%) |
| Above 100 kW | 6 550 (66%) | 8 809 (2%) |
| Total (provisional) | 9 904 | 454 394 installations |

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

# GERMANY

## PHOTOVOLTAIC BUSINESS IN GERMANY - STATUS AND PROSPECTS

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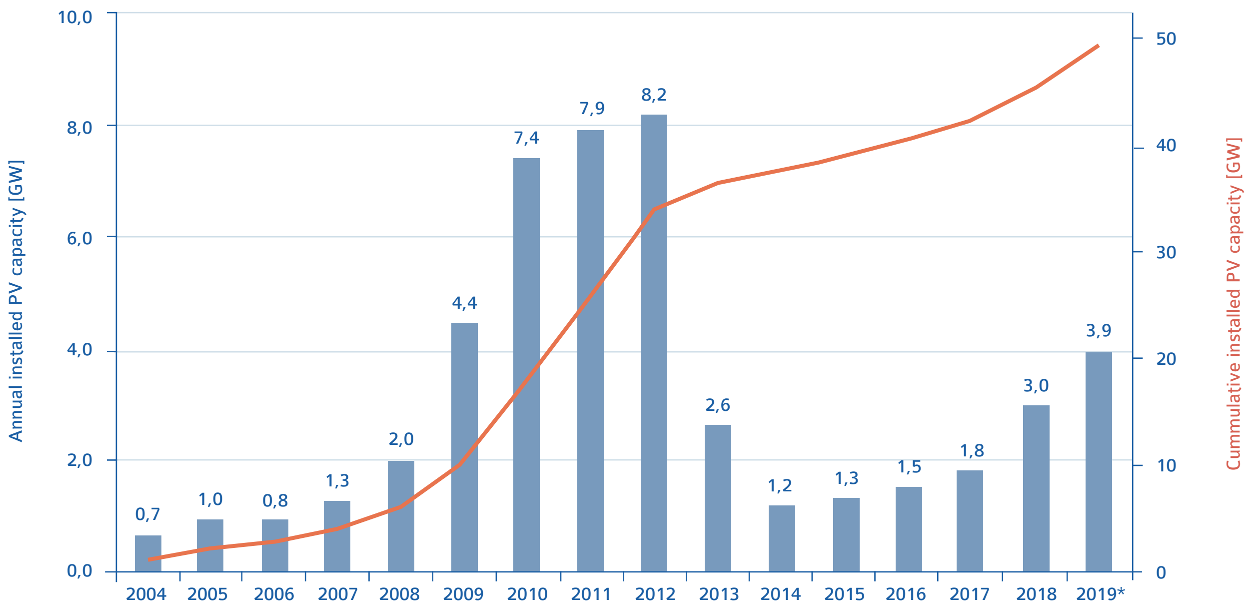


Fig. 1 - Development of grid connected PV capacity in Germany, *first estimate as of January 2020.

## GENERAL FRAMEWORK AND IMPLEMENTATION

On September 20, 2019, the German Federal Cabinet passed the Climate Action Programme 2030 [1] to achieve the climate targets Germany has set for 2030: greenhouse gas emissions are to be cut by 55 per cent of the 1990 level. This goal is to be achieved mainly by putting a price on damaging $CO_2$ emissions, introducing incentives to cut $CO_2$ emissions and foster technological solutions. The concrete implementation will be laid down in legislation.

In addition to the measures for $CO_2$ reduction in the building and transport sector, the German government aims to see renewables account for 65% of electric power consumed in Germany by 2030. It was therefore decided to phase out coal-based electricity generation until 2038. Thus, the contributions made by renewable sources such as photovoltaics and wind energy need to increase. In 2019, approximately 42% of the gross electricity consumption was already covered by renewable energies. Thereof, 9% are generated by photovoltaic (PV) systems. At the same time there was a reduction of 1,4 GW of the net installed electricity generation capacity of fossil power plants [2]. On the other hand, a total of 3,9 GW of photovoltaic capacity was newly installed, so that a total capacity of 49,1 GW PV power plants was available by the end of 2019. The development of the newly and totally installed PV power capacity can be found in Figure 1 and [3].

## NATIONAL PROGRAMME

The responsibility for all energy related activities is concentrated within the Federal Ministry for Economic Affairs and Energy (BMWi). Up until 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 (EEG) 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].

Since January 1, 2019, a new law, The Energy Collection Act, is in force which provides some changes to the EEG. This law is intended to promote the expansion of renewable energies in a cost-efficient, market-oriented and grid-synchronized manner, e.g. by the introduction of special tenders. A total of four gigawatt solar plants and wind energy plants on land are to be put out to tender additionally until 2021. The special tenders will not count towards the existing 52 gigawatt cap for solar plants fixed in the current EEG. At any rate, it is planned to remove this ceiling on photovoltaic plants within the framework of the Climate Action Programme.

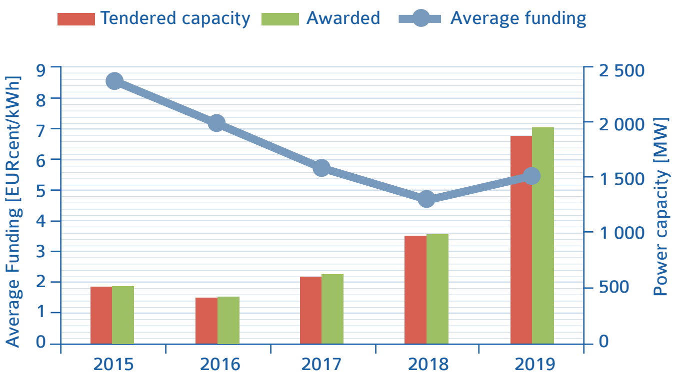


Fig. 2 – Average funding awarded in the auctions for ground-mounted PV installations.

As a result, a total volume of approximately 1 475 MW was awarded in five auctions for ground-mounted photovoltaic installations in 2019. Additional 400 MW of two technology independent mixed auctions (PV and onshore wind) were again solely awarded to PV systems. The calls were characterized by a high degree of competition. The proposed capacity was significantly over-subscribed. Figure 2 displays the development of the tendered total volume and the average funding awarded in the auctions for ground-mounted PV installations over the last years. It shows good efficiency of the auction process [6].

Medium sized 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) over the last 15 years.

Moreover, investments in PV installations become attractive even without financial support by a Feed-in-Tariff. A German electric utility announced the construction of a new 180 MW large-scale solar park which would be Germany's largest and first utility-scale solar-park to be realized without any subsidies. However, even small residential PV rooftop systems are becoming more and more financially attractive. The Levelized Costs of Energy (LCOE) for these systems are around 10 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 is accompanied by a halving of the price for battery storage systems since 2013.

## RESEARCH AND DEVELOPMENT

The 7th Energy Research Programme entitled "Innovations for the Energy Transition" [9] came into force in September 2018. 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 ongoing call for tenders which reflects the targets of the new energy research program in October 2018. 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.

The development of funding activities over recent years is shown in Figure 3. In 2019, the BMWi support for R&D projects on PV amounted to about 96 MEUR shared by 472 projects in total. In the same year, 135 new grants were contracted. The funding for these projects amounts to 99,5 MEUR in total.

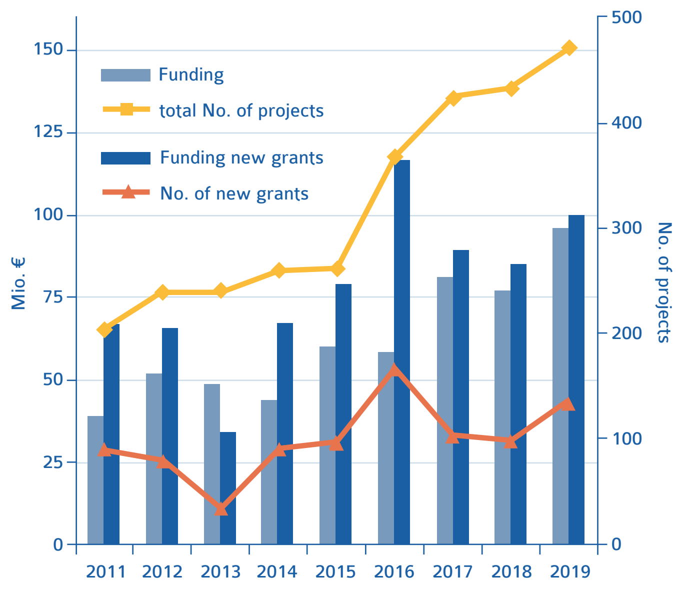


Fig. 3 – R&D support and quantity of PV projects funded by BMWi (BMU) in the 6th and 7th EFP.

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

| YEAR | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012* | 2013* | 2014* | 2015* | 2016* | 2017* | 2018* | 2019* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EURcents/ kWh | 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 degression rate between 0 – 2,8 % throughout the year

Fig. 4 – PV module production (Photo: © Heckert).

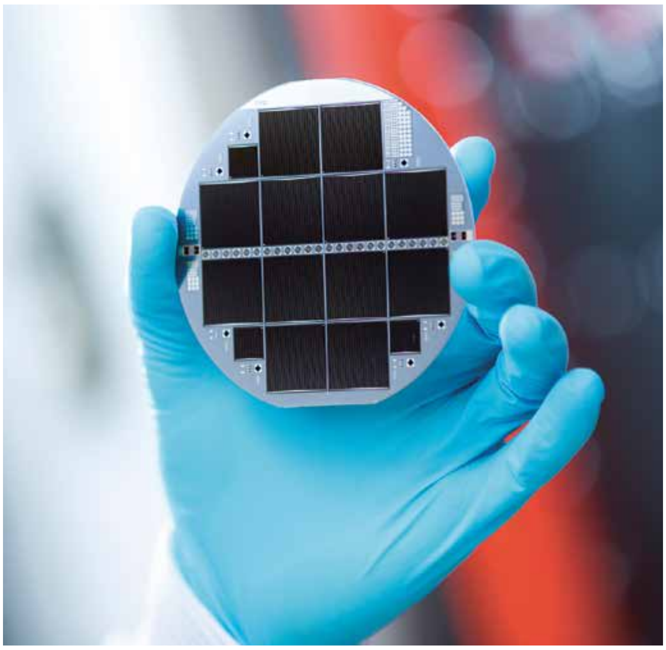

Fig. 5 – Multi-junction solar cell made from III-V semiconductors and silicon which converts exactly one third of the sunlight into electricity (Photo: © Fraunhofer ISE).

The effectiveness of successful research funding is reflected in a multitude of records and remarkable results. For example, researchers at the Helmholtz-Zentrum Berlin were able to break the world record efficiency of perovskite silicon tandem cells. They succeeded in developing a cell that converts 29.15 percent of the incident light into electrical energy. Another example is the increase in the efficiency of CIGS thin-film solar modules to a world record of 17.6 percent. A good insight into current and already completed R&D projects and results on energy research is provided by our website [10] or 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 network for research and innovation in the field of renewable energies [12] serves to support the activities within the 7th Energy Research Programme. PV and wind power are the two pillars of this network. The network serves as an information and discussion platform for players from industry, universities, research institutes and politics. It is a source of inspiration for the future focus of research on renewable energies to the BMWi and gives concrete ideas for the implementation of thematic topics or support concepts. One example for the activities of the network was the open expert forum on digitalization and PV which was conducted in November 2019. In Germany, more than 2 000 researchers and more than 65 companies are active in research for photovoltaics.

### Funding Activities of the BMBF

In 2019, the Federal Research Ministry (BMBF) relaunched its energy related funding under the "Kopernikus" initiative. Under this scheme cooperative research on four central topics of the German Energy Transition are addressed: storage of excess renewable energy, development of flexible grids, adaption of industrial processes to fluctuating energy supply, and the interaction of conventional and renewable energies. The Kopernikus projects are designed for a period of up to ten years. The BMBF is providing up to 120 MEUR for the first funding phase until 2018. Up to 2025, 280 MEUR will be made available for two further funding phases.

### Industry and Market Development

In 2019, once again a significant drop of approximately 9% in module prices was observed and requested for additional cost savings. 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 that it remains optimistic on this. While an average sales decline of 16% is expected for 2019, companies of VDMA expect sales to

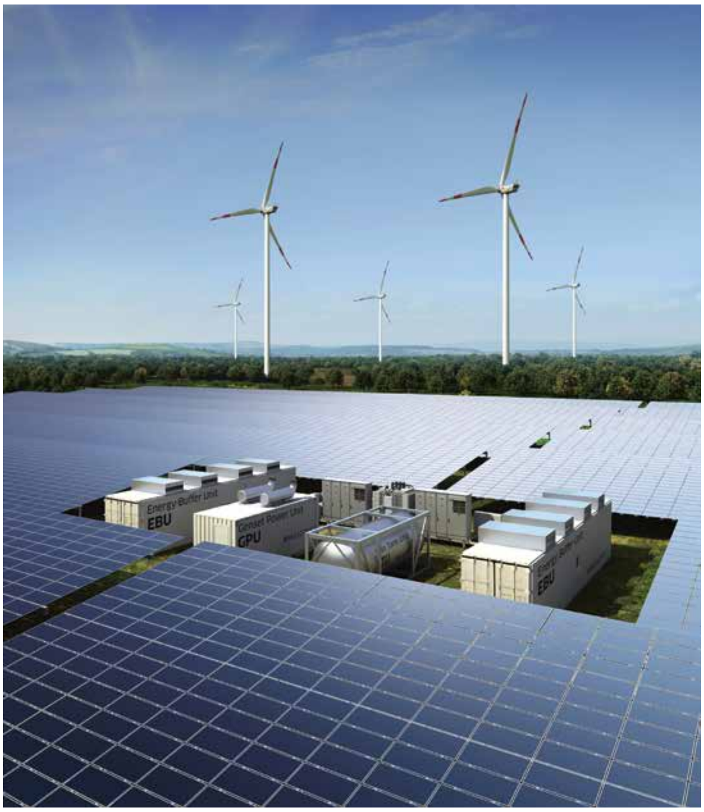


Fig. 6 – PV hybrid power plant combines photovoltaics with wind power and diesel generation (Photo: © Belectric GmbH).

rise again by 3% in 2020 [13]. Besides these activities, significant added value arises from industrial engagement in poly-silicon and module production, inverter technologies and the installation, operation and maintenance of systems. A workforce of approx. 24 400 people was employed in the solar industry in 2018 added by jobs connected to solar research in research institutions. A significant increase in employment of around 50,000 can be expected by 2030 as a result of the nuclear and coal phase-out [14].

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# ISRAEL

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

YAEL HARMAN, SECTION MANAGER OF TECHNOLOGIES & RENEWABLE ENERGY, CHIEF SCIENTIST MINISTRY OF ENERGY

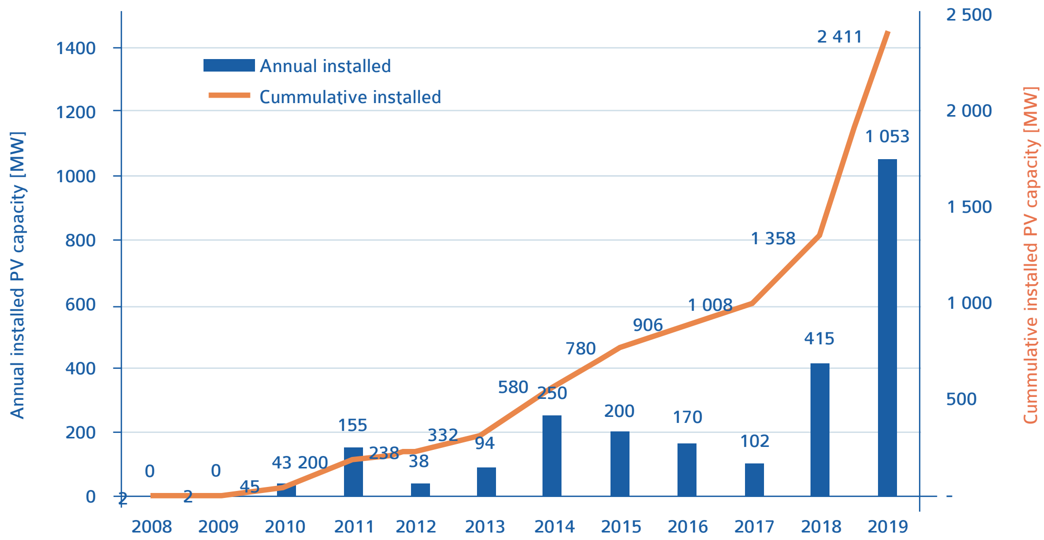



Fig. 1 – Development of grid connected PV capacity in Israel through 2019.

## 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. The RE target includes interim targets of 10% in 2020, 13% in 2025 and 17% in 2030.

During 2019, the total RE capacity in Israel has dramatically increased by 45% from 1 425 MW to 2 480 MW; a two and a half fold increase in annual installations compared with the previous year. Overall, in 2019 Israel has reached a level of ~7% RE electricity generation. PV systems are still the most abundant RE resource in Israel, accounting for approximately 97% of the installed capacity.

Two large solar projects were completed and were grid connected in 2019. The first is the largest CSP fields in Israel, 242 MW in total, located at Ashalim. The site was commissioned and became fully operational in the first half of 2019. The second project is a 60 MW PV field in Mashabei Sadeh. An additional source of high PV adoption during 2019 was PV on roof-tops that contributed 634MW in DC terms that accounts for 60% of the annual solar installation.

Although renewable energy is more competitive than ever, it is clear that in order to achieve a high percentage of electricity production from RE, energy storage solutions and smart grids are essential. Therefore, an initial competitive tender that combines the PV field with electrical storage has been published by the Public Utility Authority (PUA) in early 2020. Moreover, a new program of demand management is expected to be published during 2020/21 in order to reduce peak time consumption, and assist in the transition between day and night with high solar energy penetration.

In 2019, the price of electricity increased by 2% to 0.4713 ILS (excluding VAT), yet it is still lower than the price in 2006 and it is one of the lowest in the developed world; slightly after Norway and Iceland.

Israel continued its trend of switching from coal to natural gas. In 2019, 70% of the electricity production came from gas and by 2025 no coal will be used. In 2019, the natural gas price in Israel for electricity generation was ~5,62 USD per MMBTU.

## NATIONAL PROGRAMME

In 2018, a major reform in the Israeli energy market had begun. The reform was designed to increase competition in the electricity generation market by reducing Israel Electricity company (IEC) shares in the generation segment, separating the system operator activity from the IEC, opening the supply segment to competition, and strengthening the IEC in the transmission and distribution segment.

The reform started in 2019, by IEC selling the Alon Tavor power station. During 2020, PUA is expected to give more responsibilities to the new system management company.

The coal reduction program is accelerating, most evidently by the completion of the Leviathan gas field connection to land at the end of 2019. This will allow Israel to stop of the use of coal even before the 2030 goal set last year.

In 2019, an initial plan was formed to consider increasing Israel RE goals from 17% to 30% by 2030.

As part of the national plan for clean transportation, during 2019 grants amounting to 8,3 MUSD were given to promote installation of 2 500 EV charging stations across the country including: fast charging, semi fast and slow stations. The grants were awarded to 30 municipalities and over 15 charging, gasoline and automobile import firms. In addition, the Ministry of Energy is supporting the construction of two hydrogen pumping stations.

## RESEARCH AND DEVELOPMENT

The Chief Scientist Office (CSO) at the Ministry of Energy supports R&D through three national programmes and two international programmes:

- 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.
- Horizon 2020 – The CSO operated several joint programmes with the European Union and publishes annual calls for proposals. Among the joint programmes are Water JPI & ERA-NET CSP & SES.
- The Bird Energy Fund is a Binational Industrial Research and Development (BIRD) Foundation that support joint USA-Israel projects in the energy field.

In 2019, the Office of the Chief Scientist invested over 14 MUSD in energy related R&D projects. Among the current supported projects are:

### 3G SOLAR PHOTOVOLTAICS LTD

3GSolar produces printed dye-based photovoltaic cells that utilize fluorescent and LED light with exceptional efficiency, as well as low level outdoor light for powering wireless electronics. This eliminates the need to continuously replace and discard batteries within the soon-to-be 50 billion connected devices around the world. The 3GSolar product can be applied in many electronics markets such as Smart Home/Buildings, Smart Agriculture, Industrial IoT, Electronic Shelf Labels (supermarkets, department stores), Tracking (air and marine cargo, hospital assets, pets, etc.) and Wearables. Its initial wireless energy solution is now fully developed and launched, generating initial revenue. The company is in the late stage of developing an ultra-thin PV product, also for the electronics market.

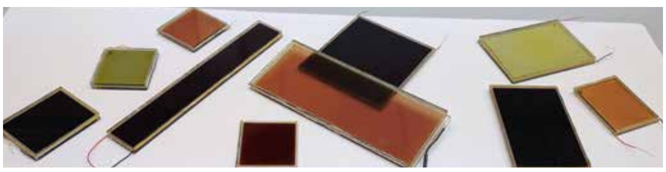


Fig. 2 – 3GSolar dye-based solar cells.

### SOLARWAT

SolarWat has developed an innovative, breakthrough, proven, patent protected Solar (PV) panel that provides significantly 10% higher energy yield under regular sunshine conditions and 35% more under partial shading conditions, a two-fold increase in system lifespan, at a low system cost per watt. The SolarWat Panel may be implemented with all types of solar cells. The SolarWat panel manufacturing process is similar to the regular Panel process and uses the same technological process, the same materials and machines. The system has been successfully operational on the company field-site for more than three years. SolarWat panels have been tested and verified by the Fraunhofer Institute (Germany) and awarded a Seal of Excellence by the European Commission. SolarWat is the only PV panel technology that provides a higher power yield at a lower panel cost per watt.

### ENER-T

Ener-t, an expert in utility-scale Concentrated Solar Power (CSP) plants, offers innovated and feasible CSP solutions also for small sites, up to twenty hectares, which are widely available. An optimized CSP solution for such locations would be competitive for regulatory reasons, low-cost storage capability, dispatchability, grid management, and for areas with limited access to grids, by supplying more reliable power day and night. These small CSP plants would also benefit from hybridization with other fuels, including biomass which is readily available in such remote areas, fossil-fuels, as well as PV and wind generators. Ener-t is achieving these goals by integrating low-cost thermal storage systems and designing solar collectors that fit smaller spaces, cost less, and require less frequent and less expensive maintenance.

### SOWILLO

Sowillo is developing a highly efficient system for recuperating building waste heat, which drastically improves the overall performance of the underlying primary heat generation system and alternatively serves as a backup heater. It is a self-contained system that extracts heat from a building's wastewater and returns it at around 60°C.

This system will employ heat pumps for driving and controlling the recuperation process. It also employs a machine learning based prediction system to only use the heat pumps when required (based on usage prediction, CoP of the installed heat pump, electricity tariffs and other parameters).
The heat pump will use a heat exchanger developed by Sowillo to extract thermal energy from building wastewater (with higher efficiency in the given workload).

System performance is constantly monitored for anomalies, allowing for automated actions whenever degradation in performance is detected such as a problem with the heat exchangers or a leak in the system.

# ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

EZIO TERZINI, ENEA
SALVATORE GUASTELLA, RSE

## GENERAL FRAMEWORK AND IMPLEMENTATION

In Italy, the trend of growth of PV installations in the year 2019 was only slightly higher than in recent years (see Figure 1). Nevertheless, the context of the PV market in Italy is rather lively, due to the Italian government's energy plan (outlined in the *"Integrated National Plan for Energy and Climate"*, PNIEC), recently published in its final version after the approval of the EU and the National Parliament, 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.

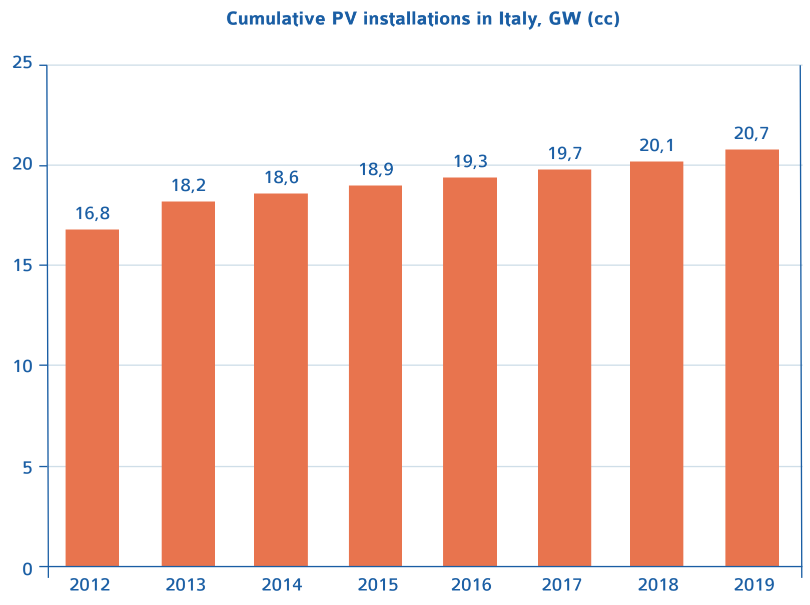
In this framework, preliminary data [1] of the photovoltaic installations in Italy in 2019 indicate a value of about 600 MW, slightly higher than the past two years' volume (435 MW in 2018 and 409 MW in 2017).

On the whole, it can be preliminarily estimated that a total cumulative PV capacity of around 20,7 GW was reached at the end of 2019 (Figure 1).

From January to October 2019, residential PV plants up to 10 kW, accounting for 43 200 units, made up 41% of the new installed capacity in 2019 [2], mainly thanks to the tax breaks mechanism; in the same period the installations of medium and large plants were 5 085, totaling 255,3 MW. Also some utility scale plants (up 30 MW) have been installed without any incentives, even more demonstrating that the "market parity" has been reached in Italian high-irradiation sites.

The PV off-grid sector for domestic and non-domestic applications confirmed the unchanged cumulative installed power, remaining as a marginal sector.

For 2019, the preliminary data on the annual energy production from grid connected PV plants is 24 326 GWh, 9,3% more than 2018 (22 266 GWh), and covering about 7,6% of national electricity demand. Moreover, with regard to the electricity production of the other RES, in the same year, it was noticed that hydroelectricity covers 14,7% of the national electricity demand, geothermal 1,8% and wind 6,3% [1].



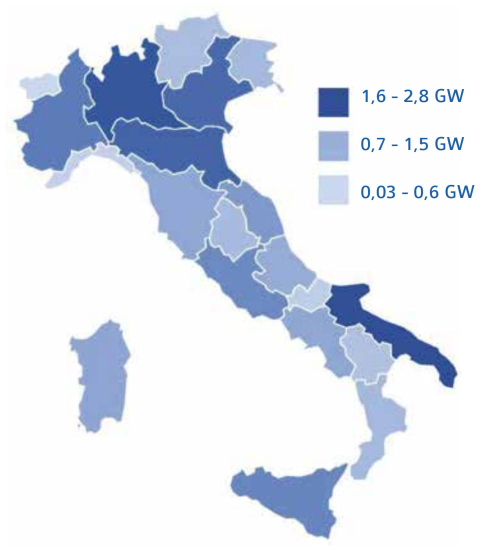




Fig. 1 - Trend of cumulative PV installations in Italy and Regional distribution (preliminary data of year 2019) (Source: TERNA Sistema elettrico).

[1] Monthly report on Italian Electric System, published by TERNA
[2] Report of ANIE Rinnovabili based on TERNA data, updated October 2019

## NATIONAL PROGRAMME

In mid-2019, the Ministry of Economic Development, in agreement with the Ministry of the Environment, issued a Decree, known as the "FER-1" Decree, which establishes new incentive schemes for renewable sources. This decree falls within the more general framework of the Italian Green New Deal and contributes to the decarbonisation plan envisaged for 2030 by the abovementioned Integrated National Plan for Energy and Climate.

Specifically, for photovoltaics, the FER-1 decree aims to support PV plants with a power greater than 20 kW, since small domestic systems are supported by other measures. The decree incentives can be accessed by the following mechanisms based on public procedures:

**1) Register Entry (PV Plant Power: 20kW <P <1MW)**

- Group A: Newly built PV plants.
- Group A2: Newly built PV plants replacing asbestos roofs of buildings and rural buildings.
  The Registers assign the available power quota on the basis of a set of priority criteria. Through this procedure, in the period 2019-2021, it is planned to boost 1 570 MW of newly installed power (in share with wind plants), 770 MW for Group A and 800 MW for Group A2.

**2) Auctions (PV Plant Power: P> 1 MW)**

- Group A: Newly constructed PV systems.

Through these procedures, in the period 2019-2021, it is planned to boost 5 500 MW of newly installed power (always in share with wind plants). Participation of aggregations of plants is allowed in view of promoting energy communities.

The reference tariffs, on which the rebate has to be applied to formulate the offer, are shown in the Table 1.

### TABLE 1 – REFERENCE TARIFFS FOR DECREE "FER-1" PUBLIC PROCEDURES

| SOURCE | POWER (kW) | REFERENCE TARIFF (EUR/MWh) |
|---|---|---|
| PV | 20 < P ≤ 100 | 105 |
| | 100 < P < 1 000 | 90 |
| | P ≥ 1 000 | 70 |

The due tariff (the effective incentive) is then formulated by applying further price reductions to the offer as stated by the Decree.

One can opt to request the "All-inclusive" tariff (namely the due tariff) or the "Incentive" which corresponds to the difference between the due tariff and the hourly zonal price of electricity.

There are also two additional premium tariffs:

- 12 EUR/MWh for the energy produced by the plants replacing asbestos roofs;
- 10 EUR/MWh for the self-consumed energy from plants up to 100 kW on buildings. This price is granted only if, at least, 40% of the produced electricity is self-consumed.

Besides the described decree, other support instruments such as *On-site exchange (SSP), Dedicated energy collection (RID), Tax breaks, EE certificates and Over-depreciation* are still in place; however, some of them are not combinable with the FER-1 decree incentives.

## 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, the company identified by the State to manage the incentive mechanisms aimed at promoting the development of energy efficiency and renewable sources), 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 public organization in the energy sector in Italy. In the PV field, its activities are focused on high efficiency solar cells based on tandem devices with c-Si or heterojunction (a-Si/c-Si) as rear cells and CZTS or perovskite top cell.

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

Further studies concern the combination of PV materials with energy–efficient building materials. Recycling oriented module design and technologies for the recovery of materials from end of life PV modules complete the frame of ENEA research.

**RSE** is the main research organization carrying out activities on the Concentrating Photovoltaic (CPV) technology in Italy, from the development of high efficiency multi-junction (MJ) solar cells to the setup of new solar tracking strategies. In particular, 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), RSE is pursuing an original research by combining the growth of III-V and IV elements of the periodic table in the same MOVPE (Metalorganic Vapour-Phase Epitaxy) growth chamber and by developing nanostructured

[2] Report of ANIE Rinnovabili based on TERNA data, updated October 2019

coating for the realization of monolithic high efficiency – low cost- four junction solar cells (Figure 2). RSE is also committed in the development of (Al)InGaP solar cells for luminescence concentrators, Ge/SiGeSn Hetero Junction (HJ) cells for Thermal-

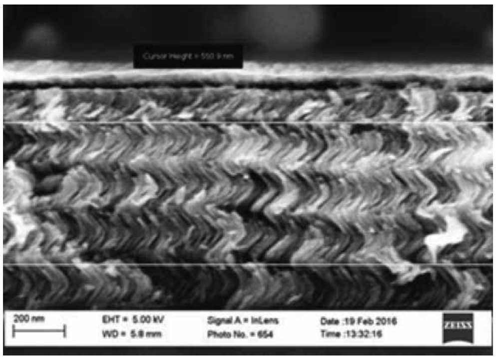


Fig. 2 - Scanning electron microscope image of a multilayer- nanostructured coating developed in RSE.

Photovoltaic (TPV) application, the design of innovative optics and advanced solar tracking technologies, as well as in the set-up of new methodologies for the design and characterization of the MJ solar cells and new CPV modules.

Moreover, RSE is engaged in the development of new quaternary chalcogenide PV thin film cells made of abundant and environmentally sustainable chemical elements to ensure a potential wide penetration of PV technology.

Furthermore, RSE carries out R&D activities aimed at facilitating the development of high-efficiency and low-cost flat PV systems also contributing to optimize the energy production of PV plants installed in the Italian territory. In this scope, studies on advanced O&M strategies (based on new diagnostic and predictive techniques) and repowering methods are carried out in the frame of research projects funded by the EU (H2020 GOPV) and the Italian government.

Research activities are in progress also to enhance the RES penetration into the microgrids of small islands not connected to the national electric grid and to provide support to institutional bodies (i.e. MiSE and ARERA) in this context.

Finally, RSE is performing Life Cycle Assessment (LCA) of innovative PV systems based on heterojunction bifacial modules installed on monoaxial trackers. The analysis, carried out for different locations across Italy, shows a relevant decrease in life cycle $CO_2eq$ emissions when compared both to electricity production from fossil fuels and to production from existing PV plants. Further ongoing research are investigating the LCA of production system that associate, on the same land, food crops and PV production (the so called agrivoltaic system) (Figure 3).

Fig. 3 - 3,2 MW plant in Monticelli d'Ongina (near Piacenza) installed by the REM TEC S.r.l (https://www.remtec.energy/agrovoltaico/impianti/30-monticelli-dongina). The free height under the PV modules is 4,5 m.

The **EURAC** Institute is active in PV research through its *PV Energy Systems Group of the Institute for Renewable Energy*. In a first area, "Performance and Reliability", the activities are focused on the definition of various methodologies for the calculation of degradation rates in PV performance. Another research area is focused on "BIPV field", managing a database for BIPV products and BIPV case studies. In the frame of a third area, "PV grid integration", EURAC has access to large amounts of data coming from several PV plants and it is investigating the impact of PV in the distribution grid, by assessing the hosting capacity and by analysing the impact of mitigation option (i.e. storage).

**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 start-ups.

Finally, to give impulse to the actual execution of the SET Plan Implementation Plan for Photovoltaics, the above mentioned PV actors in Italy, led by Enel Green Power and EURAC, are working together in order to create an "Italian PV Alliance", a collaboration network between industries, research centers and universities. The main purpose is to build a photovoltaic solar supply chain that leads basic research projects toward becoming industrial products: the strategic areas are those of the national flagship initiatives "Utility Scale PV" and "Building Integrated Photovoltaics" connected to the research priorities included in the SET Plan Implementation Plan.

## INDUSTRY AND MARKET DEVELOPMENT

The production of photovoltaic modules in Italy during 2019 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.

Fig. 4 – EGP 3SUN PV module factory: HJT cell line started production in 2019.

An important industrial initiative is represented by 3SUN, unit of ENEL Green Power, based in Catania, which continues to be the main Italian PV factory and one of the biggest in Europe. In October 2019, EGP completed the technology conversion of its production line starting the production of cells (Figure 4) and modules (Figure 5) based on the innovative Silicon Heterojunction Technology (HJT). This technological leap transforms the 3SUN production plant to allow a maximum capacity of around 200 MW per year and the leadership on automated photovoltaic manufacturing. The HJT modules have reached a power up to 400 W and an efficiency of more than 20,5%, with a very high bifacial factor (> 90%). These results will allow to achieve lower Levelized Costs of Energy (LCOE) due to additional energy generation with respect to mainstream technologies, also thanks to the very good thermal stability.

Recently, Enel Green Power together with the French National Solar Energy Institute (INES) announced the achievement of 24,63% conversion efficiency for a HJT solar cell based on a 210 mm diameter (M2) wafer. The EGP goal is demonstrate the possibility to approach the theoretical limit of silicon efficiency in the next five years, thanks to constant technological innovation, and to achieve more than 28% of efficiency through the implementation of tandem solar cell technologies.

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, such as South and Central America, South Africa and India. Among these, the biggest company is Enel Green Power, which is active especially in the field of utility scale plants, having reached 3,0 GW of RES capacity built worldwide in 2019 and 46 GW of total renewable capacity managed. Other module manufactures have been able to join the improvement on module production with the installations of large PV plants.

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.

Fig. 5 – EGP 3SUN PV module factory: HJT bifacial module assembly line.

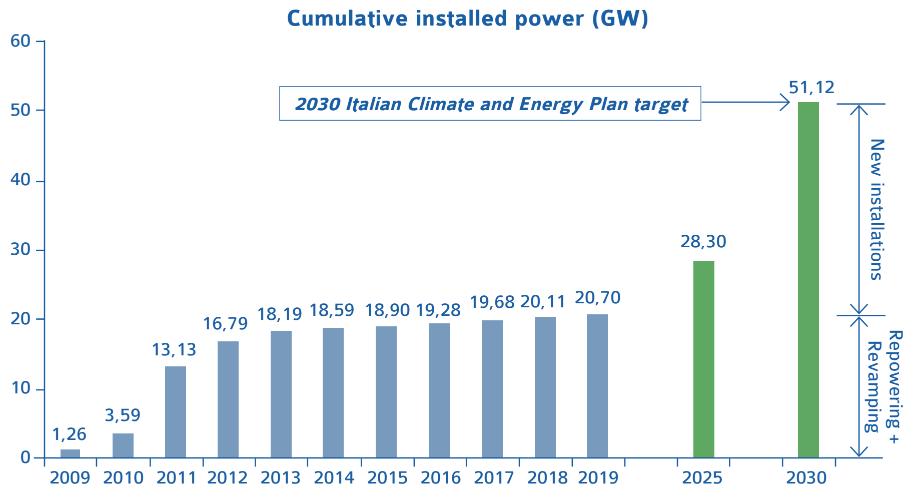



Fig. 6 – Development of cumulative installed PV power in Italy and PNIEC target by 2030 (Data sources: GSE,TERNA and PNIEC).

## FUTURE OUTLOOK

The Integrated National Plan for Energy and Climate (PNIEC) is the fundamental tool that marks the beginning of an important change in the Italian energy and environmental policy towards decarbonisation. It incorporates measures and investments for the Italian Green New Deal envisaged in the last financial law.

As already mentioned, the final text of the Plan has been published at the end of 2019, after the first submission to the EU in early January 2019 and after public consultations held during the same year. The ambitious target relating to the contribution of renewable sources to the national energy system can be clearly seen in Table 2 which summarizes the expected development of RES in the electric sector. In this context, photovoltaics will have to play a primary role.

### TABLE 2 - TARGETS OF RES INSTALLED POWER (MW) BY 2030 IN THE ELECTRIC SECTOR

| SOURCE | 2016 | 2017 | 2025 | 2030 |
|---|---|---|---|---|
| Hydro | 18 641 | 18 863 | 19 140 | 19 200 |
| Geothermal | 815 | 813 | 920 | 950 |
| Wind<br>*off shore share* | 9 410<br>*0* | 9 766<br>*0* | 15 950<br>*300* | 19 300<br>*900* |
| Bioenergy | 4 124 | 4 135 | 3 570 | 3 760 |
| Solar<br>*CSP share* | 19 269<br>*0* | 19 682<br>*0* | 28 550<br>*250* | 52 000<br>*880* |
| **TOTAL** | **52 258** | **53 259** | **68 130** | **95 210** |

The plan identifies specific drivers for the development of PV using regulatory, economic, tax and information tools.

**Regulatory Tools:**

- Charge exemption for self-consumption from small plants (< 1 MW);
- Promotion of Power Purchase Agreements (PPA) for large plants (> 1 MW);
- Aggregation of small plants for access to incentives;
- Consultation with local authorities for the identification of suitable areas for new installations;
- Simplification of authorizations and procedures for revamping/ repowering and reconversion of existing plants;
- Simplification of authorizations for self-consumers and renewable energy communities;
- Extension and improvement of the obligation to integrate renewables into existing buildings;
- Completion of the obligation to integrate renewables in new buildings.

**Economic Instruments**

- Tariff incentive with contracts for difference (CfD) to be stipulated following competitive tenders (large plants > 1 MW);
- Support for the installation of distributed storage systems;
- Incentives for the promotion of electrical and thermal renewables in small islands.

**Tax Instruments**

- Tax deduction for building energy requalification and renovation.

**Information Tools**

- Promotion of actions to optimize the production of existing plants.

Looking at the data of PV cumulative installations (Figure 6), the planned target by 2030 indicates an installed capacity of 51,12 GW about two and one-half times the current one, aiming to an energy generation of 73 TWh, about three times the current PV generation. This also implies the preservation of the latter by means of maintenance, repowering and revamping interventions on the existing plants.

All the described tools will be implemented by specific government decrees now in course of drafting.

# JAPAN

## PV TECHNOLOGY STATUS AND PROSPECTS

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OSAMU IKKI, RTS CORPORATION

Fig. 1 – PV system along the railway (SGET Chiba Newtown Megasolar PV Power Plant) (Shirai City and Inzai City, Chiba Prefecture). Installed capacity: 12,8 MWDC.

## GENERAL FRAMEWORK

In the second year of the Fifth Strategic Energy Plan, the Japanese government has been accelerating its efforts to solve the issues which have arisen from the rapid expansion of PV installations, while expanding its budget for making renewable energy a mainstream power source by setting the realization of the green growth strategy and the establishment of the robust energy supply structure as the pillars of its energy policy.

The Ministry of Economy, Trade and Industry (METI) established a scheme to let the general market to trade the surplus electricity from residential PV systems whose 10-year power purchase period has terminated. In parallel, METI advanced its actions to deal with a large amount of FIT-approved PV projects which have not started operation for a long time. Furthermore, METI set the direction of the drastic revision of the FIT program from three perspectives. The first perspective is the support scheme in accordance with the characteristics of power sources. PV installations will be promoted by categorizing renewable energy into two types of power source: competitive power source and locally-used power source. As for PV power generation, large-scale PV power plants are positioned as the competitive power source, which will be integrated into the electricity market under the FIP program which is planned to be newly established. Meanwhile, small-scale PV systems and residential PV systems are positioned as the locally-used power source, focusing on self-consumption and community consumption, and the framework of the FIT program will be maintained. The second perspective is the promotion of introduction of renewable energy taking root in local communities. With this perspective, proper project management will be secured, disposal cost will be secured, trust from local communities will be gained through safety measures, and natural energy-based power generation will be formed in harmony with local communities. The third perspective is the establishment of the next-generation network in the era of renewable energy as a mainstream power source. In order to deal with the grid restrictions coming to the surface under the conventional grid management, distributed type grids will be promoted with measures for grid enhancement and maintenance through push type grid formation and investment, as part of efforts to make renewable energy a mainstream power source.

Based on the Fifth Basic Environment Plan, the Ministry of the Environment (MoE) has been working on expanding introduction of PV power generation from the perspectives of $CO_2$ reduction, community-led support and support for developing countries, toward achieving a decarbonized society. The Ministry of Agriculture, Forestry and Fisheries (MAFF) has been promoting solar sharing (PV system installation on farmland while continuing agricultural activities) as part of the policy on agriculture, forestry and fisheries. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been promoting ZEH and ZEB using PV and other renewable energy sources to realize net zero energy buildings.

Regarding the approved and the commissioned capacities of PV systems under the FIT program which took effect in July 2012, a total of 71,8 GWAC (as of the end of June 2019, including cancelled and revoked projects) of PV systems have been approved, of which 45,7 GWAC started operation. Japan's annual PV installed capacity in 2019 is estimated to be 7 GWDC, and its cumulative PV installed capacity is expected to reach 63 GWDC level.

## NATIONAL PROGRAM

### (1) Feed-in Tariff (FIT) program for renewable energy and related issues

METI is taking initiative in introducing PV systems under the FIT program. In FY 2019, 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 14 JPY/kWh (excl. tax) for the period of 20 years. For PV systems with a capacity of below 10 kW, the tariff for FY 2019 was set at 26 JPY/kWh (24 JPY/kWh for PV systems without devices to respond to output curtailment) for the period of 10 years. The

Fig. 2 – PV Systems on farmland (Chiba City Okido Agri Energy Unit 1) (Midori Ward, Chiba City, Chiba Prefecture). Installed capacity: 777,15 kWDC.

tariffs will not be set for multiple fiscal years and the tariff for FY 2020 will be decided before the start of FY 2020 (April 1, 2020). The tariffs will be set as a uniform category irrespective of the devices to respond to output curtailment. In the period from July 2012 when the FIT program started to the end of June 2019, total capacities of approved PV systems with a capacity of below 10 kW, between 10 kW and below 1 MW and 1 MW or more are 6,5 GWAC, 30,5 GWAC and 34,8 GWAC, respectively, amounting to 71,8 GWAC in total. Mainly among large-scale PV projects, it takes time for many PV projects to start operation after they obtained approval due to the issues of development permission and grid connection. Only 45,7 GWAC of FIT-approved PV systems started operation, of which approximately 2,6 GWAC started operation between January and June 2019, a 3% increase year on year. METI's data on commissioned capacity as of the end of June 2019 are the latest data available (as of January 17, 2020). METI amended the Renewable Energy Act and shifted the approval scheme from the facility approval to the approval of the PV project business plan. In and after April 2017, information on approval of PV project business plans for PV systems with a capacity of 20 kW or more has been released. As of September 30, 2019, capacity of approval of PV project business plans for PV systems with a capacity of 20 kW or more reached about 400 000 projects totaling 60,3 GWAC, including commissioned projects.

In FY 2019, the scope of the tender was widened to include 500 kWAC or larger PV projects, changed from 2 MWAC or larger PV projects, and the fourth and the fifth tenders were held. Similar to the previous tenders, 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 fourth tender was 300 MWAC and the ceiling price was not disclosed. 146 PV projects totaling 590 MWAC applied for participating in the tender, of which 107 projects (509 MWAC) were qualified. However, out of the 107 projects, 71 projects actually participated in the tender, totaling 266 MWAC, which was below the tender target capacity. According to the tender results released, the ceiling price was 14,0 JPY/kWh and 63 projects (196 MWAC) won the bid. Among the winning bids, 55 projects (184 MWAC) paid the secondary deposit, and the lowest winning bid price was 11,5 JPY/kWh. There was an information leak on the tender system of the fifth tender, and the tender was suspended. Then, in response to the requests from the tender participants to resume the tender at an early date, it was decided to conduct the fifth tender with paper-based bidding. The results of the fifth tender are expected to be announced around January 20, 2020.

Following the increase in installations of naturally variable renewable power sources such as PV and wind power generation systems, output curtailment of renewable energy was conducted on the dates and the hours when the power generation amount was forecasted to exceed the demand. In the mainland Kyushu region, output curtailment was conducted in the spring and in the autumn, when the electricity demand decreased. Based on the results of output curtailment, concerned parties led by METI discussed measures to reduce the amount of output curtailment, and the operation of output curtailment was reviewed. In case output curtailment was 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 fuel energy value trading market was established and the non-fossil fuel energy certificates issued for the FIT electricity are being traded in the form of tender. The results of the tender were released. For example, in November 2019, 28 companies purchased the non-fossil fuel energy certificates with a total contracted electricity amount of 186,64 GWh. The weighted average price of the contracted amount was 1,30 JPY/kWh, which was the lowest bidding price. In order to respond to the efforts to achieve RE100, non-fossil fuel energy certificates with tracking information were also sold. The revenues gained through the trading of non-fossil fuel energy certificates of FIT electricity are used for reducing the financial burden of the nation. The non-fossil fuel energy 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-$CO_2$/kWh), as well as for appealing to customers. Regarding residential PV systems, for which surplus power has been purchased under the FIT program since November 2009, the purchase period expired or will expire from November 2019 onwards. Accordingly, approval of non-FIT and non-fossil power sources is being promoted, and the tender is expected to be conducted in 2020.

### (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) Efforts toward reconstruction and regeneration of the Fukushima Prefecture; 2) Promotion of innovation toward energy transition and decarbonization and 3) Enhancement of energy security. The amounts of budget regarding technology development and installation support of PV systems and related fields vary largely. While the items of the FY 2019 budget are mainly a continuation of the FY 2018 budget, 3,85 BJPY has been appropriated for "Subsidy for project expenses to promote installation of residential storage systems which can be used at the time of disaster", as a new budget item for FY 2019. As for technology development and demonstration, 3,35 BJPY for the "Technology development project to reduce levelized cost of energy of PV power generation", 1,9 BJPY for the "R&D project to develop technology for discovering technology seeds and commercializing developed technologies such as new and renewable energy", and 3,0 BJPY for the "Demonstration project to establish virtual power plants using consumer-side energy resources", and 16,27 BJPY for the "Demonstration project to establish supply chain of hydrogen derived from unused energy" have been appropriated. As for support of dissemination, 2,1 BJPY has been appropriated for the "Project to support establishment of distributed energy systems by private entities" and 8,48 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)** allocated budget to promote the dissemination of renewable energy from wide perspectives of supporting PV introduction, $CO_2$ reduction, support with the initiative of local communities, finance and support for developing countries. Among the major continued budget items, 5,0 BJPY for the "Project to promote self-sustainable dissemination of renewable energy-based electricity and thermal energy", 9,7 BJPY for the "Project to promote low-carbonization of houses by establishing net zero energy houses (ZEHs), etc.", 2,6 BJPY for the "Model project for advanced measures against $CO_2$ emissions for public facilities, etc.", 5,0 BJPY for the "Project to promote ZEBs and $CO_2$ saving in commercial buildings, etc.", 2,57 BJPY for the "Project to promote low-carbonization of social infrastructure by utilizing renewable energy-based hydrogen", 4,6 BJPY for the "Project of fund to promote low-carbon investment in local communities", and 8,1 BJPY for the "Subsidy for projects under the Project to support funds for the Joint Crediting Mechanism (JCM)" have been appropriated. Among new budget items for FY 2019, 2,0 BJPY for the "Project to create and disseminate low-carbon technologies for developing countries by co-innovation" and 3,4 BJPY for the "Project to promote installation of independent and distributed energy facilities, etc., which realize disaster prevention and reduction, as well as low carbonization of local communities in parallel" have been allocated.

The **Ministry of Land, Infrastructure, Transport and Tourism (MLIT)** obliges the buildings to conform to the energy conservation standards, based on the "Act on Improvement of Energy Consumption Performance of Buildings" and so on. As a budget item to realize these efforts, the budget was continuously allocated to the "Promotion of achieving energy-saving and longer life time of houses and buildings" (22,983 BJPY), etc. Introduction of renewable energy is an important issue in other activities as well such as enhancement of disaster prevention functions of governmental facilities (12,486 BJPY) and promotion of disaster-prevention and disaster-reduction measures of sewage facilities (included in 15,6 BJPY).

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 the introduction of renewable energy to these industries. With the budget (included in 1,533 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 earthquake 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 0,68 BJPY to 0,854 BJPY.

Among **local authorities**, activities included the invitation of applications for subsidy programs to support the introduction of residential PV systems and storage batteries, etc., as well as collective purchase of these products. Through partnerships with private enterprises, activities to promote local production and local consumption of electricity have continued. Toward making renewable energy a mainstream power source, co-existence with community and long-term stable operation have become significant subjects, which have also led to promoting the formulation of ordinances and guidelines for appropriate installation of PV systems. In addition, the "Renewable Energy 100 Declaration - RE Action" was established, under which small- and medium-sized enterprises (SMEs), municipalities as well as educational and other organizations, aim to shift to using electricity 100% from renewable energy.

## 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 is conducting two projects of PV technology development, which are designed to solve five issues in the society with a large volume introduction of PV power generation. In the "Development of high-performance and reliable PV modules to reduce levelized cost of energy (FY 2015 to FY 2019)," which is designed to develop mainly PV device technology and technology to evaluate

Fig. 3 – BIPV System for a net zero energy building using SUNJOULE®, glass-integrated PV modules (PV System at AGC Kashima Plant) (Kamisu City Ward, Ibaraki Prefecture). Power generation capacity: 14 kW.

system reliability, aiming to reduce the cost of PV power generation, R&D is conducted on different types of solar cells and PV modules, and achievements such as the world's highest conversion efficiency for each of the different PV technologies have been made. In 2019, with Cd-free CIS thin-film technology, Solar Frontier and Idemitsu Kosan achieved 23,35% conversion efficiency on a solar cell, 194,3 W of output and 15,8% conversion efficiency on a commercial PV module. The University of Tokyo achieved the world's highest 20,7% conversion efficiency on a perovskite 3-cell solar minimodule. Both Kaneka and Panasonic are developing mass production technology of heterojunction back contact combined solar cell and conducting R&D on a high efficiency perovskite and crystalline silicon tandem solar cell. As part of this project, in July 2019, NEDO, Sharp and Toyota Motor started public road trials of an electric vehicle equipped with the world's highest-level high-efficiency GaAs thin-film solar cells (over 34% conversion efficiency) Sharp modularized, which Toyota installed on its PRIUS PHV and produced a demo car for public road trials. The "Development project for enhanced photovoltaic efficiency and maintenance technologies (FY 2014 to FY 2018) and the "Development project for photovoltaic recycling technology" (FY 2014 to FY 2018)" were terminated in February 2019. As a new project for FY 2019, NEDO started the "Development project on technologies for reliable photovoltaic power generation system," under which projects on the evaluation of technologies effective to improve reliability and safety of PV power generation facilities in the installation environment such as PV system installation on slopes, agri-PV (PV system installation on farmland while continuing agricultural activities) and floating PV (FPV) systems, where new applications are being developed. Also, development project on elemental technology for recycling solar cell materials was conducted. These NEDO projects on PV technology development are scheduled to be terminated in FY 2019 ending March 2020. From FY 2020, a new five-year project, the "Development project on technologies for expanding possible introduction volume of PV power generation, etc." is planned to start. Under this project, development of innovative PV system technologies to reduce the weight and to overcome restrictions of location such as followability to a curved surface, formulation of guidelines and technology development to secure reliability and safety of PV power generation facilities, development of material recycling technology, as well as technology demonstration to ease the impacts of the grid will be conducted.

NEDO also conducts "Research and development on new energy technology for discovering technology seeds and commercializing developed technologies" (former name: "Innovative project for new energy venture technologies (from FY 2007)." In FY 2019, research themes on development of perovskite PV modules suitable for various applications, as well as a real-time simulator for the power source used for the development of inverters 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 of PV-related technology is continued, focusing on perovskite PV and semiconductor polymer-based 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", R&D on Pb-free perovskite PV, ultra-thin type c-Si triple junction PV and low-cost grid system for large-volume introduction of renewable energy-based power sources is continued, with the aim of realizing low-carbon society and super-smart society. Furthermore, in 2019, under the "Project to deploy R&D accomplishments," development of modularization technology for high efficiency inverted perovskite solar cells fabricated at a low temperature was newly selected, as a theme of public-private joint project.

## DEMONSTRATION

Demonstration research is mainly promoted by NEDO. Under the "Development project for enhanced photovoltaic efficiency and maintenance technologies (FY 2014 to FY 2018)," NEDO conducted 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 a snow load test, an experiment on wind pressure resistance, as well as a sink test were conducted. As the accomplishments of these efforts, NEDO released the "2019 edition of the design guidelines" in July 2019. NEDO plans to implement technology demonstration tests toward formulation of the new editions of the design guidelines for new projects in and after FY 2020.

Demonstration activities on technologies for utilization of PV systems are conducted by METI and NEDO. NEDO conducted a technology demonstration project on the use of a large-scale PV system, etc., in an industrial complex and a green hospital demonstration project at a medical facility with the introduction of an ICT and PV system in India under the "International demonstration project on Japan's energy efficiency technologies" and terminated them in 2019. Moreover, in 2019, NEDO conducted demonstration projects on the power transmission and distribution operation of storage batteries designed to deal with surplus electricity from renewable energy, etc., in the USA, Germany and Indonesia, technology demonstrations of automated demand response (ADR) and energy management technologies in Portugal, Slovenia, Poland and China, in order to expand introduction of renewable energy and promote energy conservation.

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 a possible hosting capacity of renewable energy and to control the grid. Supported by METI, a demonstration project on the establishment of a virtual power plant (VPP) also continues to be conducted in the form of a large-scale consortium. MoE started a full-scale demonstration in which real-time trading is carried out in order to make trading of $CO_2$ emission reduction value available in case of self-consumption of renewable energy. In addition to demonstration research of environmental value trading using blockchain technology, application to electricity trading also entered into the demonstration phase. As well as demonstration experiment of the service which manages residential PV surplus electricity in the deposit market utilizing blockchain technology, demonstration experiment of peer-to-peer (P2P) trading in which electricity is traded between the PV-equipped houses or plug-in hybrid electric vehicles (PHEV) and the offices, and a demonstration test of simulated electricity trading which matches customers who supply renewable energy-based electricity (PV electricity) and customers who hope to purchase such electricity started. METI launched the "Demonstration experiment on non-fossil fuel energy certificate with tracking information". New business models are being created by private companies participating in this demonstration experiment, such as the use of non-fossil fuel energy certificates with tracking information issued for electricity generated by PV power plants toward achievement of RE100, etc.

On the user side, in 2019, major convenience store chains launched demonstration experiments to procure all electricity consumed for store operation from renewable energy and demonstration experiments to exchange solar energy between neighboring houses and stores. Demonstration experiments of $CO_2$-free hydrogen production technology that uses renewable energy such as PV are being implemented at various locations by companies such as Tokuyama, IHI and Panasonic. The National Institute of Advanced Industrial Science and Technology (AIST) and Shimizu Corporation jointly started a demonstration project in Koriyama City, Fukushima Prefecture to establish the ZEB utilizing hydrogen supply by PV and storage batteries.

## INDUSTRY STATUS AND MARKET DEVELOPMENT

In the PV cell/ module and PV system business in Japan, there were many trends which impressed the reverse of positions between domestic and overseas companies. Major domestic PV manufacturers shifted their business strategies from "manufacturing of individual equipment" to provision of "comprehensive solution services" and aim to enhance competitiveness through business tie-ups with Chinese companies in the areas of development and manufacturing. Mitsubishi Electric announced that it will discontinue the manufacturing business of PV modules and inverters of its own brand by March 2020. Panasonic transferred most of the manufacturing business to GS Solar of China, whereas Solar Frontier signed a Memorandum of Understanding (MOU) with Triumph Science and Technology Group of China, a subsidiary of China National Building Materials (CNBM), on the development of building material-integrated CIS thin-film PV modules. Overseas manufacturers have already grown to occupy top-ranking positions in the shipments to Japan, and they seem to have further expanded their market share in 2019. The ratio of import products in the Japanese market could further increase. In addition, transition of business models is undertaken by launching the zero-Yen installation business directly or indirectly in view of the post-FIT market and entering into the electricity service business, etc. as a part of the post-FIT measures.

In the material and equipment areas, there was a trend of business strategy shifts similar to that of the PV cell/ module business. Shin-Etsu Chemical, Nakamura Choukou and other companies licensed their patents and transferred the business to Chinese companies.

In the area of PV inverters, new products have been launched that made use of technological development. Fuji Electric introduced the world's lightest and highly efficient inverter using SiC power semiconductors. Large-capacity products demonstrated competitiveness such as Toshiba Mitsubishi-Electric Industrial Systems (TMEIC) achieving cumulative sales of 20 GW worldwide. However, the share of overseas products is increasing in Japan.

In the area of mounting structures, new proposals have been made that contribute to expanding the scope of applications such as lap roofing and bonding method of aluminum mounting structures.

In the housing industry, signs of market expansion started to appear again in response to the development of the net zero energy houses (ZEH) and increasing demand for improvement of resilience such as disaster prevention. Each company offers products corresponding to menus such as high-level ZEH-plus


Fig. 4 – EV equipped with high efficiency solar cells for public road trials by NEDO, Sharp and Toyota. Power generation capacity: approximately 860 WDC. Triple-junction compound PV module (InGaP, GaAs, InGaAs).

(ZEH+), ZEH+ resilience (ZEH+R) and ZEH-mansion (condominium in Japanese)(ZEH-M). With the rise of the post-FIT market, new business models such as a zero-Yen installation plan and proposals for self-consumption are emerging. It is reported that the sales of a package of products as a system which generates and stores electricity are growing in a part of the market. Although there had been concerns over the shrinkage of the market due to the impacts of consumption tax increase which was introduced in October 2019, the impacts were small and the sales are steadily recovering.

In the area of electricity storage, new products for residential storage batteries have been launched one after another in order to promote self-consumption of residential PV systems whose FIT purchase period terminated (will have terminated) from November 2019 onwards. There is a trend by some companies that focus on the sales of power storage systems in response to the increasing awareness of disaster prevention. However, due to a series of natural disasters, the importance of the electricity generation function has been recognized as well and a trend to sell a package of products as a system which generates and stores electricity has expanded. Development for larger capacity and lower price products is also being promoted. As well as the expansion of the industrial stationary power storage system business, demonstration projects on the establishment of VPP (virtual power plant) have continued with an increasing number of participants.

In the area of the PV power generation business, construction and operation of large-scale PV systems under the FIT program continue to be active. Especially, in response to the government's political measures on the FIT-approved PV projects which have not started operation, there are a number of constructions of MW-scale PV power plants with an output capacity of more than 10 MW. Moreover, large-scale projects are increasing, such as NTT's plan to invest 600 BJPY in the electricity business including development of its own power transmission grids. Meanwhile, the importance of responses to safety and reliability was recognized due to damages caused by natural disasters, etc., such as a fire which broke out at the Chiba Yamakura MW-scale Floating PV (FPV) Power Plant because of Typhoon No. 15. Outside Japan, development of the PV system business is also increasing, mainly led by trading companies such as Marubeni which started operation of a 1,17-GW PV power plant in the United Arab Emirates (UAE).

In the area of the PV power generation business support service, following the expansion of PV installations, efforts are increasingly promoted for remote monitoring of systems, various types of maintenance and improvement of forecasting power generation amount. Activities related to PV systems in local communities such as self-consumption, local production and local consumption are drawing attention. Also, as the awareness of the future disposal of PV modules is increasing, companies are starting the recycling business in full scale.

In the area of PPS (power producer and supplier), activities such as customer acquisition, development of new menus, electricity procurement and supply from renewable energy are actively carried out mainly in the energy industry (electricity, gas, oil, etc.). A part of the electricity has been sold as "100% renewable energy" electricity and has been gaining support from customers, against the backdrop of a growing demand from consumers who agree with the RE100 initiative. From November 2019, a movement to purchase electricity from residential PV systems whose FIT purchase period was terminated has become more active and enclosure of customers in electricity trading has been intensified. In view of the expansion of local production and local consumption of electricity, a number of operating companies have been established in various places one after another. Under a trend of utilizing blockchain technology, Digital Grid is conducting the environmental value trading business for self-consumed electricity using ICT whereas ENERES is promoting efforts aiming for conducting the wholesale electricity trading business through storage batteries for surplus electricity from households. Minna-denryoku started a matching service of surplus electricity.

As for the finance-related business, funding for large-scale PV systems and renewable energy-related businesses in Japan and overseas continues to be active. In addition to the growth of green bond issuance targeting at these businesses, the number of listed companies on the infrastructure fund market increased to six and acquisition of PV and other renewable energy power plants was active after the listing. Nippon Export and Investment Insurance (NEXI) supports overseas expansion of businesses through the environmental innovation insurance. Moreover, in response to the expansion of the post-FIT business, local banks are enhancing financing activities for small- and medium-sized enterprises (SMEs) toward introduction of PV systems for self-consumption.

# REPUBLIC OF KOREA

## TECHNOLOGY STATUS AND PROSPECTS

DONGGUN LIM, KOREA NATIONAL UNIVERSITY OF TRANSPORTATION


Fig. 1 – 18,7 MW Floating PV system at Gunsan-si, Jeollabuk-do, Korea.

## GENERAL FRAMEWORK AND IMPLEMENTATION

In June 2019, the Korean government announced the 'Third Energy Master Plan', which has set the goal of raising the share of renewable energy in power generation from 7,6% in 2017 to 30-35% by 2040. Nuclear power will be gradually phased out as no further extensions will be made to the lifespan of aged reactors and no new reactors will be constructed. At the same time, coal-fired power generation will be drastically reduced to within the range necessary to secure a stable supply and demand. Natural gas, which emits the least amount of greenhouse gas and fine dust amongst fossil fuels in addition to its relatively low geographical risks compared to oil, will continue to play a greater role in the future. Korea will transform its energy mix by prioritizing the public's requests for a clean and safe environment.

The Korean government announced the "Implementation Plan for Renewable Energy 3020" in 2017, which aims to increase the share of renewable energy generation from 7% to 20% by 2030. Its goal is to establish 63,8 GW of renewable source capacity by 2030. About 63% of the new facilities will be in solar power and 34% in wind. The newly installed renewable energy capacity in the last two years is 7,1 GW, which is nearly half of the cumulative capacity 15,1 GW installed by 2017. The share of renewable energy generation increased from 7,6% in 2017 to 8,6% (estimated) in 2019.

Since 2012, Renewable Portfolio Standard (RPS) has been introduced as a main renewable energy program to replace FIT. Thanks to new RPS scheme (with PV set-aside requirement), it has installed 244 MW in 2012, 389 MW in 2013, 863 MW in 2014, 986 MW in 2015, 803 MW in 2016, 1 120 MW in 2017, 1 897 MW in 2018, and 2 985 MW in 2019, respectively. At the end of 2019, the total installed capacity was 9 287 MW.

## NATIONAL PROGRAMME

In June 2019, the Korean government also announced the 'Third Energy Master Plan' which stated that electricity generation by renewable sources will increase to account for 30-35% in the electricity mix by 2040. In terms of cumulative generation capacity, an increase of 103-129 GW will be necessary to achieve this goal. Nuclear and fossil-powered sources will decrease due to the Korean government's commitment to a clean and safe environment. The detailed breakdown for the 2040 generation power mix scenario will be available in 2020.

### 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 obligators (electricity utility companies with electricity generation capacity of 500 MW or above) are required to supply 10% of their electricity from NRE sources by 2023, up

Fig. 2 – 3 MW Floating PV system at Cheongpoong lake, Jecheon-si, Chungcheongbuk-do, Korea.

Fig. 3 – 1,1 MW Urban PV system at KCC Central Research Institute, Yongin-si, Gyeonggi-do, Korea.

from 2% in 2012. In 2019, 2 985 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), Ministry of Trade, Industry and Energy (MOTIE) launched a new long-term (max. 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. To facilitate the involvement of local communities, MOTIE also launched a new REC weighting scheme, in which maximum 20% increase in REC weighting when community residents are involved in the projects. Grid connection of PV systems is guaranteed up to 1 MW by the Government since 2017. Newly adjusted REC weighting scheme is summarized below.

### TABLE 1 - REC WEIGHTING SCHEME IN RPS

<table>
<tr><th rowspan="2">REC WEIGHTING</th><th colspan="2">ENERGY SOURCE AND CRITERIA</th></tr>
<tr><th>FACILITY TYPE</th><th>CRITERIA</th></tr>
<tr><td>1,2</td><td rowspan="3">Facility installed on general site</td><td>Less than 100 kW</td></tr>
<tr><td>1,0</td><td>100 kW ~ 3 000 kW</td></tr>
<tr><td>0,7</td><td>More than 3 000 kW</td></tr>
<tr><td>0,7</td><td>Facility installed on forestland</td><td>Regardless of capacities</td></tr>
<tr><td>1,5</td><td rowspan="2">Facility installed on existing building</td><td>Less than or equal to 3 000 kW</td></tr>
<tr><td>1,0</td><td>More than 3 000 kW</td></tr>
<tr><td>1,5</td><td colspan="2">Facilities floating on the water</td></tr>
<tr><td>5,0</td><td rowspan="2">ESS (connected to PV)</td><td>From 2018 to June 30, 2020</td></tr>
<tr><td>4,0</td><td>From July 1 to December 31, 2020</td></tr>
</table>

## 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 systems on 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 2019, 46,3 MW was installed under this programme.

## 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 a maximum of 80% of the 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 2019, 15,7 MW was installed under this programme.

## REGIONAL DEPLOYMENT SUBSIDY PROGRAMME

In an effort to improve the energy supply & demand condition and to promote the development of regional economies by supplying region-specific PV system that are friendly to the environment, the government has been promoting the regional deployment subsidy programmes designed to support various projects carried out by local government. The government supports up to 50% of installation cost for NRE (including PV) systems owned and operated by local authorities. In 2019, 20,7 MW was installed under this programme.

## 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 2019, 35,0 MW was installed under this programme.

### 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 fee and selling REP (Renewable Energy Point) having no multiplier. In 2018, 19,1 MW was installed under this programme.

### PUBLIC BUILDING OBLIGATION PROGRAMME

The new buildings of public institutions, the floor area which 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 2019, 57,2 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 total 69,8 Billion KRW in 2019. In the PV R&D budget, about 58% was invested for c-Si area, about 38% for thin film area, and about 4% for inverters and monitoring system.

## INDUSTRY AND MARKET DEVELOPMENT

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

TABLE 3 – CAPACITY OF PV PRODUCTION CHAIN IN 2019

| POLY-SI (TON) | INGOT (MW) | WAFERS (MW) | CELLS (MW) | MODULES (MW) |
|---|---|---|---|---|
| 82 000 | 2 000 | 2 000 | 7 525 | 9 615 |

### PRODUCTION OF FEEDSTOCK AND WAFER

OCI achieved its total production capacity of poly-silicon feedstock up to 52 000 tons. Woongjin Energy has reached a 2 000 MW ingot capacity and a 2 000 MW wafer capacity.

### PRODUCTION OF PHOTOVOLTAIC CELLS AND MODULES:

Hanwha Solutions has 4 300 MW in both c-Si solar cells and modules. LG Electronics has a capacity of 2 000 MW and 1 500 MW in the c-Si solar cells and modules, respectively. Hyundai Energy Solutions has a capacity of 600 MW and 1 000 MW in the c-Si solar cells and modules, respectively. Shinsung E&G has a capacity of 600 MW and 200 MW in the c-Si solar cells and modules, respectively.

The RPS scheme was the main driver for PV installation in 2019, and a remarkable size of 2 985 MW was recorded. At the end of 2019, the total installed PV capacity was about 10 498 MW, among them the PV installations that were made under RPS scheme accounted for 88,5% of the total cumulative amount.

TABLE 2 – ANALYSIS OF PV R&D BUDGET IN KOREA (2017~2019)

| TYPE | 2017 | | 2018 | | 2019 | |
|---|---|---|---|---|---|---|
| | BUDGET (BILLION KRW) | SHARE (%) | BUDGET (BILLION KRW) | SHARE (%) | BUDGET (BILLION KRW) | SHARE (%) |
| C-Si | 30,6 | 51,6 | 36,2 | 53,9 | 37,0 | 53,0 |
| Si thin film | 0,8 | 1,3 | 0,7 | 1,0 | 0,5 | 0,7 |
| Dye-sensitize | 0,7 | 1,2 | 0,5 | 0,7 | 0,5 | 0,7 |
| Organic | 6,2 | 10,5 | 5,6 | 8,3 | 4,3 | 6,2 |
| Compound | 10,6 | 17,9 | 11,2 | 16,7 | 10,8 | 15,5 |
| Perovskite | 3,9 | 6,6 | 7,5 | 11,2 | 10,7 | 15,3 |
| Others | 6,5 | 11,0 | 5,4 | 8,0 | 6,0 | 8,6 |
| Total | 59,3 | 100,0 | 67,1 | 100,0 | 69,8 | 100,0 |

# MALAYSIA

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

Fig. 1 – 23 MWac rooftop solar system, Xinyi Energy Smart (Malaysia) Sdn Bhd, Melaka, under the Net Energy Metering (NEM) scheme.

## GENERAL FRAMEWORK AND IMPLEMENTATION

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 the grid-connected PV market in the country of Malaysia save for the state of Sarawak. This is because the four prevailing grid-connected PV programmes [i.e. Feed-in Tariff (FiT), Net Energy Metering (NEM), Large Scale Solar (LSS) and Self-consumption (SELCO)] are not applicable to Sarawak, as the state is governed by its own electricity supply ordinance.

The FiT and NEM are implemented by the Sustainable Energy Development Authority (SEDA) while the LSS and SELCO are implemented by the Energy Commission (EC) of Malaysia. Both statutory bodies report to the Ministry of Energy and Natural Resources.

## NATIONAL PROGRAMME & MARKET DEVELOPMENT

In 2019, the PV market growth in Malaysia was largely driven by Large Scale Solar (LSS) and Net Energy Metering (NEM) programmes. The solar PV market has organically progressed to Large Scale Solar (LSS), Self-consumption (SELCO) and Net Energy Metering (NEM) schemes. In the third tranche of LSS′ price discovery, the first four projects received by Energy Commission (EC) were bids at prices lower than the gas power generation cost which is 0,2322 MYR / kWh. This indicated that the solar PV generation is reaching gas parity. As at end of 2019, cumulative installed capacity of PV from LSS was 628,36 $MW_{ac}$, FiT 322,44 $MW_{ac}$, SELCO 98,34 $MW_{ac}$ and NEM 37,56 $MW_{ac}$. In 2019, the total new PV capacity added was 385,98 $MW_{ac}$.

**FiT Update:** The FiT scheme began in December 2011 and is funded by a surcharge imposed on electricity bills of 1,6%. Due to the rapid declining in the cost of PV, the solar PV scheme has progressed to LSS, NEM, and SELCO. As at 31 December 2019, a cumulative installed capacity of 322,44 $MW_{ac}$ of PV projects was operational; of which the 68,59 $MW_{ac}$ was for the individuals, 8,13 $MW_{ac}$ was for the community, 244,89 $MW_{ac}$ was for the non-individual PV projects and 0,83 $MW_{ac}$ was for the MySuria [1] project. This translated to 8 899 individuals, 437 communities, 586 non-individuals and 332 MySuria recipients. More information on PV quota, FiT rates and operational capacity can be viewed at www.seda.gov.my. In 2019, the new PV capacity added under FiT scheme was 2,11 $MW_{ac}$; based on previous quota awarded under FiT before 2017.

**LSS Update:** The LSS was implemented in 2016 as an organic progression of the FiT scheme. The cumulative quota awarded under the LSS as at end of 2019 was 1 698,76 $MW_{ac}$, of which 270 $MW_{ac}$ was granted direct award under the fast track programme and the rest was based on competitive biddings held over three tranches; 400,90 $MW_{ac}$ in 2016, 554,67 $MW_{ac}$ in 2017 and 490,88 $MW_{ac}$ in 2019. As at the end of 2019, the total capacity achieving commercial operation was 628,37 $MW_{ac}$. The remaining capacity, excluding 82,40 $MW_{ac}$ which had already been revoked / withdrawn, is expected to achieve commercial operation between 2020 and at the latest by 2023. In 2019, the new PV capacity added under LSS projects was 317,87 $MW_{ac}$.

**NEM Update:** The NEM has been implemented since November 2016 but the take-up rate has been slow, up to 2018. Effective from 1st January 2019, the Government has improved the NEM scheme from the previous net-billing scheme to a true net energy metering scheme, based on a one-to-one energy offset. The enhancement of the NEM policy improved the take-up rate three folds in 2019 alone, compared to the three years combined. As at end of 2019, the cumulative capacity approved was 130,21 $MW_{ac}$ compared to only 27,81 $MW_{ac}$ capacity approved from 2016 to 2018. The stark increase was mostly contributed by the industrial and commercial sectors which benefited the most from the self-generation and the selling back to the grid when there is an excess during weekends or public holidays. The breakdown of the approved capacity in 2019 was as follows: 8,18 $MW_{ac}$ for the domestic sector, 33,44 $MW_{ac}$ for the commercial sector, 88,46 $MW_{ac}$ for the industrial sector and 0,13 $MW_{ac}$ for the agriculture sector. In 2019, the cumulative operational capacity under the NEM was 37,56 $MW_{ac}$ with an addition of 27,65 $MW_{ac}$ in 2019 alone.

## R&D, D

In May 2018, the Government of Malaysia announced a target to achieve 20% renewable energy (RE) penetration in the national installed capacity mix by 2025. Subsequently, the Renewable

[1] The MySuria programme was introduced in 2017 where solar PV systems were installed at the households of the bottom 40% to the middle-class population.

Energy Transition Roadmap (RETR) 2035 was mandated to SEDA to develop and the roadmap should outline the strategies and action plan to achieve the committed 20% target. The roadmap also provided aspirational RE target by 2035.

The RETR's study has revealed that Malaysia has vast solar PV technical potential, able to support at least 269 $GW_{ac}$ of solar PV installations. This technical potential off solar is dominated by ground mounted configurations (210 $GW_{ac}$), followed up rooftop space (42 $GW_{ac}$), and floating configurations (17 $GW_{ac}$). Given the vast technical potential, solar PV has been identified as one of the key resources for Malaysia to achieve the 20% renewable energy target. The RETR document will be available to the public once it is launched in April 2020.

## INDUSTRY DEVELOPMENT

On the PV manufacturing front, Malaysia remains a significant PV producer. It was estimated that over 90% of the PV products were exported to Europe, the USA and Asia.

In 2019, the total polysilicon manufacturing nameplate capacity was at 27 kilo metric tonnes with employment of 612. For ingot, wafer, solar cells and PV modules manufacturing, the total nameplate capacity was 18 030,50 MW with employment of 17 731. Table 1 shows the major PV manufacturing statistics in Malaysia classified under four categories for 2019 and 2020 (estimate): Metallurgical/ Poly Silicon, Ingot /Wafer, Solar Cells, and PV Modules.

Within the PV industry, there were 143 PV service providers and more than 40 Registered Solar PV Investors (RPVIs) active in the market in 2019. To further help spur interest and encourage more commercial and industrial participation in the adoption of solar, RPVIs provide behind-the-meter (BTM) solar businesses such as solar leasing and PPA in the country. The list of these registered PV service providers and RPVIs can be found at www.seda.gov.my.

### TABLE 1 – MAJOR PV MANUFACTURING STATISTICS IN MALAYSIA

| METAL SI/ POLY SI | | 2019 | | 2020 (ESTIMATE) | |
|---|---|---|---|---|---|
| **No.** | **Company Name** | **Capacity (kilo metric tonnes)** | **Jobs** | **Capacity (kilo metric tonnes)** | **Jobs** |
| 1. | OCIM Sdn. Bhd. (Poly Si) | 27 | 612 | 27 | 607 |
| | **Total** | **27** | **612** | **27** | **607** |
| **INGOT/WAFER** | | **2019** | | **2020 (ESTIMATE)** | |
| **No.** | **Company Name** | **Capacity (MW)** | **Jobs** | **Capacity (MW)** | **Jobs** |
| 1. | LONGi (Kuching) Sdn. Bhd. (Ingot & Wafer) | 500 | 344 | 500 | 379 |
| 2. | Sun Everywhere Sdn. Bhd. (Wafer) | 49,80 | 45 | 8,90 | 40 |
| | **Total** | **549,80** | **389** | **508,90** | **419** |
| **CELL** | | **2019** | | **2019 (ESTIMATE)** | |
| **No.** | **Company Name** | **Capacity (MW)** | **Jobs** | **Capacity (MW)** | **Jobs** |
| 1 | Hanwha Q CELLS | 2 000 | 2 263 | 2 000 | 2 356 |
| 2 | LONGi (Kuching) Sdn. Bhd. | 880 | 597 | 880 | 662 |
| 3 | LONGi Technology (Kuching) Sdn. Bhd. | 1 250 | 1 373 | 2 750 | 1 858 |
| 4 | Jinko Solar Technology Sdn Bhd | 3 450 | 2 117 | 4 200 | 1 800 |
| 5 | Sun Everywhere Sdn. Bhd. | 229,50 | 226 | 132,20 | 223 |
| 6 | SunPower Malaysia Manufacturing Sdn Bhd | 773 | 1 600 | 837 | 1 500 |
| | **Total** | **8 582,50** | **8 176** | **8 799,20** | **8 399** |
| **MODULE** | | **2019** | | **2020 (ESTIMATE)** | |
| **No.** | **Company Name** | **Capacity (MW)** | **Jobs** | **Capacity (MW)** | **Jobs** |
| 1 | First Solar | 3 200 | 2 531 | 1 750 | 2 443 |
| 2 | Hanwha Q CELLS | 2 000 | 2 263 | 2 000 | 2 356 |
| 3 | LONGi (Kuching) Sdn. Bhd. | 900 | 744 | 900 | 759 |
| 4 | Jinko Solar Technology Sdn Bhd | 2 480 | 3 113 | 3 500 | 2 500 |
| 5 | Sun Everywhere Sdn. Bhd. | 318,2 | 515 | 217,6 | 505 |
| | **Total** | **8 898,20** | **9 166** | **6 367,60** | **8 563** |

# MOROCCO

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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## GENERAL FRAMEWORK AND IMPLEMENTATION

Since the launch of the national Moroccan energy strategy, Morocco has shown a strong commitment to lower its carbon emission through maximizing the use of renewable energy sources in its energy mix. In 2019, Morocco has reached a share of 34% of renewable energy, translated by the general capacity of 3 701 MW, where solar energy has a capacity of 711 MWp [1].

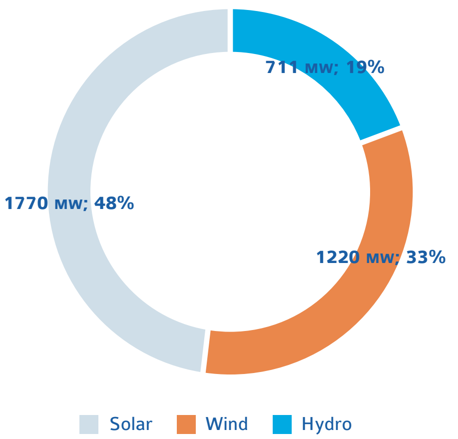



Fig. 1 – Share of Renewable Energy Mix per Source.

The energy policy is primarily the responsibility of the Ministry of Energy, Mines and Environment (MEME) 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

The ONEE and MASEN are piloting different programs on utility scale plants aiming to achieve 52% of renewable energy share by 2030. Nonetheless, a new aim has been set up by the government for 2023, with a willingness to achieve 2 015 MWp of solar, 1 356 MWp of wind power, and 350 MW in terms of hydropower. At the same time, the MEME is launching different tenders for small and medium size PV plants with capacities varying between 5 and 40 MWp. This last program will from a side that contributes to the setup of a 400 MWp additional capacity based on solar photovoltaics, and on the other hand, will enhance and allow capacity building for Moroccan SMEs in the sector of EPC and Escos, since only Moroccan companies are allowed to participate in it.1

The Moroccan government has also set up a new roadmap for the certification of photovoltaic solar components (modules, inverters and batteries) aiming to protect the local market against fraud and reinforce its surveillance. Green Energy Park's testing laboratory has been designated as a qualified laboratory by the National Certification Body to perform the tests according to the Moroccan standards based on the IEC 61215 and IEC 61730.

The MEME is also leading a study to establish the national grid codes that will ease and reinforce the penetration of smaller scale solar installation in the middle and low voltage grid. A new law is under approval by the Head of the Government that will manage the modalities of injection of renewable energy in middle voltage grid.

## R&D, DEVELOPMENT

In Morocco, the Research Institute of Solar Energy and New Energies (IRESEN) and its research platforms lead the R&D activities regarding solar technologies. Created in 2011, it 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. In 2019, IRESEN signed five cooperation agreements to support the creation of 5 SMEs in the field of renewables by providing technical and financial support. On the other hand, IRESEN is also a research institute through the setup of mutualized infrastructures dedicated for R&D. Therefore, it has set up in cooperation with the OCP Group the Green Energy Platform, unique model of its kind in Africa that allows for the creation of synergies and the mutualization of infrastructures of several Moroccan research institutions in order to create a critical mass and achieve excellence. It also supports the local players in the acquisition of knowledge and know-how through 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.

[1] Ministry of Energy, Mines and Environment

IRESEN and the OCP Group have also set up a new platform, the Green and Smart Building Park (GSBP), dedicated for smart-grids, energy efficiency, and green mobility expected to be operational by the 3rd quarter 2020. From the 13th to 27th September 2019, this platform hosted the first edition of the Solar Decathlon Africa, the biggest worldwide student competition organized by IRESEN jointly with the University Mohammed VI Polytechnic. During this period, 18 teams formed by more than 1 000 students and 50 universities constructed 18 solar powered houses under 3 weeks. Judges from around the world composed by experts in the field of photovoltaics, architecture, energy efficiency and other branches awarded the three most sustainable houses. These solar houses, through the local grid of the GSBP, will serve as testing grounds to study the impact of different flows of energy into a micro-grid. This study will contribute to lay down the future sustainable African city. The GSBP will also host a grid simulation laboratory to study the interaction of different sizes of renewable systems' capacities and develop solutions suited for the local conditions.

## INDUSTRY AND MARKET DEVELOPMENT

Three PV modules manufacturers have laid down 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. Nonetheless, different modules producer ranked among the tier 1 manufacturers are willing to install their production units in the Kingdom. All other related industries dedicated for the Balance Of System (BoS), the solar cabling sector, electrical components (DC breakers, fuses, etc.), PV modules structures as well as engineering expertise are already well developed where 43 installers are already in the EnFsolar database.

# THE NETHERLANDS

## PV TECHNOLOGY STATUS AND PROSPECTS

OTTO BERNSEN, NETHERLANDS ENTERPRISE AGENCY RVO, ENERGY INNOVATION

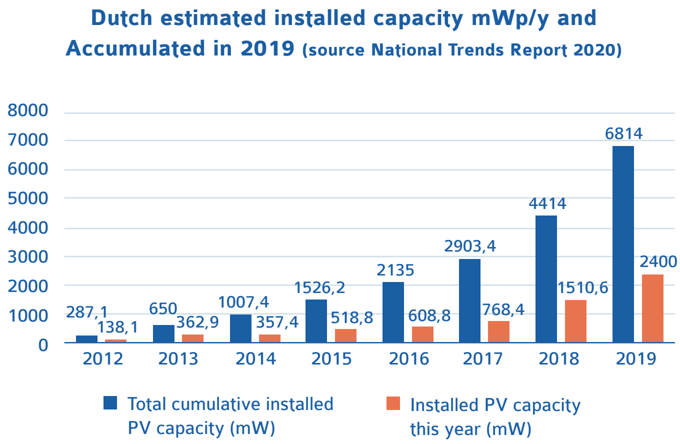
Fig. 1 – Floating Solar Project in Weurt, Netherlands (Photo: INNOZOWA Consortium).

## GENERAL FRAMEWORK

In 2019, the Dutch solar PV market continued its steady growth with an estimated 2,4 GWp installed capacity according to the "Nationaal Solar Trend Report" (Feb, 2020). The estimated cumulative installed capacity reached almost 7 GWp. Official figures by the CBS will follow in spring. The Netherlands have shown to be not only a reliable growth market for solar but also as an innovative market for new products and services. Due to the relative high population density of the Netherlands, the available space is limited and grid connections are widespread. The integration of solar PV is therefore paramount to reach a higher percentage in the energy mix.

The national Climate Goals are set on 16% renewable energy sources (RES) in 2023 and close to no emissions in 2050. The Netherlands are on target to achieve these goals. In 2019, the efforts continued to replace natural gas as the main energy resource 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




## NATIONAL PROGRAMMES

In 2019, the national efforts on renewable energy where redefined in societal missions with a clear focus for solar on the integration and implementation on land and in the long term, also at sea. In 2020, this new approach will come into play. The innovation was 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 still varied and complementary. For small roof top systems a net metering scheme exists until 2023 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 "Postcoderoos", covering members with a similar postal codes. An energy label is mandatory (the EPC) for new build houses coming on the market, which stimulates the installation of roof top PV panels. As of 2020, all new buildings will need to be "energy neutral". In addition, several Dutch provinces and municipalities offer local subsidies for solar panels.

The renewable energy subsidy (HE) 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 2019, there existed a R&D budget for solar divided over the two program lines of the TKI Urban energy "solar technologies" and "multifunctional building parts". In addition, there were separate programs for fundamental research (NWO and STW), for renewable energy and technical innovation in general, as well as 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/adocumenten/Projectcatalogus_UE_projecten_2020.01.10_PL0_PL2.pdf

Research into solar technologies, production and applications is dispersed in the Netherlands over many universities including in the cities of Utrecht, Leiden, Amsterdam, Delft, Nijmegen, Groningen, Eindhoven and 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 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 is merited on the development of the Lightyear One, an electrical vehicle with many innovations, such as curved solar panels. Lightyear One is planned to be on the market in 2021. Lightyear is a start-up from the Technical University of Eindhoven. https://lightyear.one/

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, vehicles and floating PV systems. For these specific niche markets, dedicated platforms are formed by industry and the universities together. The platform for floating solar panels, both on the sea and the river and lakes, can be found at https://www.zonopwater.nl/ Integration in the infrastructure can be found at https://zonopinfra.nl/home Integration in buildings at https://www.bipvnederland.nl/ and in the landscape at https://zoninlandschap.nl/over-zon-in-landschap

## IMPLEMENTATION AND MARKET DEVELOPMENT

The Dutch solar PV market showed sustained growth and even acceleration in 2019, with an estimated added amount of 2 400 MWp installed capacity. The share of solar PV in the electricity production had already risen in 2018 to around 3% (CBS Statline) and therefore that amount has further grown in 2019 to approximately 4,5% based on the previous estimate. In 2019, congestion in the grid became a sporadic problem in some of the outer regions and the situation has already led to additional measures, as well as putting the development of some larger solar parks on hold.

The expectations for the potential of the total installed capacity solar PV are to be at least the same as the in previous year; moreover, there are still some delayed projects in the pipeline that will add to that. This is without considering major players, holding large amounts of land and surfaces, becoming active. Therefore grid congestion will very likely spread further throughout the electricity grid without additional measure by the grid operators and government. A more effective planning process is being put into place at a regional level and short term changes in the regulation are considered. This scarcity of transportation capacity will predominantly effect the roll out of larger PV systems. Higher self-consumption rates for all systems combined with storage will of course improve the situation and result in a more flexible grid while maintaining an acceptable business case.

# NORWAY

## PV TECHNOLOGY STATUS AND PROSPECTS

TROND INGE WESTGAARD, THE RESEARCH COUNCIL OF NORWAY

## 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. This was not the case in 2019, where probably hydrological factors and electricity market conditions caused reduced hydropower production. In 2019 hydropower generated 93,4% of the total electricity production of 135 TWh, while the gross domestic electricity consumption was also 135 TWh. The generation from wind power is increasing from year to year due to increased installed capacity, and it contributed 4,1% of the total electricity generation in 2019. 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 has, in practice, not been accessible for small scale producers due to the registration fees. In order to be eligible for this scheme Norwegian installations need to be completed by the end of 2021, and entry to the scheme will then be closed in Norway.

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 PROGRAMMES

Norway's programmes in the energy sector are generally aiming for promoting renewable energy and increasing energy efficiency. Support for implementation of PV is integrated into these programmes.

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 (reduced to 7 500 NOK from April 1, 2020) and 1 250 NOK per installed kW maximum capacity up to 15 kW. This programme also incorporates leisure homes with grid connection, but apartment buildings are in practice excluded from the programme.

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 grid connection fees that are charged from electricity suppliers. Such installations are not allowed to exceed a limit of 100 kW electric power feed-in to the grid. Current rules for grid transmission fees are unfavourable with respect to PV installations for residential apartment buildings, but it is planned to modify the rules for grid fees to remedy this situation.

Enova SF has a programme that supports energy efficiency projects for commercial buildings and apartment buildings, but installation of PV systems does not qualify for support unless it is combined with other innovative technologies.

## 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 80 MNOK (9 MUSD) for 2019. The portfolio consists of R&D projects on the silicon chain from feedstock to solar cells research, on novel solar cell concepts, and on applied and fundamental materials research.

Leading national research groups and industrial partners in PV technology participate in the Research Center for Sustainable Solar Cell Technology (www.susoltech.no), which is funded by RCN and Norwegian industry partners. The research activities are within silicon production, silicon ingots and wafers, solar cell and solar panel technologies, 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, which all participate in the Research Center:

- Institute for Energy Technology (IFE): Focuses on poly-silicon production, silicon solar cell design, production, characterization, and investigations of the effect of material quality upon solar cell performance. A solar cell laboratory at IFE contains a dedicated line for producing silicon-based solar cells. Additionally, there are a characterization laboratory and a polysilicon production lab, featuring three different reactor types.
- University of Oslo (UiO), Faculty of Mathematics and Natural Sciences: The Centre for Materials Science and Nano-techology (SMN) is coordinating the activities within materials science, micro- and nanotechnology.
- Norwegian University of Science and Technology (NTNU) Trondheim: Focuses on production and characterization of solar grade silicon, and on materials science, micro- and nanotechnology.

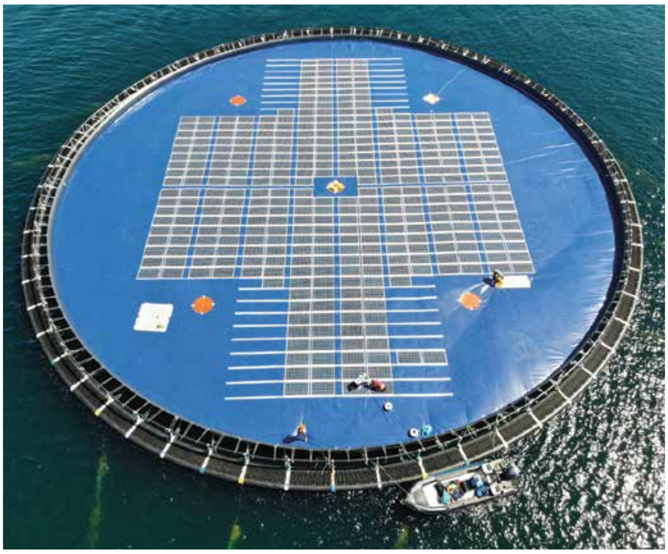


Fig. 1 – Flexible floating structure with PV modules (Source: Børge Bjørneklett, Ocean Sun).

Fig. 2 – Installation of PV panels on the flexible floating structure (Source: Børge Bjørneklett, Ocean Sun).

- SINTEF Trondheim and Oslo: Focus on silicon feedstock, refining, crystallisation, sawing and material characterisation.
- Norwegian University of Life Sciences (NMBU): Focuses on fundamental studies of materials for PV applications and assessment of PV performance in high-latitude environments.
- Agder University (UiA): Research on silicon feedstock. Renewable Energy demonstration facility with PV systems, solar heat collectors, heat pump, heat storage and electrolyser for research on hybrid systems.

## INDUSTRY

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 production plants for solar grade silicon (ESS). The company 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.

**NorSun** manufactures high performance monocrystalline silicon ingots and wafers. Annual ingot production capacity exceeds the equivalent of 450 MW of solar panel capacity. Most of the ingots are converted to wafers utilizing diamond wire sawing.

**Norwegian Crystals** produces monocrystalline silicon blocks. 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 1 200 MW, consisting of power plants in Europe, Africa, Asia and South America. Large projects are under construction in Argentina, South Africa, and Ukraine.

In recent years new companies have been formed for developing new services or solutions for the PV markets. One example of such a company is **Ocean Sun**, which has developed a system with PV panels deployed on flexible floating structures (Figures 1 and 2). Such systems can e.g. be located on water reservoirs.

## MARKET DEVELOPMENT

The Norwegian PV market is small on an international scale, but the growth rate is high. In total, approximately 50 MW of PV capacity was installed in 2019, while the total PV generation capacity installed before 2019 was approximately 70 MW. Reduced installation costs for both commercial and residential rooftop installations continue to be 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 a fairer distribution of grid costs compared to the existing tariffs. NVE's proposal will have 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 revised proposal will be reviewed in 2020.

# PORTUGAL

ANTONIO JOYCE AND CARLOS RODRIGUES, LNEG (LABORATORIO NACIONAL DE ENERGIA E GEOLOGIA)
JOSE MEDEIROS PINTO, SUSANA SERÔDIO AND MADELENA LACERDA, APREN (ASSOCIAÇÃO PORTUGUESA DE ENERGIAS RENOVÁVEIS)

Fig. 1 – PV plant at Monte das Flores, Évora, with an installed peak power of 2,90 MW.

## GENERAL FRAMEWORK AND IMPLEMENTATION

The Portuguese National Carbon Neutrality Roadmap for 2050 (RNC 2050) was approved, by the Portuguese government (RCM n° 107/2019), in July 2018; which includes the new strategies for renewable policies. It sets the targets from 2030 to 2050, which underline the ambition to reach carbon neutrality in 2050, supported by well-defined trajectories for the different economy sectors.

In conjunction with the objectives of the RNC 2050, ambitious but achievable targets were established for the 2030 horizon, which are reflected in the National Energy and Climate Plan (NECP) for the period 2021 to 2030, which constitutes the main instrument of national energy and climate policy towards a carbon neutral future.

The NECP 2030 settled a target of 47% renewable energies (RES) share in the final energy consumption and of 80% renewable energies share in the electricity consumption by the end of 2030. Table 1 presents the major targets of NECP 2030 and RNC 2050:

### TABLE 1 – TARGETS OF DECARBONIZATION UNTIL 2050 (SOURCE: NECP 2030 AND RNC2050)

| | 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

At the end of 2019, Portugal had an accumulated PV installed capacity of **828 MW**, including a total capacity of 17 MW of concentration photovoltaic power plants.

According to provisional data of the Directorate General of Energy and Geology (DGEG), the increase in installed capacity was **155 MW** in 2019:

- Decentralized PV (Self-Production legislation, DL 153/2014 of 20 October) was responsible for an increase of **21 MW**;
- New utility scale power plants had an increase of capacity of **134 MW**.

**1 276 GWh** was reached, in terms of total PV energy produced, which represents about **2,5%** of the total electricity production in Portugal.

Solar energy is expected to have an important role in the increase of decentralized power production.

(Source of data: DGEG, "Estatísticas rápidas - n° 181" - December 2019)

## NATIONAL PROGRAMME

The National Renewable Action Plan (NREAP) 2020, still in place, defined 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 these targets, for which the Solar PV contribution is of paramount relevance.

In the framework of the new National Energy and Climate Plan (NECP) 2030, the electricity scenario presents an increasing evolution of solar PV capacity, reaching around 9 GW in 2030, which implies a well-defined strategy to boost the high amount of installed capacity supported by grid reinforcement, regarding the infrastructural system, smart management and cross border transfer capacity.

Portugal launched an important capacity auction in July 2019, to install a total photovoltaic capacity of 1 400 MW at 24 locations in the country, with an effective awarded value of 1 292 MW. This auction is part of Portugal's efforts to speed up the increase of installed PV capacity. The auction had good participation and one of the allocations, for 150 MW, has broken a world record by reaching a guaranteed tariff of 14,76 EUR/MWh.

On the decentralized side, the regulatory framework for the self-consumption regime until 2019 (Decree-Law DL 153/2014 of October 20, 2019) ruled 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 into the grid the surplus of production at 90% of the wholesale average market price. This regulation has been an asset for small scale PV development and public awareness.

In 2019, a new legal framework for self-consumption regime was published (DL 162/2019 of October 25, 2019), which will come into force on January 2020. This new Decree-Law transposes partially the RED II Directive, namely introducing the legal framework for jointly acting renewables self-consumers and renewable energy communities.

In the future, concerning the decarbonization of the economy and the targets set for 2030, the promotion of renewable energy sources, namely PV, is one of the purposes of the national energy policy. The ambitious targets that have been established are expected to lead to a significant contribution of RES in final energy consumption 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, $Cu_2O$, 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 photoelectrodes 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 2019 registered an incorporation rate for renewable energy sources (RES) into the electricity production mix of about **55,1%** (28,7 TWh), within an annual total gross electricity production of **52,0 TWh**. The remaining **44,9%** (23,4 TWh) were produced by fossil fuels. Solar PV accounted for **2,5%** of the total generation.

The 2019 annual average daily market price of the Iberian Electricity Market (MIBEL) where Portugal operates was of 47,9 EUR/MWh, which represents a fall of around 16 % related to the 2018 value.

Figure 3 shows the evolution of monthly electricity market prices for 2018 and 2019 in Portugal, reflecting the positive impact of renewables related to electricity consumption for the same period. It is worth noting that in December 2019, a lowest monthly average electricity market price of 33,7 EUR/MWh was reached.

The power sector in Mainland Portugal was responsible for a total of 10,4 million tonnes of $CO_2$ emissions, which represents a specific $CO_2$ emission of 213 g/kWh. See Figure 2.

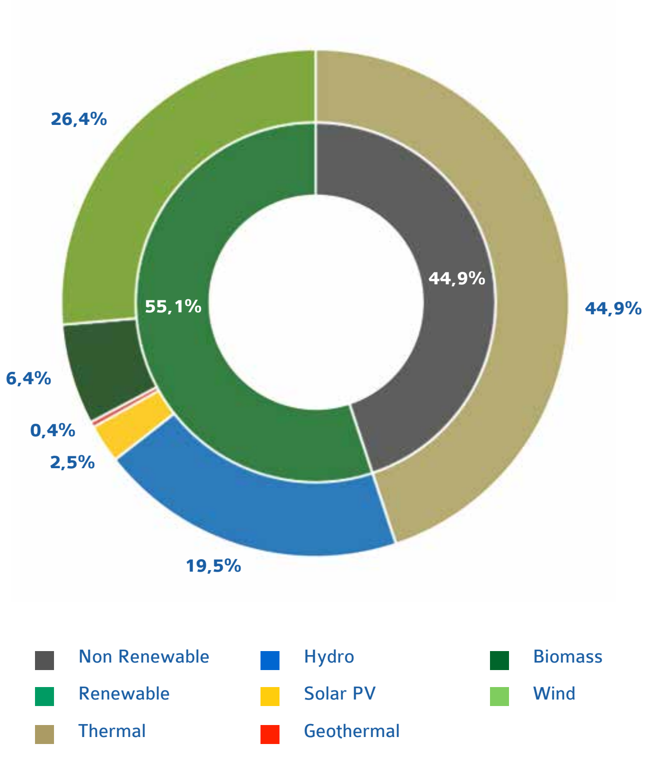



Fig. 2 – Electricity generation by energy source in Portugal 2019 (Data from DGEG, provisional).

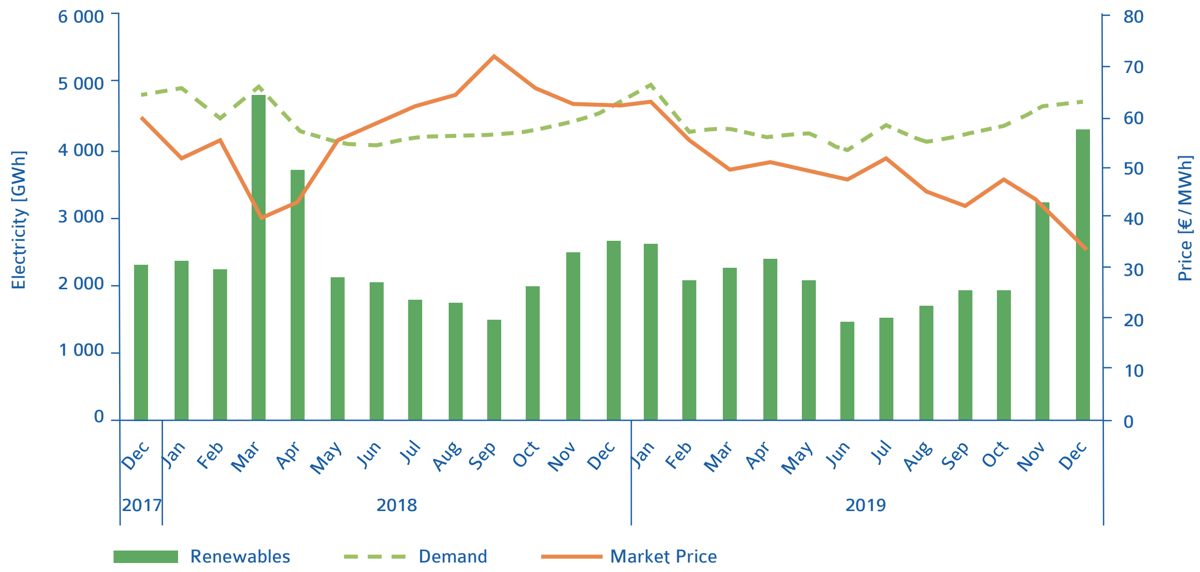



Fig. 3 – Renewable Electricity Production and Iberian Wholesale Electricity Price (December 2017 to December 2019). Source: OMIE, REN; APREN's analysis.

# SOLARPOWER EUROPE

## SOLARPOWER EUROPE'S ACTIVITIES

AURELIE BEAUVAIS, POLICY DIRECTOR, SOLARPOWER EUROPE


Fig. 1 – SolarPower Europe wins 'Overall Best European Association' at the European Association Awards 2019 (Photo: © CAPTURISE).

SolarPower Europe is a member-led association that represents organisations active along the entire value chain. SolarPower Europe's aim is to ensure that more energy is generated by solar than any other energy source by 2030 and lead its 200+ members to make solar the core of a smart, sustainable, secure and inclusive energy system in order to reach EU climate neutrality before 2050.

In 2019, SolarPower Europe was delighted to welcome a new Chief Executive Officer, Walburga Hemetsberger. She joined the association in February 2019, after nine years as Head of the EU Representation Office at VERBUND. Prior to this, she worked as Advisor of Financial and Capital Markets at The Association of German Public Banks and Association of Public Banks (VÖB / EAPB). Earlier in her career, Hemetsberger worked as a competition lawyer at Haarmann Hemmelrath, and has experience with the European Parliament and European Commission. Hemetsberger has also been a board member of Hydrogen Europe.

In Europe, 2019 was a transition year for the solar energy sector. Following the adoption of the EU's 'Clean Energy for All Europeans' package, which set the scene for a new era of growth for renewables in Europe, European institutions braced for a new political cycle with the elections of the European Parliament in May 2019, and the official start of the new European Commission on 1 December 2019.

With the new EU institutions and policymakers in place, it has been the right time to highlight the immense progress that solar has made over the past five years and to highlight how solar has become the most cost-competitive and easily deployed renewable technology.

For this reason, SolarPower Europe has been active on the EU digital and media scene, to raise awareness of the benefits of solar to power the European Green Deal:

- SolarPower Europe launched its "Solar Rooftop Campaign", supported by representatives of the newly elected European Parliament and leading renewable players. This campaign called for legislation to have solar power installed on all new and renovated buildings in the EU, as a key driver for job creation and the decarbonation of EU building stock, as well as to help mitigate climate change.
- SolarPower Europe published its first "Solar factsheets", a comprehensive communication and policy material, highlighting the benefits of solar technologies from various aspects: costs, sustainability, raw material uses, recycling, and job creation.
- Finally, SolarPower Europe launched the "7 Solar Wonders Campaign", aiming to demonstrate the multitude of ways that solar can contribute to the European Green Deal to the newly elected policymakers.

These achievements resulted in SolarPower Europe being named "Best Overall European Association" at the European Association Awards 2019. The association also won a Silver Award for "Best Advocacy Campaign" related to the successful results on the removal of the solar trade barriers.

SolarPower Europe has worked relentlessly to position the solar industry's priorities within the European Green Deal, the flagship initiative of newly elected Commission President Ursula Von Der Leyen. The association developed, with the support of its Strategy Committee, five top priorities of the solar sector for the year 2020:

- **Remove national bottlenecks to the massive uptake of renewable generation towards 2030** (Grid access, PPA barriers, access to land, etc.), supporting the ambitious

Fig. 2 – SolarPower Europe's CEO Walburga Hemetsberger on stage together with EU Energy Commissioner Kadri Simson at the emPOWER Energy Transition Summit (Photo: ©Fred Beard).

implementation of the Clean Energy Package and creating bridges between the EU, and national and local governments, to promote best-practices and ambitious investment programs

- **Accelerate the deployment of renewable electricity across all sectors**, as the most efficient way to achieve $CO_2$ emission reduction in the next decade. Being a constructive interlocutor in the frame of the upcoming sectoral integration strategy will be key in this regard, as well as a successful advocacy on critical infrastructure policies such as the review of the Trans European Electricity Network Regulation.
- **Develop a comprehensive Industrial Strategy for renewables**, ensuring that the current momentum to foster Europe's leadership in clean energy technologies is seized to support cutting-edge manufacturing in Europe, as a cornerstone to ensure Europe's security of technology and energy supply on the way towards a carbon-neutral economy.
- **Enshrining climate neutrality in law with clear milestones for 2030 and 2040 to procure stability and visibility for solar investors.** The efforts of the association will focus on the Climate Law and supporting the European Commission's impact assessment to define a higher $CO_2$ target for 2030.
- **Facilitate access to private and public finance for renewable projects across EU regions**, with the creation of a new financing workstream and active advocacy on the sustainable finance initiative.

In 2019, SolarPower Europe continued to expand its policy activities:

- The Emerging Market workstream published 7 market reports in 2019, covering emerging solar markets such as Mozambique, Senegal, Ivory-Coast, India, Kazakhstan, Myanmar, and Tunisia. On top of this, the association has now established working partnerships with the solar associations of Tunisia, Mexico, India, Jordan, Kazakhstan, and Mozambique.
- SolarPower Europe created 3 new workstreams to support the work of its members on issues related to Grids, Financing, and AgriPV.
- SolarPower Europe published new business and market intelligence reports, including the first edition of the European Market Outlook, Solar Mobility Report, BIPV and cities report and Asset Management guidelines
- SolarPower Europe became a full member of the IEA Business Council

In 2019, SolarPower Europe organised a number of highly successful events, including:

- RE-Source – with over 930 registrations and over 300 pre-scheduled B2B meetings
- The first emPOWER event with the Energy Commissioner and key Members of Parliament attending
- Digital Solar & Storage – for the first-time taking place in Brussels to position digital and innovative solar solutions to the newly elected EU policymakers. The event included our first-ever electric mobility exhibition, where participants could test drive the latest in e-mobility
- SolarPower Summit – our flagship event with over 300 participants and 55+ expert speakers
- Midsummer Rooftop Solar Celebration – a sold out event with over 500 registered participants for an epic sunset rooftop party and launch of our campaign #Solar4Buildings
- 2019 was also a strong year for SolarPower Europe's media and digital presence:
- Close to 3,000 mentions in the media in 2019 including coverage in world-leading press such as FT, Forbes, and Politico
- SolarPower Europe published 72 press releases, blogs, and news articles in 2019
- 42% average increase in followers across SolarPower Europe's social media channels

Overall, 2019 was a very successful year for SolarPower Europe, winning "Overall Best European Association" and pushing forward our policy and advocacy in what can be described as a transition year for the European institutions. Now, we look forward to further positioning solar as a key clean energy technology to power the European Green Deal and to help reach energy and climate targets.

# SPAIN

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

## GENERAL FRAMEWORK

Expectations for an increase in PV capacity installed during 2019 were big in Spain due to the tender auctions approved in 2017 for accomplishing the de-carbonization compromises with the European Union. On the other hand, the feeling of society concerning PV technology has also turned very positive as with actual PV component´s price and average Spain´s irradiation, the cost of electricity self-generated is really competitive in comparison with the standard grid prices.

In these circumstances, preliminary information for 2019 from grid operator Red Eléctrica de España (REE) showed a record total increase in RREE capacity installed of 6 456 MW and on those new additions, the PV grid connected installation of 3,7 GW, almost all the capacity awarded in the tender (192 MW left out of 3,9 GW possible). This information is still preliminary data and confirmation is expected on July 2020.

Concerning PV self-consumption, the total capacity installed, (UNEF´s information this time) was 459 MW with 10% of it as isolated capacity while 90% grid connected. The self-consumption numbers have since doubled that which was installed in 2018, and contribute to approaching the total self-consumption installed in the country, now close to 1 GW.

In summary, the total installed PV capacity for the year has been 4 548 MWp, accounting for peak power grid connected and isolated.

With these numbers and having some uncertainty on the electricity coming out of self-consumption that cannot be easily estimated, the contribution of PV to the electricity demand coverage in the country during 2019 appears in Figure 1, together with the contribution from the other RREE sources, but considering only the grid connected generation.

As can be seen in Figure 1, the total demand coverage by grid connected RREE in 2019 is slightly lower than the prior year (36,8% versus 37,5%). In the distribution per technology it should be highlighted the increase of wind up to 20,6% (53 770 GWh) and the decrease in generation through hydropower (going down to 9%). PV percentage demand coverage is 3,5% with a total number of 9 136 GWh generated, which represents an absolute 0,5% higher than 2018. The growth has been due to the gradual increase of capacity added throughout the year 2019. Considerable increase is expected for next year when at least the total new 3,7 GW will be operative the full year, together with the new additions.

Demand coverage due to self-consumption cannot be easily estimated yet. However, it is very promising that the more than 400 MW grid-connected has been installed on top of the isolated. Information presented corresponds to consolidated values up to 2018, as reported by the grid operator REE (Red Eléctrica de España). For 2019, data are estimations as of 19 December 2019, for both peninsular and extra-peninsular territories. Consolidated final information for the year will appear in the July 2020 time-frame. Demand coverage due to off-grid and self-consumption has not been considered at all in the Figure 1 graph.

In absolute numbers, the total electricity demand out of the grid for the country was close to 261 TWh and the big decrease in generation from coal due to recent plants being stopped and stationary lower hydropower generation, have been compensated by combined cycle, that almost doubles its generation from the prior year, together with the contribution from renewable thermal (1,7%), the slight increase in wind (1,6%), and PV (0,5% more) as can be seen in Figure 2.

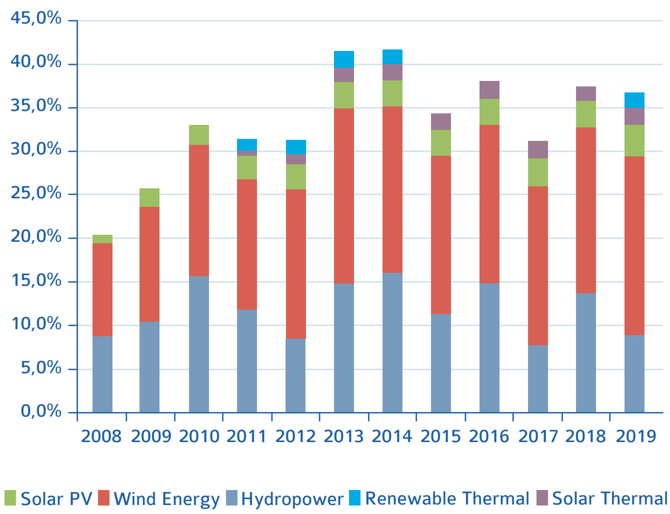



Fig. 1 – Percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 -2018, REE, 2019 REE- preliminary information).

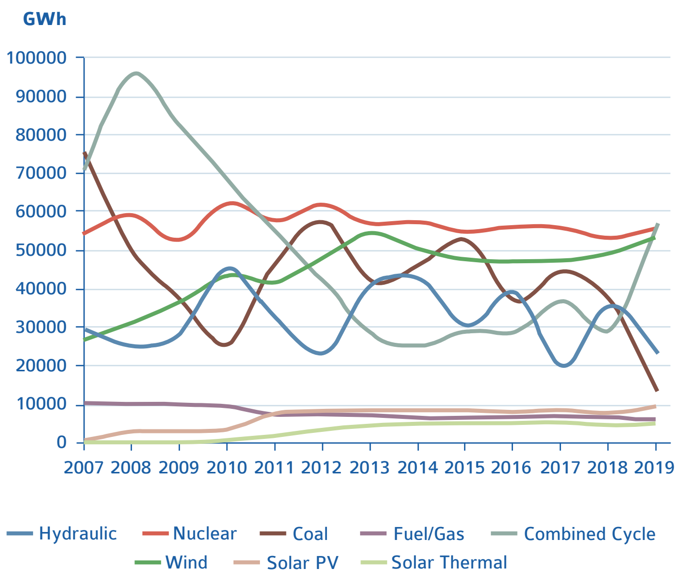



Fig. 2 – Evolution of electricity generation (all sources).

With this mixture of generation, the average monthly spot price had a profound decrease for the year 2019, from its high start in January.

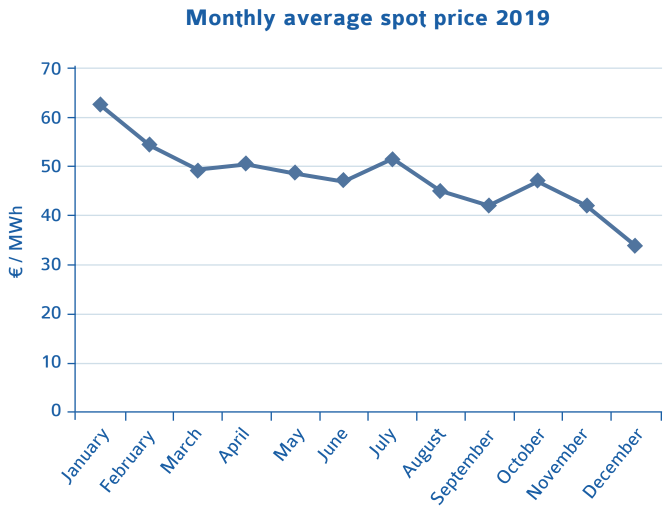



Fig. 3 – Evolution of monthly average MWh spot price (all generation technologies).

## NATIONAL PROGRAMME

There is no specific change on the National Programme, apart from the tenders in 2017, however, the last modifications in some regulatory laws are supporting the important development of PV. Actual prices of components and solar irradiation characteristics in the country make the LCOE value attractive for investors and new big PV plants not driven by governmental tenders 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. The increase in PV could also be seen on the very sunny islands starting slowly in Balearian (mostly self-consumption) and not so much in Canary Islands yet, as priority has been given to wind there.

In summary, Figure 4 shows the evolution of installed capacity, both grid connected and off-grid, with specific separation of self-consumption for the year 2019.

## R&D +I

The big deployment of PV technology is taking advantage not only of the lower prices on some components coming from abroad, but also of the new developments and product optimization obtained through the R&D activity. That is a key aspect in order to support the returning of PV manufacturing activity to Europe.

During the past year, new international projects have been awarded to Spanish R&D institutions and among them it should be mentioned the HIPERION project (Hybrid Photovoltaics for Efficiency Record using Integrated Optical technology) financed by the H2020 call. The project is led by CSEM from Switzerland and has, among its 16 members, both the Spanish Solar Photovoltaic Institute of Polytechnic University Madrid (IES-UPM) and the industrial company Mondragón Assembly. The project's technical goals are to obtain highest efficiency of PV modules by using micro concentrators that can even absorb diffused radiation. Going from the module technology to the final

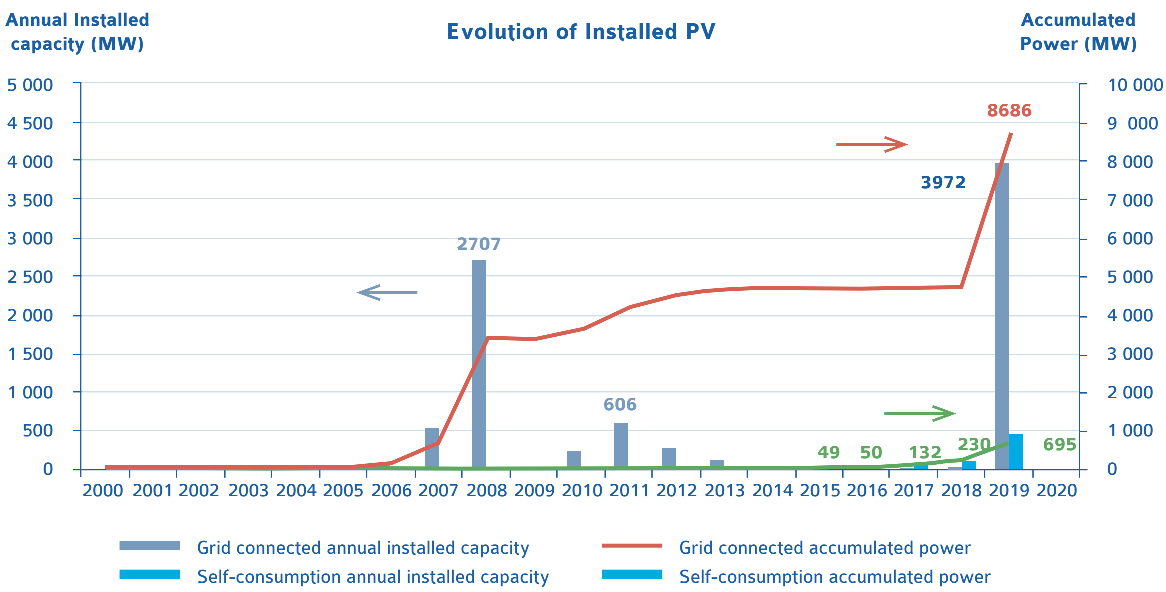



Fig. 4 – Evolution of installed PV 2000 – 2019, including grid connected and self-consumption.

Fig. 5 – Puerto Libertad, 405 MWp built by ACCIONA in Mexico entered in service first half of 2019.

electricity generation conditions, the Spanish institution CIEMAT participates in the recently awarded project POSYTYF (POwering SYstem flexibiliTY in the Future through renewable energies) also from H2020 (H2020-LC-SC3-2019-NZE-RES-CC), that has as its objective the study and modeling of the dynamic stability of electric networks in the case of high penetration of renewable energies under the concept of "Virtual Power Plants".

The R&D and D activity, both on the basic and the more applied side continue also through the participation in another new projects corresponding to national calls and in some cases closer to directly support the companies in the real market. This is the case of the development projects concerning activities for improvement of O&M activities that are becoming now the cost limiters in the case of installation in novel geographical environments and with configuration and plant sizes also new. Non-destructive diagnosis and on-site inspections are becoming the subject of interest, in order to identify as soon as possible, and avoid, unwanted evolution of electricity generation.

Finally and with a slightly longer range of application, the integration of PV in consumer products is becoming more usual as well as the Spanish manufacturers of building components being interested in developing their products with the added value of PV. All of them are focused on supporting the goals of de-carbonization that are presented in the PNIEC (Plan Nacional Integrado de Energía y Clima). Among those PV "in products" application, are not only BIPV (Building Integrated PV), but in a near future, VIPV (Vehicle Integrated PV) together with the control software for optimum management of re-charge cycles and the use of the energy stored are the subject of developments.

## INDUSTRY STATUS

Although industrial development in the country for the specific PV business was low, the Gross Domestic Product has had a continuous growth in the last years, which will be exceeded in 2019. The main contributors are engineering and installer companies followed, at a distant second, by manufacturers and distribution activities. EPC Spanish companies are active all throughout the world in the main PV markets from Central and South America to the Gulf region. Important activity has also been developed this year by smaller and more local companies due to the strong installation in the country that will influence for better results for the distributors, too. In a special way, it is worthwhile to mention the biggest plant in Europe, at 500 MW, built by IBERDROLA in Badajoz that will enter into production in first quarter of 2020 and other multi-MW plants from COBRA, ACCIONA, PRODIEL and more.

Spanish companies and manufacturers of BOS (structures and electronic components) continue leading the world market on the side of one axis trackers and inverters; however, PV modules producers still have not ramped up. In this sense, manufacturing activity is related mostly to very specific BIPV components' fabrication and installation. Nevertheless, this market is still missing products that might be volume consumer products.

The trend of PV technology during 2019 in Spain continues on the positive track that was started last year and all forecasts point towards its increase in capacity installed towards achieving the 100% of electricity generated by Renewable energies in 2050. Intermediate goals are established on 39 GW of PV electricity generation installed by 2030. However, a more positive evolution on it could be also influenced by the further demonstration of efficiency coming and versatility of applications that the PV technology might develop during this time frame.

# SWEDEN

## PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TOBIAS WALLA, SWEDISH ENERGY AGENCY
CHRISTOPHER FRISK, SWEDISH ENERGY AGENCY

Fig. 1 – Nya Solevi, the largest PV-plant in Sweden to date at 5,5 MWp. The plant lies outside of Gothenburg and was installed by Solkompaniet for Göteborgs Energi (© Göteborgs Energi).

## 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 increased this goal to a renewable energy share of at least 50% of the total energy use and had a share of 54% in 2019.

In 2016, the Social Democratic Party, the Green Party, 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.

While the common agreement still exists, the Moderate Party and Christian Democrats left the agreement in 2019 due to disagreements about the first target above.

### 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 0,25% 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.

The certificates are no longer a prerequisite for new investments in wind power, and although the incentive has accelerated on the current expansion other factors has played a larger role; technology development, good access to large wind power projects, low competition for the projects, low interest rates and new financing agreements.

### 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 was lowered to 30% to enterprises and 20% to individuals in 2014. The subsidy was increased to 30% to individuals starting from beginning of 2018 and again lowered to 20% for everyone in May 2019. The subsidy has become popular and the demand through applications has throughout the last few years been higher than available funds in the budget. 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, however the government increased the budget by 28 MEUR in the spring and additionally 47 MEUR in the autumn. In 2020 the budget for the subsidy was set to 70 MEUR. The capital subsidy for PV installations ends by the end of 2020, and according to the governmental supporting party the Center Party a green tax deduction will take its place.

Since November 2016, there is an additional capital subsidy for households investing in electricity storage in order to increase the PV self-consumption. The current budget for this subsidy is almost 6 MEUR per year.

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.

### PUBLIC PERCEPTION

There is a strong opinion in favor 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 funding 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.

Fig. 2 – Largest roof-top PV system in Sweden at 1,5 MWp. Installed by Solkompaniet on the warehouse of Apotea.se in Morgongåva (© Apotea.se).

With an annual budget of 140 MEUR, some 50 programmes and 1000 projects running is therefore the main funding source for research and innovation projects within PV.

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 (2016-2023) 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 programme, 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 Angstrom 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 collaborated with the spin-off company Solibro Research AB (a company of Hanergy that is undergoing bankruptcy), and Midsummer AB. Before bankruptcy Solibro Research increased the world record efficiencies for CIGS modules and cells at 21% and 23,5% respectively.

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 (that filed for bankruptcy in 2019).

[1] Svenska folkets åsikter omolika energikällor - https://som.gu.se/digitalAssets/1656/1656970_svenska-folkets---sikter-om-oilka-energik--llor-1999-2016.pdf

Fig. 3 – Examples of BIPV in Sweden. Left: PV roof called RooF by Soltech on a family home in Täby at 6 kWp. Right: Façade by Soltech on a parking garage in Linköping (© Soltech).

An ongoing collaboration between Linkoping 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. Exeger announced their first customer to be JBL in autumn of 2019.

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. The company also won the Postcode Lotteries Green Challenge 2019 and was awarded 500 000 EUR to their company.

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

## INDUSTRY AND MARKET DEVELOPMENT

The cumulative installed grid-connected power has grown from only 250 kW in 2005 to 411 MW in 2018. The market for solar cells in Sweden grew by 87%, or 158,5 MW, installed capacity compared to 85 MW in 2017. However, PV still accounts for only about 0,2% of the Swedish electricity production (159,7 TWh under 2018), 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, but large centralized systems are becoming more common and larger. To date, the largest planned PV plant (project start planned in Mars 2020) will be placed outside of Strängnäs and will be 20 MW in size. The plant will be built by EnergiEngagemang and the first stage of 14 MW is planned to be in operation by the summer 2020.

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 – Floating PV installation in the Swiss Alps, situated at 1 810 meters above sea level on the hydro reservoir "Lac des Toules". A pilot plant has been installed end of 2019. The production is expected to be up to 50% higher due to the use of bifacial modules with high albedo in wintertime and the higher irradiation. Challenges are the extreme climatic conditions (snow, ice, strong winds, temperature variations) as well as seasonal variances in water levels (0 to 50m) (Photo: © Romande Energie, www.solaireflottant-lestoules.ch).

### GENERAL FRAMEWORK AND IMPLEMENTATION

The current Swiss energy policy [1] describes how Switzerland can withdraw from nuclear power (36% of total power production [2]) on a step-by-step basis and gradually restructure the Swiss energy system by 2050. These moves are to take place without endangering Switzerland's currently high level of supply security and its affordable energy supply. The strategy calls for a significant increase in energy efficiency, the increased use of renewable energy and the reduction of energy-related $CO_2$ emissions. The corresponding energy legislation was accepted in a popular referendum in May 2017 and entered into force in January 2018.

In the climate sector, and with reference to the reduction of use of fossil energy, the focus is now on the next stage of the Swiss climate policy which is currently being debated in Parliament and which involves national implementation of the Paris Convention by 2030. In summer 2019, the Swiss government also decided that the net greenhouse gas emissions shall be reduced to zero by 2050. Simultaneously, the administration was asked to draft a corresponding long-term climate strategy for 2050.

In the fall of 2019, the Swiss government expressed its determination to fully liberalise the electricity market which should ensure that innovative products, services and the process of digitalisation will penetrate the market. As an accompanying measure, it was proposed at the same time to increase the incentive to invest in domestic renewable energies. Guide values for the expansion of hydropower and new renewable energies for 2035 should be declared binding. Accordingly, the investment contributions currently limited to 2030 will be extended until the end of 2035. A guideline is also determined for the period up to 2050. If the effective expansion of renewable energies falls too far below the defined expansion path, additional measures can be requested. Especially in the photovoltaics sector, competition shall be intensified by the one-off remuneration for large photovoltaic systems being newly determined through tenders. The administration is commissioned to submit a consultation proposal for the revision of the Energy Act.

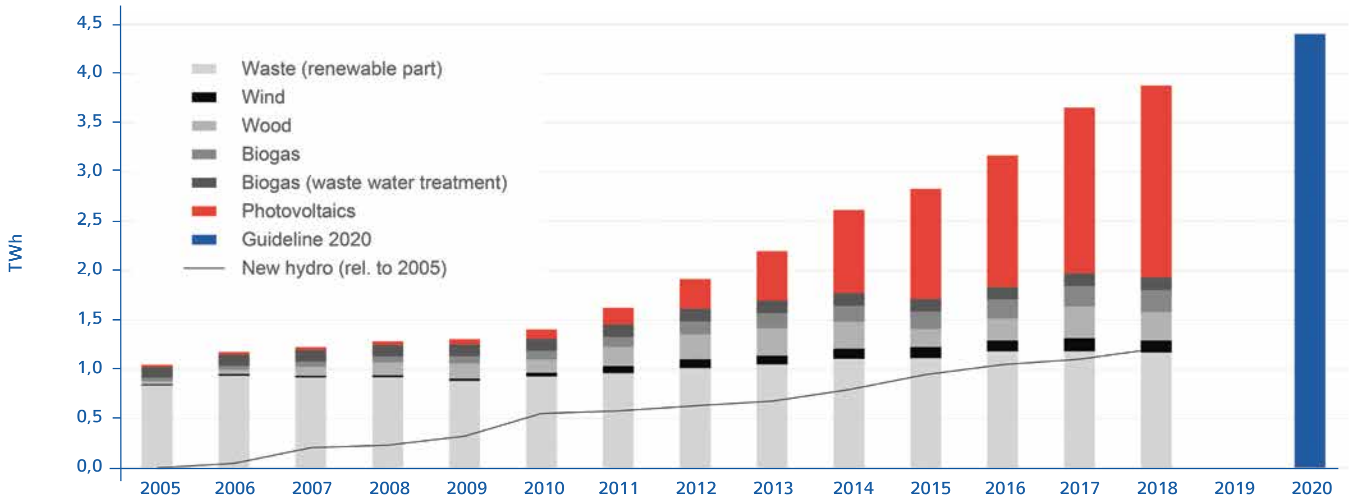



Fig. 2 – Development of electricity production from new renewable energies since 2005. Guidelines are 4,4 TWh and 11,4 TWh for 2020 and 2035, respectively. The total for 2018 is 3877 GWh (5,4% of total production), thereof 53% from PV (2,9% of total production). Official data for 2019 are not yet available. The added hydropower since 2005 is shown for comparison (total production of 35 986 GWh in 2018) (Source: SFOE, www.energymonitoring.ch).

Electricity production from photovoltaics is one of the key pillars in the strategy for the future Swiss electricity supply. According to a recent study by the Swiss Federal Office of Energy (SFOE) based on data from a solar potential cadastre (http://www.sonnendach.ch) and meteodata, Swiss houses and factories could generate up to 67 TWh of photovoltaic power per year (current power consumption is around 60 TWh) [3]. These are 50 TWh from rooftops in combination with an additional potential of 17 TWh on façades. Thereby, only larger surface areas with economically useful insulation have been considered.

A new monitoring report of the "Energy Strategy 2050" in 2019 [4] shows, that the increase in renewable power production in Switzerland is on track to reach the benchmark for 2020 (see Figure 2). The contribution from photovoltaics is thereby above the long-term scenarios. The total installed capacity 2018 was 1,9 GW with a plus of 261 MW compared to 2017, which is slightly below the net addition averaged over the last five years (289 MW). Official market data for 2019 are not yet available, but estimates show that the capacity addition in 2019 could be up to 30% higher than in previous years. Reasons are additional new opportunities (since 2018), such as the collective grid connection of various end consumers to increase self-consumption and flexibility. In addition, an existing long waiting list for onetime investment subsidies has been strongly decreased in 2019.

## NATIONAL PROGRAMME

The Swiss Federal Office of Energy (SFOE) runs a 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 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 RTD from basic research, over applied research, product development, pilot and demonstration projects. On average, the volume of the 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). As of January 2020, there are 86 ongoing photovoltaic projects, 29 funded through SFOE, 12 by the Swiss Agency for Innovation, 17 by the Swiss National Science Foundation and 28 as European projects (https://pv.energyresearch.ch/projects).

The SFOE photovoltaics programme supports research and pilot & demonstration 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 topics are life cycle analysis, solar forecasting and 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 programme.

## RESEARCH, DEVELOPMENT AND DEMONSTRATION

Swiss actors in academia and in industry are dealing with all kinds of different aspects of photovoltaics (see Figure 4). In the field of solar cells, the focus lies on high-efficiency crystalline silicon solar cells (heterojunction technology, PERC, passivating contacts) and in CIGS cells. Perovskite solar cells and tandem cells (c-Si with perovskite or III/V, CIGS with perovskite) are other topics of high interest.

The development of new module architectures especially for building integration applications is another large field of research with new approaches and solutions for coloured, light-weight and flexible modules, as well as customized modules. In 2019, a new web platform has been set up (https://solarchitecture.ch) to help architects, planners and engineers to use solar energy. The information provided ranges from the project overview to the solar technologies used to the depth of the constructive details. Grid integration of photovoltaics, photovoltaics in combination with heat pumps and storage technologies (batteries, thermal storage), photovoltaics and electromobility (bidirectional charging) are other themes with ongoing and increased activities. System performance of photovoltaics is a topic at various universities and research centers, some of them such as the Bern University of Applied Sciences (BFH) and the University of Applied Sciences of Southern Switzerland (SUPSI) with the monitoring of photovoltaic installations for many decades.

Fig. 3 – Plus energy multi-family house completed in 2019, with an active solar façade (glass/glass with monocrystalline cells). The total PV surface is 690 m$^2$ with a nominal power of 65 kWp. Final yield: 385 kWh/kWp. The ventilated construction was pre-assembled in the factory, avoiding the need to measure and set the substructure on the building. The whole installation was greatly simplified (Photo: © Viridén + Partner AG).


Fig. 4 – Swiss photovoltaics technology landscape. Circles denote academic institutions, squares industrial actors (Source: https://pv.energyresearch.ch/actors).

Fig. 5 – CIGS solar cells on flexible polymer substrate (Photo: © Empa).

### CIGS Solar Cells on Flexible Polymer Substrate

Efficiencies of CIGS cells grown on polymer substrates at low temperatures (450 °C) are lower than the ones of cells grown at high temperature on glass. In 2019, researchers from the Swiss Federal Laboratories for Materials Science and Technology (Empa) were able to increase the efficiency of such "low-temperature" CIGS cells to 20,8%. The improvement is the result of a careful adjustment of the chemical composition of the absorber layer, the development of new methods for alkali metal doping and the adaption of the properties of the absorber-buffer interface [5].

Fig. 6 – Vertically installed, specially designed bifacial modules on a green roof (Photo: © ZHAW).

### Bifacial PV Modules in Combination with Green Roofs

Bifacial photovoltaics is a major research topic at the Zurich University of Applied Sciences ZHAW. In a recent work, the combination of green roofs with vertically mounted bifacial PV modules was analysed in detail. It is shown that the specific energy yield of such a vertical bifacial system is comparable to monofacial standard modules and that special greening can result in higher albedo with increased system performance [6].

## 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 3). A broad range of competitive technologies, products and services are offered to the growing photovoltaic market, both domestically and abroad.

In 2019, the Swiss start-up company Insolight, with its new concentrator technology based on planar optical micro-tracking, obtained a large European funding via the HIPERION project coordinated by the Swiss Center for Electronics and Microtechnology CSEM. The goal of this project is to scale production and show manufacturers how to adapt existing production to collect 50% more energy by panel size [7].

Last summer, a memorandum of understanding for a strategic collaboration between the Swiss technology provider Meyer Burger and the REC Group, a leading European brand of solar panels, has been signed [8]. In fall 2019, the REC Group started mass production of its new Alpha modules manufactured on Meyer Burger Heterojunction (HJT) and SmartWire core equipment. The produced modules feature the world's most powerful 60-cell solar panel and best-in-class power out-put of 380 Wp. It was also announced, that REC plans to increase its 600 MW HJT/SmartWire manufacturing capacity to multiple GW (detailed information is outstanding). In exchange for adequate exclusivity protection for specific HJT and SmartWire Connection technologies, REC would be prepared to enter into a profit sharing agreement with Meyer Burger [9].

## REFERENCES

[1] http://www.energystrategy2050.ch

[2] In 2019, there were four nuclear power plants with five reactors in operation. Thereof, a first reactor (355 MW) was closed in December 2019 and is now being prepared for nuclear decommissioning.

[3] SFOE, press release, 2019-04-05 (http://www.sfoe.admin.ch)

[4] SFOE, Energy Strategy 2050 - Monitoring Report 2019, 2019-11-01 (http://www.energymonitoring.ch)

[5] R. Carron et al., Advanced Alkali Treatments for High-Efficiency Cu(In,Ga)Se2 Solar Cells on Flexible Substrates, Advanced Energy Materials, https://doi.org/10.1002/aenm.201900408 (2019)

[6] T. Baumann et al., Photovoltaic systems with vertically mounted bifacial PV modules in combination with green roofs, Solar Energy, https://doi.org/10.1016/j.solener.2019.08.014 (2019)

[7] https://insolight.ch, press-release September 4, 2019

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# THAILAND

## PV TECHNOLOGY STATUS AND PROSPECTS

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MR. SUREE JAROONSAK, DIRECTOR OF SOLAR ENERGY, DEDE

Fig. 1 – The 5 MWp Floating PV farm located at Siam Cement Group (Tha Luang) Company Limited in Saraburi province of Thailand. SCG has undergone several development projects on Floating PVs including the first floating PVs farm of Thailand (1 MWp size) located in Rayong province (Photo: SCG).

## GENERAL FRAMEWORK AND IMPLEMENTATION

Thailand has continually promoted PV system installations for a long time. However, during this period there has been a major transformation of Thailand's overall energy strategies. In 2019, Thailand has adopted the newly revised Power Development Plan 2018 (PDP 2018) that will incorporated the total of 10 000 MWp solar PV target alone and 2 725 MW floating PV targets by 2037. The Alternative Energy Development Plan (AEDP) is also now being revised and is expected to be finalized soon. Currently, electricity production from Thailand's PV systems is now at 2 982,43 MW; at nearly half-way through the target of the 6 000 MW current AEDP plan by 2036. Thailand's PV schemes can be generally divided into on-grid and off-grid PV systems, either in the form of ground mounted systems, rooftop systems, or floating PVs. 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 2 928,47 MW.

## NATIONAL PROGRAM

Under Thailand's 2018 national reformation plan, the liberalization of solar PV rooftops is one of the focus aspects that will allow the independent trading of electricity produced from solar PV from the utility grid. The new PDP2018 plan will increase the target of Thailand solar PV installed capacity to 10,000 MW and the floating PV target of 2 725 MW by 2037. This will open more opportunities for the investment in Thailand's solar PV sector.

The household residential PV rooftop incentive program is one of the key measures in achieving such a target. The program allows the households which install solar PV on their rooftops to sell the excess electricity back to the grid at the FiT rate of 1,68 THB/kWh. The program has the installation target of 100 MW per year for the duration of 10 years.

## R&D, D

The comprehensive studies of reliability of energy storage systems and competent technology for PV systems and other renewable energies are the area of focused projects led by Electricity Generating Authority of Thailand (EGAT), National Science and Technology Development Agency (NSTDA), Rajamangala University of Technology Lanna Changmai (RMUTL) and King Mongkut's University of Technology Thonburi (KMUTT).

In order to respond to the modernization of global trends, the invention and development of information technology applications, including smart metering systems and smart grids are being carried out by the Provincial Electricity Authority (PEA), the Metropolitan Electricity Authority (MEA), Chulalongkorn University (CU), Naresuan University (NU) and King Mongkut's Institute of Technology Ladkrabang (KMITL).

Furthermore, the study of new material on PV fabrication, especially the perovskite cells is also being studied.

## INDUSTRY AND MARKET DEVELOPMENT

PV systems are expected to continue to flourish in the upcoming future since the cost of PV electricity production is now becoming more competitive with the conventional electricity production.

There are 15 PV module manufacturers in 2019 in Thailand (the number is similar to that of 2018). They consist of eight Thai manufacturers and seven international manufacturers. There are seven manufacturers in cell and module production with the capacity of 3 850 MW, and eight manufacturers that produce only PV modules with the production capacity of 531 MW. The international manufacturers primarily aim to export.

The local market mainly focuses on supporting the use of PV systems in various applications, such as solar pumping projects and rooftop systems of government and residential buildings.

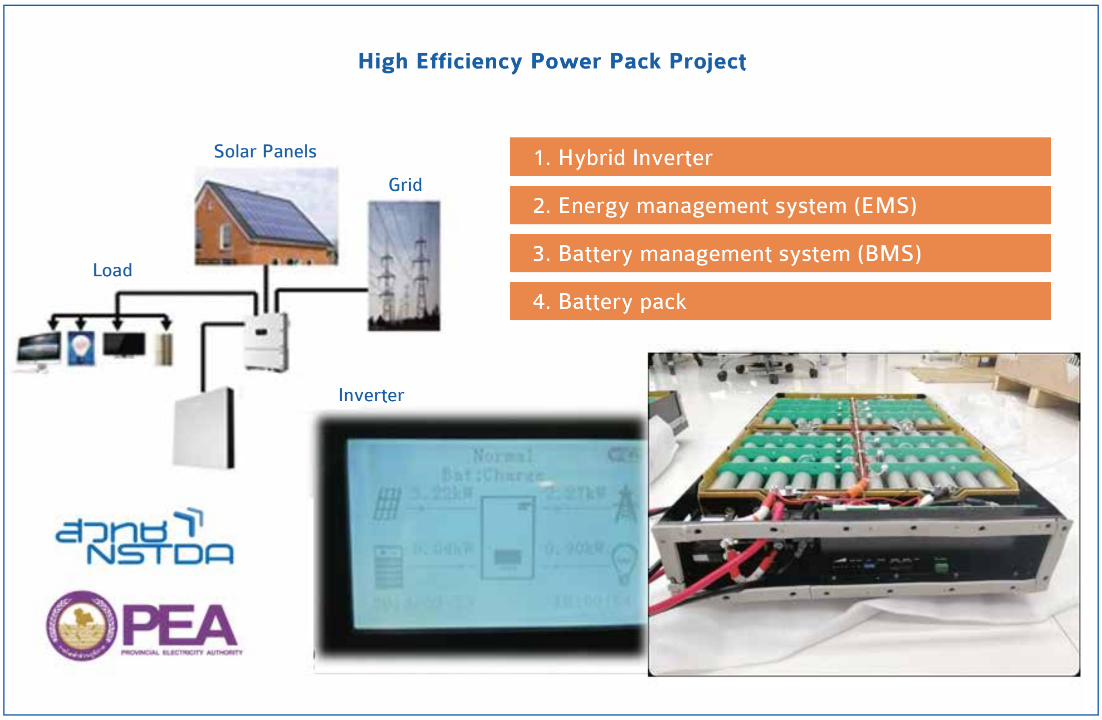


Fig. 2 – The High Efficiency Power Pack project led by the National Science and Technology Development Agency and Provincial Electricity Authority (PEA) of Thailand. The project was the prototype of 5 kWh energy storage system size deployment with grid-connected solar PV system using hybrid inverter, energy management system, battery management system, and battery pack itself (Photo: NSTDA).

# IEA PVPS COMPLETED TASKS

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**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 inDeveloping 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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ISBN 978-3-906042-95-4