Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

PVPS

ANNUAL REPORT 2020

PHOTOVOLTAIC POWER SYSTEMS TECHNOLOGY COLLABORATION PROGRAMME

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2020

Cover photo

FIRST LARGE-SCALE HIGH-ALPINE PV SYSTEM, ALBIGNA DAM, SWITZERLAND

A high-alpine 410 kWp PV system was commissioned by the Zurich power utility ewz at the Albigna Dam, at 2,165 m.

The 1,280 PV module array can produce approximately 500 MWh of electricity per year; enough to power about 210 households annually. The analysis of the yield data, periodic measurement of the module output, thermal imaging and examination of the general condition of the system will be used to gain insights on the long-term reliability of installations installed at comparable locations.

Photo: © ewz

Technical Data
Installed Capacity: 400 kWp
Expected Annual Production: 500 MWh
Number of PV Modules: 1,280 (two rows)
Solar Radiation Value: approximately 1,200 KWh/kWp
PV Plant's Length: approximately 670 meters
Construction Period: July to September 2020
Start-Up: September 2020

COLOPHON

Cover Photograph
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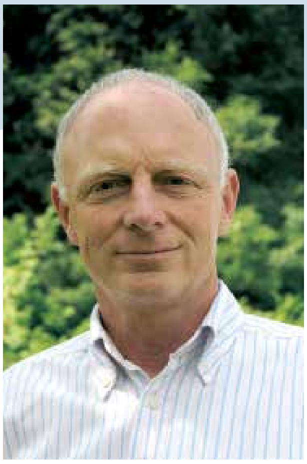
Task Status Reports
PVPS Operating Agents
National Status Reports
PVPS Executive Committee Members and Task 1 Experts
Editor
Mary Jo Brunisholz
Layout
Autrement dit
Type set in
Colaborate
ISBN
978-3-907281-16-1

CHAIRMAN'S MESSAGE



A particularly warm welcome to the 2020 annual report of the International Energy Agency Photovoltaic Power Systems Technology Collaboration Programme, the IEA PVPS TCP! In this very special period of the COVID-19 pandemic, not surprisingly, also our global collaborative work has suffered from the many restrictions in place, in particular not to have the possibility of in-person meetings of our different expert groups and the IEA PVPS TCP Executive Committee. In spite of this difficult situation, our collaborative efforts have continued and – as many others – we have found new ways to take our important work forward, some of which will likely also remain in the future. We are pleased to provide you with some highlights and the latest results of our work, as well as relevant developments in PV research and technology, applications and markets in our member countries and organizations worldwide.

In spite of the COVID-19 pandemic and associated lower expectations for the global deployment of photovoltaic (PV) systems throughout the first half year, 2020 has confirmed and even accelerated the strong development of the global photovoltaic (PV) market of previous years and the continuous increase in competitiveness of solar photovoltaic power systems. Indeed: *"Solar is the new king of the electricity markets"* was one of the first key statements of the IEA Executive Director Fatih Birol when launching the most recent IEA World Energy Outlook in October 2020. Due to this remarkable development, PV continues to evolve as 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 below 1.5 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 2019, our market analysis for 2020 estimates an increase of more than 20%, or approximately 140 GW, installed worldwide, raising the cumulative installed capacity to well above 750 GW. China, the USA, Vietnam and Japan represented the largest markets in 2020, accounting for more than 60% of the additional installed capacity in these four countries alone. Fourteen countries had more than 10 GW of cumulative PV systems capacity at the end of 2020, five had more than 40 GW and 20 countries installed at least 1 GW in 2020 alone. Meanwhile, in 25 countries, PV contributes with 3% or more to the annual electricity supply. With the total installed capacity by the end of 2020, PV can now contribute to more than 3.5% of the world's electricity generation.

These dynamic market developments, progress in PV technology and industry and a rapidly changing overall framework form the basis for the activities of the IEA PVPS TCP. In 2020, IEA PVPS continued its focus on the integration of PV in the energy system and the outreach in content and cooperation with other organizations. Besides fostering an increased cooperation within the IEA technology network, the collaboration with other international organizations such as IRENA, the IEC and the International Solar Alliance ISA is progressing. Apart from our ongoing work on PV market, business and policy analysis, many new results have become available from our technical projects related to environmental assessment of PV; reliability and performance investigations as well as grid, building and vehicle integration. 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. Bringing the best added value to our members and target audiences is the goal that we pursue together.

This foreword is the last foreword to an IEA PVPS annual report from my side. Indeed, after almost 20 years of serving as Chair of the IEA PVPS TCP, it is time for me to hand over this responsibility to Daniel Mugnier from France who has just been elected as the new IEA PVPS Chair. I wish to warmly congratulate Daniel and the team which will guide the IEA PVPS TCP in the years to come! Having had the opportunity and privilege to work for the success of the IEA PVPS TCP for such a long period was an exceptional experience, both in my professional and personal career. Professionally, because during these last 20 years, I was able to closely follow the staggering worldwide development of PV from its infancy to a young, dynamic, eager and very capable adult. Personally, because I could experience a wealth of new relationships, insights into different cultures and many long-lasting friendships. I would therefore like to express my sincere and deep gratitude to all Executive Committee members, colleagues in the PVPS Management Board, the Executive Secretary, Operating Agents and Task Experts who have accompanied and always supported me in this long period. Their ongoing and devoted efforts to our international collaboration are truly unique! It is my desire to extend my gratitude to the many individuals in numerous international organizations, in particular from the IEA Secretariat, who made this period so enriching in all aspects.

I wish that the team which will guide the IEA PVPS TCP in the future will also have the pleasure of such a supportive environment in taking the cooperative efforts of this unique global programme to the next levels and will thereby achieve many new successes towards a sustainable worldwide PV development and deployment!

Stefan Nowak
Chairman

April 2021

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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 2020, 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.

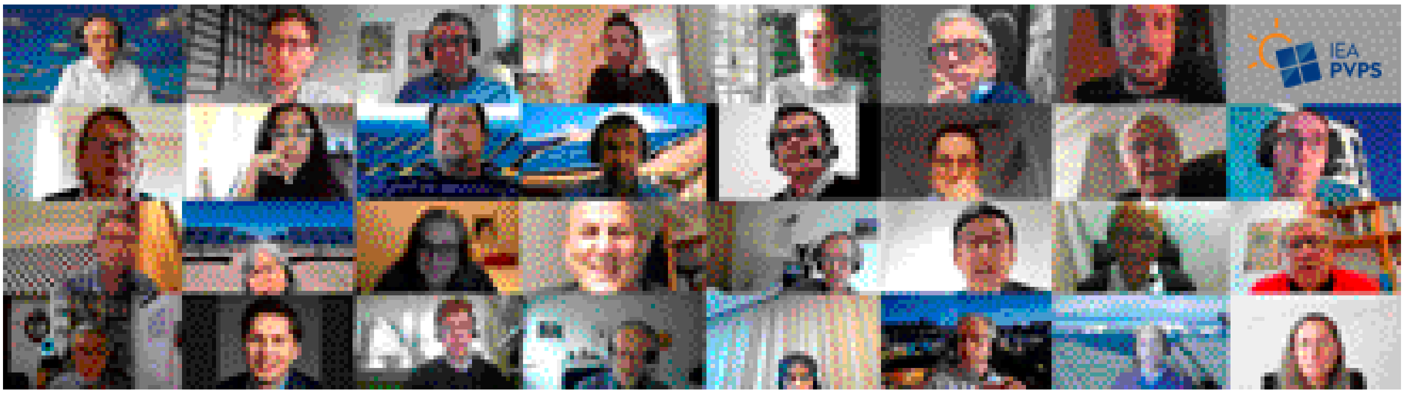
Therefore, in this term, the IEA PVPS TCP is placing particular emphasis on:

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 organisations and agencies;



56th IEA PVPS Executive Committee Meeting, online @ zoom, November 2020.

- 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 the 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.

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

Expertise

- Task 1 researches market, policies and industry development.
- Task 1 serves as the "Think Tank" of the IEA PVPS Technology Collaboration Programme (TCP), 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 TCP. 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 TCP. 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

Fig. 1 - PVPS Report: A Snapshot of Global PV Markets; Report IEA PVPS T1-37:2020.

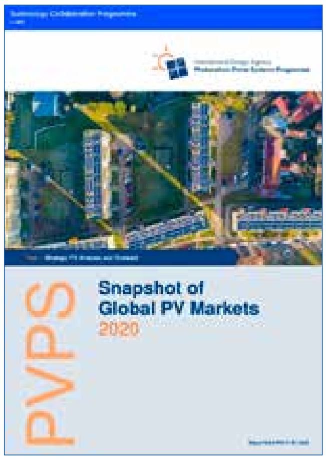


Fig. 2 - PVPS Report: Trends in Photovoltaic Applications – Survey Report of Selected IEA PVPS Countries between 1992-2019; Report IEA PVPS T1-38:2020.

market frameworks, public budgets, the industry value chain, prices, economic benefits, as well as new initiatives including financing and electricity utility interests.

25th 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 TCP, 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 and 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. Copies are distributed by Task 1 participants to their identified national target audiences by post and e-mail, are provided at selected conferences and meetings and can be downloaded from the website. From 1995, twenty-five issues of *Trends* have been published. They are all available on the IEA PVPS website.

A Snapshot of Global PV Report

Since 2013, an additional report, *A Snapshot of Global PV*, is compiled from the preliminary market development information provided annually by all countries participating in the IEA PVPS

Technology Collaboration Programme. The Snapshot report aims at presenting a first sound estimate of prior year's PV market developments and is published at the beginning of April. 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.

Data Model and Data Acquisition for PV Registration Schemes and Grid Connection – Best Practice and Recommendations

The *Data Model and Data Acquisition for PV Registration Schemes and Grid Connection – Best Practice and Recommendations*, jointly written by Task 1 and Task 14, provides a first comprehensive set of recommendations to properly register PV installations, follow and update them. The aim is to provide grid operators but also policymakers with a clear picture of the situation of the fleet of PV plants, their characteristics and more.

Review and Analysis of PV Self-Consumption Policies

The *IEA PVPS Review and Analysis of Self-Consumption Policies* report published in 2016 will be updated in 2021. 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 TCP's Think Tank, while providing the IEA PVPS Executive Committee and dedicated PVPS Tasks with ideas and suggestions on how to improve the research content of the PVPS TCP. In this respect, from 2013 to 2020, Task 1 has identified 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 delocalized self-consumption, new grid financing schemes and access to electricity markets for prosumers. Given the important changes, the 2016 report is currently being revised.

PPAs and Merchant PV: With falling PV electricity prices, utility-scale PV started to develop outside of the existing financing schemes: this has been researched by Task 1 in 2020 with a focus on PPA schemes and merchant PV (remuneration through electricity markets). In 2020, Task 1's work was focused on studying these emerging models through dedicated workshops and conferences.

PV for Transport: the electrification of transport is one of the key elements to decarbonize that sector. Moreover, the connections between PV and electric vehicles are numerous: from embedded PV cells in cars, bus, trucks, trains and planes to the use of e-mobility as an accelerator of PV development, all of these subjects will be part of Task 1's research activities in the months and years ahead.

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.

Policy Recommendations and Analysis: the rapid development of PV on all continents requires that regulators and authorities perfectly understand the key features of the PV technology development. IEA PVPS will provide a set of recommendations in various fields, to disseminate the vast experience acquired by its experts over the last years.

SUBTASK 1.3: COMMUNICATION ACTIVITIES

Task 1 aims at communicating about the main findings of the PVPS TCP through the most adequate communication channels. In that respect, five main types of communication actions are conducted throughout the year. Due to the travel and meeting restrictions in 2020, the usual activities have been virtualized.

- *Events*: Task 1 organizes or participates in events during energy or PV-related conferences and fairs. Workshops are organized on various subjects, sometimes in cooperation with other PVPS TCP's Tasks or external stakeholders. In 2020, the following workshops were organized in several locations around the world:
  - *France*: Foreseen with the Task 1 meeting, a workshop dedicated to promoting PV for French stakeholders was organized online in June 2020.
  - *Virtual 37th EU-PVSEC*: the IEA PVPS Task 1 Workshop - *New Trends in PV Applications: Self-Consumption Business Models in Energy Communities and the Use of Corporate PPAs for Utility-Scale PV at the 37th EU-PVSEC* was organized within the conference programme, focusing on innovative applications self-consumption, but also on innovative PPAs and merchant PV, hydrogen production from PV, and the connection between self-consumption and energy communities. Task 1 also coordinated the organization of the Task 13 and Task 15 events held at the 37th EU-PVSEC.
  - *Virtual 30th PVSEC, 20th GPVC, Jeju Island, Korea*:
    - A workshop titled ***"PV Powering the Energy Transition: a look at innovations & latest trends"*** during the 30th PVSEC has been organized with the PVSEC organizers on market and industry trends, PV for transport and buildings, and the role of green hydrogen.
    - Another workshop was held, dedicated to ***"PVSEC Special Forum: PV Industry in the Post-Pandemic Era - Challenges and Solutions"***, with a focus on the industry and PV for transport.
  - In addition, IEA PVPS was partner of several events in 2020, including the International Solar Alliance Industry event. Task 1 speakers represented the program in several conferences in various places.

- *Webinars*: to increase its visibility, Task 1 speakers participated in webinars organized by Leonardo Energy, through the IEA PVPS member Copper Alliance, 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 IEA PVPS TCP's www.iea-pvps.org website. IEA PVPS is also present on Twitter *IEA PVPS (@IEA_PVPS) / Twitter* and LinkedIn.
- Task 1 published two issues of the *PV Power Newsletter* in 2020. Task 1's ambition is to provide accurate and complete information 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 media and national PV association's contacts. The IEA PVPS contact list is expanded with more media from Asian, African and Latin American countries in a progressive way. Translation of press releases is done by some countries to expand PVPS visibility.

SUBTASK 1.4: COOPERATION ACTIVITIES

In order to gather adequate information and to disseminate the results of research within Task 1, cooperation with external stakeholders remains a cornerstone of the PVPS programme.
This cooperation takes 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 DELIVRABLES PLANNED FOR 2021

Task 1 activities will continue to focus on the development of quality information products and effective communication mechanisms in support of the PVPS strategy. Furthermore, Task 1 will continue to analyze PV support policies and provide adequate and accurate information to policymakers and others stakeholders. In addition to the recurrent market and industry analysis, Task 1 will continue to study the evolution of business models, the role of utilities 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 2021 on the IEA PVPS website.
The target date for publication of the 9th issue of the Snapshot of Global PV report is the beginning of Q2 2021.
The target date for publication of the 26th issue of the *Trends in Photovoltaic Applications* report is the Q4 2021.
An update of the self-consumption policies report is foreseen.

SUBTASK 1.2: THINK TANK ACTIVITIES

The main subjects to be developed in 2021 through Task 1's Think Tank activities for PVPS 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.
- Expand the analysis on PPA and merchant PV schemes for utility-scale PV plants.
- 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 IEA PVPS 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 2021. 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 2021. It will reinforce the link with IEA in particular, and enhance its cooperation with IRENA, ISA, REN21, ISES and other organizations. Regarding the cooperation between 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 (2020 AND PLANNED 2021)

The 54th Task 1 Experts Meeting was held virtually during several days from April to June 2020.
The 55th Task 1 Experts Meeting was held virtually during several days from November to December 2020.
The 56th Task 1 Experts Meeting will be either held virtually or possibly partially on site in Sophia Antipolis, France, in the first half of 2021, depending on possibilities.
The 57th Task 1 Experts Meeting in the second half of 2021, will be either held virtually or possibly partially on site, depending on the possibilities.

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 or MEMBER ORGANISATION	PARTICIPANT	ORGANISATION
Australia	Ms. Linda Koshier	UNSW
Austria	Mr. Hubert Fechner	Austrian Technology Platform Photovoltaics
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
Copper Alliance	Mr. Angelo Baggini	ECD
Denmark	Mr. Kenn HenrBournonville Frederiksen	KEnergy
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. Daniel Mugnier	TECSOL
	Mr. Pierre Rale	
Germany	Dr. Georg Altenhöfer-Pflaum	Forschungszentrum Jülich
Israel	Mr. Gideon Friedmann	Ministry Of Energy
	Ms. Yael Harman	GSE S.p.A.
Italy	Ms. Francesca Tilli	Elettricità Futura
	Ms. Luisa Calleri	
	Mr. Andrea Zaghi	RSE S.p.A.
	Mr. Giosuè Maugeri	ENEA
	Dr. Franco Roca	
Japan	Ms. Izumi Kaizuka	RTS Corporation
	Mr. Osamu Ikki	
	Mr. Masanori Ishimura	NEDO
Korea	Mr. Chinho Park	Yeugnam University
Malaysia	Mr. Hazril Izan Bahari	SEDA
	Ms. Siti Aishah binti Mohammad	
Morocco	Mr. Ahmed Benlarabbi	IRESEN
Norway	Mr. Jarand Hole	NVE
Portugal	Mr. Pedro Paes	EDP
SolarPower Europe	Mr. Raffaele Rossi	SolarPower Europe
South Africa	Mr. Kittessa Roro	CSIR
Spain	Mr. José Donoso	UNEF
Sweden	Mr. Johan Lindahl	Becquerel Institute Sweden
Switzerland	Mr. Lionel Perret	PLANAIR
	Mr. Léo Heiniger	
Thailand	Mr. Arkorn Soikaew	Department of Alternative Energy Development and Efficiency
	Mr. Watcharin Pachittyen	
The Netherlands	Mr. Otto Bernsen	Agentschap NL
Turkey	Dr. Kemal Gani Bayraktar	TTMD
	Prof. Dr. Bulent Yesilata	Gunder
	Dr. Ahmet Yilanci	Ege University
USA	Christopher Anderson	US DoE
	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.

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 its new Workplan in 2018, and that 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.

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 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 (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. Culminating recent focus of Task 12 on PV module recycling, members of Task 12 came together with other international experts to publish a Perspectives article in Nature Energy entitled, "**Research and development priorities for silicon photovoltaic module recycling to support a circular economy.**"

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

Additional work items under this Subtask which are planned for completion in 2021 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 resulted 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. This standard is actualized in the marketplace through the Global Electronic Council's Electronic Product Environmental Assessment Tool (https://epeat.net/search-pvmi) where large purchasers can easily identify products meeting the standards criteria and thereby 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 (**Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems**, T12-19-2020), having previously been postponed, was accomplished at the end of 2020. Without updated primary data on many supply chains, Task 12 was nevertheless able to identify many while utilizing 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 also saw another update to Task 12's flagship **LCA Methodological Guidelines** (T12-18:2020). Extending further the topics on which Task 12 conducts LCA, in 2021, Task 12 intends to complete the development and application of a new LCA metric on primary mineral resource intensity of PV, as well as a fact sheet/slide deck covering many of the LCA metrics in one, easy-to-read file.

Finally, Task 12 expanded beyond the bounds of photovoltaics to assess the environmental aspects of a now common practice of deploying batteries along with PV modules in **Environmental LCA of Residential PV and Battery Storage Systems** (T12:17-2020).

SUBTASK 3: OTHER SUSTAINABILITY TOPICS

With the publication of the third and final part of the Human Health Risk Assessment Methods for Photovoltaics (**Human Health Risk Assessment Methods for PV | Part 3: Module Disposal Risks, T12:16-2020**), 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 end of life PV modules disposed in landfills. 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 landfill conditions, 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.

ACTIVITIES IN 2020

2020 of course was a very different year than all before it owing to the global pandemic. Task 12's work was altered in many ways and it did slow progress as members experienced very different national, regional and personal approaches to keeping safe and healthy. Task 12 persevered, publishing several key publications and maintaining contact through virtual meetings, though did have to postpone several activities planned for completion owing to the extraordinary circumstances.

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.

GOVERNANCE, DISSEMINATION AND NEXT MEETINGS

Leadership:

An important accomplishment of 2020 was to elevate Dr. Jose Bilbao of the University of New South Wales as Deputy Operating Agent of Task 12! Task 12 continues its tradition of Operating Agents from different continents, now including the Southern Hemisphere, and welcomes Jose's experience as a researcher, practitioner and leader.

Membership:

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

Next Meetings:

The regular cadence of expert meetings are currently planned virtually for Spring 2021, leaving open the possibility of being able to meet in person in Fall 2021, if possible.

PUBLICATIONS

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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.

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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:
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TABLE 1 - TASK 12 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Susanne Schidler	University of Applied Science, Fachhochschule Technikum Wien, Department of Renewable Energy
Australia	Jose Bilbao	University of New South Wales
Belgium	Tom Rommens	VITO
China	Lv Fang	Institute of Electrical Engineering, Chinese Academy of Sciences
	Xinyu Zhang	Zhejiang Jinko Solar Co,. Ltd
Solar Power Europe	Andreas Wade	Solar Power Europe
France	Isabelle Blanc	MINES ParisTech
France (alternate)	Paula Perez-Lopez	
France	Claire Agraffeil	Department of Solar Technologies – CEA-LITEN
	Anne Grau	EDF
Germany	Michael Held	LBP Stuttgart University
	Wiltraud Wischmann	ZSW
Italy	Lucio Sannino	ENEA
	Pierpaolo Girardi	RSE (Ricerca sul Sistema Energetico)
	Andrea Danelli	
Japan	Satoru Shimada	NEDO (New Energy and Industrial Technology Development Organization)
Japan (alternate)	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
Switzerland	Rolf Frischknecht	treeze Ltd., fair life cycle thinking
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

Fig. 1 - A multi-technology photovoltaic test facility for the detailed performance evaluation of different module technologies and mounting systems was set up by EURAC research in cooperation with Airport of Bolzano Dolomiti (ABD). It is operating since 2010 (Photo: EURAC /Othmar Seehauser).

INTRODUCTION

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

Together with Task 1, Task 13 will continue to be needed for the predictable future, 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 operators. The PV industry continues to undergo rapid change, both in magnitude with a near-doubling of global capacity every 3-4 years, and new technology uses (e.g. changing cell thicknesses, PERC technology uptake and 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 require 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 and PV applications.

Performance and reliability of PV modules and systems is a topic that is attracting more attention every day from various stakeholders. In recent times, it also comes in combination with the terms of quality and sustainability. Task 13 has so far managed to create the right framework for the calculations of various parameters that can give an indication of quality of components and systems as a whole. The framework is now there and can be used by the industry who has expressed appreciation in many ways 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 current work programme until October 2021.

OVERALL OBJECTIVES

The general setting of Task 13 provides a common platform to summarize and report on technical aspects affecting the quality, performance, and reliability of PV systems in a wide variety of environments and applications. By working together across national boundaries 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. 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, as well as 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, the Asia-Pacific, and the USA.

- The industry has a continued high interest in information on performance and reliability of PV modules and systems. In addition, financial models and their underlying technical assumptions have gained increased interest in the PV industry, with reliability and performance being key parameters used as input in such models.
- Companies, which have the respective data of reliability and performance at their disposal, however, tend to be reluctant to share this information. This is particularly true, if detailed numbers in question allow for financial insights.
- Here, legal contracts that restrict partners to secrecy on financial details often prohibit 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 to investors, manufacturers, plant owners, and EPCs. These stakeholders are keenly interested in gaining more information about such technological innovations. But new technologies also present challenges to current practices and standards.

Subtask 1's objectives are to gather and share information about new PV module and system design concepts that enhance the value of PV by increasing either the efficiency/yield/lifetime or by increasing the flexibility or value of the electricity generated. This Subtask 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.

In 2020, Subtask 1.1 explored the use of new materials in PV modules and surveyed research in this area being done around the world. In a new report that will be released in early 2021, researchers are investigating new materials for transparent frontsheets, optical coatings, encapsulants, cell metallization and interconnects, and backsheets. Thinner glass and transparent polymers are investigated. These serve to reduce the weight of modules and can also allow flexible modules that can conform to curved surfaces. Testing is performed to ensure durability while exposed to UV radiation. New encapsulant development is focused on replacing EVA with materials that do not generate acetic acid during optical degradation and are easier to recycle. Materials such as polyolefin elastomers (POE) and thermoplastic polyolefin (TPO) are becoming more popular, especially for glass-glass module designs. Recent innovations have resulted in the production of silicone encapsulants in the form of sheets designed to be laminated using conventional equipment. As the cost of this material decreases, it may become more popular for PV applications in the future due to its long-term stability and excellent optical properties. New materials are being investigated for cell metallization. Composites of silver and carbon nanotubes developed by Osazda Energy in the USA show promise in making PV cells more crack tolerant. When the cells crack the carbon nanotube fibers can bridge the crack and maintain conductivity over crack widths of tens of microns, resulting in PV modules that are less susceptible to power loss due to cell cracks.

Bifacial cells and modules continue to increase their market share. In 2020, Subtask 1.2 focused its efforts on documenting factors that control bifacial system performance including characterization and modeling methods. They conducted a bifacial performance modeling comparison exercise that included thirteen different models. A number of scenarios were defined, and participants were asked to simulate each scenario using the model of their choice. Scenarios included various fixed tilt and tracking system designs. One of the scenarios was based on actual measured bifacial performance and weather data while the others did not have measured data. An analysis of the results helps to indicate

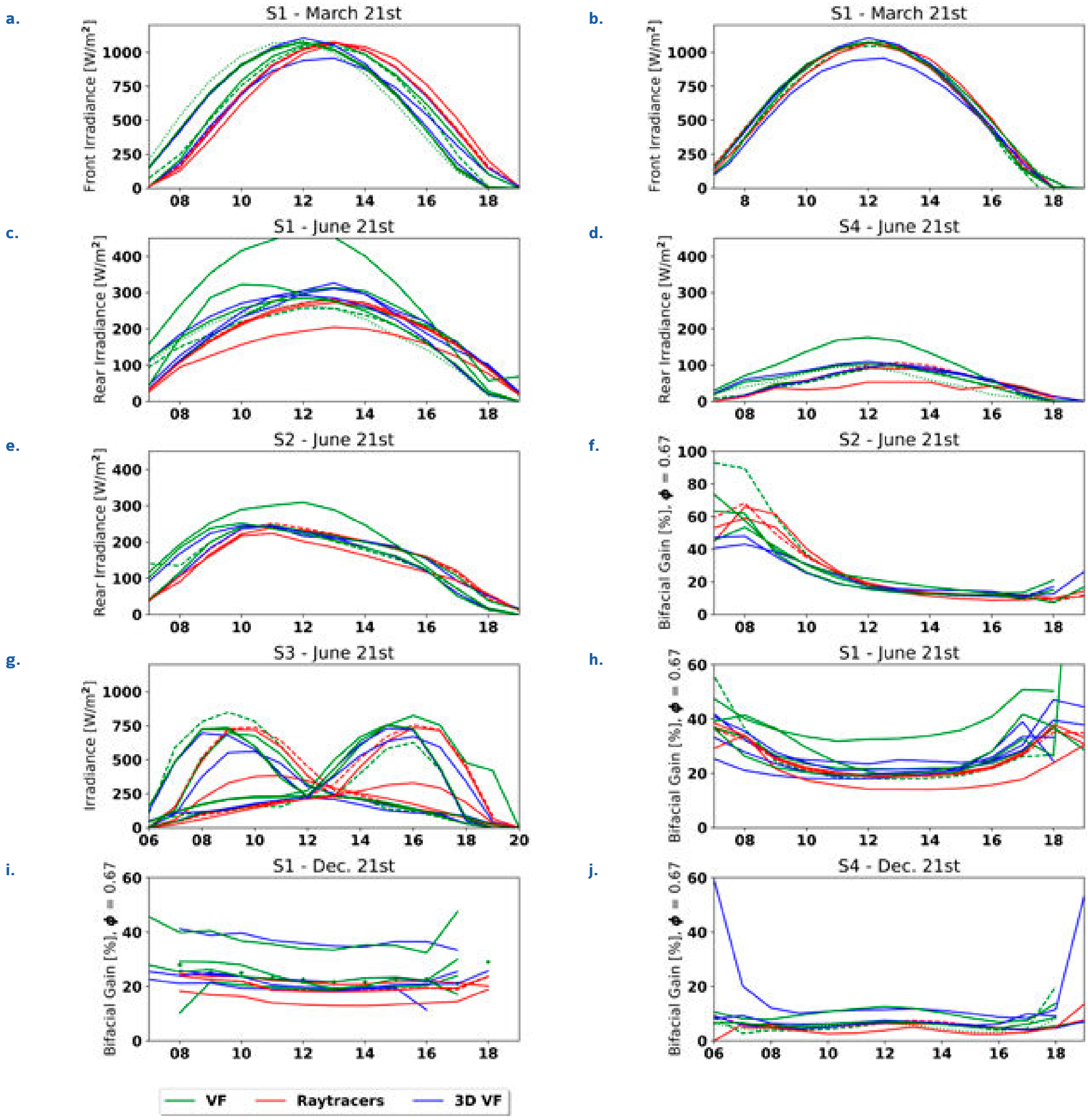

Fig. 2 - Example of modelling results run by ST1.2 experts for scenarios (S1-S4). The three model classes are denoted by colour: view factor models (green), raytracing models (red) and 3D VF and others (blue).

the level of uncertainty in these models and suggest opportunities for improvements. Figure 2 shows some examples of the variations between different models for selected days. Additionally, the final report for the activity includes a chapter that presents twelve bifacial field research sites around the world and summarizes the field-testing methodology and some results. The report will be published in early 2021.

Subtask 1.3 is concerned with performance and characterization of new types of PV systems, including PV + energy storage, PV + heat pumps, PV + agriculture, foldable, lightweight PV, and floating PV systems, among others. Such PV systems may provide a dual or even a triple use and system components are specifically designed and operated to meet these multiple-usage requirements. Because of these differences, characterization methods for such systems are different than for simple PV systems designed to maximum energy output. For example, PV + energy storage systems may be designed to minimize energy required from the grid or to control when that energy is needed (e.g., peak shifting). Because such objectives may be different than simply maximizing energy production, alternative methods for evaluating system performance may be necessary. The expert team is compiling a collection of methodologies to characterize such complex, multi-use systems. They are planning to complete and publish a report in first quarter of 2021.

Subtask 1.4 is evaluating methods for making service life predictions for PV modules. In 2020, efforts focused on developing and evaluating new scientific approaches to making these predictions. Two approaches are being considered, one using statistical data analysis techniques, which allow handling of big data sets from monitoring of large systems. The other approach combines established mathematical models that describe specific degradation processes and mechanisms. Good results can be achieved by combining several process models that represent multi-step degradation processes as they can be found in experimental and real operational data of modules. A report summarizing the results of this activity is planned to be published in 2021.

SUBTASK 2: PERFORMANCE OF PHOTOVOLTAIC SYSTEMS

Subtask 2's objectives are to study the uncertainty related to the main parameters affecting yield assessment and long-term yield prediction. This will in turn have an impact on the LCOE and on the business model selected. As availability has an important impact on yield, 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.

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 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 the link to Subtask 3 in terms of what economic impact soiling and snow will have. Finally, all the degradation factors will be taken into account to analyse performance loss rates on large amounts of high quality and low quality data, in order to shed light on the impact of data quality and filtering to the evaluation of operational data. This analysis will include the data collected in the past and is provided in the Task 13 PV Performance Database.

In 2020, the focus of Task work moved to the finalization and editing of the five technical Task reports within Subtask 2.

The report "Uncertainties in Yield Assessments and PV LCOE" will be published in the first quarter of 2021 and the reader will find useful information in answer to the question: How reliable are Yield Assessments (YA)? This is an apparently simple question; however, the answer is not equally simple. Typically, investors require one YA. In some cases, more YAs might be requested if results are unclear. The various YAs can be averaged to assign a purchase value to a given project. In any case the question remains unanswered: why different assessors obtain different answers? Is one YA more reliable than others? Investors know that past performance is no guarantee for future results. This maxim also applies to long-term yield assessments and the LCOE that can be determined from these, also within the context of a changing climate. Yield Assessment is an essential step in a PV project, as it helps to determine whether a system will be funded or not. However, the YA is not only about which software will be used, it is mainly about the user. YAs may not be as reliable as expected, and in the report, we demonstrate how seven highly skilled specialists did not arrive at the same result, having been provided the same detailed input data (see Figure 3). The differences in the YA results were then used to estimate the impact on business models and LCOE. The results were also presented in a conference paper during the Online EU PVSEC 2020.

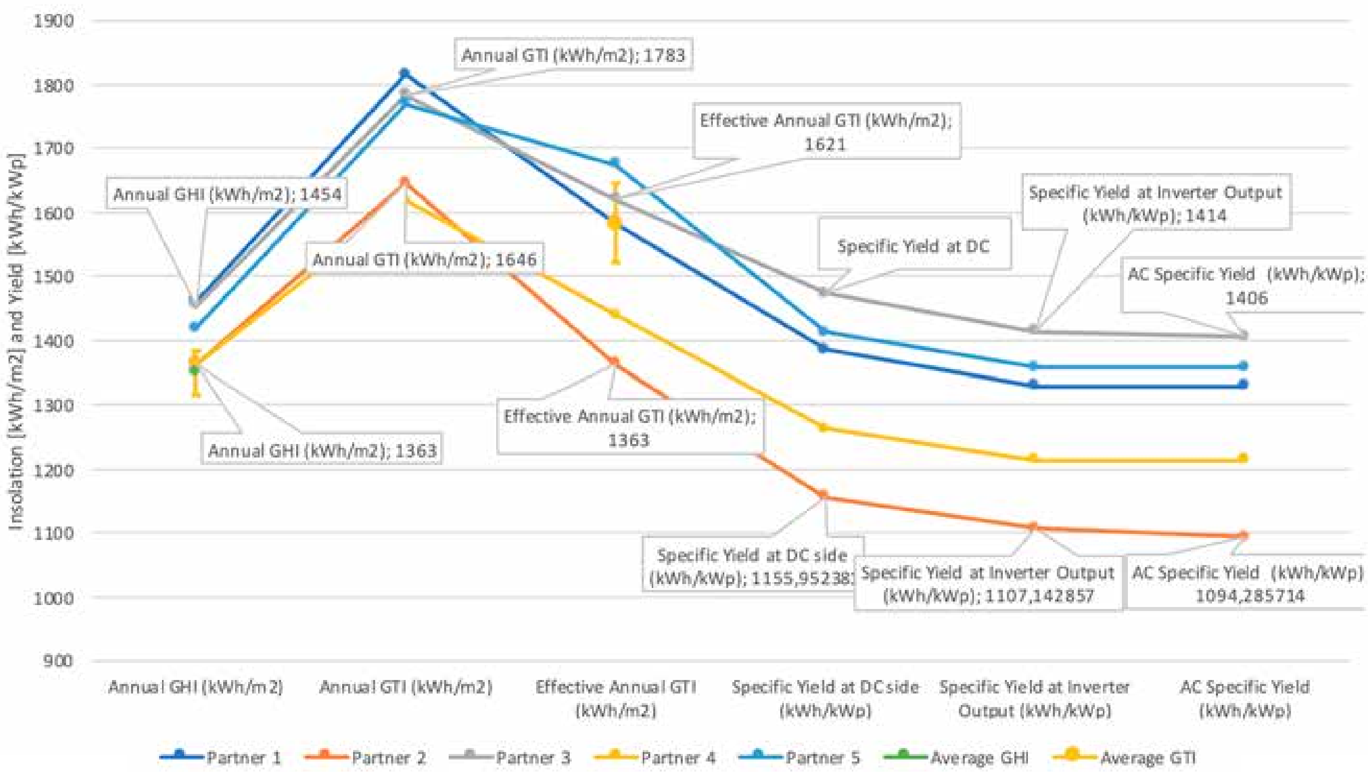

Fig. 3 - Detailed analysis of the contribution of each yield assessment modelling step from GHI to Alternating Current (AC) specific yield for the Bolzano site. The orange dots represent measured values over 2011-2019 with σ.

The impact of climate on energy yield of PV modules was further investigated within a dedicated activity (ST 2.3) with the final aim of providing a guidance in energy rating of different PV module technologies in different climates. The report is a compendium of the current status of energy rating, ranging from input data on technologies (whether measured in the laboratory or outdoors) and on climate, to the description and evaluation of existing methods (IEC 61853 and from other solar institutes). It also opens the discussion on the application of these methods in new technologies such as bifacial modules, BIPV and coloured PV, competitions on method uncertainties and evaluation at system level. The basic data sets for individual reader analysis are also provided. The report on "Climatic Rating of Photovoltaic Modules: Different Technologies for Various Operating Conditions" was completed in 2020 and will be published in January 2021.

One of the parameters affecting yield assessments and performance is soiling - either by mineral dust or by snow. In Subtask 2.4, a dedicated activity investigates the physical principles related to dust soiling and the impact of soiling on PV performance and reliability. The work was focused in three parts, namely summarizing the physical principles of soiling and collecting information about soiling metrics and available sensors for soiling and snow on the one hand. Secondly, in estimating energy losses of utility-scale systems, in listing available models, and in providing mitigation measures and experiences in PV module cleaning, as well as also looking into generic best-time-to-clean approaches and possible new system designs. Thirdly, looking into snow shading of PV systems, into performance factors for PV at high latitudes and design optimizations of PV systems in snowy climates. Detailed results are presented in the technical report entitled "Soiling Losses – Impact on the Performance of Photovoltaic Power Plants", which will be published in 2021.

The activity ST 2.5 focused on the assessment of Performance Loss Rate (PLR) and resulted in the technical report "Assessment of Performance Loss Rate of PV Power Systems" 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 in the exercise was asked to apply the preferred filtering, metric and methodology showing high variability in the final outcome. Results related to the assessment of performance loss rates were presented during the IEEE PVSC conference 2020 and published as R pipeline with the name PVplr (https://cran.r-project.org/package=PVplr). The report "Assessment of Performance Loss Rates of PV Power Systems" will be published in the first quarter of 2021.

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 for 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 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.

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 the technical report on professional risk assessment for PV investments in 2021. In 2020, progress was made on the collection of Failure Sheets of most important risks. These failure sheets for each failure mode and component will be included in the annex of the report (about 60 pages). They will also be compiled as a separate document for website download.

The main objectives of Subtask 3.2 "Characterization of PV Power Plants using Mobile Devices" are to present the methodologies and procedures to identify defective PV modules in PV power plants as origin of power loss. This work includes the description of commercially available portable devices to qualify PV power plants. The report is structured in ten methods including electrical performance measurements (4), imaging techniques (4) and spectroscopic methods for materials analysis (2). Besides technical information and existing field experience, also good practice recommendations for field use and uncertainties compared to laboratory inspection methods are covered. A brief summary of the ten inspection methods covered in this report is given in the executive summary. From here, the reader can jump directly into the relevant chapter of this report, where detailed information on the inspection method is given.

Characterization of PV power plants in the field is crucial to understand performance and degradation mechanisms to improve reliability and lifetime. On-site inspection methods with portable test equipment (mobile devices) are helpful tools to diagnose drivers for underperforming PV power plants. The particular strength is that the tests are carried out in the field and that the PV modules do not have to be shipped to the laboratory, which often means long transport routes, transport risks and a long down time of the PV strings. Furthermore, on-site inspection methods allow a more targeted failure analysis, as PV modules are not blindly selected. Test experience has shown that the significance of the results is comparable to laboratory tests.

On the other hand, on-site inspections are dependent on the weather conditions, which is a disadvantage compared to work under controlled conditions in a laboratory. Thus, on-site inspections require a higher organizational effort and careful planning. A single inspection method mainly deals with a specific type of PV module defect and cannot deliver a comprehensive failure analysis. For example, electroluminescence (EL) or photoluminescence (PL) imaging can reveal cell cracks in a PV module or can give an indication for PID. However, no conclusions can be made concerning the output power of the PV module. Accordingly, it makes sense to combine imaging inspection techniques with output power measurements. In this sense, the objectives of on-site inspection must be specified in advance. If applicable, the most appropriate combination of inspection methods must be considered in order to obtain meaningful results. The technical report "Qualification of Photovoltaic (PV) Power Plants using Mobile Test Equipment" will be published in the second quarter of 2021.

One of the main challenges in customization of an O&M programme for a specific climate zone at present is the lack of comprehensive guidelines to guide the users to do so. Existing guidelines and standards do not fill the gaps or clarify at the very least the minimum requirements of climate-specific O&M and their implementation. In this context, the Subtask 3.3 report has been prepared with an objective to provide a comprehensive guidance on setting up a customized O&M practice for PV plants in seven different climate zones, four of which are general (moderate, hot and dry, hot and humid, desert in high elevation), and three which are more specific to extreme condition (flood-prone region, cyclonic region, snowy region). The recommendations are built based on field experiences of the contributing experts from various countries representing the climate zones addressed.

The climate-specific O&M guidelines presented in this report aim to serve different functions to various stakeholders depending on their roles in the entire value chain of PV. The most direct application is for PV plant operators and owners for use is setting up an optimal and appropriate O&M programme for their PV plants in specific climates. PV plant engineers and designers would also benefit the relevant O&M measures and recommendations to use as inputs or design criteria during the design and engineering of the plants. At the other end of the spectrum, financing parties and investors could use these guidelines as a benchmark for PV plant operational risk assessment, inputs of which are used in the decision-making process of project finance/investment.

With these in mind, the technical report consolidates and discusses key recommendations, guidelines and best practices towards optimized O&M for PV plants. On the latter, we emphasize, through the different chapters on the site-/climate-specific aspects of PV O&M; ranging from the regulatory, risk/safety and asset management level, up to the operational level, notably the monitoring/ inspections, data analytics, maintenance, and optimization. Figure 4 gives an overview of exactly all these different, yet interrelated, "components" that assemble the over-all O&M agenda throughout the technical lifecycle of PV plants.

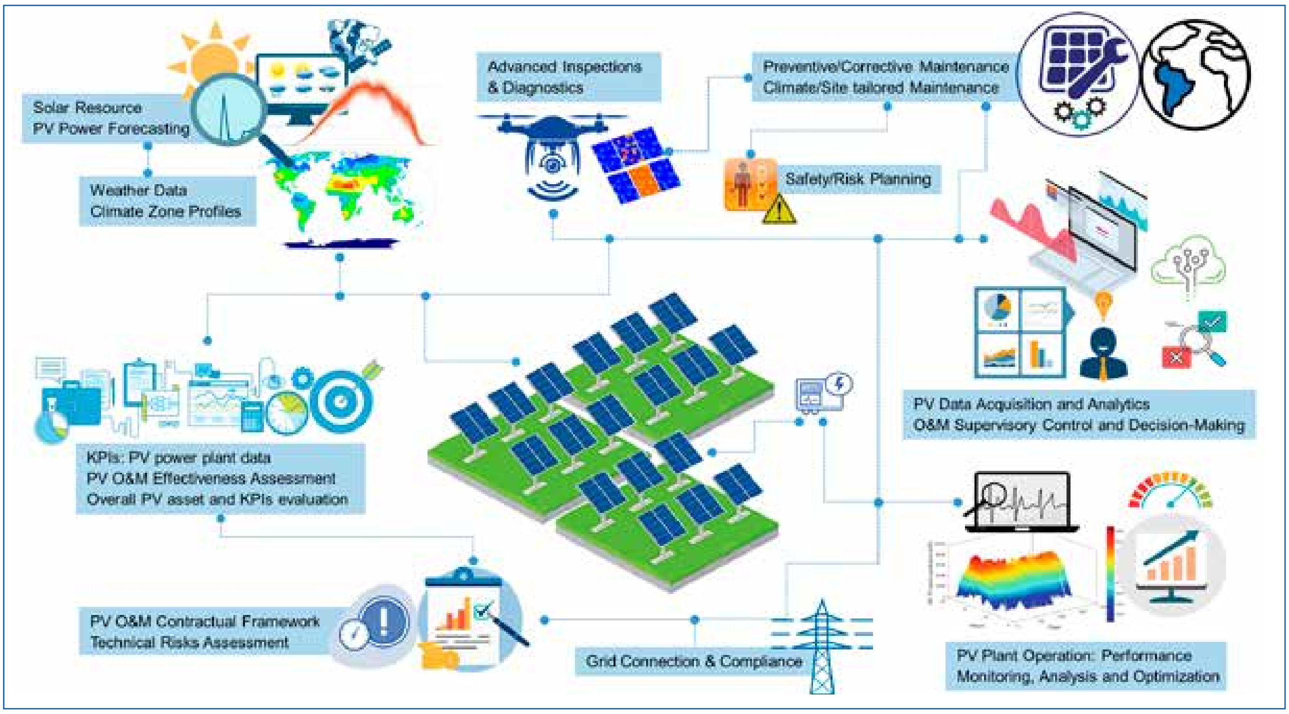

Fig. 4 - Overview of operation & maintenance aspects and services for PV power systems during their technical lifecycle (source: CEA-INES).This ST3.3 Report "Guidelines for Operation and Maintenance in Different Climates" will be published in 2021.

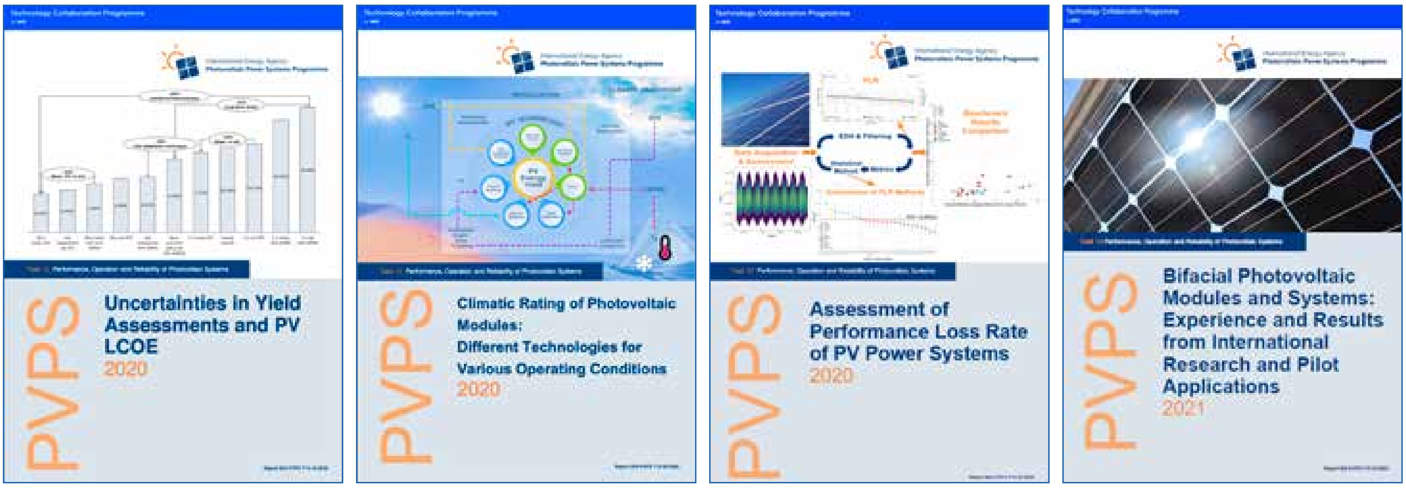

Fig. 5 - Task 13 published four Technical Reports in 2020, which are available at: http://www.iea-pvps.org/index.php?id=483.

SUBTASK 4: DISSEMINATION

This Subtask is focused on the information dissemination of all deliverables produced in Task 13. The range of activities in this Task includes expert workshops, conference presentations, technical reports and international webinars.

The following **Technical Reports** were published in 2020:

[1] Report IEA-PVPS T13-18:2020. ISBN 978-3-907281-06-2
Uncertainties in Yield Assessments and PV LCOE
D. Moser, S. Lindig, M. Richter, J. Ascencio Vásquez, I. Horvath, B. Müller, M. Green, J. Vedde, M. Herz, B. Herteleer, K.A. Weiß, and B. Stridh.

[2] Report IEA-PVPS T13-20:2020. ISBN 978-3-907281-08-6
Climatic Rating of Photovoltaic Modules: Different Technologies for Various Operating Conditions
J. Bonilla Castro, M. Schweiger, D. Moser, T. Tanahashi, B.H. King, G. Friesen, L. Haitao, R.H. French, B. Müller, C. Reise, G. Eder, W. van Sark, Y. Sangpongsanon, F. Valencia and J.S. Stein.

[3] Report IEA-PVPS T13-22:2020. ISBN 978-3-907281-10-9
Assessment of Performance Loss Rate of PV Power Systems
R.H. French, L. Bruckman, D. Moser, S. Lindig, M. van Iseghem, B. Müller, J.S Stein, M. Richter, M. Herz, W. van Sark, F. Baumgartner, and J. Ascencio Vásquez.

[4] Report IEA-PVPS T13-14:2021. ISBN 978-3-907281-03-1
Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications
J.S. Stein, C. Reise, J. Bonilla Castro, G. Friesen, G. Maugeri, E. Urrejola and S. Ranta.
For download at: https://iea-pvps.org/?id=483

Task 13 experts presented their results at the 37th EU PVSEC, which was organized as online event. Four papers were presented, two of the talks were made in the plenary session. One paper about the Bill-of-Material (BOM) control was selected as session highlight and was mentioned as a topic highlight during the closing session of this conference.

Task 13 expert Matthias Littwin of ISFH and Ulrike Jahn as Task 13 Operating Agent organized two workshop sessions on ST 1.3 New PV System Designs at the online 37th EU PVSEC on 10 September 2020. Task 13 experts presented recommendations on how to characterize the performance of innovative PV systems where the current methods cannot be applied, including economic aspects. Also, performance experiences with innovative PV systems (floating PV systems, agriculture PV systems and foldable PV arrays) were presented and discussed with the experts. The slides can be downloaded from https://iea-pvps.org/events/eupvsec37.

During the panel discussion, it was concluded that performance indicators besides the PV yield are necessary to rate PV installations with multiple use and multiple benefits. The online workshops attracted many international viewers and encouraged a lively discussion (see Fig. 6).

Fig. 6 - Task 13 Workshop speakers at EU PVSEC 2020, Online Conference.

Furthermore, Task 13 experts participated in the following events in 2020:

- PV Module Technology Forum, Cologne, Germany, 18-19 Feb, 2020
- NREL Reliability Workshop, Denver, CO, USA, 24-27 Feb, 2020
- 18. Nationale Photovoltaik-Tagung, Lausanne, Switzerland, 12-13 March, 2020.
- SNEC PV Power Expo, Shanghai, 25-27 May, 2020.
- SiliconPV Conference 2020, Hangzhou, China, 01-03 June, 2020.
- Bifi PV Workshop, Hangzhou, China, 04-05 June, 2020.
- 47th IEEE Photovoltaic Specialist Conference, Online Conference, 14-19 June, 2020.
- Intersolar Europe Conference 2020, Online Conference, 16-17 June, 2020.
- 37th European PVSEC, Online Conference, 07-11 September 2020.

MEETING SCHEDULE (2020 AND PLANNED 2021)

The twenty-third PVPS Task 13 expert meeting took place on 24-26 March, 2020 (Web Meeting).
The twenty-forth PVPS Task 13 expert meeting took place on 29 Sep to 01 Oct, 2020 (Web Meeting).
The twenty-fifth PVPS Task 13 expert meeting will take place on 23-25 March, 2021 (Web Meeting).
The final PVPS Task 13 expert meeting will take place in Freiburg, Germany, 28-30 September 2021.

TABLE 1 – TASK 13 PARTICIPANTS IN 2020 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	European Energy, Birkerød
Finland	Turku University of Applied Sciences
France	Electricité de France (EDF R&D)
	Institut National de l'Energie Solaire (CEA-INES)
Germany	Fraunhofer Institute for Solar Energy Systeme (ISE)
	Institute for Solar Energy Research Hamelin (ISFH)
	TÜV Rheinland Energy GmbH (TRE)
	VDE Renewables GmbH (VDE)
Israel	Green Power Engineering Ltd.
Italy	European Academy Bozen/Bolzano (EURAC)
	Gestore dei Servizi Energetici - GSE S.p.A
	Ricerca sul Sistema Energetico - RSE 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)
Taiwan	PV Guider Consultancy
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 THE 100% RES BASED POWER SYSTEM

Fig. 1 - Solar-Siedlung Vauban and Sonnenschiff, Freiburg, Germany. Decentralized solar energy systems lead to a transformation of the building sector. The projects of the solar architect Rolf Disch take a leading role in this process Photo: © Rolf Disch SolarArchitektur info@rolfdisch.de).

INTRODUCTION

PV has today become a visible player in the electricity generation not only on a local level, but also on nationwide levels in many 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 level, as well as at the industrial level. With PV becoming a game changer on the bulk power system level in several markets, new fundamental challenges arise, which are being addressed through global cooperation.

To ensure further smooth deployment of PV and avoid potential need for costly and troublesome retroactive measures, proper understanding of the key technical challenges facing high penetrations of PV is crucial. Key issues include the variable nature of PV generation, the "static generator" characteristics through the connection via power electronics, as well as 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 allow 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 Technology Collaboration Programme, Task 14 aims at preparing the technical base for PV as a 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.

Task 14 addresses high penetration PV throughout the full interconnected electricity system consisting of local distribution grids and wide-area transmission systems. Furthermore, also island and isolated grids in emerging regions are within the scope of Task 14.

From its beginning as global initiative under the PVPS TCP, Task 14 has been supporting stakeholders from research and 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

Fig. 2 - Smart Meter Infrastructure providing secure bidirectional communication with decentralized energy systems. The Smart Meter is shown in the background. The Smart Meter Gateway (secure router) is the Connexa 3.0 CX component on the left side. The SX-module on the right side hosts the secure communication with the solar inverter, storage or e-charging wallbox (Photo: © THU, Theben AG).

work contributes to a common understanding and a broader consensus on methods to adequately evaluate the value of PV in a 100% RES based power system. The objective is to show the full potential of grid integrated photovoltaics, mitigate concerns 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, ISGAN).

Through international collaboration and its global membership base, Task 14 provides an exchange platform for experts from countries, where solar PV already contributes a significant share to the electricity supply and in countries with emerging power systems, as well as 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.

Fig. 3 - Registration process for a Smart Meter Gateway before installation: A PIN/TAN registration process for the installation of the Smart Meter Gateways implemented in Germany to improve the security of the smart grid information system (Photo: © PPC AG).

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

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. IT-Security aspects in the communication with DER is an additional important topic.

PROGRESS AND ACHIEVEMENTS

In 2020, Task 14 work focused on the preparation of joint reports and publications.

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

- In May 2020, Task 14 contributed to the IEA "Inter-TCP Meeting on Integrated Energy Systems", organized by the IEA System Integration of Renewables unit. The contribution included an overview of relevant PVPS activities as part of a joint presentation on "Modelling flexibility needs and contributions of wind/PV at system level".

Fig. 4 - Ground mounted PV system in the south of Germany. Transmission system operators need a more detailed view into the distribution network. A TSO-DSO communication framework has to be established. Curtailment of PV systems became part of the redispatch process. Daily local forecast of the solar redispatch potential has to be processed in Germany from October 2021 (Photo: © Transnet BW).

- In August 2020, Task 14 co-chaired a panel session on "Hosting Capacity Assessment with Advanced Inverters" at the 2020 IEEE PES General Meeting. The presentations addressed recent developments related to the state-of-the-art research and demonstrations activities on hosting capacity with advanced inverter functions. Panellists presented points of views from national laboratories, utilities and software companies from around the world. Task 14 experts from the USA, Australia, Austria and Germany gave talks on recent developments in the USA, Europe and Australia.

INDUSTRY INVOLVEMENT

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

In 2020, Task 14 has also been collaborating with national and international standardization bodies and 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.

In 2020, Task 14 published the following reports:

- *Communication and Control for High PV Penetration under Smart Grid Environment*
  In the report, the communication and control system architecture models to enable distributed solar PV to be integrated into the future smart grid environment were reviewed. The existing communication technologies, protocols and current practice for solar PV integration are also introduced in the report. The survey results show that deployment of communication and control systems for distributed PV systems is increasing. The public awareness on the communication and control of grid-connected solar PV systems are raising.

- *Data Model for the Grid Connection of PV Systems - Data Model and Procurement for Data Collection – Best Practice and Recommendations:*
  This report shows how different countries deal with the DER data collection, with a focus on PV systems. It also provides a complete overview of all the relevant aspects that need to be addressed and foresees information that will be relevant in the future. Different use cases are addressed and recommendations for the implementation of a database are given.

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.

Due to the global pandemic situation, the successful series of utility workshops related to high PV penetration scenarios in electricity grids were suspended in 2020, along with the cancellation of most relevant events. As soon as the restrictions are lifted, the series of events is planned to be revived in 2021.

MEETING SCHEDULE (2020 AND PLANNED 2021)

Due to the global pandemic situation, both Experts' meetings in 2020 were organised as virtual meetings.

As global travel restrictions are not expected to be lifted before the end of 2021, Experts' meetings are also planned as virtual meetings.

TABLE 1 – LIST OF TASK 14 PARTICIPANTS 2020 (INCLUDING OBSERVER)

COUNTRY	PARTICIPANT	ORGANISATION
Australia	Iain McGill	University of NSW
	Navid Haghdadi	
Austria	Roland Bründlinger	AIT Austrian Institute of Technology
Canada	Patrick Bateman	CANSIA
Chile	Ana Maria Ruz Frias	Comité Solar
China	Wang Yibo	Chinese Academy of Science
Denmark	Kenn H. B. Frederiksen	Kenergy
EC	Arnulf Jàger-Waldau	European Commission
Germany	Gunter Arnold	Fraunhofer IEE
	Martin Braun	
	Markus Kraiczy	
	Shuo Chen	Technische Hochschule Ulm
	Gerd Heilscher	
	Basem Idibi	
Italy	Giorgio Graditi	ENEA-Portici Research Centre
	Adriano Iaria	RSE – Ricerca Sistema Eletrico
Japan	Takeshi Maeno	NEDO
	Yuzuru Ueda	Tokyo University of Science
Malaysia	Akmal Rahimi	SEDA
	Koh Keng Sen	
Spain	Ricardo Guerrero Lemus	University of La Laguna
Switzerland	Christof Bucher	BFH
	Lionel Perret	Planair SA, Switzerland
United States	Barry Mather	National Renewable Energy Laboratory NREL
	Tom Key	EPRI
Singapore (observer)	Thomas Reindl	SERIS

TASK 15

ENABLING FRAMEWORK FOR THE ACCELERATION OF BIPV

INTRODUCTION

Building-Integrated PV (BIPV) can be an enabling technology to reduce CO_2 emissions in the building sector, which is responsible for nearly 40% of total direct and indirect CO_2 emissions. On the way towards zero-energy buildings, BIPV can help to cover the remaining energy demand in a way that respects architectural, aesthetic, environmental, economic and technical requirements. BIPV elements as electricity-generating construction products can replace conventional construction products. Building envelopes that can be activated with BIPV can provide a significant fraction of the area that is required by PV systems in renewable energy systems.

However, the BIPV market continues to occupy only a niche of both PV and building markets. Bringing the PV industry and the construction sector together requires several stakeholders and a number of barriers which still need to be overcome, especially regulatory, technical, economic, knowledge and communication barriers.

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.

Task 15 is currently in its second phase with a Workplan for 2020-2023, 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. 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, tools and knowledge resources that assist them.

ACTIVITIES OF IEA PVPS TASK 15 IN 2020

Task 15 is divided into five main Subtasks:

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

SUBTASK A: TECHNOLOGICAL INNOVATION SYSTEM (TIS) ANALYSIS FOR BIPV

This Subtask's aim is to identify strengths and weaknesses of the BIPV innovation ecosystem and value chain, specifically related to market development, and to propose policy and strategy measures for governments, individual firms and industry collectively. This is to be achieved by analysing national markets and value chains using the Technological Innovation System framework, a scientifically established method that is commonly used by policy makers, e.g. in the Netherlands and Sweden.

The Subtask consists of the three activities described below. Moreover, several efforts have been made to attract new countries to the Subtask in order to increase its scope and potential impact.

A.1 Guide for BIPV TIS Analysis

In this activity, an internal guide and template for the analysis of national innovation systems is developed. The main objectives of the guide are to guarantee that all national analyses are conducted in a similar way and that their results will be comparable. Furthermore, the guide will support and simplify the work of the national experts in activity A.2.

A first, well-established version of the guide has been developed during the first half year of 2020. Rather than to stop the activity there, it was decided to suspend it while the guide is put to test in the first national TIS analyses. A second and final version of the guide, updated with adjustments and extensions based on lessons learned, will be finalized during 2021.

A.2 TIS Analysis per Country

This is the central activity of this Subtask, where national experts will conduct TIS analyses for BIPV in their country. At the kick-off of Task 15, an initial group of two countries (the Netherlands and Sweden) had committed to perform a TIS analysis and two more countries expressed interest. By the end of 2020, the number of committed countries was up to five with serious interest from a further three countries.

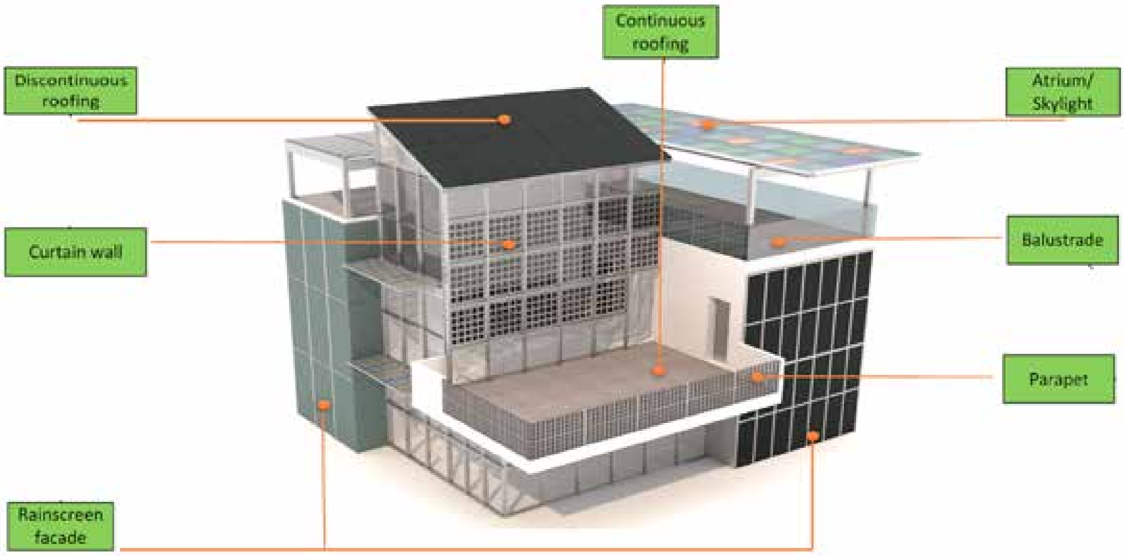

Fig. 1 - Illustration of BIPV installation scenarios categorized in activity B.2. (Source: SUPSI).

The analyses for the Netherlands and Sweden were initiated during 2020, while preparations have been made for a study of Italy. Spain and Austria secured Master Thesis students to conduct TIS analyses during 2021.

A.3 BIPV TIS synthesis

Subtask A's third activity is planned to start in 2021 and will focus on analysing and combining the respective national TIS reports. In this synthesis report, regional and/or global trends, weaknesses and strengths will be summarized and measures to accelerate global BIPV market development will be discussed.

SUBTASK B: CROSS-SECTIONAL ANALYSIS: LEARNING FROM EXISTING BIPV INSTALLATIONS

The building integration and the energy performance of existing and future BIPV installations will be determined and evaluated (via performance indicators). The development and application of a multidimensional evaluation matrix will allow for the comparison of different potential BIPV projects for a given building (as in a call for tenders). The results of the evaluation data are location-independent. The results must be transferred to the specific conditions (irradiation, grid-energy mix, etc.) at a given geographical location. This Subtask's objective is the determination, analysis and assessment of the multifunctional performance of selected BIPV plants using the newly developed multi-dimensional evaluation matrix. Subtask B is further sub-divided into the following five activities:

B.1 Definition of Performance Indicators for the Characterisation of the Electrical and Building Function of BIPV

Performance indicators for BIPV systems collected in four areas: energy-related, environmental, economic and visual impact. Completed 01.2021, report in preparation

B.2 Identification of Representative BIPV Installation Scenarios (Archetypes)

Categorization for BIPV applications, systems, modules, components and materials developed. Completed 01.2021, report in preparation

B.3 Development of a Multidimensional Evaluation Matrix

Based on the performance indicators from B.1 and the BIPV system categories from B.2. Activity in progress since 12.2020

B.4 Identify a Set of Real BIPV Installations with Available Data

B.5 Determination, Analysis and Assessment of the Multifunctional Performance and Dissemination of Best Practice Results

SUBTASK C: BIPV GUIDEBOOK

This Subtask's scope is to support the implementation of best BIPV practices and drive the decision-making process that could lead to an effective BIPV design, as well as to a resilient and robust BIPV installation while maintaining a good architecture. The objective is to consolidate existing BIPV knowledge and compile it into a technical guidebook for building professionals (architects, engineers and consultants). This Subtask follows a holistic approach to the design, implementation, operation and maintenance of BIPV systems, considering the expertise within not only the Subtask and Task 15, but also the BIPV and building industry.

STC has 16 participants from 11 countries, and more than 20 BIPV observers from 15 countries. Eight of the participants constitute the multidisciplinary editorial team for the development of the BIPV Guidebook.

Fig. 2 - One of the selected BIPV projects analysed for the guidebook in preparation: BIPV roof at Varennes Library, Canada, and corresponding technical CAD drawings.

Subtask C's Activities and Status:

This Subtask has the single task of developing and publishing a technical BIPV guidebook. During 2020, Subtask C's main activities have focused on:

- Identification of more than 50 representative international BIPV projects (and related products) and collection of preliminary technical information;
- Collection of in-depth technical information for 38 selected international BIPV projects;
- Development of the guidebook's chapter dedicated to BIPV requirements.

Monthly Subtask online meetings and two editorial meetings have been held to coordinate activities between participants, provide updates and ensure that internal deadlines and deliverables are met. Finally, STC has a strong collaboration with and provides input to STD (Activity D2, by connecting to key national and international industry-based organizations for the distribution of the survey) and STE (activity E3 by sharing technical information associated to fire safety for existing BIPV projects).

SUBTASK D: DIGITALIZATION FOR BIPV

Since building professionals currently rely on digitalised tools and skills to implement the building design, simulation and assessment process, Subtask D will enable BIPV to be applied speedily in the era of digital twins. Subtask D's experts aim to identify operative approaches, methods and workflows relevant under each domain of BIPV digitalised design and management, collect requirements for digital product data models from the perspective of different stakeholders, as well as define the main information modelling/ management (IM) strategies to effectively implement a digital process to improve interoperability along the value chain and pre-normative recommendations and standards, and explore the decision-making process with data mining.

A global survey was conducted in 2020 (D2). The aim of the survey is to investigate the operative methods and workflows relevant to building envelope design and digital processes and formalize a framework for design and management of BIPV projects. The survey was distributed through 20 professional bodies/channels in 13 countries. More than 80 valid responses have been collected. A report on the survey results is in preparation and will be completed later in 2021.

Regarding the data management of digital product data models (D3), the major activities are: literature review of existing digital product data models for BIPV in existing tools, databases, national and international BIM standards and guidelines and scientific literature; collection of requirements for digital product data models from the perspective of different stakeholders, and comparison between requirements and existing approaches. D3 started in 01.2021.

Regarding the digital BIM-based process for BIPV (D4), in 2021, the major work in this activity is to map out the current workflow based on the outcomes in D2.

Regarding the BIPV project case data mining (D5), this activity will be started in 2021 once the BIPV performance matrix in STB is confirmed.

SUBTASK E: PRE-NORMATIVE INTERNATIONAL RESEARCH ON BIPV CHARACTERISATION METHODS

The aim of Subtask E is to carry out pre-normative international research to develop new and optimized characterization methods for BIPV modules and systems, based on the topics identified during the first phase of IEA PVPS Task 15 and by analysis of national building codes that are relevant to BIPV installations. Both experimental and model-based approaches are being pursued. Many of the participants in the first phase of Task 15's Subtask C on the "International Framework for BIPV Specifications" are also participating in the current Subtask E and ensuring continuity in the work, but there are also new participants who have joined, increasing the number of countries represented. As with the previous Subtask C, the current Subtask E benefits from close cooperation with IEC TC 82 and CENELEC TC 82. As a result, significant contributions from Task 15 participants were included in the IEC BIPV standard, IEC 63092, which was published in September 2020. Also, within the reporting period, the final report from the previous Subtask C, entitled "Multifunctional

Characterisation of BIPV - Proposed Topics for Future International Standardisation Activities" (report IEA-PVPS T15-11:2020) was published in May 2020 and provides a useful basis for the work in the current Subtask E.

Subtask E (STE) is now sub-divided into four activities. Aspects of outdoor measurement, originally planned as a separate activity E2, will be taken into account within Activities E1 and E5. Each activity leader has been identified and leads his or her working group. Regular Subtask E conference calls ensure the exchange of information between the different Activities and with IEC TC 82 and CENELEC TC 82.

E.1 Determination of SHGC/g Value (Hisashi Ishii, Japan and Patrick Hendrick, Belgium)

An overview table of international standards on SHGC/g value has been prepared and is available for consultation by the E1 participants. In order to quantify the effect of the electrical state (MPP or open circuit) and other parameters on the solar heat gain coefficient (SHGC) of semi-transparent BIPV, the group agreed on the set of fixed and variable parameters for a sensitivity study by calculation, which is currently in progress. A proposal has been made by Hisashi Ishii for a New Project on SHGC of BIPV within the planned IEC/ISO joint working group on BIPV.

E.3 Fire Safety of BIPV Modules and Installations (Veronika Shabunko, Singapore)

An overview of the fire testing facilities in different countries is being prepared, with contributions from 13 different countries already submitted. The referenced fire safety standards and regulations also provide a starting point for the planned review of the regulatory situation with regard to BIPV installations.

E.4 Electrical and Mechanical Safety and Reliability of BIPV (Fabio Parolini, Switzerland)

Information was initially gathered on relevant testing facilities and methods accessible to participants as a starting point. Current work is focusing on preparing an updated overview of the state of the art, drawing on the report IEA-PVPS T15-11:2020 mentioned above, work of the BIPVBoost project and national construction codes. The aim is to identify missing gaps in the testing procedures which could be filled by research benefitting from the expertise represented by the participants.

E.5 Standardised Procedures to Quantify the Annual Electricity Yield of Installed BIPV systems (Fred Edmond Boafo, Korea)

Metrics have been defined to evaluate the agreement between the modelled and monitored electricity yield of BIPV installations. Participants are currently applying the SAM tool from NREL to model the yield from BIPV installations in five countries where the necessary meteorological and electrical parameters are monitored.

Fig. 3 - Complete BIPV building envelope at the Wohnhaus Solaris in Zürich by huggenbergerfries. Coloured modules from ertex solar (Photo: © ertex solar, Dieter Moor).

SELECTION OF OUTREACH EVENTS – 2020

- February 2020: Webinar on "Coloured BIPV - Market, Research and Development"
- September 2020: 37th EU-PVSEC and associated BIPV Task 15 parallel event, online
- October 2020: Solelmässan (Solar electricity exhibition), online event, Sweden
- November 2020: PVPS parallel event at PVSEC, Jeju, Korea

PUBLICATIONS AND DELIVERABLES

- Report "Multifunctional Characterisation of BIPV - Proposed Topics for Future International Standardisation Activities" (Report IEA-PVPS T15-11:2020)
- Report "Development of BIPV Business Cases – Guide for Stakeholders" (Report IEA-PVPS T15-10:2020)

MEETING SCHEDULE (2020 AND PLANNED 2021)

- **1st Task 15 Experts Meeting** of phase 2: combined online and in-person meeting in Freiburg, 11th-13th March 2020
- **2nd Task 15 Experts Meeting**: online, 30th October-3rd November 2020
- **3rd Task 15 Experts Meeting**: planned for mid-2021 as online meeting.
- **4th Task 15 Experts Meeting**: planned as in-person meeting at the end of 2021.

TABLE 1 – CURRENT LIST OF TASK 15 PARTICIPANTS

COUNTRY	PARTICIPANTS	ORGANISATION
Australia	Rebecca Yang	RMIT University
Austria	Karl Berger	AIT
	Momir Tabakovic	University of Applied Sciences Technikum Vienna
	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
	David Rinnerthaler	University of Applied Sciences Salzburg
Belgium	Patrick Hendrick	Université libre de Bruxelles
	Jonathan Leloux	Lucisun
	Philippe Macé	Becquerel Institute
	Jens Moschner	KU Leuven / Energyville
Canada	Veronique Delisle	Natural Resources Canada
	Costa Kapsis	University of Waterloo
	Andreas Athienitis	Concordia University
	Hua Ge	
China	Limin Liu	China Renewable Energy Society
	Duo Luo	Zhuhai Singyes Co.
	Pengfei Chen	Longi
Denmark	Karin Kappel	Solar City Denmark
Finland	Janne Halme	Aalto University
	Farid Elsehrawy	
Germany	Helen Rose Wilson	Fraunhofer ISE
	Johannes Eisenlohr	
	Astrid Schneider	Solar Architecture
France	Simon Boddaert	CSTB
	Jerome Payet	Cycleco
	Ioannis Tsanakas	CEA-INES
Italy	Francesca Tilli	GSE
	Alessandra Scognamiglio	ENEA Research Center Portici
	Laura Maturi	EURAC
	Jennifer Adami	
	Carolina Girardi	Universita di Napoli
	Enza Tersigni	
Japan	Hiroko Saito	PVTEC
	Hisashi Ishii	LIXIL
	Seiji Inoue	AGC
	Michio Kondo	AIST
	Takuya Matsui	
Korea	Jun-Tae Kim	Kongju National University
	Fred Edmond Boafo	
The Netherlands	Michiel Ritzen	Zuyd University of Applied Sciences
	Zeger Vroon	
	Tjerk Reijenga	bear-ID
	Otto Bernsen	RVO
	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
	Ragni Fjellgaard Mikalsen	RI.SE
	Tore Kola	SINTEF
	Jens Hanson	UiO
	Gaute Otnes	IFE
Spain	Nuria Martin Chivelet	CIEMAT
	Eduardo Román	Tecnalia
	Asier Sanz	
	Jose Maria Vega	
	Elena Rico	Onyx
	Juan Manuel Espeche	R2M
	Teodosio Del Cano	Onyx
Sweden	Michiel van Noord	RI.SE
	Bengt Stridh	Mälardalen University
	Peter Kovacs	RI.SE
	Rickard Nygren	White arkitekter
	Kersti Karltorp	RI.SE
	Anna Svensson	Soltech Energy
Switzerland	Francisco Frontini	SUPSI
	Pierluigi Bonomo	
	Fabio Parolini	
	Erika Saretta	
	Peter Roethlisberger	Solaxess
	Karl Viridén	Viridén + Partner
Singapore (observer)	Veronika Shabunko	SERIS

TASK 16

SOLAR RESOURCE FOR HIGH PENETRATION AND LARGE SCALE APPLICATIONS

INTRODUCTION

Solar resource Tasks have a long tradition in the IEA Technology Collaboration Programmes (TCP). The first Task dealing with resource aspects was IEA Solar Heating and Cooling (SHC) started in 1977. The current solar resource Task was started mid-2017 in the IEA PVPS TCP and runs until June 2023.

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.

IEA PVPS Task 16 currently includes 49 participants of 18 countries.

OVERALL OBJECTIVES

The main goals of Task 16 are to lower barriers and costs of grid integration of PV, as well as lowering planning and investment costs for PV by enhancing the quality of the forecasts and the resources assessments. Solar resources are introducing the highest share of uncertainty in yield assessments.

To reach these main goals, Task 16 has the following objectives:

- Lowering uncertainty of satellite retrievals and Numerical Weather Prediction.
- 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.
- Develop enhanced analysis for e.g. point to area forecasts, solar trends, albedo, solar cadastres and firm PV power.
- Contribute to or setup an international benchmark for data sets and for forecast evaluation.

The scope of Task 16's work concentrates on meteorological and climatological topics needed to plan and run PV, solar thermal, concentrating solar power stations and buildings.

SUBTASKS AND ACTIVITIES

On one hand, Task 16's work programme addresses scientific meteorological and climatological issues to high penetration and large scale PV in electricity networks, but also includes a strong focus on user needs. Dissemination and user interaction is foreseen in many different ways from workshops and webinars to paper and reports and online code archives.

The project involves key players in solar resource assessment and forecasting at the scientific level (universities, met services and research institutions) and commercial level (companies). The Workplan is focused on work that can only be done by international collaboration, such as definition and organization of benchmarks, definition of common uncertainty and variability measures.

The work programme is organized into three main technical Subtasks (Subtasks 1 – 3) and one dissemination Subtask (Subtask 4), including three to four activities (Table 1):

TABLE 1 – TASK 16'S SUBTASKS AND ACTIVITIES

SUBTASK	ACTIVITY
Subtask 1: Evaluation of current and emerging resource assessment methodologies	1.1 Ground based methods
	1.2 Modelling for NWP / satellite data
	1.4 Benchmarking Framework
Subtask 2: Enhanced data & bankable products	2.1 Data quality and format
	2.4 Long-term inter-annual variability
	2.5 Products for the end-users
	2.6 PV at urban scales
	2.7 Data and models for bifacial modules
Subtask 3: Evaluation of current and emerging solar resource and forecasting techniques	3.2 Regional solar power forecasting
	3.3 Probabilistic solar forecasting
	3.4 Forecasts based on all sky imagers
	3.5 Firm power generation
Subtask 4: Dissemination and Outreach	4.2 Produce a periodic Task Newsletter
	4.3 Conduct periodic (annual) Subtask-level webinars and/or conference presentations
	4.4 Update of solar resource handbook
	4.5 Solar Resource Assessment in Python

ACCOMPLISHMENTS OF IEA PVPS TASK 16

In 2020, the first report of Task 16 has been published (https://iea-pvps.org/key-topics/regional-solar-power-forecasting-2020/). The final and main result of the first three years of the Task – the update of the solar resource handbook – has been written and is currently under final review (Version 2017 was published at NREL: https://www.nrel.gov/docs/fy18osti/68886.pdf). Figure 1 shows the overview of which data for which state of a project is used for what size of system.

Webinar on "Products for the end-users"

In June 2020, a webinar was given by the group under the lead of Birk Kraas and Anne Forstinger of CSP Services (with own webinar tool). The topic was "Products for the end-users" (covered by sub-activity 2.5). The webinar was held instead of a workshop at Intersolar Europe Conference, which was cancelled due to the COVID-19 pandemic. Speakers were: Birk Kraas, Jan Remund, Manuel Silva (Univ. Sevilla), Carlos F. Perruchena (Cener), Philiipe Blanc (Mines Paristech) and Robert Höller (FHOO).

Webinar on "Updates on solar forcasting and other solar resource work of IEA PVPS Task 16"

In August 2020, a webinar was given under the lead of Elke Lorenz and Carmen Köhler (Subtask 3 co-leaders). The topic was "Updates on solar forcasting and other solar resource work of IEA PVPS Task 16". It was presented on the ISES webinar channel. Speakers were: Dave Renne, Jan Remund, Lennard Visser (Univ. Utrecht), Patrick Keelin (Cleanpower Res.), Richard Perez (SUNY) and Dennis van der Meer (Univ. Uppsala). The webinar is available online: https://youtu.be/7uOXjdhkHao

Report on benchmarking of spatial aggregation methods

In May 2020, Task 16's first report was released (Betti et al., 2020). In this work, the accuracy of several upscaling methods for regional PV power forecast were compared.

The upscaling approaches are applied to map meteorological forecasts of numerical weather prediction (NWP) models to regional PV power generation. All the upscaling methods used in the study directly predict the regional PV power generation, i.e. they consider the PV power output of the whole PV fleet (rather than predicting PV power for a representative set of PV power plants).

The focus of this work is on the comparison of different PV power upscaling methods. Since accuracy of a PV power forecast model is greatly affected by the input NWP data, the same NWP forecast has been used within each case study. Among the benchmarks methods there are artificial neural networks, analog ensembles, cooperative ensembles of machine learning algorithms, quantile regression forests, random forests and gradient boosted regression trees. These methods use state-of-the-art machine-learning approaches and allow researchers to compare their new models against them.

Probabilistic forecast evaluation is not in the scope of this report, although several models presented are capable of producing probabilistic forecasts. Besides the description of the benchmark models, the report also describes several feature engineering techniques and pre-processing procedures aimed at improving the accuracy of the benchmarks presented herein. The

System Size →

Phase ↓

	Small	Medium	Large
1. Pre-feasibility & Planning	• Long-term averages • Monthly data • Solar cadastres / maps • Simple shading analysis	• TMY • Hourly data • Shading analysis	• Long-term satellite data • Hourly data
2. Feasibility			• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
3. Due diligence & Finance		• Satellite data • Time series (>10 y) • Minute data • Shading • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)	• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Minute data • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
4. Operation & Maintenance	• Simple monitoring	• Local measurements • Forecasts	• Local measurements • Forecasts

Fig. 1 - Data application techniques for the various stages of project development.

accuracy of the benchmark models is assessed extensively, both quantitatively and qualitatively. The forecasts and measurements are normalized with respect to the installed capacity in the area.

For the PV power forecasts at the zonal levels of Italy, the analog ensemble model achieves a root mean squared error (RMSE) skill score between 20% and 36% and a mean bias error (MBE) between -1.9% and 1.5% for all forecast horizons (i.e., 1-3 days ahead). Considering the 24h ahead forecasts of the entire PV fleet of Italy, the benchmarks achieve an RMSE skill score between 28% and 47%, while the MBE lies between 0.1% and 1.9%.

The so called "smoothing effect" has been also investigated over Italy, demonstrating that the RMSE decreases with the root of the area under control following an exponential or hyperbolic trend and decreasing from almost 5.5% of the installed capacity on average over market zones down to 3.6% over Italy. In addition, blends of the models are also applied to this dataset, which improves the RMSE skill score from 47% (the best model) to 51% using a nonlinear blending technique. Finally, the benchmark models achieve RMSE skill scores between 42% and 44% on the PV power production forecasts over the province of Utrecht, the Netherlands, while the MBE lies between 0% and 0.8%.

PUBLICATIONS

Betti, A., Pierro, M., Cornaro, C., Moser, D., Moschella, M., Collino, E., van Sark, W. G. J. H. M. (2020). Regional solar power forecasting 2020. Report IEA-PVPS T16-01: 2020. ISBN 978-3-906042-88-6. https://iea-pvps.org/key-topics/regional-solar-power-forecasting-2020/

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Perez, Marc, Richard Perez, Karl R. Rabago, Morgan Putnam, Overbuilding & curtailment: The cost-effective enablers of firm PV generation, Solar Energy, Volume 180, 2019, Pages 412-422, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2018.12.074. (http://www.sciencedirect.com/science/article/pii/S0038092X18312714)

IEA PVPS Task 16 has an own project site on Researchgate: https://www.researchgate.net/project/IEA-PVPS-Task-16-Solar-resource-for-high-penetration-and-large-scale-applications

MEETING SCHEDULE 2020 AND PLANNED 2021

Task 16's Operating Agent, Jan Remund from Meteotest organised two official Task meetings in 2020. Due to the COVID-19 pandemic, they were held online with Zoom. The main meetings in spring and autumn were each split into a general session and three technical sessions covering the Subtasks. Each of them took approximately 2.5 hours.

- March 25-26th, April 3rd-7th 2020: **6th Task 16 Experts Meeting** (online instead of Meeting in Rome, Italy)
- November 3-6th: **7th Task 16 Experts Meeting** (online, instead of Meeting in South Korea)
- For 2021 two meetings are foreseen:
- March 17-19th 2021: **8th Task 16 Experts Meeting** (online)
- September 20-22nd 2021: **9th Task 16 Experts Meeting** (Rome, Italy)

TABLE 2 – TASK 16 PARTICIPANTS IN 2020 AND THEIR ORGANIZATIONS

COUNTRY	TCP	ORGANISATION	PARTICIPANT
Australia	PVPS	Univ. of New South Wales	Merlinde Kay
		University of South Australia	John Boland
		Solcast	Jing R. Huang
Austria	PVPS	University of Applied Sciences Upper Austria	Robert Höller
Canada	PVPS	Natural Resources Canada	Sophie Pelland
Switzerland	PVPS	Meteotest	Jan Remund
		Eastern Switzerland University of Applied Sciences	Christof Biba, Michael Haller
Germany	PVPS Solar-PACES	Fraunhofer (ISE & IEE)	Elke Lorenz
		DLR (both TCP)	Stefan Wilbert
Denmark	PVPS	Danish Meteorological Institute	Kristian P. Nielsen
		Technical University of Denmark	Adam Jensen, Simon Furbo

COUNTRY	TCP	ORGANISATION	PARTICIPANT
Spain	PVPS Solar-PACES	CIEMAT (both TCP)	Jesus Polo, José L. Balenzategui
		CENER	Carlos Fernández Peruchena
		Public University of Navarra	José Luis Torres Escribano, Marían de Blas Corral, Ignacio García Ruiz
		University of Jaen	David Pozo Vazquez
		University of Seville	Manuel A. Silva Pérez, Miguel Larrañeta, Sara Moreno-Tejera
		University of Malaga	José Antonio Ruiz-Arias
		Universidad de Las Palmas de Gran Canaria	Luis Mazorra Aguiar, Albert Oliver Serra
		Univ. Almeria	Joaquín Alonso Montesinos
EU	PVPS	JRC	Ana Gracia-Amillo
France	PVPS	MINES ParisTech	Philippe Blanc, Yves-Marie Saint-Drenan
		Lab. PIMENT, Université la Réunion,	Philippe Lauret, Mathieu David
		EDF R&D	Stéphanie Dubost
		Univ. des Antilles et de la Guyane	Ted Soubdhan
		Reuniwatt	Nicolas Schmutz
		Ecole Polytechnique à Palaiseau	Jordi Badosa, Sylvain Cros
Italy	PVPS	i-em	Alessandro Betti
		Univ. Roma 2	Cristina Cornaro, Marco Pierro
		RSE	Elena Collino, Dario A. Ronzio
Netherlands	PVPS	Univ. Utrecht	Wilfried van Sark
Norway	PVPS	Arctic University	Tobias Boström
Sweden	PVPS	SMHI	Sandra Andersson, Tomas Landelius
		Univ. Uppsala	Dennis van der Meer, Joakim Widen
		AFconsult	Marco Cony
USA	PVPS	National Renewable Energy Laboratory (NREL)	Manajit Sengupta
		National Aeronautics and Space Administration (NASA)	Paul Stackhouse
		State Univ. of New York at Albany	Richard Perez
		Univ. of California San Diego	Jan Kleissl
		University of Oregon	Frank Vignola
		Clean Power Research	Dave Renne, Skip Dise
		Solar Consulting Services	Chris Gueymard
Great Britain	SHC	Peakdesign Ltd.	John Wood
		Rina Consulting	Daniel Ruiz
		World Energy & Meteorology Council	Alberto Troccoli
		Univ. of Strathclyde	Jethro Browell
Slovakia	SHC	Solargis	Marcel Suri, Tomas Cebecauer
Greece	Solar-PACES	Univ. of Patras	Andreas Kazantzidis
Morocco	Solar-PACES	IRESEN	Abdellatif Ghennioui

TASK 17

PV AND TRANSPORT

Fig. 1 - PV-powered vehicles driving on the road in Japan (Photo: NEDO).

OVERALL OBJECTIVES

The main goal of Task 17 is to deploy PV in the transport, which will contribute to reducing CO_2 emissions of the 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 to proposal 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, and PV applications for electric systems and infrastructures, such as charging infrastructure with PV, battery and other power management systems.

Task 17 consists of the following four Subtasks under the Workplan:

- 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 2020

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 vehicles 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 state-of-the-art of PV-powered vehicles and related information including present technology regarding design of PV cell/modules integrated into vehicles and their likely evolution and ultimate potential in terms of costs and performance.

Activities 1.2 and 1.3 are focusing on PV-powered passenger vehicles. Activities on vehicle test, simulation model analysis and market survey have been conducted in Australia, the Netherlands, Switzerland, and Japan.

A test vehicle equipped with four irradiance sensors was assembled and tested to measure irradiance under the Netherlands project. The data of vehicle irradiance was compared to KNMI data (fixed point). Dynamic shading under overpass was also analysed. Task 17's Australian team developed an advanced measurement system; crowdsource vehicle irradiance measurements by using irradiance sensor. A road test was conducted during a 568 km daytrip from Sydney to Canberra. Vehicle irradiance monitoring was conducted in Melbourne and a lot of data during 123 days and from 64,000 data points were collected and analysed. 80% of solar irradiance falls on the vehicle when parked. Task 17's Switzerland team has conducted vehicle tests and concludes the vehicle gets around 75% of GHI, and the parking situation is dominant. Vehicle tests have also been conducted in Japan. More than 90% of passenger vehicles are parked during daylight hours, and vehicle irradiance depends largely on parking conditions. Two types of demonstration passenger vehicles, a plug-in hybrid EV with 860 W-PV and a battery EV with 1,150 W-PV, were developed by a NEDO project and have been tested under the actual driving/ parking conditions.

An energy flow model was developed by Task 17's Netherlands team to evaluate the energy flows of on-board PV generation and SOC of batteries of EVs. Expected CO_2 reduction and cost savings by on-board 800W-PV, without shade, were analysed. Also, Japan estimated CO_2 savings and the reduction in the number of plug-in charging were estimated under various driving/parking conditions in Japan.

Activity 1.4 is focusing on PV-powered commercial vehicles. Currently, light commercial vehicles, cooling trucks and heavy-duty vehicles are being discussed. A study on the transient behaviour of the shading during a drive through the urban environment was carried out under Task 17's project in Germany. A LCA study on environmental impacts of integrating PV modules on vehicles concluded that GHG emission by PV-powered commercial vehicles may be larger than conventional PV, and PV-powered commercial vehicles will contribute to reducing GHG emission of EVs compared to charging grid-mix electricity. Degrees of reduction will be depending upon solar irradiation, shadowing scenario, operational years, GHG emissions from grid-mix including electricity for PV production stages, etc. Also, Task 17's expert from Spain has been performing a study on PV-powered reefer trailer trucks.

The results of Subtask 1's findings above will be published in 2021, as the first Task17 technical report.

SUBTASK 2: PV-POWERED APPLICATIONS FOR ELECTRIC SYSTEMS AND INFRASTRUCTURES

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

Subtask 2 consists of following activities:

- Activity 2.1: State-of-the-art of PV-powered Applications for Electric Systems and Infrastructures
- Activity 2.2: Requirements, Barriers and Solutions
- Activity 2.3: New Services
- Activity 2.4: Social Impact and Social Acceptance of New Associated Services

Subtask 2 aims at presenting the intelligent infrastructure dedicated to the recharge of EV (IIREV) as a charging station empowered by PV-based micro-grid, for example. Based on surveying literatures regarding a state-of-the-art and discussions with the PV industry, micro-grid experts, and automotive industry, Activities 2.1 and 2.2 summarize requirements, barriers and solutions for PV-powered applications for electric systems dedicated for EV charging. The real-time rule-based algorithm for EV charging stations empowered by direct current (DC) micro-grids are very often presented in the literature. Such a DC micro-grid model consists of EVs, an electrochemical storage system, a public grid connection, and photovoltaic sources. Currently, a state-of-the-art for PV charging station and IIREVs has been investigated and will be developed as a Task 17 technical report.

Activity 2.3 has discussed new services realized by IIREV such as V2G and V2H. There are still many difficulties to unravel and solutions to find. In order for the V2G/V2H systems to be commercialised, it is necessary to deeply study the technical characterization of these new services associated with the PV-powered infrastructure for EV charging.

At present, the study and knowledge about the EV users' habitus are too rarely taken into account during the charging stations project stages. Therefore, social impact and social acceptance of IIREV and new associated services are discussed as Activity 2.4.

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 by 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 THE 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;

- Possible global contribution and benefits;
- Survey and discussion with the PV industry, the network operators, the storage industry and the automotive industry.

In addition, resilience of PV-powered vehicles will be discussed under Subtask 3. Expected advantages of resilience in PV-powered vehicles will be: Low risk of empty battery, spontaneous move to sunshine, transferring both energy and goods, self-sufficient energy at the point of consumption (regional shelters) and energy accommodation. Quantifying such resilience will be valuable.

SUBTASK 4: DISSEMINATION

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

Task 17 implemented the following dissemination activities in 2020:

- Contribution to 'Special Session: Towards 100% Renewable Energy' at the 47th IEEE-PVSC on 16 June 2020;
- Organizing and presentations at 'Solar Mobility Forum' on 16 September 2020;
- Contribution to the IEA PVPS Workshop: PV Powering the Energy Transition: a Look at Innovations & Latest Trends, at the PVSEC-30 on 10 November 2020.

Additionally, Task 17 members contributed to the 37th EU-PVSEC in September 2020, and 'Solar in Mobility and Transport Systems', organized by a Dutch consortium on 15 October 2020.

MEETING SCHEDULE [2020 AND PLANNED IN 2021]

The **4th Task 17 Experts Meeting** was organized online, on 18-20 May 2020.
The **5th Task 17 Experts Meeting** was organized online, on 30 October, 2 and 5 November 2020.
The **6th Task 17 Experts Meeting** will be organized online on 26-28 May 2021.
The **7th Task 17 Experts Meeting** will be organized in December 2021, in conjunction with the PVSEC-31 (tbd).

ACTIVITIES PLANNED FOR 2021

Task 17 will continue to discuss and implement activities for deployment of its concept: PV and Transport, and first results coming from Subtask 1 and Subtask 2 will be published as technical reports. Dissemination activities at the international conferences and communication with stakeholders will be organized as well.

EXPECTED DELIVERABLES

The following technical reports will be published in 2021:

- State-of-the-art and Expected Benefits of PV-powered Vehicles (T17-1: 2021)
- PV-Powered Electric Vehicle Charging Stations: Preliminary Requirements and Feasibility Conditions (tentative title) (T17-2: 2021)

DISSEMINATION ACTIVITIES

Dissemination activities based on the technical reports will be planned.

TABLE 1 - LIST OF TASK 17 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
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)
France	Manuela Sechilariu	Université de Technologie de Compiègne
	Youssef Kraiem	
	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 Research & Technologies, Ltd.
	Kenji Araki	University of Miyazaki
Morocco	Aboubakr Benazzouz	Green Energy Park
The Netherlands	Ruud Derks	IM Efficiency
	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	Eduardo Roman Medina	TECNALIA

TASK 18

OFF-GRID AND EDGE-OF-GRID PHOTOVOLTAIC SYSTEMS

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 (concluded in 2004), Task 9 – Large-Scale Deployment of PV in Emerging and Developing Regions (concluded in 2018) and Task 11 – PV Hybrid Systems within Mini-grids (concluded in 2011), Task 18 will dedicate the majority of its efforts to exploring the new technologies, systems, markets and environments within these types of systems are being developed. The overall objective of Task 18 is to:

1. Obtain 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 PVPS Task was concluded, 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.

APPROACH

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 a Workplan, as well as its first face-to-face meeting in February, 2020, at the Technical University of Delft, in Delft, Netherlands. At this meeting, the Task 18 Workplan was discussed and updated and assignments were made for activities which were deemed the first priority for Task 18.

Since then, Task 18 has been challenged by the COVID-19 pandemic, but has regrouped by organising monthly teleconference meetings in order to keep making progress.

The activities which have been resourced are described in further detail below in the Subtask sections. An activity which has run in parallel to the Workplan of creating a global case study map of off-grid systems has employed two post-graduate students from the University of New South Wales and who are working with the Australian representative from Mission Innovation Challenge #2 (MICh2). Task 18 and MICh2, via the post-graduate students, have performed outreach activities to collect data from recent off-grid projects around the globe. To date, Task 18 has collected 13 completed case studies from seven countries and has another 27 case studies that have nearly been completed which will cover 14 countries. The interactive map (https://task-18.com/task-18) which displays these case studies is now complete and an example of its display is shown below.

The map is now live and will be handed over to Morocco to continue the work that Australia has started. Morocco will focus on gathering more case studies from the African region.

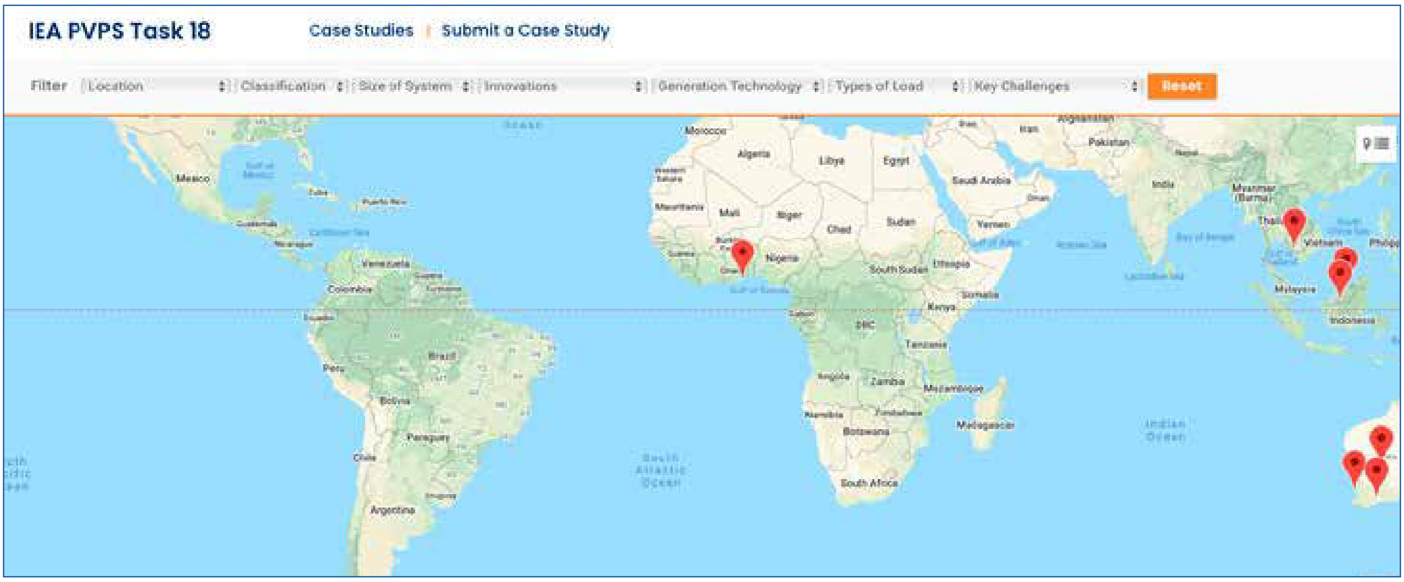

Fig. 1 - Task 18's interactive map (https://task-18.com/task-18) displays collected case studies.

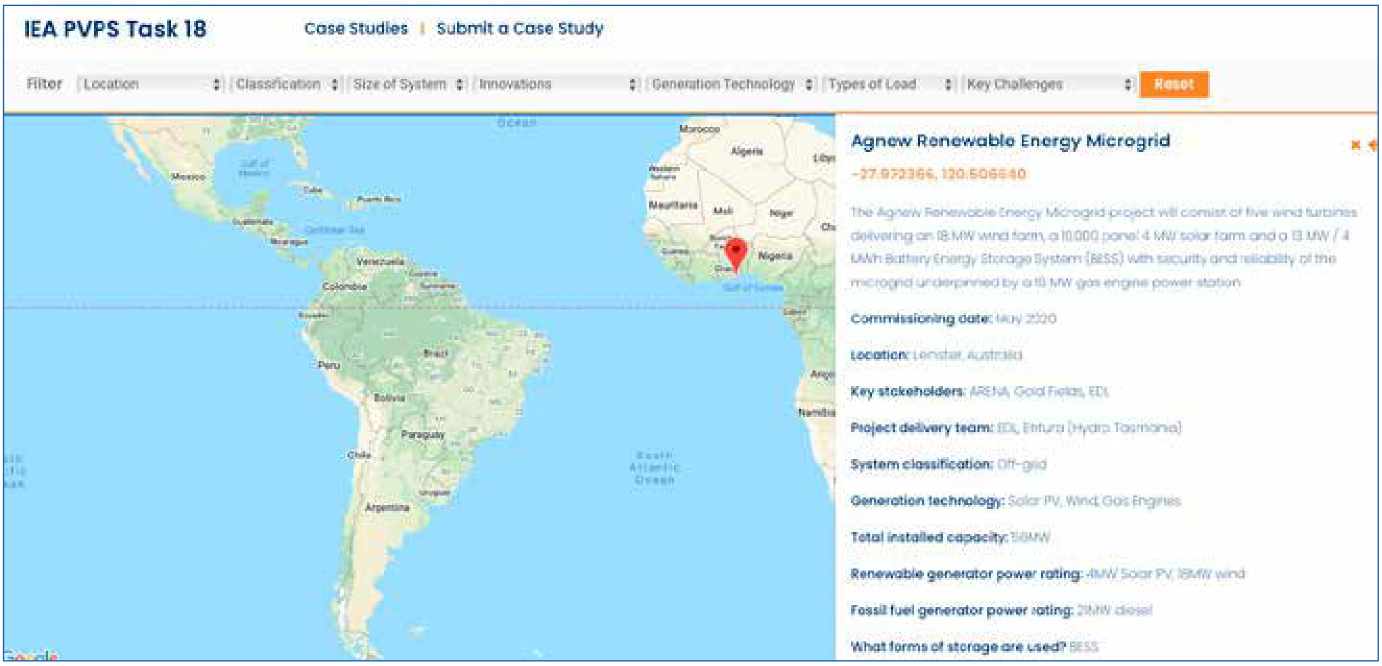

Fig. 2 - One case study as seen on Task 18's global case study map of off-grid systems.

SUMMARY OF TASK 18 ACTIVITIES

Since the Delft, Netherlands Task 18 meeting, Task 18 has met virtually 10 times in order to progress its various initiatives.

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

The 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 are led by Michael Mueller from OFRES (Germany) and all Task 18 Experts support Activity 1.1. Activity 1.1 has begun by collecting global case studies of off-grid and edge-of-grid PV systems which utilise Lithium-Ion energy storage systems. These case studies will differ from the parallel Activity done in collaboration with MICh2, in that these case studies specifically focus on Lithium-Ion Energy Storage Technology. The case studies are collected so that the following questions can be asked of each case study:

- What benefits does Lithium-Ion bring to this project?
- What risks does Lithium-Ion pose and how have these risks been mitigated?
- How has Lithium-Ion affected the business case?
- If this project were done with Lead Acid technology, what would be the key differences?
- How has the project been affected operationally by using Lithium-Ion (ie. Commissioning and Handover, Operations and Maintenance, End-of-Life, etc.)

Activity 1.1 has put together a matrix in order to collect data from various systems. To date, Activity 1.1 is still in the data gathering phase.

Activity 1.2 is led by Pablo Diaz Villar of University of Alcalá, Madrid, Spain. This activity is concerned with the compatibility of off-grid systems as they grow, as well as the potential of two or more off-grid systems interconnecting. This activity, in a large part, conducts a comparison of global grid codes as they pertain to off-grid systems. The comparison identifies where grid codes overlap, where there is compatibility and where there are limitations. The activity also discusses how to forecast and mitigate suppressed demand and how to ensure power quality in growing isolated microgrids. This activity has progressed with the aggregation of grid codes from various countries and the next step will be to assess each one for overlaps and variances.

Dr. Pavol Bauer and Laura M. Ramirez Elizondo have begun work on Activity 1.4 which will take a cross section of design tools and optimisation models used for off-grid PV systems. This activity assesses which off-the-shelf tools and modelling programs are used for commercial system design and optimisation. Activity 1.4 seeks to find correlations and key differences between the tool sets, as well as to perform a gaps analysis on the tool sets.

SUBTASK 2- FINANCIAL OPTIMISATION IN HYBRID OFF-GRID SYSTEMS

Subtask 2 is led by Dow Airen from Rolls Royce, representing Australia, and Lachlan McLeod from Ekistica, also representing Australia. This Subtask specifically looks at the financial optimisation of hybrid off-grid systems (hybrid being generator set combined with renewables). Subtask 2 provides an in-depth analysis on the constraints and variables required to create a model and also reviews currently available modelling software against these predefined constraints in variables in order to conduct a gaps analysis.

This Subtask continues 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.

Subtask 2 will also write a best practice guide for conducting project feasibility where the project approval criteria address social, environmental and economic factors. This guide could be used by NGOs and equity holders who require government and community engagement. To date, a blueprint for this best practice guide has been produced and funding is being sought to turn this into a full report for Task 18 to publish. Task 18 is looking to complete this work by September 2021.

SUBTASK 3 – OPERATION AND MAINTENANCE OF REMOTE AREA POWER SYSTEMS

Subtask 3 reviews 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 include local skill sets, weather conditions, logistics difficulties, environmental constraints/hazards, telecom quality/availability, 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 also addresses 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 organizations such as the Alliance for Rural Electrification, the International Renewable Energy Agency (IRENA), and Mission Innovation Challenge # 2 (MICh2).

UPCOMING ACTIVITIES

Task 18 continues to develop detailed activities within the existing Task 18 Workplan and seeks to assign responsibilities and deadlines to these activities. Task 18 is also seeking to add resource to the Task, in order to reach a critical mass necessary to achieve its Workplan set forth in the given timeline

MEETING SCHEDULE (2020 AND PLANNED 2021)

The 1st **Task 18 Experts Meeting** (Kick-Off Meeting) was held in Delft, The Netherlands, in February 2020.
The 2nd **Task 18 Experts Meeting** was held as an online meeting, in August 2020.

Monthly online Task 18 Experts Meetings were held during the rest of 2020.

In 2021, due to the ongoing COVID-19 crisis, Task 18 plans to continue it Expert Meetings on a monthly basis in order to progress its agenda.

DISSEMINATION ACTIVITY SCHEDULE IN 2021

Expected Deliverables

- Activity 1.1 – PV Systems Hybrid Analysis (Task 9 Conclusion Document) – June 2021
- Activity 1.4 – Digitisation in Off-Grid PV Systems Part 1: Market analysis of existing design tools and optimisation models: December 2021
- Activity 2.1 – Hybrid System Optimisation Best Practice Guideline – September 2021

SUMMARY OF TASK 18 PARTICIPATION, ORGANISATION AND EFFECTIVENESS

Task 18 has struggled to get a foothold. Task 18 received a notable boost after its first face-to-face meeting at TU Delft in February 2020, however since the COVID-19 crisis has continued, it has been difficult to make progress. Task 18 has taken to meeting monthly in order to progress its agenda, however progress is still very slow. Task 18 will look to engage more with academia in order to develop its agenda further as, at the moment, Task 18 is over-represented by utilities and industry.

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	OFRES
Malaysia	Dr. Chen Shiun	Sarawak Energy Berhad
Morocco	Ahmed Benlarabi	IRESEN
	Zakarai 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

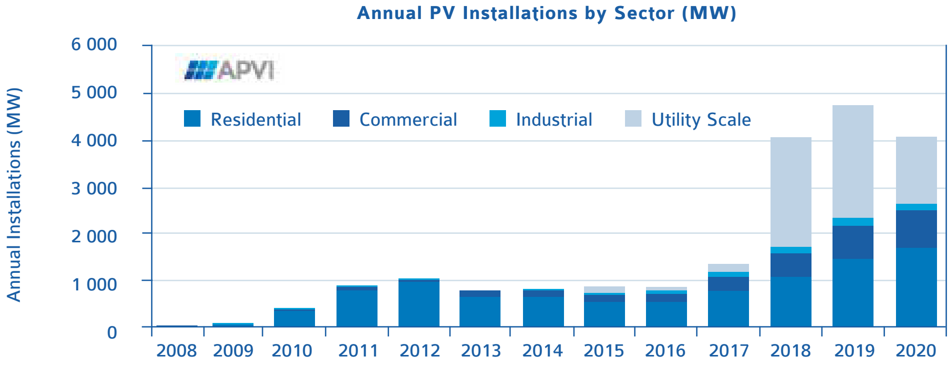

Fig. 1 - Historic trends in annual PV installations in Australia by sector.

GENERAL FRAMEWORK AND IMPLEMENTATION

Australia has remained in the top ten PV markets in the world for over ten years, and 2020 looks like it will come close to matching the 2019 record year for capacity additions. Final numbers are not yet in, but current numbers indicate over 4,0 GW commissioned in 2020. This is a conservative estimate as records are updated for months after year end.

New records were set in 2020 with an incredible year for residential solar with over 1,6 GW added. Commercial and industrial markets remain strong – providing a combined total for rooftop solar of over 2,5 GW. Utility scale solar fell in 2020 to 1,4 GW newly accredited systems.

Over 2,65 million Australian homes and businesses now have a rooftop PV system – with a record 334 000 new installs in 2020. Residential penetration levels are now at close to 30% of free-standing homes and reach over 70% in some urban areas. (data from https://pv-map.apvi.org.au/)

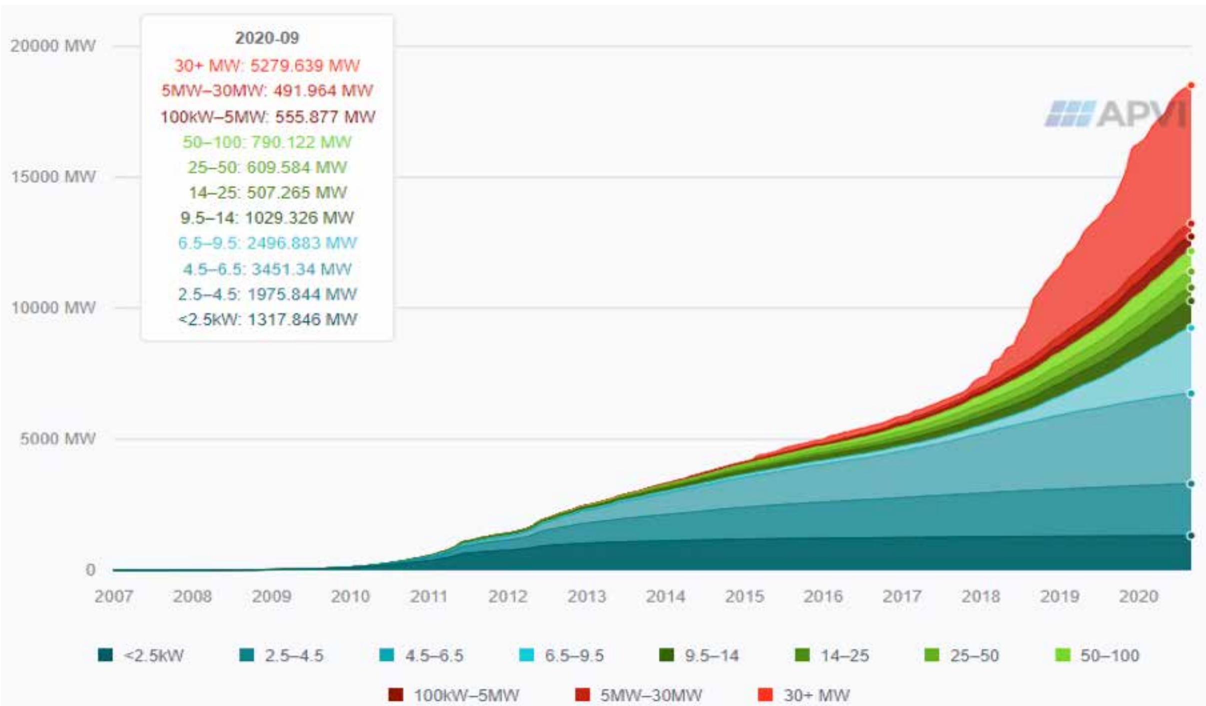

Fig. 2 - Cumulative installed capacity by system size to end of September 2020.

Over 8 000 new batteries were installed with solar in 2020, increasing the total number of batteries installed to 30 005 to the end of 2020.

Deployment has been driven by increasing awareness of the benefits of PV to businesses, large corporate PPA market, plus various State and Territory government schemes.

2020 saw the end of the Australian Large-Scale Renewable Energy Target (LRET), the last national energy policy to incentivise investment in large scale renewables. Smaller installations, up to 100 kW will continue to be supported through to 2030, with the level of support declining each year.

With the price of distributed solar now super-competitive with retail electricity pricing, the rooftop solar market (residential, commercial and industrial) is expected to remain strong for years. With a view to retiring coal-fire power generators, Australian States are now leading with state-based incentives for utility, business and household solar and batteries, as well as strategies to improve grid resilience.

National 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.

A number of large-scale plant investments have been frustrated by delays in network connections and by adjustments in a mechanism used by the market operator to reflect average losses associated with additional load and generation in different parts of the network. Known as the Marginal Loss Factor (MLF), this value is dynamic and has the effect of discounting the value of the output of a solar plant – when output is concentrated, with the addition of too many large solar plants in the one location and/or at too great a distance from the load. 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 2021, 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 2,2 GW of utility scale solar projects with an ongoing decline in forward commitments beyond that due to policy and market uncertainty and the associated risks around connection costs and performance requirements.

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 has now been met by existing renewables plants and will not drive additional renewable capacity over the coming decade. Support for small-scale systems (up to 100 kWp) will 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. The value of the STCs is decreasing every year toward 2030.

Deployment of large scale solar receives ongoing support from the Clean Energy Finance Corporation (CEFC), a statutory authority established by the Australian Government, which 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 2019-20 declined again compared to earlier years, reflecting broader market conditions, including the maturity of solar and wind technologies and pricing, plus also grid and transmission constraints and the build out of the Renewable Energy Target.

Adding to the National Programmes, the Australian Renewable Energy Agency (ARENA) holds a portfolio of 654 MAUD in solar projects (ARENA Annual Report, 2019). ARENA was established by the Australian Government to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia. The National Government has committed to extending the program of work by ARENA for a further ten years from 2022. ARENA will focus on Low Emissions Technologies identified in an annual assessment of technology opportunities.

RESEARCH, DEVELOPMENT & DEMONSTRATION

PV research, development and demonstration are supported at the national, as well as the State and Territory level. In 2020, research was funded by the Australian Renewable Energy Agency (ARENA), the Australian Research Council and Co-operative Research Centres.

ARENA is the largest funder of photovoltaics research in Australia. In 2019-20, ARENA committed over 15,1 MAUD for accelerating solar PV innovation, with a focus on end-of-life, advanced silicon technologies and new materials.

In addition, ARENA supported significant investments in lowering the cost of renewable technologies, addressing grid integration challenges to increase the supply of, or improve the competitiveness of, renewable energy in Australia.

INDUSTRY AND MARKET DEVELOPMENT

2020 saw a stabilisation of the PV market, after significant growth in 2018. Average system sizes in the sub-100kW market grew further to 8,0 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 2020, to an average 1,05 AUD per Watt including STCs, or 1,57 AUD per Watt on average without STC support (https://www.solarchoice.net.au/blog/solar-power-system-prices).

The Australian storage market remained strong in 2020, with the Clean Energy Regulator now tracking and reporting battery installations. Over 8 000 new batteries were installed with solar in 2020, increasing the total number of batteries installed to 30 005 to the end of 2020. 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.

2021 is expected to see stability in rooftop solar – with continued growth in commercial and industrial installations. 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 2021. Commercial PV deployment is likely to accelerate as solar awareness grows, and corporate interest in solar PPAs is building.

After an extra-ordinary year in 2018, centralised, utility-scale solar continues to decline, as the investment market navigates regulatory challenges and transmission limitations. While a short-term down-turn is expected, state governments are acting to improve transmission networks and there is a growing awareness 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.

Fig. 3 - Residential Rooftop, Byron Bay NSW, Springers Solar Pty Ltd. (Photo: Eddie Springer).

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY AND PROSPECTS

HUBERT FECHNER, TPPV – TECHNOLOGY PLATTFORM PHOTOVOLTAIK ÖSTERREICH

Fig. 1 - Multi-family house with PV façade; Winner of the 2nd Austrian Award for building integrated PV (Photo: © Rene Schmid Architekten und Kioto Photovoltaics).

Fig. 2 - M Preis Supermarket's deep-freeze warehouse, Innsbruck, Austria. Winner of the 2nd Austrian Award for building integrated PV for their complete energy concept including hydrogen (Photo: © ATB-Becker, Tyrol).

GENERAL FRAMEWORK AND NATIONAL PROGRAMME

Photovoltaic in Austria seems to be on its way to become a significant electricity source. Even though only 3% of the national electricity had its origin from PV in 2020, there are now binding political decisions to increase this share to about 15% in 2030. Backed by the general target to get completely rid of fossil electricity by 2030 and have a 100% renewable electricity (on basis of the annual balancing); PV with plus 11 TWh and wind energy with +10 TWh of annual generation are the most important technologies to achieve this goal. Targeting another 11 TWh of PV generation in 2030 means that the installation rated would face a need to be increased by a factor of nearly five compared to current installation rates. Currently, about 75% of the electricity is made by renewable sources, dominated by hydropower, which represents typically 60% of the electricity. Meanwhile, wind energy plays a significant role with approximately 11%; with nearly 5% of bio-electricity completing the renewable portfolio together with photovoltaics.

Austria has never produced electricity from nuclear energy and has a clear policy against nuclear.

A new energy law will be operational from spring 2021 on, which includes these above mentioned targets and significantly improves the frame conditions for photovoltaic and wind as leading technologies for further increase; the further potential in hydro is seen as limited, mainly due to environmental restrictions.

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, a greater need of electricity is expected for the communication sector, due to the growth of the digitalisation. Beyond 2030, there are considerations to cover the increased storage requirements with renewable hydrogen, which would increase the renewable energy generation need even further.

Up to now, only a few larger ground mounted PV systems are in operation, most of them installed in 2020; still, there is no PV system in operation which exceeds the 20 MW range. Nevertheless, many much larger ground mounted PV systems are currently planned and might supplement the typical Austrian way of decentralized, smaller PV installations close to the electricity use.

The integration of PV into buildings, into applications of the transport sector, as well as integration into the agricultural sector by using synergies as much as possible is seen as the approach with the most valuable effects for the country and as a way to keep the acceptance of this technology high, even in a high dissemination scenario. Local and regional PV solutions might lead to further positive synergy effects in the field of electro-mobility and energy efficiency.

A total of approximately 2,1 GW of PV power had been installed in Austria by the end of 2020, mainly as roof top systems on buildings with more than 90% of the total installed capacity. Even though there are no final numbers available, 2020 was obviously the year with the highest number of PV installations by far.

In addition to some possible simplifications in the legal frame conditions and bureaucratic measures, Austria's support schemes are essential for the installation rates; besides some regional support mechanism, the following 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 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 2020, the tariff was set with 7,67 EURcent/kWh for PV on buildings and with no incentive for PV on open landscape; an additional 250 EUR subsidy per kWp (max. 30% of total investment cost) was offered.

- Additionally, a federal investment support for systems up to 500 kWp, introduced in 2019 was made available. The PV system is supported with up to 250 EUR per kWp, electricity storage with 200 EUR per kWh. There is also a new restriction on the maximum storage capacity that can be funded: Both PV and storage systems can be built larger, but a maximum of 500 kW for PV systems or 50 kWh for electricity storage are funded. Within this scheme, 24 MEUR for the funding of PV systems (2019: 9 MEUR) and a further 12 MEUR for electricity storage (2019: 6 MEUR) were available.

About 6,2 MEUR were dedicated to PV investment support for small systems up to 5 kWp in 2020 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 250 EUR per kWp for roof-top systems and 350 EUR per kWp for building integrated systems, the support per kWp was slightly lower than in 2019. This support has led to about 5 370 new PV systems with a total capacity of 31,4 MWp in 2020.

For the sixth time, there was an additional offer for the agricultural sector – systems from 5 kWp to 50 kWp, owned by farmers, obtained a comparable incentive per kWp (275/375 EUR) as other private owners, which has led to approx. 22,7 MWp installed in 2020. Regions that participate in the Programme "Climate and Energy Pilot Regions" are eligible to receive funding for PV installations that are in special "public interest". In 2020, 265 PV installations were funded with 4,0 MEUR. In total, 8,7 MWp were submitted.

The mean system price for private systems went further slowly down to 1,568 EUR/kWp (excluding VAT) for a 5 kW system according to the Austrian PV market report for 2019.

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 showing the value of a strong national PV research community and creating a better coherence of the national PV research. The platform experienced a good development once again in 2020; initially supported by the Ministry of Transport, Innovation and Technology (now the Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology) this loose platform now acts as a legal body since 2012. The PV Technology Platform brings together about 30 Austrian based industries and commercial entities, active in the production of PV relevant components and sub-components, as well as the relevant research community, in order to create more innovation in the Austrian PV sector. The transfer of latest scientific results to the industry by innovation workshops, trainee programmes and conferences, joint national and international research projects, and other similar activities are part of the work programme, in addition to the needed awareness raising, as well as aiming at further improving the frame conditions for manufacturing, research and innovation in Austria at the relevant decision makers. In March 2020, the PV platform awarded the prices for the second "Austrian Innovation Award for Building integrated PV". 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 the different IEA PVPS Technology Collaboration Programme's Tasks. The national Energy Research Programme from the Austrian Climate and Energy Fund, as well as the programme "City of Tomorrow" from the Ministry of Climate Action cover quite a wide range of research topics on energy technologies including PV. The recent calls of the above mentioned programmes have taken a more systemic approach. However, the further development, improvement and system integration of PV technologies is also implicitly covered, even if the formulations are kept technology-neutral and do not explicitly focus on any individual technology.

The total expenditures of the public sector for energy research in Austria was about 149 MEUR in 2018, dominated by energy efficiency projects with a total of 75 MEUR including electro-mobility with more than 15 MEUR; about 23,5 MEUR was dedicated to renewable energy with a share of 7,1 MEUR for photovoltaics.

Within the IEA PVPS TCP, Austria is leading the PVPS Task 14 "Solar PV in a Future RES Based Power System" as well as the PVPS 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 more and more also on all types of integration; from building integration to the integration into the transport sector (e.g. PV covering of roads) and integrating PV production with agricultural needs.

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 Climate Action.

IMPLEMENTATION & MARKET DEVELOPMENT

Self-consumption is generally more and more an additional driver of the PV development; however, this strategy is more often criticized since it leads to the fact that the available roofs are covered only partly with PV in order not to exceed the owner's electricity needs.

About one hundred projects in multifamily-buildings were realised in 2020, which was legally enabled in 2018; nevertheless, this sector is still facing a tedious time, mainly due to complex contract structures and billing difficulties along with low financial benefits for the users. Local energy communities will be implemented by the above mentioned new energy law, which fulfils the EU Renewable Energy directive RED-II. The legal framework for local energy communities is just available at a preliminary status. It might foresee the distribution grid level as a boundary condition with some incentives, such as a reduced grid fee (only for the locally used electricity) and reduction in electricity taxes. 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 if significantly driven, but not exclusively, by more and more PV and wind systems falling out of the 13-year feed-in-tariff period.

Fig. 3 - PV parking lot at the Arrival Center Schönbrunn (Photo: © ertex solar, Dieter Moor).

The Ministry announced a "One Million PV Roofs" action in 2020, and by this, showing the willingness to put a focus on the building-applied PV; however, no further details were available before end 2020.

MARKET DEVELOPMENT

The Federal Association Photovoltaic Austria (PV-Austria) is the non-governmental interest group of the solar energy and storage industries in Austria. This 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 systems 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 conferences, workshops and industry meetings. By the end of 2020, the association counted 244 companies and persons involved in the PV and storage industries 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. The association team will take this path together with the board members and in the interest of the Austrian photovoltaic and storage industries.

The 18th annual National Photovoltaic Conference took place in Vienna in 2020; again a two-day event, jointly organised as an online version, due to the COVID-19 pandemic, by the Technology Platform Photovoltaic and the Federal PV Association, and supported by the Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology. This strategic conference is well established as THE annual come together of the innovative Austrian PV community, bringing together about 450 PV stakeholders in industry, research and administration.

Many other workshops and webinars were organized by the Austrian Technology Platform PV and the PV Association PV Austria, dedicating to topics such as floating PV, PV sound barriers and other applications in the mobility sector, quality aspects of PV and much more. A specific IEA PVPS Task 1 workshop was organised with many Austrian participants in April 2020, discussing the possibility of peer2peer electricity trade, which might specifically be a promising possibility for PV use in energy communities.

FUTURE OUTLOOK

The official policy target of 100% renewable electricity until 2030 dominates the energy policy in Austria right now. This target is supplemented with a "CO_2 neutrality target" for 2040. Both the increase in consumption but also the replacement of fossil driven energy will create a 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. The existing PV target with +11 TWh until 2030 can only be seen as an intermediate goal, since for climate neutrality and the use of significant new storage capacities much more PV will be needed. There is a clear need to plan the significant expansion of PV in much more detail, not only with regard to the total amount, but also the question of how PV can be implemented to the greatest benefit for the country. Research and innovation seems to need more attention in order to increase the national value and focus specifically on integration solutions, also in order to keep the public acceptance of this technology at a high level.

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. However, there is a clear need to boost the aspect of "solar renovation" means to complement each renovation project with the installation of PV.

Initiatives for local energy communities where PV together with storage, heat pumps, electric-vehicles and other technologies that are in the center of a new energy system, offer a wide spectrum for new activities. Thus, 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 their efforts to compete on the global market, mainly by close collaboration with the public research sector, in order to boost the innovation in specific niches of the PV market. International collaboration is a high priority for Austria.

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

Electric cars are subsidised in Austria since March 2017, with up to 5 000 EUR. More than 40 000 completely electric cars were registered in Austria at the end of 2020. In December 2020, about 10% of all newly commissioned cars were battery only driven, supplemented by many hybrid driven cars. A further strong growing e-vehicle sector might have a significant influence on the PV development, moreover, since the decision for getting subsidy depends on the 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

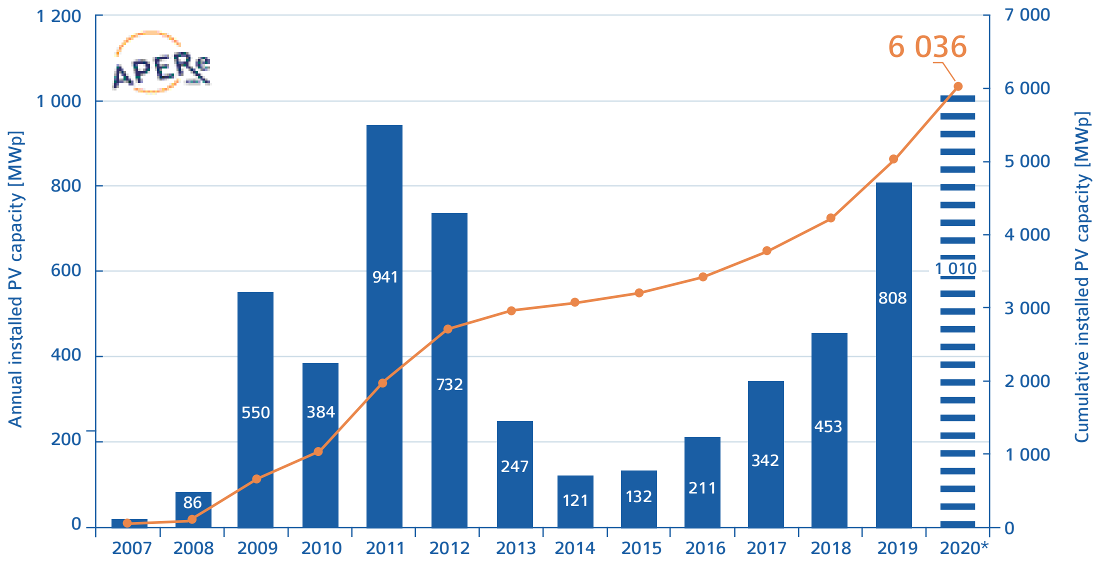

Fig. 1 - Belgium's Annual Installed PV Capacity and Cumulative Installed PV Capacity (MWp).

GENERAL FRAMEWORK

The first forecast for the Belgium PV market at the end of 2020 indicates a cumulative installed PV capacity of approximatively 6 GWp. Despite the COVID pandemic, 2020 is expected to be the best year for solar in Belgium, since 2011, with 1 GWp of PV capacity installed on a year (+25% compare to 2019).

The total value of 6 GWp* (see Table 1) is reached by considering the upgrade of 2019 official data, the first 2020 official data that are still quite partial (700 MWp officially reported for 2020) and the information collected from the Belgian inverter market. 73% of the capacity is built in Flanders, 24% in Wallonia and 3% in Brussels.

The Belgian PV park is composed of more than 750 000 systems and characterized by a large share (98%) of small systems (< 10 kVA). With 15% of households owning a PV system, the total installed capacity reached an average of 525 Wp per inhabitant.

Nevertheless, small systems represent 66% of the total installed capacity compared to 19% for the commercial (10-250 kWp), 8% for industrial (250-750 kWp) and 7% for utility scale (> 750 kWp).

Belgian solar electricity production represents a share of 6% of the total internal electricity consumption of Belgium (80 TWh) in 2020. The total electricity consumption was reduced by 7%, compared to 2019, due to the pandemic situation.

NATIONAL PROGRAM

The first Belgian National Renewable Energy Plan set a target of 1,34 GWp for 2020. It was reached in 2011.

In December 2019, Belgium introduced a revised version of its Climate-Energy National Plan to the European Commission. The new objectives for photovoltaics suggest 5 GWp for 2020 and 11 GWp in 2030. The 2020 objective for PV was reached at the end of 2019. Starting from 6 GWp at the end of 2020, the pace of equipment to reach 11 GWp by 2030 must be 600 MWp/year. This is the average made within the past five years meaning that the Climate-Energy National Plan is in the business as usual scenario regarding the current market dynamics.

As suggested within the study "Fuel for the Future" published by the Federal Planning Bureau at the end of 2020, Belgium could have 40 GWp of solar by 2050, in connection with various storage capacities (Li-Ion batteries, as well as hydrogen and pumped storage).

Looking at the Belgian history and past trends, the current cost of solar PV systems, the new business models that are coming (individual as well as collective self-consumption) and the efforts that are requested from Europe to Belgium regarding its Climate-Energy Plan, Belgium could be able to reach 20 to 22 GWp in 2030 without great additional efforts.

Fig. 2 - The biggest ground mounted PV power plant of Belgium (Lommel). The Kristal Solar Park - 99 MWp – was built in 2018-2019 and provides solar energy to the nearby zinc specialist company Nyrstar. This generates a yearly reduction of 30 000 tonnes of CO_2 (Photo: Engie).

This would represent between 15 to 20% of the electricity consumption of Belgium at the 2030 horizon, depending on the evolution of the electrification of some fueled-based usages (such as cars, for instance).

Nevertheless, such a new target still needs to be confirmed and embraced by Belgian politics.

RESEARCH AND DEVELOPMENT

R&D efforts in the PV sector are proportionally less focused purely on PV technology alone, but also more diversified in connection with integrating (new) business models such as individual and collective self-consumption, battery storage, power-to-X transformation (including hydrogen) or the recycling process.

Specific solar R&D efforts are concentrated on highly efficient crystalline silicon solar cells, thin-film and perovskites. In February 2020, the IMEC Research Institute reached an energy efficiency of 25 percent with a thin-film solar cell. This achievement is opening a potential new era for high efficiency solar cells in BIPV or VIPV, due to the thin and flexible characteristics. They are expecting 30% efficiency within three years.

Energy Ville, IMEC and other Belgian research centers are partners of various PV research project covering different subjects.

The ANALYST PV project attempts to obtain data and analyze PV system performance to detect faults on PV plants (end 09/2021). The CUSTOM-ART project aims at developing next generation BIPV and PIPV modules based on earth-abundant and fully sustainable thin-film technologies (such Kasterites based thin-film technologies) (en 02/2024). The LASERGRAPH project aims to develop an in-situ laser processing for the development of interlayers and TCEs, essential for the commercial success of the tandem solar cells based on perovskite and CIGS thin-film (end 12/2021). The PERCISTAND project is the development of all thin-film perovskite on CIS tandem photovoltaics to increase the efficiency of cells above the Shockley-Queisser single junction limit. The target is 30% at the cell level and 25% at the module level (end 12/2022). The POSITIF project analyses the two-side poly-SI passivated contact to go towards 24% efficiency into bifacial SI cells (end 06/2021).

INDUSTRY

The solar industry in Belgium is like the country: quite small but creative and specific. Belgium does have some BIPV companies such Issol and Sunsoak, active in the architectural PV systems. There is a producer of modules (classic size and shape): Evocells. Soltech and Reynaers, are the two main companies focusing on embedded applications. Derbigum is specialized in integrated amorphous silicon.

MARKET DEVELOPMENT

New business models are coming through the emergence of energy communities and collective self-consumption. However, their developments are still at too early of stages in order to impact the market. However, their influence should grow in the coming years.

Even considering that the increase of the > 250 kWp segment in 2019 was exceptional (due to the 99 MWp Cristal Park ground mounted system, see Figure 2), a significant decrease of the dynamic in the > 250 kWp segments of installations in 2020 can be observed.

The market shows an increasing trend of the DC/AC ratio in all segment of systems. If a ratio of 1 was the rule until 2015, it increased to reach the 1,3 level, in average for all market segments, from 2017.

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

YEAR	ANNUAL GROWTH (MWp)	CUMULATIVE (MWp)
2007	18	22
2008	83	105
2009	550	656
2010	384	1 039
2011	941	1 980
2012	732	2 712
2013	247	2 959
2014	121	3 079
2015	132	3 211
2016	211	3 423
2017	342	3 765
2018	453	4 218
2019	808	5 026
2020*	1 010	6 036

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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Fig. 1 - The Old Crow Solar Project, a 940 kW system installed by the Vuntut Gwitchin Government in Old Crow, Yukon, 128 km north of the Arctic Circle (Photo: Solvest Inc.). [3]

GENERAL FRAMEWORK AND IMPLEMENTATION

As part of its commitments under the Paris Agreement, the Government of Canada, in collaboration with provinces and territories, developed the Pan-Canadian Framework on Clean Growth and Climate Change. The Pan-Canadian Framework, released in December 2016, set greenhouse gas reduction targets of 30% below 2005 levels by 2030 [1]. In addition, Canada currently produces approximately 80% of its electricity from non-emitting sources and has committed to increase this amount to 90% by 2030. The Pan-Canadian Framework has four parts: (1) carbon pricing, (2) complementary climate actions to reduce emissions, (3) adaptation measures to mitigate the damage of global heating, and (4) supporting low carbon technologies. The Government of Canada implemented countrywide carbon pricing in 2018. The price was 30 CAD per CO_2 equivalent tonne in 2020 increasing by 10 CAD per year until 2022 and 15 CAD per year thereafter until reaching a total of 170 CAD per tonne in 2030. Provinces or territories can manage their own carbon pricing policy as long as it meets federal government targets. However, despite the progress on emissions reductions, the March 2018 publication by the Office of the Auditor General of Canada, "Perspectives on Climate Change Action in Canada," highlights that far more must be done, both at the federal and provincial level, if the 2030 reduction targets are to be reached [2]. In this context, increased adoption of PV and other renewables such as wind, hydro, and geothermal will help Canada deliver on its commitments.

There are no specific capacity targets for PV set by the federal, provincial, or territorial governments. Rather than a federal mandate, local governments decide their own PV support measures. Support policies at the residential and commercial level include feed-in tariffs, capital subsidies, self-consumption, and net metering. As of December 31, 2019, Canada's PV sector reached approximately 3,3 GW of installed capacity of which 94% is located in Ontario. The PV market in Ontario is experiencing a slowdown due to the closing of the Large Renewable Procurement, Feed-In-Tariff (FIT), and microFIT programs. Ontario's net-metering regulation now forms the basis for future project development in that province. Across the country, there is strong growth in distribution-connected PV capacity particularly in Alberta, Saskatchewan, Nova Scotia, British Columbia, and Québec. According to the Canada Energy Regulator, Canada's future PV capacity is expected to reach 20 GW by 2050 [3].

NATIONAL PROGRAMME

As mentioned above, there are no direct support measures at the national level to encourage PV capacity growth. Instead, each province and territory implements its own policies, which may be adapted as market conditions change. New PV capacity installation in 2019 was concentrated in Ontario (170,3 MW), Alberta (31,8 MW), and Manitoba (20,5 MW). Several provinces also offer Property-Assessed Clean Energy (PACE) programmes whereby PV system costs are repaid through property taxes. At the national level, PV is eligible for several federal support programmes including the 500 MCAD Low Carbon Economy Fund, the 220 MCAD Clean Energy for Rural and Remote Communities program [4], and the 100 MCAD Smart Grid program [5].

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Fundamental materials research into PV cell or module optimization is conducted mostly through university and industry research groups, while research and deployment of PV systems tends to be the purview of industry, local utilities and government institutions.

The Renewable Energy Integration (REI) Program of Canmet ENERGY in Varennes strives to improve sustainable, reliable and affordable access to renewable energy. To this end, the REI program conducts PV research activities related to the performance, durability, and cost of PV systems and components as well as their integration into buildings and electricity grids. CanmetENERGY in Varennes also studies the integration of PV systems in remote

1 CanmetENERGY in Varennes is a Government of Canada research centre specialized in renewable energy integration, energy efficient buildings, improvment of industrial processes, and renewable energy project assessment.

2 CanREA is a national trade association that represents the renewable energy industry throughout Canada.

3 Note on figures: All dollar amounts in this report are in Canadian currency (CAD). PV power estimates are in DC. Where conversion from AC to DC was required, a conversion coefficient of 0,85 was used.

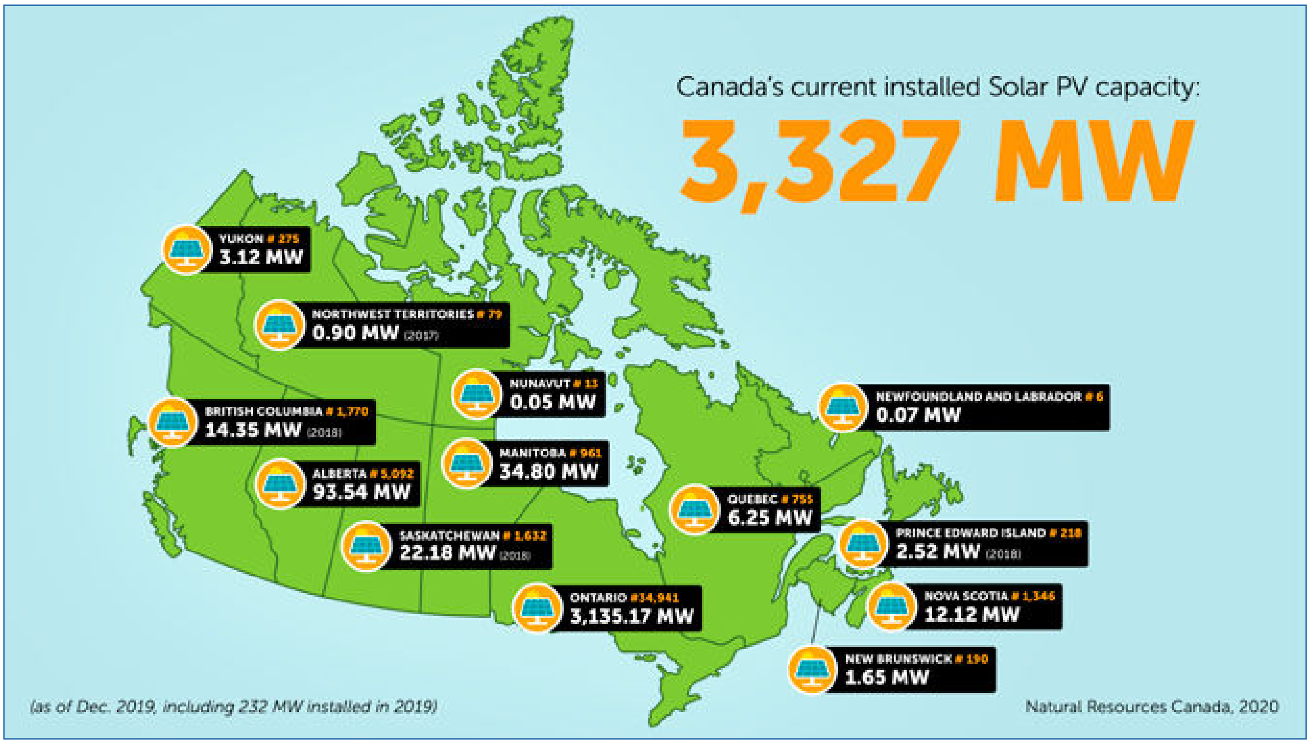

Fig. 2 - Map showing PV power capacity (MW) and number of installed systems as of December 31, 2019. This map is for illustrative purposes only and sizes or distance scales are approximate. Note: PV data for the Northwest Territories, British Columbia, and Saskatchewan were not available in 2019, and so values from previous years were reported. Estimated accuracy of data is ±3%. [3]

Arctic communities in Nunavut, the Yukon, the Northwest Territories and Nunavik (the northern part of the province of Québec). Renewable energy deployment in these communities reduces dependence on diesel fuel and builds experience in developing the grid flexibility and storage necessary to achieve high penetration of variable renewable electricity sources. In 2014, a partnership between government and business created the Refined Manufacturing Acceleration Process (ReMAP), which is supported by 17,7 MCAD from 2014-2024. The ReMAP network utilizes 38 laboratories and manufacturing lines across the country to aid product commercialization in the renewable energy sector, healthcare, communications technologies, and aerospace [6].

INDUSTRY AND MARKET DEVELOPMENT

Of Canada's cumulative 3,3 GW PV capacity, approximately 83% is connected to the low voltage distribution grid with the remaining 17% connected to the high voltage transmission grid. During 2019, approximately 231,8 MW of new PV capacity was installed. A map of cumulative capacity across the country is given in Figure 2. Estimation of the value of the Canadian PV industry to the country's economy in 2019 was approximately 403 MCAD. The number of estimated manufacturing, installation, electric utility and research positions in this sector has reached 5 500 jobs [7]. 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 [7].

Turnkey PV system prices varied from 1,80-2,50 CAD/W for commercial roof-mounted systems between 10-250 kW in size. By contrast, centralized PV arrays larger than 1 MW had costs of approximately 1,25 CAD/W [7].

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3 Note on figures: All dollar amounts in this report are in Canadian currency (CAD). PV power estimates are in DC. Where conversion from AC to DC was required, a conversion coefficient of 0,85 was used.

CHINA

PV TECHNOLOGY AND PROSPECTS
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GENERAL FRAMEWORK

The Influence of COVID-19

In May 2018, the Chinese government launched a series of PV application policies. The general goal of these policies is to encourage the related parties to adapt the swift decline of subsidies, guiding the rapid realization of grid-parity by a "price-bidding" mechanism, and ensuring the smooth landing of the PV industry. The growth of PV installation in China slowed down in 2018-2019. A positive influence of this policy is the rapid reduction of PV system installation costs, while the LCOE and grid-parity have been realized in many regions in China in 2019.

The outbreak of COVID-19 at the beginning of 2020 produced a series of impacts on PV, with the grid-connected PV installation in Q1 2020 in China decreasing by 23% compared to that of 2019. However, the situation changed since Q2 2020, due to the rapid control of the epidemic in China; and hence, the photovoltaic industry has rapidly returned to normal. Another factor is the timeline requirement of the grid-parity bidding projects held in 2019 and in June 2020. These positive factors played a great role and PV installation showed a positive growth in Q2 and Q3 in 2020, compared to that of 2019. On September 2020, Chairman Xi Jinping made an important speech at the 75th United Nations General Assembly. This stimulated the Q4 2020 installed capacity towards an explosive increase. The annual installed capacity reached 48,2 GW in 2020; a 60,1% increase compared to that of 2019. The cumulative installed capacity reached 253 GW, and the new and cumulative installed capacity maintained China's first place for PV in the world.

The cumulative installed capacity of China's photovoltaic industry has ranked first place in the world for six consecutive years, and the newly added installed capacity has ranked first place in the world for eight consecutive years. China's poly-silicon production has ranked first place in the world for 10 consecutive years, and its module production has ranked first place in the world for 14 consecutive years. China's photovoltaic industry is a powerful driving force.

"The 14th-5-year Plan" Arrives

At the 75th United Nations General Assembly on September 22nd 2020, President Xi Jinping further started China's commitment to:

- Reach CO_2 emissions peak before 2030;
- Reach "Carbon Neutrality" by 2060;
- Scale up intended national determined contributions (INDC) by adopting more vigorous policies and measures;
- Calling for a "Green Recovery" in the post-COVID-19 era.

In order to achieve the goals of 2030 and 2060, China will vigorously develop the new energy industry. In the next 14th-Five-Year Plan and 15th-Five-Year Plan, China's photovoltaic and wind power industry

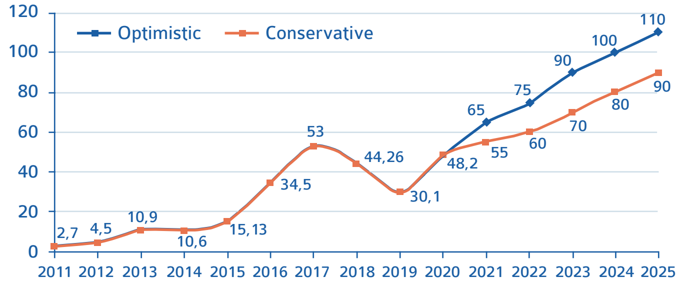


Fig. 1 - Newly installed capacity from 2011 to 2020 and forecast of newly installed capacity from 2021 to 2025 GW) (Source: CPIA).

will achieve a significant growth. The newly installed capacity of PV is expected to reach 55-65 GW in 2021 and 90-110 GW in 2025. Figure 1 shows the CPIA's forecast of new photovoltaic installations in China during the 14th-Five-Year Plan period.

Due to the layout of new energy industry in the 14th Five-Year Plan, photovoltaics is outstanding in the stock market. The total market capitalization of the listed companies in China stock market reached 2 000 BCNY (285 BUSD); the market value of LONGi Ltd. exceeds 450 BCNY (65 BUSD). Investment institutions are optimistic about the photovoltaics industry.

In 2020, total exported value of PV products was 19,75 BUSD, among these, the silicon wafers exported 27 GW with the value of 1,77 BUSD, PV cells exported 9 GW with the value of 0,99 BUSD and PV modules exported 78,8 GW with 16,99 BUSD.

NATIONAL PROGRAM

Large Scale PV Systems

According to CPIA's data, large scale ground-based PV plants are still the mainstream of PV applications in China, with their annual installation reaching 32,7 GW in 2020; an 83% increase compared to that of 2019.

China new installed capacity situation (GW)

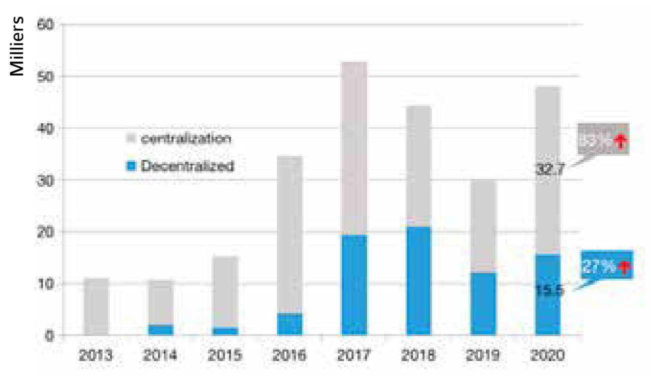


Fig. 2 - China's newly installed capacity situation (GW) (Source: CPIA).

Large-scale power plants will be the mainstream of PV development in China in the long term. It shows that China is accelerating energy transformation. Large-scale power plants can rapidly expand the scale of clean energy assets of enterprises, while effectively improving the quality of power generation and economic benefits, which is an effective way to achieve carbon peak.

The large-scale power stations are mainly invested in by several large stated-owned energy enterprises, along with the comprehensive development of wind, solar, hydropower, thermal power and energy storage. The competitiveness of private enterprises is slightly insufficient.

For instance, China Energy Construction Co., Ltd (CEEC) invested 23,8 BCNY to build a 5 GW PV and storage project and 1 GW wind power project in Ordos City, Inner Mongolia. China Guodian Corporation invested 12 BCNY to build a 2,65 GW PV, 1 GW wind power, and 0,46 GW storage project in Dalate Banner, Inner Mongolia. SUNGROW invested 5,5 BCNY to build a 1 GW PV, wind power, and storage project in Baicheng City, Jilin Province.

Fig. 3 - Baicheng PV Project (Photo: SUNGROW).

For now, large-scale PV power plants are mainly located in the northern and western parts of China. The potential of the central and eastern regions is being stimulated.

Fig. 4 - Ningxia 2 GW PV project (Photo: SUNGROW).

RESEARCH & DEVELOPMENT (R&D)

2020 Solar Cell Best-Efficiency Table of China

CPVS has been publishing the Solar Cell Best-Efficiency Table of China for four years, since 2017. On September 21st 2020, CPVS published the 2020 Solar Cell Best-Efficiency Table of China, as shown in Table 1.

TABLE 1 – LAB. LEVEL HIGHEST CELL EFFICIENCY

NO	TECHNOLOGY	CELL EFFICIENCY (%)	AREA (cm²)
1	HIT	25,11 ± 0,35	244,54 (t)
2	N-TOPCon (bifacial)	24,87 ± 0,16	267,8 (t)
3	N-TOPCon (bifacial)	24,90 ± 0,35	235,80 (a)
4	N-TOPCon (multicrystalline cell, bifacial)	24,40 ± 0,34	267,50 (t)
5	N-TOPCon (multicrystalline cell)	23,81 ± 0,3	246,44 (t)
6	CZTSSe (on glass)	11,563 ± 0,088	0,1066 (ap)
10	Perovskite (minimodule)	18,04 ± 0,58	19,276 (da)
1. Hanergy 2. Jinko 3. Jinko 4. Jinko 5. Canadian Solar 6. NJU 7. Microquanta			

Source: CPVS 2020

PV Technological Evolution

PERC has basically replaced the traditional BSF technology, from 9% in 2016 to 85% in 2020. However, due to the upper limit of PERC efficiency, CPIA estimated that HJT, TOPCon will have a great share by the year 2024-2025. Many enterprises have arranged the R&D and setup pilot/production line of HJT and TOPCon technology in advance.

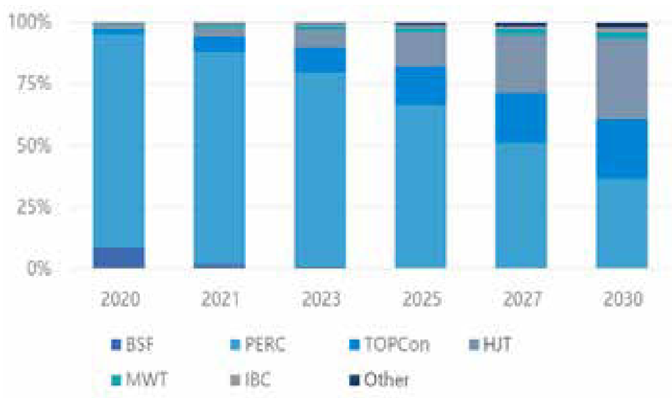


Fig. 5 - Forecast of China technological evolution (Source: CPIA).

Silicon Size Development

China's photovoltaic technology competition is full of vitality and industrial technology diversification. 210 mm and 182 mm wafers are gradually occupying the market. As CPIA estimated, by 2021, the 156,75 mm and 158,75 mm, which were the mainstream in 2020 and past years, will gradually be withdrawn from the market, with the market share of 158,75 mm wafers being reduced to 5% in 2021. While 210 mm and 182 mm wafers will occupy 50% of the wafer market, 500w+ and 600w+ even 800w+ power will quickly be leading in the market, as well. This will promote cost reduction of PV modules.

Fig. 6 - Trend of silicon wafers with different sizes.

INDUSTRY AND MARKET DEVELOPMENT

PV Industry in China

China has been the largest producer of PV modules in the world since 2007. PV productions of the entire manufacturing chain in 2020 are shown in Table 2.

TABLE 2 - PV PRODUCTION AND CHINA'S SHARE IN 2020

SECTORS	CHINA
Poly-Silicon (103Ton)	39,2
Silicon Wafer (GW)	161,3
PV Cells (GW)	134,8
PV Modules (GW)	124,6

Source: CPIA

Supply Chain Conflict

Affected by COVID-19, each link of the industrial chain is being impinged on differently, which highlights the importance of scientific supply chain management.

Silicon production belongs to the field of chemical industry, which needs a long period of expansion. Natural disasters and/or accidents led to a serious shortage of supply in the short term. As a result, the price of silicon increased 50% in 2020.
In addition, under the influence of national macro-control, the overall production capacity of photovoltaic glass in the whole year is in a tight balance. Large size and 2 mm glass structures are in short supply. As a result, the price of photovoltaic glass increased 100% in 2020. Based on this situation, photovoltaic module enterprises seek to replace float glass. The policy of capacity replacement is expected to be liberalized.

Affected by COVID-19, EVA particle material resources ran lower, thus, suppliers increased the output of photovoltaic materials through substantial price increases. The price of POE and EVA is at an inversion. This meant a 50% price increase in 2020.

Being able to control the supply chain becomes key to winning the competition.

PV Market Development

By the end of 2020, the cumulative installed capacity reached 253 GW. The 2020 annual installation reached 48,2 GW and among these capacities, the distributed PV was at 15,5 GW, with a 32,16% share.

TABLE 3 - PV INSTALLATION BY SECTORS IN 2020

MARKET SECTOR	ANNUAL (MWp)	CUMULATIVE (MWp)	SHARE (%)
Off-grid		360	0,14
Distributed	15 520	78 940	31,12
Power Plant	32 680	174 340	68,74
Total	48 200	253 640	100

Source: CPIA 2020

Energy Transition Target and Future Forecast

2020 is the last year of "The 13th Five-Year National Plan" and 2021 is the first year of The 14th Five-Year National Plan. In 2021, the cost of PV is already reaching to the level of grid-parity. Except for PV home systems, the other PV projects will no longer have any subsidy and the Grid Company will purchase PV electricity with the same price as coal-fired power plants. Since 2021, the total PV market quota will not be controlled by NDRC or NEA. Instead, the PV installed capacity will be arranged by provincial governments according to the "Mandatory Share of Non-Hydro Renewable Energy Power", issued by NEA, just like RPS in western countries. For the target of the 2030 reach to CO_2 peak, and the 2060 reach to "carbon neutral", the PV market will be expanded further. It is estimated that during the 14th 5-year plan (2021-2025), the annual PV installation in China will be at least 50 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 NUNO, PROJECT MANAGER, COPPER ALLIANCE

Fig. 1 - The main renewable electricity generation technologies require copper to operate. In a PV plant, copper is present in the conductive strips of cells and modules, in cables, inverters and transformers.

The International Copper Association (ICA) and the Copper Alliance® are active in all stages of the copper value chain. Through its market defence and growth programme, the Copper Alliance promotes copper applications to multiple target audiences. Its policy, advocacy, education and partnership initiatives are designed to translate copper's excellent technical properties into user benefits with added value. Considering the strong linkages between carbon reduction and copper use, the Copper Alliance aims to accelerate the energy transition.

CLEAN ENERGY TRANSITION

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.

Since 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 which, together with demand-side management, can deliver an effective decarbonisation of the sector and support the integration of renewables;
- Promotion of electric mobility using sustainable materials in a circular economy system;
- Capacity building and knowledge transfer on best practices on renewables through application notes, webinars and e-learning programmes.

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 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 several PVPS webinars, gathering more than 700 registrations.

ABOUT COPPER ALLIANCE

The Copper Alliance® represents a network of regional copper centres and their industry-leading members, led by the International Copper Association (ICA). The ICA aims to bring together the global copper industry to develop and defend markets for copper and to make a positive contribution to the UN's sustainable development goals.

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS

FLEMMING V. KRISTENSEN, FKSOL APS DENMARK
KENN H. B. FREDERIKSEN, KENERGY APS DENMARK

Fig. 1 - Thin-film modules with 6 kWp on a private home (Photo: KlimEnergi A/S).

GENERAL FRAMEWORK

The majority of the members of the Danish parliament have the ambition, that Denmark will be among the countries that do most – both domestically and abroad – to combat climate change and the deterioration of our environment and nature. In order to reach their targets, a very significant effort will be required throughout the next decade and must take place in a socially balanced way.

On December 6, 2019, the Government reached an agreement on a new Climate Act with eight out of the ten parties in the Danish Parliament. The act will include a legally binding target to reduce greenhouse gases by 70% by 2030 (relative to 1990 level), to reach net zero emissions by 2050 at the latest, and to set milestone targets based on a five-year cycle.

It is stated that a reduction of 70% by 2030 is a very ambitious goal, and it will be particularly difficult to realize the last part of the goal, i.e. from 65% to 70%. This will require currently unknown methods and therefore, also a close collaboration with a broad range of organizations and experts.

The climate act will be followed by climate action plans, which will contribute to ensuring that national reduction targets are met. The Climate Action Plan in 2020 includes sector strategies and indicators as a minimum for central sectors such as agriculture, transport, energy, construction and industry. Moreover, Denmark has already taken the first steps towards establishing a professional and efficient energy sector as the basis for the transition to a sustainable green society.

Renewable energy (RE) is very much a present and considerable element in the energy supply. By the end of 2020, more than 50% of the national electricity consumption was generated by renewable energy sources including incineration of waste.

During 2020, PV provided more than 3% of the national electricity consumption. Ongoing research, development and demonstration of new energy solutions including renewable energy sources, storage and Power-to-X have high priority in the energy plans. To support this policy, the amount of R&D funding allocated to RE has increased the last couple of years. Renewable energy technologies, in particular wind, play an important role, with PV as a minor but cheap and reliable technology with potential to contribute with a significant amount of green energy and therefore an important technology to fulfil the green transition. The above mentioned 2020-2030 plan with technology neutral auction schemes may provide a firmer base for a future PV market without support. The technology neutral auctions exhibit for PV (and wind) a negligible need for a price adder on top of the electricity market price.

Regions and municipalities have potential for playing an increasingly more active role in the deployment of PV as an integral element in their respective climate and energy goals

Fig. 2 - Vester Skerninge, Fyn. Privately owned with 20 kWp PV plant with a 16 kWh lithium battery (Photo: KlimaEnergi A/S).

and plans, and these organisations are expected to play an important role in the future deployment of PV across 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. New signals from the parliament indicate that new regulations, hopefully with fewer barriers, will be implemented in 2021.

NATIONAL PROGRAMME AND IMPLEMENTATION

Denmark has no unified national PV programme, but during 2020 a number of R.D.D. projects has been supported mainly by the Danish Energy Agency's EUDP programme. Some additional technology-oriented support programmes targeted R&D in the green energy transaction have been initiated.

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

In 2019, the new requirements for generating plants to be connected in parallel with distribution networks (EN 50549-1) were implemented with national specific requirements.

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 or based on PPAs is growing both in number and volume, and several commercial PV developers have activities in deploying PV across the EU, as well as internationally.

The main potential for deployment of PV in Denmark has traditionally been identified as building applied or integrated systems. However, the number of ground-based centralised PV systems in the range of 50 to >200 MW has been growing. Mostly, the projects are based on commercial PPAs or providing power to the actual market price (Nordpool). The government's technology neutral auction scheme has given a push to this trend, although public concerns regarding large scale ground mounted PV parks are rising.

In early 2016, the Danish Energy Agency forecasted PV to reach 1,75 GW by 2020 (5% of the annual electricity consumption) and more than 3 GW by 2025. 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 5 GW of PV can be grid connected in Denmark with only minor network problems, although they are aware of 18 GW PV plants under planning.

RESEARCH AND DEVELOPMENT

R&D efforts are concentrated on polymer cells, BIPV 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.

At a limited effort, penetration and high penetration of PV in grid systems are being researched and verified by small demonstrations, often including batteries and demand side management.

As mentioned above, the Danish TSO has published a study indicating that about 5 GW PV can be accommodated in the national grid system with only minor network problems; 5 GW PV will correspond to almost 15% of the national electricity consumption.

Fig. 3 - Midtlangelands Fjernvarmeværk in Rudkøbing (district heating) 110 kW PV plant (Photo: KlimaEnergi A/S).

INDUSTRY AND MARKET DEVELOPMENT

A Danish PV Association was established late 2008. With now approximately 30 members, the association has provided the emerging PV industry with a single voice and is introducing ethical guidelines for its members. In 2020, the association formulated a new and ambitious strategy based on the political target for 2030, with a reduction of the CO_2 emission at 70%. In this plan, green electricity will play an important role and therefore the Danish PV Association expects the cumulative capacity of PV has to be ten times more than in 2019.

A few PV companies producing tailor-made modules such as window-integrated PV cells can be found. A Li-Ion battery manufacturer and a vanadium redox flow battery (VFB) manufacturer have shown interest in the PV market and are now offering storage solutions. A few companies develop and produce power electronics for PV, mainly for stand-alone systems for the remote-professional market sector such as telecoms, navigational aids, vaccine refrigeration and telemetry.

A growing number of companies are acting as PV system developers or integrators designing, developing and implementing PV systems for the home market and increasingly at the international level. Danish investors have entered the international PV scene on a rising scale 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 2020 is estimated at around 225 MWDC in Denmark. The cumulative installed PV capacity in Denmark by end-2020 is estimated to be just above 1,5 GW.

EUROPEAN COMMISSION

SUPPORT TO RESEARCH AND INNOVATION ACTIVITIES ON PHOTOVOLTAICS AT THE EUROPEAN UNION LEVEL

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

THE EUROPEAN GREEN DEAL

The European Green Deal is the new growth strategy that aims to transform the European Union 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 the use of resources [1]. To accomplish climate neutrality in 2050 and turn this political commitment into a legal obligation, the European Commission proposed a European Climate Law [2].

Reaching this target will require action by all sectors of our economy. The European Commission already adopted the Energy System Integration Strategy [3] and the Hydrogen Strategy [4], as well as the Offshore Renewable Energy Strategy [5]. It also adopted a far-reaching Renovation Wave initiative [6]. Together with the annual State of the Energy Union report, the European Commission published the Competitiveness Progress Report, which tracks progress achieved by the clean energy industry [7]. Key clean energy technologies, such as solar photovoltaics, onshore wind and, more recently, also offshore wind, batteries, and heat pumps recorded considerably lower costs through innovation and scaling up. The Competitiveness Progress Report shows that the European clean energy industry can considerably contribute to reaching our climate targets while creating more and better jobs than in other sectors. The EU is well-positioned in some of the key technologies expected to greatly expand in the coming years (offshore wind, smart grids, ocean energy, and renewable hydrogen). While for photovoltaics, the strong knowledge of the EU research institutions, the skilled labour force, and the existing and emerging industry players could provide a basis for re-establishing a strong photovoltaic supply chain. However, this competitive position is at risk given the fall in investments in clean energy R&I in the European public and private sector.

DEPLOYMENT

A total of 131,9 GW are the estimated photovoltaic cumulated capacity installed in the EU by the end of 2019, a 14% increase over the 115,2 GW operating the year before. In 2019, Spain recorded an estimated addition of 4,7 GW, Germany of 4 GW, the Netherlands of 2,5 GW, and France of 1,1 GW [8].

Reported in Figure 1 is the consolidated figures on the cumulated PV capacity installed in some EU Member States by the end of the year 2019.

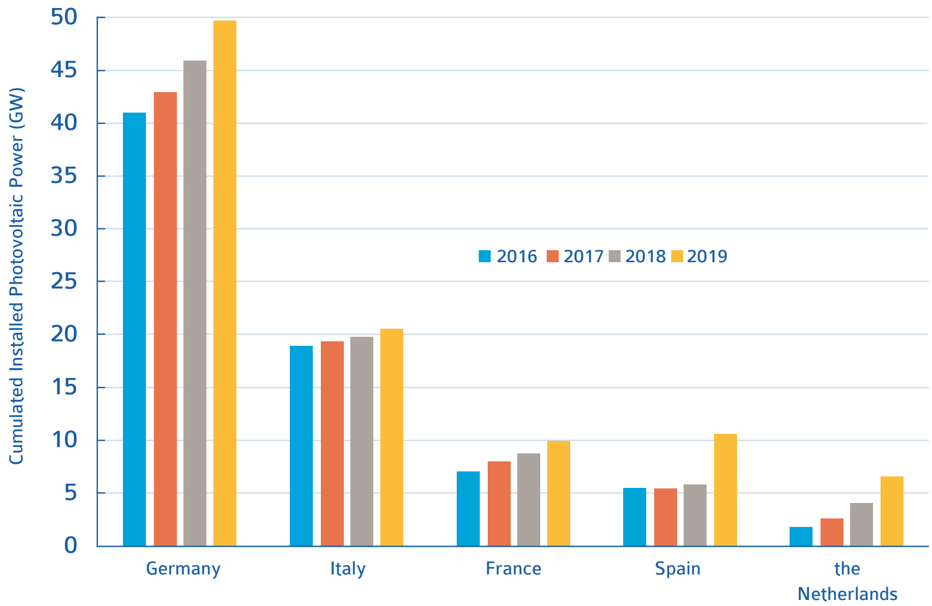


Fig. 1 - Cumulative installed photovoltaic capacity in some EU countries [8].

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION

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, was structured along three strategic objectives: 'Excellent science', 'Industrial leadership', and 'Societal challenges' [9].

An overall view of the budget invested in photovoltaics, under different Horizon 2020 activities, is provided in Figure 2.
A total EU financial contribution of about 259,5 MEUR is being invested, under H2020, in activities which are related to photovoltaics [10]. This contribution is mostly spent for innovation actions (43%), research and innovation actions (30%), and grants to researchers provided by the European Research Council (8%). Fellowships, provided under the Marie Skłodowska-Curie programme, absorb 6% the same share going to actions for SMEs, which amount to 6% of the overall investment. Coordination actions, such as ERA-NETs, represent 7% of the budget.

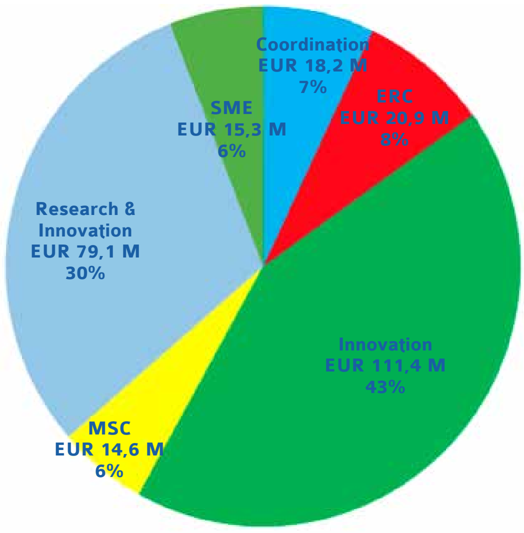


Fig. 2 - Photovoltaic activities funded under Horizon 2020.

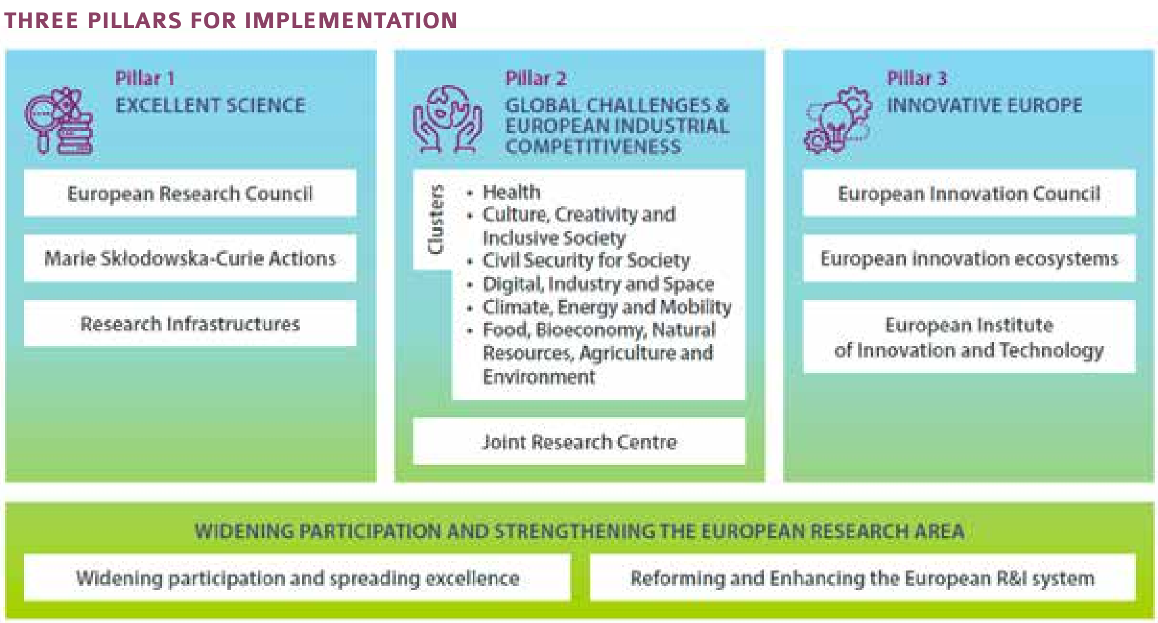
Horizon Europe: The EU Framework Programme for Research and Innovation (2021-2027)

Horizon Europe [11] will have a budget of around 95,5 BEUR for 2021-2027 (current prices). This includes 5,4 BEUR from *Next Generation EU* to boost recovery and make the EU more resilient for the future, as well as an additional reinforcement of 4,5 BEUR. Over 35% of Horizon Europe spending will contribute to climate objectives.

Learning the lessons from Horizon 2020, the Horizon Europe design and implementation modalities will rationalise the EU funding landscape for research and innovation, and maximise its impact, its relevance to society and its potential for breakthrough innovation.

There will be a strong degree of continuity: three pillars, excellence at the core, as well as changing rules and procedures as little as possible for participation.

TABLE 1 – THREE PILLARS FOR IMPLEMENTATION



Energy supply and photovoltaics R&I will mainly be dealt with in 'Cluster 5: Climate, Energy and Mobility' of the second pillar. Intervention areas of this cluster include climate science, energy supply, energy systems and grids, communities and cities, industrial competitiveness in transport, clean transport and mobility, smart mobility and energy storage.

SET PLAN ACTIONS AND INITIATIVES

Since 2008, the SET Plan has been the core instrument to help in aligning European and national clean energy R&I priorities across Europe, by fostering cooperation between governments, the research community and industry on a commonly agreed agenda. With the introduction of the national energy and climate plans – NECPs [12]), the SET Plan has oriented Member States on how to address Research and Innovation, in order to achieve their 2030 and 2050 climate and energy targets. The recent COVID-19 pandemic presents critical challenges, and many opportunities for the EU to boost the recovery towards a greener, more digital and more resilient Europe through the Next Generation EU initiative, and the SET Plan will deliver the necessary R&I plan.

The SET Plan is structured around 13 Implementation Plans (IPs) [13], covering all energy R&I priorities of the Energy Union. Countries aim at mobilising funding at the national level but also through partnerships which will be supported by Horizon Europe; one of them being the Clean Energy Transition (CET) Partnership [14].

The IP for PV identifies a set of six technology-related priority activities for the future development of PV technologies and applications in Europe [15]:

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. The IP for PV aims to contribute to the Renovation Wave, Offshore Renewable Energy Strategy and the Energy System Integration Strategy [16].

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FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS
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JERO AHOLA, PROFESSOR, LUT UNIVERSITY

Fig. 1 - LUT two-axis tracking solar PV system (Photo: Teemu Leinonen).

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, 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, 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 2020, a total of 6,6 MEUR investment subsidies for 308 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 to about 10-15% of the total PV system's 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 Metropolia, Satakunta and Turku Universities of Applied Sciences. There is also active research on silicon solar cells at Aalto University, on high-efficiency multi-junction solar cells based on III-V semiconductors at Tampere University of Technology, and on roll-to-roll printing or coating processes for photovoltaics at VTT Technical Research Centre of Finland. In addition, there are research groups working on 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 finance company-driven development and demonstration projects. In Finland, there are no specific budget lines, allocations or programs for solar energy R&D&I, but PV is funded as part of open energy research programs.

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 2020, the installed grid-connected PV capacity was estimated to be approximately 300 MW and the number of PV plants more than 30 000. In 2020, hourly net-metering and energy communities were legislated in Finland. These both are expected to impact positively on the number of PV installations in coming years.

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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MELODIE DE L'EPINE, HESPUL

Fig. 1 - Solar parking canopies on the site of automotive industrial JTEKT Technical Center, in the Vallée de la Chimie near Lyon, France (Photo: Terre et Lac).

GENERAL FRAMEWORK AND IMPLEMENTATION

The year 2020 was marked by the COVID-19 lockdown which started in March and the subsequent economic slowdown that led to both difficulties in the supply chain and a stop and go market. It led to a freeze on feed-in tariffs, extended delays for commissioning, whilst the July competitive tender was split in two with 2/3 of the volume available in an additional submission date in November. The promise of feed-in tariffs for systems in the 100 kW to 500 kW range (awaiting EU notification as of January 2021) is part of the government's response to the sector, struggling with these impacts.

Public awareness on the use of polluting or rare materials in renewables was increased by the publication of a controversial book and television documentary, and maintained by opponents to renewable energies, despite increasing "fact-checking" responses.

Notable framework publications include mandatory solar or living roofs for new buildings over 1 000 m^2, the transcription into French law of the European Network Code, changes to grid access costs for some small to medium systems, a modification in the feed-in tariff calculation method and the revised annual target volumes in the PPE (Energy Programme Decree).

The revised PPE goal targets are 3 GW/year, a long way from the consistently less than 1 GW commissioned per year of the past eight years. Reaching this goal is possible if all projects currently in the queue are commissioned. Indeed, nearly 2,5 GW of projects have signed a preliminary grid access contract, and a further 5 GW with a grid request could be signed (with long lead times, it is difficult to obtain a clear picture on how much of this will eventually reach commissioning, and in what timeframe). This comes at a time when EU reporting has highlighted that of all its member states, France is the furthest from reaching its European agreed renewable energy targets, lagging by a remarkable 5,8% points.

Further difficulties may be ahead, with a controversial and contested move by the government, adopted in December 2020 despite being rejected by the Senate, for renegotiating contracts for the approximately 800 systems over 250 kW commissioned with 2006-2010 feed-in tariffs. With the stated aim of economising around 600 MEUR a year, the negative impact on investor and financial sector confidence is still to be measured.

National photovoltaic capacity grew by 973 MW in 2020, compared to 955 MW in 2019, for a cumulative capacity of 10 860 MW.

NATIONAL PROGRAMME

France's photovoltaics targets are described in the regularly revised PPE (Energy Programme Decree). The 2020 revision, published in April, sets a goal of 3 GW/year minimum to reach 20 GW in 2023 and 35 GW in 2028. The government continues its policy of relying on large scale systems to reach this target, with higher volumes in the competitive tenders for the largest systems - ground-based photovoltaics, preferably on urbanised land or degraded areas and parking canopy systems, ensuring that projects respect biodiversity and farming lands.

This year was to see the end of the 2016-2019 cycle of competitive tenders, however they will be extended to the end of 2021 to ensure continuity. The consultation with industry actors on adapted specifications for the next (2020-2026) was only concluded in September 2020. The new cycle will see a technology neutral tender and a reduction in the number of categories. A target of 3 GW/year over five years within the tenders was announced in January 2021, with a significant reduction in the volumes available for self-consumption systems and 2/3 of the volume reserved for ground-based systems.

As previously, overseas territories will see specific tenders called, in line with territorial energy program decrees.

There were 11 national calls for tenders in 2020, with results published for five, including the Innovation and Fessenheim tenders.

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

- Ground mounted installation, peak power between 500 kWp to 5 MWp,
- 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 north-east of France) aims to develop ground, building, greenhouse, agricultural hangar and parking canopy 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 in 2020.

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** 2017–2021	Call for Tenders 2017–2020	Call for Tenders 2019-2020
VOLUME	1 175 MW in 11 calls of 75 MW to 150 MW)	1 200 MW in 11 calls of 75 MW to 150 MW	5,78 GW in 9 calls of 330 MW to 850 MW	450 MW in 12 calls of 20 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)	10th call: 94,0 EUR/MWh	10th call: 83,0 EUR/MWh	8th call: 57,4 EUR/MWh	8th call: 13,8 EUR/MWh	3rd call: 85,1 EUR/MWh	2nd call: **Family 1** (Ground-based): 57,6 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.

After a significant increase in winning tendered tariffs in the under-subscribed 2019 tenders, 2020 saw a reduction in the volumes available in most tenders to avoid under-subscription and to ensure "continued competitiveness" – although there was little discussion on the structural reasons that could be driving the under-subscription. The second tender for the Fessenheim region (north-eastern France) remained attractive, with tendered prices relatively close to the open tenders despite the lower insolation levels.

An increasing number of major PPAs have been signed in 2020, with high profile French-owned companies such as SNCF and Decathlon leading the way.

Reserved for building mounted systems and parking canopies, smaller sized systems (under 100 kW) were supported through feed-in tariffs, with less than 14% of the cumulative peak power of new projects under instruction. The COVID-19 shutdown led to a freeze on tariffs until June, whilst the method used to calculate the quarterly drop in tariffs was simplified and modified in September; penalising the market with steeper reductions in the tariff whenever project volumes stray from the target corridor (either below or above!).

Because of the new method, the feed-in tariffs across 2020 for systems under 36 kWp dropped 3%, and the tariff for systems under 100 kWp dropped a significant 6%.

Conditions for an extension of the feed-in tariff for systems up to 500 kWp were drafted, and should be published in spring 2021.

TABLE 2 – PV FEED-IN TARIFFS FOR THE 4TH QUARTER OF 2020 (EUR/KWH)

TA (NO SELF-CONSUMPTION) TARIFF Q4 2020	POWER OF PV INSTALLATION (kW)	PA (PARTIAL SELF-CONSUMPTION) TARIFF Q4 2020
0,1797 EUR/kWh	≤3 kW	0,10 EUR/kWh (+0,38 EUR/W installed)
0,1527 EUR/kWh	3 kW to 9 kW	0,10 EUR/kWh (+0,28 EUR/W installed)
0,1135 EUR/kWh	9 kW to 36 kW	0,06 EUR/kWh (+0,17 EUR/W installed)
0,0987 EUR/kWh	36 kW to 100 kW	0,06 EUR/kWh (+0,08 EUR/W installed)
Average selling price (EUR/AverakWh) 0,094 (10th Call)	Call for Tenders 100 kW to 500 kW	Average bonus for self-consumption (EUR/AverakWh) 0,014 (8th Call)

R&D

Research and Development for photovoltaics in France ranges from fundamental materials science, to pre-market development and process optimisation, 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 organisations, with the goal of coordinating national energy research efforts. Members include the CEA (Atomic Energy and Alternative Energies Commission) and the CNRS (National Centre for Scientific Research), whilst the research financing agencies ADEME (Agency for Ecological Transition) 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 decreased for the 4th consecutive year, from 58,7 MEUR in 2015 to 38,5 MEUR in 2019. Over the same period, the amount dedicated to hydrogen rose from 19,5 MEUR in 2015 to 25,9 MEUR in 2019.

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

IPVF works across a number of fields both industrial and upstream, including a solar-to-fuel programme, work on perovskites, on silicon tandem modules, and III/V on silicon tandem cells. In May, IPVF initiated the Solar Europe Now coalition, calling on states to recognise the strategic value of photovoltaics and give it a more visible place in the Green Deal. Support has been widespread across Europe amongst both research organisations and market suppliers.

INES works with industrial partners on subjects ranging from building integration components to grid integration and storage technologies, also covering transport and road-based integrated technologies, as well as fundamental research on silicon and cell technologies.

INES reached a record efficiency of 25% for a heterojunction cell on a pilot line, built on getting passivated contact cells to industry, launched a joint programme on perovskite/silicon heterojunction cells with IPVF and continued investing both in equipment and research on flexible cells for space applications.

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. Only a handful of projects awarded through the general ANR 2020 calls concerned photovoltaics, an increased decline from previous years; these were mostly on cell materials;
- The French Agency for Ecological Transition (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 TCP and SOLAR-ERA.NET pan-European network.

The year's major events were all impacted by the COVID-19 lockdowns – either postponed until 2021, or postponed and reorganised online in late 2020. These include the National PV Days (JNPV) finally held late January 2021 at the initiative of the Fed-PV, (CNRS PV research federation) and IPVF, the IPVF Solar Industry Days postponed until November 2021, and the Energaïa industry forum held online in December 2020. This also included a Symposium to celebrate the 200th anniversary of Edmond Becquerel's birth, also postponed and held online in December 2020.

INDUSTRY AND MARKET DEVELOPMENT

This year's market was reasonably steady in terms of overall volumes, despite the COVID 19 impacts. Competitive tenders were no exception to the past, with major players winning significant volumes. For nearly all tenders, the biggest winner won more than 30% of the allocated volume. There was some movement within the top 10, with EDF winning significant volumes, but no room for new players. The French company Total, number two in France behind France's Engie, announced in January 2021 a reinforcement of its shift to solar, with the planned acquisition of 20% of Adani, the world's number one solar developer.

REC confirmed its intentions to build a 4 GW factory in north-eastern France, with a preliminary public consultation opened for a site in December. The news has been welcomed in the economically struggling region, with a strong industrial past. The factory will create more than 1 500 jobs and will require an investment of 680 MEUR. REC plans to manufacture their heterojunction modules, trialled in a smaller Singapore site, to provide low-carbon footprint modules to the local market, where competitive tenders continue to give bonus points according to environmental and carbon content criteria.

France's solar developers had some significant successes in foreign markets, from Akuo in Mali, Engie in the USA and Neon in Australia. Many are venturing into either big battery storage or green hydrogen (or both), with projects planned in France and overseas.

In response to the COVID-19 disruption of supply chains, and with the possibility of a low carbon and increasingly competitive manufacturing industry in Europe (on the one hand, transport is a growing proportion of module costs, and on the other hand manufacturing is increasingly automated), the Strategic Industry Committee for New Energy Systems launched a call to identify all actors in the value chain to create a shared roadmap (expected for May 2021) to meet local demand in line with the PPE goals of 3 MW/year to 5 MW/year.

Total annual installed capacity held steady despite the unprecedented COVID-19 crisis. There was little change in the proportions installed across the different segments. Overall grid-connected volumes grew by an estimated 973 MW as compared to 962 MW in 2019 and 876 MW in 2018. Systems over 100 kW continue to dominate grid connections, with 55% of new capacity (522 MW). The trend for partial self-consumption in the below 36 kW segment continues with an overwhelming majority of systems choosing this model. The COVID-19 lockdown had the unexpected result of a sharp uptake in this sector – industry actors speculate that homeowners had the time to plan investments that may not otherwise have been undertaken.

TABLE 3 – GRID CONNECTED CAPACITY AT THE END OF DECEMBER 2020 (PROVISIONAL)

POWER CATEGORY	CUMULATIVE POWER (MW)	CUMULATIVE NUMBER OF SYSTEMS (NUMBER)
Up to 9 kW (Ta FiT)	1 540 (14%)	435 251 (89%)
9 kW to 100 kW (Tb FiT)	2 260 (21%)	41 944 (9%)
Above 100 kW	7 060 (65%)	9 280 (2%)
Total (provisional)	10 860	486 475

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

GERMANY

PHOTOVOLTAIC BUSINESS IN GERMANY – STATUS AND PROSPECTS

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

GENERAL FRAMEWORK AND IMPLEMENTATION

Germany is undergoing a transformation process of its energy supply away from nuclear power and fossil fuels towards renewable energies and a significantly increased energy efficiency. The Federal Government decided to take measures for a binding reduction of 55% of greenhouse gas emissions by 2030 via the Climate Action Programme 2030 [1] and the Climate Change Act (Klimaschutzgesetz). Thus, Germany is moving away from coal, wants to renovate more buildings to make them energy-efficient and pushes climate-friendly mobility forward.

This goal is to be achieved mainly by putting a price on CO_2 emissions, introducing incentives to cut CO_2 emissions and foster technological solutions. 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. Coal-based electricity generation will phase out by law (Kohleausstiegsgesetz [2]) until 2038. Germany's last nuclear power plant will be shut down at the end of 2022. Therefore, contributions from renewable energy sources such as photovoltaics and wind energy must increase significantly.

In 2020, approximately 50% of net electricity generation was already covered by renewable energies of which 10% was generated by Photovoltaic (PV) systems [3]. The reasons for this are continuous investments in renewable energies, lower electricity generation from fossil fuels and an overall reduction in electricity consumption by an estimated 3,5% due to the COVID-19 pandemic.

NATIONAL PROGRAMME

The responsibility for all energy related activities is concentrated within the Federal Ministry for Economic Affairs and Energy (BMWi). The main driver of the PV market in Germany so far has been the Renewable Energy Sources Act [4]. A continuous revision process adapts the Renewable Energy Sources Act (EEG) to the current and planned expansion of renewable energies. The last important change to the EEG as a result of the climate protection programme was the lifting of the 52 GW cap on the expansion of photovoltaic plants.

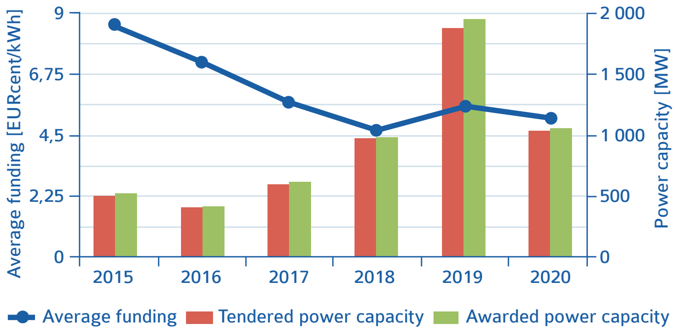

Fig. 1 - Average funding awarded in the auctions for ground-mounted PV installations.

Since January 1, 2019, the Energy Collection Action law is in force, which also provided 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 power plants and onshore wind energy farms are to be put out to tender additionally until 2021.

As a result, a total volume of approx. 1,056 MW was awarded in five auctions for ground-mounted photovoltaic installations in 2020. An 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 1 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 a good efficiency of the auction process.

Medium-sized photovoltaic systems below 750 kW are still eligible for a guaranteed Feed-in-Tariff (FiT) for a 20-year period. Systems with more than 100 kW power capacity are obliged to undertake 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 [6]. Table 1 shows the development of the FiT for small rooftop systems (< 10 kW) over the last 15 years.

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

YEAR	2005	2006	2007	2008	2009	2010	2011	2012*	2013*	2014*	2015*	2016*	2017*	2018*	2019*	2020*
EURcents/ kWh	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	9,87

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

Fig. 2 - 187 MW commercial subsidy-free solar park in Weesow-Willmersdorf (Photo: © EnBW).

Fig. 3 - Demonstration BIPV façade at Fraunhofer ISE, Freiburg with CIGS (bottom), OPV (middle) and Silicon modules (top) (Photo: © FhG ISE).

Moreover, investments in PV installations become attractive even without financial support by a Feed-in-Tariff. In particular, several energy suppliers and municipal utilities are currently planning and implementing a number of solar parks for the direct marketing of green electricity. The electric utilities company EnBW AG recently announced the commissioning of a new 187 MW large-scale solar park (see Fig. 2). It is Germany's largest and first utility-scale solar park, which is realized without any subsidies. An expansion of this installation is already planned via two directly adjacent solar parks with a total capacity of 500 MW.

RESEARCH AND DEVELOPMENT

The 7th Energy Research Programme entitled "Innovations for the Energy Transition" [7] came into force in September 2018. It still defines the guidelines for energy research funding. 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 in different aspects of PV. The main parts of the programme are administrated by the Project Management Organisation (PtJ) in Jülich.

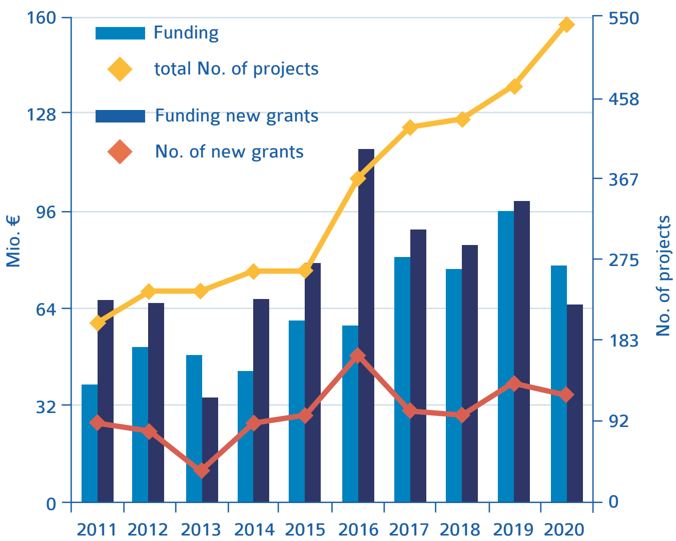

Fig. 4 - R&D support and quantity of PV projects funded by BMWi (BMU) in the 6th and 7th EFP.

Funding Activities of the BMWi

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

- Efficient process technologies to increase performance and reduce costs for Silicon wafer and thin film technologies;
- New PV materials and cell concepts (e.g. tandem perovskite solar cells);
- Quality and reliability issues of PV components and systems;
- System technology for both, grid-connection and island PV plants;
- Cross-cutting issues such as Building Integrated PV (BIPV) (see e.g. Fig. 3), Vehicle-integrated PV (ViPV) or avoidance of hazardous materials and recycling of PV systems.

Within this broad approach, the 2020 focus areas were on silicon-perovskite tandem solar cells, process technologies using modern smart digitalization technologies and BIPV.

The development of funding activities over recent years is shown in Figure 4. In 2020, the BMWi support for R&D projects on PV amounted to about 78 MEUR shared by 541 projects in total. That year, 122 new grants were contracted. The funding for these projects amounts to 65 MEUR in total.

Examples of research projects are published on the BMWi website [8] or via a web-based database of the Federal Ministries [9]. One highlight of 2020 is the investigation of new manufacturing technologies including Industry 4.0 aspects to better exploit the benefits of heterojunction solar cells and modules.

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 a close and ongoing dialogue between the relevant stakeholders by initiating high-level energy transition platforms. This also creates a high degree of transparency, contributing to greater public acceptance of the energy transition.

The network for research and innovation in the field of renewable energies [10] 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. As part of a completed consultation process with leading representatives from industry and research, the research and development needs for a successful photovoltaic development in Germany for the next 5 to 10 years were drawn up.

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 BMBF funds, in particular, basic research projects and feasibility studies at a lower technology readiness level (TRL).

INDUSTRY AND MARKET DEVELOPMENT

The market of photovoltaic systems in Germany has been steadily growing over the last six years. A total of 4,9 GW of photovoltaic capacity was newly installed in 2020, which sums up to a total capacity of 54,3 GW PV power plants (see Figure 5 and [3]). This increase is supported by the fact that wholesale prices for standard photovoltaic modules have fallen by 12% since the beginning of the year [11]. This market development influenced the Meyer Burger company to turn into a cell and module producer and to build a new production site in Germany for advanced heterojunction solar cells and modules with smart wire technology.

Again, the engineering industry could prove their competitiveness when selling innovative production equipment, especially in the area of thermal treatment, coatings and wet chemical processes.

Beside 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 [12].

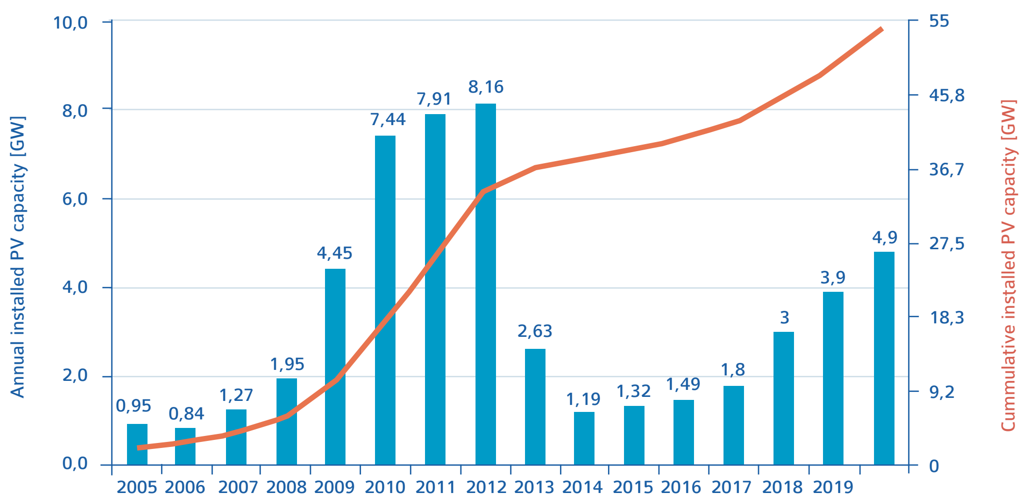

Fig. 5 - Development of grid connected PV capacity in Germany, *first estimate as of January 2021.

Fig. 6 - 750 kW floating PV on a dredging lake of a gravel pit (Photo: © Energieagentur.NRW / Rheinland Solar).

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ISRAEL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE

YAEL HARMAN AND MICHAEL SHERMAN, THE MINISTRY OF ENERGY

GENERAL FRAMEWORK

On July 29th 2020, the Israeli Minister of Energy announced that the renewable energy target in electricity generation would be raised from 17% to 30% by 2030, most of which will come from PV combined with energy storage. Moreover, as part of the efforts of Israel to deal with climate change, on November 29th 2020, the Ministry of Energy published the proposed targets for reducing emissions in the energy market in 2050. The energy market, according to the plan, will reduce greenhouse gas emissions by up to 80% by 2050.

In 2020, the Israeli Public Utility Authority (PUA) had published two competitive bid rounds for distribution grid connected PV + storage. 609 MW of bids were accepted in the second round at a tariff of 0,1745 ILS (0,053 USD) per KWh while 168 MW were taken in the first round at a tariff of 0,199 ILS (0,06 USD) per KWh. The PUA also published the third large rooftops and water reservoirs PV bid round. 435 MW were taken at a tariff of 0,1818 ILS (0,055 USD).

In 2020, total RE capacity in Israel was increased by only 323 MW to a total capacity of 2,531 MW. The small increase is also due to a correction of the 2019 total, so installations during 2020 were higher, but the total compared to the last annual report has increased by 323 MW, due to the COVID-19 outbreak and two lockdowns. Overall, by the end of 2020, Israel reached a level of 7,2% RE electricity generation measured in potential terms (meaning, taking the installed capacity at the end of 2020 and multiplying it by the average hourly production per installed MW). PV systems are still the most abundant RE resource in Israel, accounting for approximately 98% of the installed capacity. Due to the COVID-19 crisis, many PV installations were postponed and are expected to be completed during 2021.

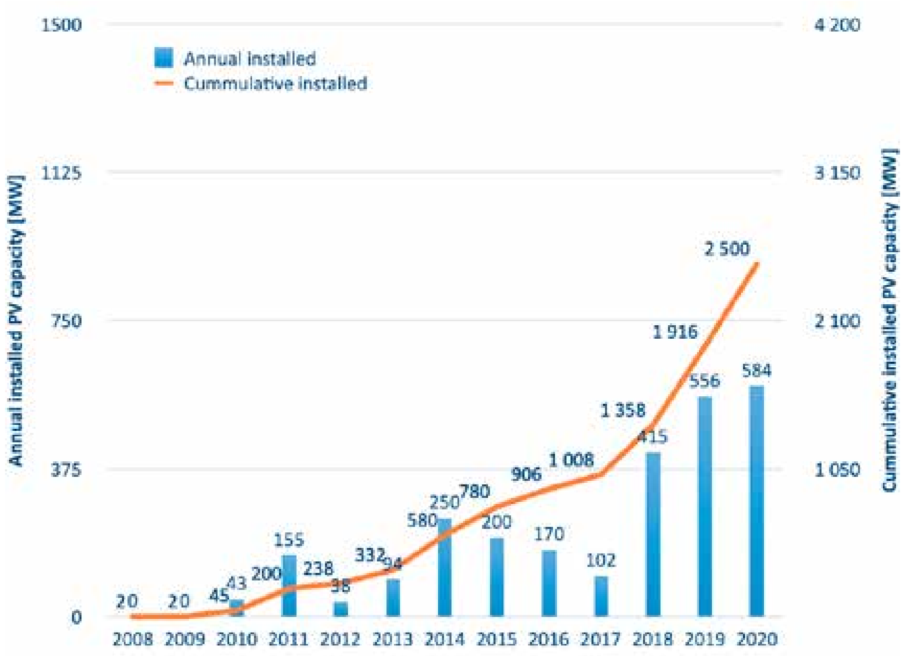

Fig. 1 - Development of grid-connected PV capacity in Israel through 2020.

In 2020, the price of electricity decreased by 5% to 0,4484 ILS, excluding VAT (0,14 USD), per KWh, one of the lowest in the developed world.

In November 2019, the government had announced that Israel would move into a coalfree era of power generation by the end of 2025, five years earlier than originally planned. Over the past five years, coal-fired electricity production has been reduced from 60% to 30%, making Israel one of the world leaders in coal phaseout efforts. In 2020, close to 70% of the electricity generation came from gas. In 2020, the natural gas price in Israel for electricity generation was ~5,57 USD per MMBTU.

NATIONAL PROGRAMS

An updated National Outline Plan (NAP) N° 10/d/10 has been published for the public hearing in the beginning of 2020; the plan contains renewable energy plans and plans for small power plants. This NAP includes descriptive plans for renewable energy (photovoltaic production facilities and wind turbines), as well as plans for small power plants that generate electricity up to 250 MW.

On November 16th 2020, the Ministry of Energy presented the updated national plan for energy efficiency for the years 2020-2030. The Ministry recommends an intermediate target of 11% improvement in energy consumption intensity by 2025 compared to 2015, and an 18% improvement in energy intensity by 2030 compared to 2015. The implementation of the policy measures is expected to lead to a reduction in energy consumption of about 16,5 TWh (compared with business as usual total consumption of roughly 210 TWh by 2030) - a reduction of about 6 million tons of greenhouse gas emissions, which is expected to be about 7,5% of the total greenhouse gas emissions in Israel in 2030.

The Ministry of Energy has continued its efforts to decarbonize the transportation sector throughout 2020. Despite the COVID-19 pandemic, a total of 400 new AC and 20 DC charging points were installed across the country, and an additional 2,000 AC and 80 DC points will be installed by the end of 2021. Moreover, the Ministry has conducted research to assess the impact of large EV uptake on the local grid and will continue to do so during 2021. As part of this initiative, the Ministry is about to start two pilot projects that will test the possibility of using Smart Charging to alleviate EVs' stress on the local electricity grid, mainly during peak hours.

RESEARCH AND DEVELOPMENT

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

- Direct support for academic research - support is 100% for research projects.
- Support for start-up companies - support is 62,5% for projects with technology innovation.
- Support for Pilot and Demonstration projects - support is 50% for commercial deployment of novel technologies.
- Horizon 2020 – The CSO operates several joint programs with the European Union and publishes annual calls for proposals. Among the joint programs are Water JPI, Solar, CSP, SES & Digitalization Era-Nets.
- The Bird Energy Fund is a Binational Industrial Research and Development (BIRD) Foundation that supports joint US-Israel projects in the energy field.
- The US-Israel energy center of excellence is a Bi-National five-year program to support research in four core areas: Energy Storage, Cyber Security for infrastructure, Water and Energy, Natural Gas. It is operated by the BIRD Foundation.
- In 2020, the Office of the Chief Scientist invested over 14 MUSD in energy related R&D projects. Among the current supported projects are:

AGRI-LIGHT

Agri-Light has developed and is now piloting a fully integrated agri-voltaic system with the aim of increasing both energy generation and agricultural output.

Agri-Light's solution is a solar system, powered by proprietary algorithmic models, that combines photovoltaic bifacial panels with a tracking system and IoT sensor inputs to best capture the sun's energy and optimize agricultural crop cultivation.

Agri-Light's technology automatically adjusts the tilt angle of the solar panels to ensure sufficient solar radiation, required for the photosynthesis process of the agriculture crops, based on crop type, geographic location, season of the year, weather, and time of day.

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ORION - IMPLEMENTING AGRIVOLTAICS IN ORCHARD PLANTATIONS, A FIELD STUDY

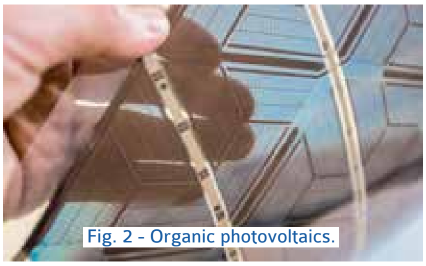
Fig. 2 - Organic photovoltaics.


Fig. 3 - OPV in a greenhouse.

The overall aim of ORION is to develop an intelligent integrated framework for the use of organic photovoltaics (OPV) in the greenhouse industry. To achieve this, ORION will develop, test, and evaluate innovative organic photovoltaic modules, which will be incorporated on top of the greenhouse roof or inside the greenhouse above the crop. Co-developing the same area of land for both photovoltaic electricity generation, as well as for the production of agricultural products (vegetables, fruits and flowers) is one of the main objectives of this study. In parallel, ORION will develop a wireless sensor system for smart management of the whole system (crop, microclimate and energy from OPV) and a computational fluid dynamic code for extending, via simulations, the use and adoption of the proposed system in different greenhouse types, different areas and different crops. The project results will contribute to optimizing the application of OPV in greenhouses. The project will advance the technological development of the most intensive branch of agricultural production (greenhouse). The participation, in the project, of universities, research institutes and industry, with experts from both the photovoltaic and agricultural sectors, provides a unique synergetic approach.

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TECHNION - EFFICIENT HEAT ENGINE AT SMALL CAPACITY FOR SOLAR AND WASTE HEAT

TECHNION
Israel Institute
of Technology

Concentrated solar power operates at typical temperatures of 560 oC (833 K) for towers and 400 oC (673 K) for troughs. The energy density of such temperatures is low compared to fossil fuels, which challenge the efficiency of heat engines in converting this heat into electricity. Steam turbine becomes efficient (>40%) only at a capacity above 30 MW. As far as it is known, there is no current small capacity (<1 MW) and high efficiency (>40%) heat engine. SCo2 turbine aims to meet this challenge, but its Levelized Cost of Electricity (LCOE) is too high to be applied in the solar and wasted heat market.

It is the aim of this proposal to demonstrate low-cost (<250 USD/kW), efficient (>40%) conversion of solar heat to electricity.

The first-ever heat engine will be built where the heat transfer fluid (HTF) supplies the heat to air bubbles, realizing a near-ideal Carnot engine by allowing isothermal expansion of the air while performing the thermodynamic work. This new engine relies on a well-established hydro-electric technology with proven high efficiency and low cost. Successful realization of this HTF-engine is a game-changer in wasted heat recovery and solar energy conversion. Such a heat engine can also operate on hydrogen, bio-diesel, or fossil-fuels when the sun is not available for a few days, offering a 24/7/365 supply that replaces gas and coal power stations, and which leads to boosting the solar energy portion to above 50%.

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ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES

EZIO TERZINI, ENEA
SALVATORE GUASTELLA, RSE

GENERAL FRAMEWORK AND IMPLEMENTATION

In Italy, the trend of growth in PV installations in 2020 was higher than the recent years (see Figure1), thanks the context of the PV market in Italy which is rather lively, although with a trend not yet adequate to achieve the objectives of the Italian government's energy plan (outlined in the "Integrated National Plan for Energy and Climate", PNIEC), approved by the national Parliament and by the EU, 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 2020 indicate a value of about 0,8 GW, which is almost the same volume of 2019 (0,76 GW), and higher than the 2018 one (0,43 GW).

On the whole, it can be preliminarily estimated that a total cumulative PV capacity of around 21,7 GW was reached at the end of 2020 (Figure 1).

From January to October 2020, residential PV plants up to 20 kW, accounting for 44 800 units, made up 36% of the new installed capacity [2], mainly thanks to the tax breaks mechanism; in the same period the installations of medium and large plants (> 20 kW) were almost 400, totaling near 400 MW. Also, some utility scale plants 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 2020, the preliminary data on the annual energy production from grid connected PV plants is 25 594 GWh, which is 9,6% more than in 2019 (23 320 GWh), and covering about 8% of national electricity demand. Moreover, with regard to the electricity production of the other RES, in the same year, it was noticed that Hydroelectric covers 15% of national electricity demand, Geothermal 1,8% and Wind 5,8% [3].

NATIONAL PROGRAMME

There were many expectations from the effects of the incentive measures for renewable sources adopted in Italy with the FER-1 Decree (the decree of July 2019 to incentivize the RES), the results of which, unfortunately, were strongly influenced by the spread of COVID-19 and the related lock-down measures in 2020. The results of the first three auction procedures to incentivize new power plants having power P>1 MW, and those of Register Entry for plants with power between 20 kW and 1 MW were not favourable.

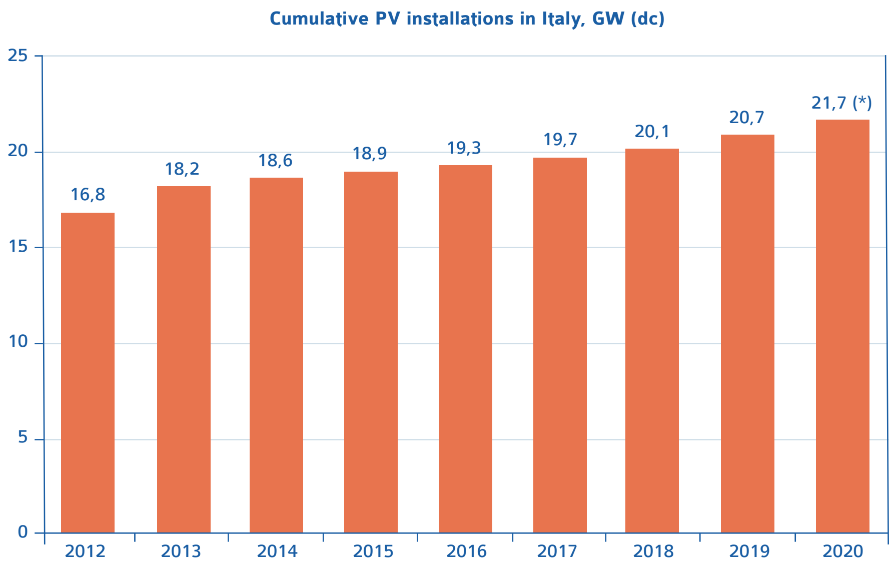


Fig. 1 - Trend of cumulative PV installations in Italy (*) preliminary data of year 2020 (Source: Data as of October 2020 by TERNA plus December 2020 forecast based on operators' information).

[1] Preliminary data of year 2020, estimated from TERNA statistics at October plus December forecast based on operators' information)
[2] TERNA data, updated October 2020
[3] Monthly report on Italian Electric System, published by TERNA

TABLE 1 – RESULTS OF TENDERS FOR PLANTS' SIZE P>1MW

POWER AVAILABLE IN THREE AUCTIONS (MW)		ASSIGNED POWER (MW)		
Decree quota	Actual quota with reallocation of unassigned power	Total	PV	In-shore Wind
1 890	1 964,7	1 390,4	176,5	1 213,9

As shown in Table 1, the available quota of power in the three executed procedures (total 1 890 MW), for the aforementioned classes of plants (to be shared with wind power), was partially assigned for a total of 1 390 MW (73,5% of the available amount); of this, only 176,5 MW were assigned to PV plants, equal to 9,3% of the total quota. This assigned quota is even lower (about 9%) in consideration of the actual power offered in auction resulting from putting back into tender the not assigned power lot by lot.

TABLE 2 – RESULTS OF TENDERS FOR PLANTS' SIZE 20kW<P<1MW

POWER AVAILABLE IN THREE CALLS FOR REGISTER (ONLY FOR PV REPLACING ASBESTOS ROOFS) (MW)		ASSIGNED POWER (MW)
Decree quota	Actual quota with reallocation of unassigned power	
300	561,6	49

Table 2 shows that the procedures reserved exclusively for PV systems built to replace asbestos roofs have not gone any better. This class of systems had an available power of 300 MW in the total of the three tenders. The result was an allocation of 49 MW, only 16,3% of the total available, which becomes 8,7% when considering the power reallocation in each lot.

Overall, the described procedures, the last of which concluded at the end of September 2020, awarded incentives for 225,5 MW of new PV installations, equal to only 10,3% of the total tendered power.

No major trend reversals are expected from the results of the fourth procedure whose rankings have not yet been published.

If these incentive measures are shown to be hobbled, on the other hand, the other measures in place, linked primarily to building renovations and energy efficiency, have favoured the installation of residential plants (up to 20 kW) thanks to the existing tax break mechanism, paying back 50% of the value of the installed PV plants. This measure was further strengthened with the "Relaunch Decree", adopted in May 2020, which introduced a tax relief called "Superbonus 110%" which provides a tax credit of 110% of the cost of the plant if the installation is foreseen within interventions for energy improvement of buildings resulting in an energy class increase of two levels. The Relaunch Decree reintroduces the possibility of assigning this tax credit directly to the supplier or to a third party, including banks, allowing the user to build the system without the initial investment burden.

These measures account for an Italian PV market which in 2020, despite the difficulties of the pandemic crisis, recorded 0,8 GW of new installations. A not inconsiderable result, but, at the same time, still far from an annual average compatible with the 2030 target of the National Energy and Climate Plan (PNIEC).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research, development and demonstration activities in the field of PV technology are mainly led by ENEA (the Italian Agency for New Technology, Energy and Sustainable Economic Development), RSE (a research company owned by GSE), CNR (the National Council for Scientific Research), Eurac, ENEL, several universities and other research institutes, including companies' organizations.

ENEA is the most relevant research public organization in the energy sector in Italy. In the PV field, its activity is focused on both solar cell fabrication technologies and system development. Interesting results have been achieved for high efficiency solar cells based on tandem devices with c-Si or heterojunction (a-Si/c-Si) in combination with Perovskite or Kesterite based top cells. A Perovskite/Silicon solar cell mechanically stacked two terminal tandem, having 26% efficiency has been obtained with the research efforts in cooperation with Chose Centre of Rome University "Tor Vergata".
ENEA is giving great boost to the development of Agri-PV, while finalizing its studies to several demonstration sites, with new plant solutions designed by national companies (see Figure 2), to show how to convert simple agricultural sites into possible resources of open space for communities, adding to the productive values (electricity and food) the recreational one, with maximum landscape integration to favour the social acceptability of agrivoltaic systems.

To report, in the field of PV grid integration and of digital PV development, there is the initiative to realize an experimental multivector smart nanogrid (electric - thermal) that allows the development, implementation and testing of advanced conceptual models of operation of distributed energy systems (see Figure 3). This project is in the frame of the Mission Innovation initiatives and is carried on in cooperation with RSE and CNR.

Activities on eco-design and recycling technologies of PV modules also belong to the core of ongoing research.

Fig. 2 - REM Tec PV system solution for integration with standard agricultural operation.

(A) (B) (C)

Fig. 4 - CPV cells and modules developed by RSE: (A) CPV MJ solar cell, (B) Test of (Al)InGaP solar cells for luminescence concentrators, (C) new hybrid CPV/PV module.

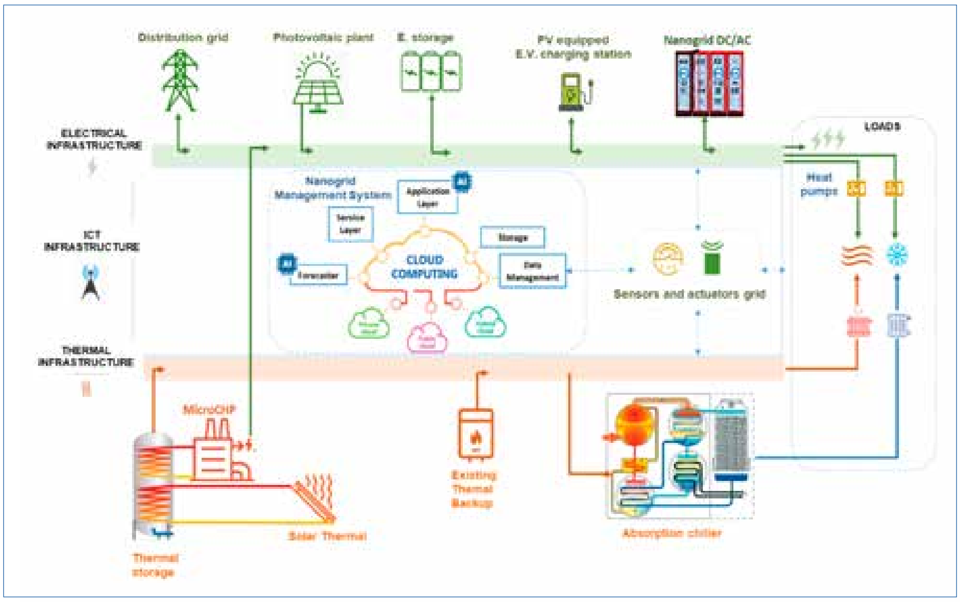


Fig. 3 - ENEA experimental multivector smart nanogrid layout.

RSE is the main research organization carrying out activities on the concentrating photovoltaic 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), RSE is pursuing an original research on: i) monolithic integration of SiGe(Sn) and III-V-based materials for high efficiency - low cost- MJ solar cells, ii) advanced (Al) InGaP solar cells for luminescence concentrators and iii) new Ge/ SiGeSn Hetero Junction (HJ) solar cells for thermal-photovoltaic (TPV) application. RSE is also committed to solar cell modelling, development of nanostructured coatings, design of innovative CPV/PV hybrid modules and set up of new characterization methodologies for CPV solar cells and modules (see Figure 4).

Concerning thin film PV technology, RSE is working to validate new chalcogenides based on earth-abundant elements grown via high-throughput process, fundamental per mass-scale production; the compounds under investigation are ranging from doped-CZTS materials (e.g. Ge, Mn, Fe) up to pure materials (i.e., Cu2MnSnS4 or CFTS and Cu2FeSnS4 or CMTS); these compounds are studied also as top layer materials for Si-Tandem cells.

Furthermore, RSE's research and development activities are focused on exploring the development of both high-efficiency and low-cost flat photovoltaic systems to contribute to their optimal use for the energy production of photovoltaic systems installed in the Italian territory. In this context, studies on O&M strategies, based on advanced diagnostic and predictive techniques, as well as studies of efficient repowering methods are carried out within two research projects: EU H2020 "GOPV" and Italian RdS "High efficiency PV". Research activities are also underway to identify environmental and plant solutions that can allow an adequate penetration of RES in the microgrids of small islands not connected to the national electricity grid. This latter activity is conducted by providing scientific support to institutional bodies (e.g. MiSE and ARERA).

Finally, RSE is performing Life Cycle Assessment (LCA) of the most promising innovative PV technologies. In the recent past, RSE has

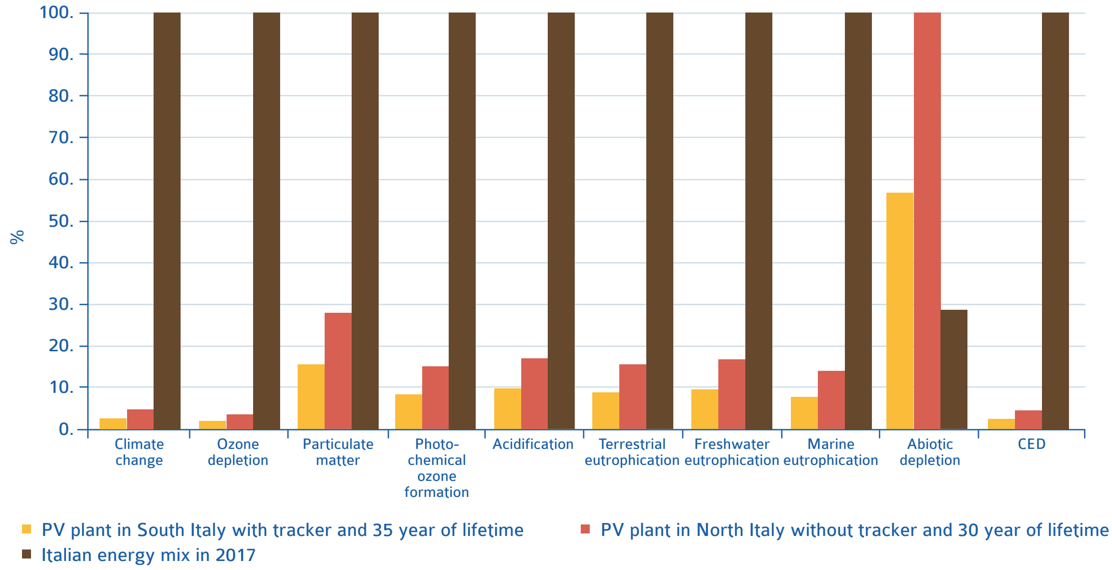


Fig. 5 - Comparison among the environmental impacts calculated by LCA for Italian energy mix and for two PV plants using HJT cell technology, in their best case (installation with tracker in southern Italy and with a useful life of 35 years) and in their worst case (installation on fixed plane in northern Italy and with a useful life of 30 years).

estimated, in accordance with the IEA PVPS guidelines, a series of environmental indicators for a hypothetical PV plant based on heterojunction bifacial modules installed on monoaxial tracker. Nowadays, the environmental impact of PERC module technology is going to be assessed. The obtained results clearly show the strong contribution of the PV sector to the decarbonisation of the national electricity sector: if the greenhouse gas emissions to produce a kWh according to the Italian energy mix are greater than 400 g CO_2 eq., these are less than 20 g CO_2 eq. for innovative photovoltaics (Figure 5).

CNR is active in PV research mainly in the frame of the Italian electric system research programme RdS, pursuing research on the evaluation in an environment similar to the industrial one of two types of innovative low cost process for thin film cells: standard DSSC and GIGS-LTPED. The new processes are based on printing deposition techniques.

EURAC Research 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 and in assessing uncertainties in yield assessments. Several projects are also focused on the digitalisation of the PV sector, to increase performance and reliability thanks to the use of Industry 4.0 concepts and Digital Twins creation. 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 a large amount 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, e-mobility, sector coupling).

Enel is involved in R&D activities in PV especially, but also in RES, in its *Innovation Hub* located in Catania (Sicily), where research and innovation are carried out in close cooperation with several research institutes and young startups, leveraging on an accredited lab for PV modules and on a large outdoor experimental area.

Finally, in the frame of the SET Plan Implementation Plan for Photovoltaics, the above-mentioned PV actors in Italy are working together in an "Italian PV Alliance", being a collaboration network between industries, research centers and universities. The main purpose is to build a photovoltaic solar supply chain that leads basic research to become industrial products, mainly in the national flagship initiatives "Utility Scale PV" and "Building Integrated Photovoltaics".

INDUSTRY AND MARKET DEVELOPMENT

The production of photovoltaic modules in Italy in 2020 consisted of a moderate quantity, based on several manufacturers who produced new modules characterized by high quality and efficiency values.

3SUN, unit of ENEL Green Power, continues to be the main Italian PV factory and one of the biggest in Europe. Consolidation of the 200 MW capacity of Silicon Heterojunction Technology (HJT) cells and modules took place in 2020 (Figure 6), which achieved record efficiencies: 25,0% for HJT cells based on M2 wafer in August 2020 and 20,5% for modules which have reached a power up to 400 W and a very high bifacial factor (>90%). At the end of 2020, EGP launched the project "3SUN Gigafactory" to increase the production to 3 GW/year and thus positioning itself as the largest PV producer in Europe.

Fig. 6 - EGP 3SUN PV module factory: HJT bifacial cells' and modules' assembly lines (Photos: EGP).

In the inverter sector, the Italian manufacturers confirmed their broad 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. Among them, the biggest company is Enel Green Power, which is active especially in the field of utility scale plants, having reached 3,1 GW of RES plants built worldwide in the 2020, mainly wind (2 284 MW) and PV (803 MW). EGP currently manages around 49 GW of total renewable capacity, confirming itself as the largest private operator in the sector in the world.

FUTURE OUTLOOK

The objectives of installed power to 2025 and then to 2030 envisaged by the Integrated National Plan for Energy and Climate (PNIEC) remain the main beacon necessary to illuminate the future of photovoltaics in Italy. As mentioned above, the installation data in 2020 has shown reaching a cumulative PV installation of about 21,7 GW, with an increase of about 4% in the cumulative installed power. The annual rate of installation shows only a limited increase of about 5% compared to the previous year and, certainly, the value of 0,8 GW/year will have to be increased to meet the cumulative power target of 28,5 GW by 2025 and that of 52 GW by 2030.

New installations, with an average rate of 1,4 GW/year for the 2025 target, and a far higher rate (4,7 GW/year) in the period 2025-2030 will be needed.

There is a cautious optimism on being able to increase the rate of new installations on the wave of the results of the new "110% Superbonus" tax credit mechanism and of the contributions to self-consumption, both showing excellent signals in supporting residential and commercial PV installations.

However, undoubtedly, for the utility scale plants, whose installations are necessary to achieve the most ambitious objectives, a great effort is needed to simplify the authorization procedures and to identify innovative solutions to overcome environmental reserves about the land use.

Many actions are in place to demonstrate the interesting prospects of Agri-PV which seems to be the way to allocate, with a synergistic approach between agriculture and photovoltaics, important shares of new large-scale installations.

These issues and, more generally, the support to the development and diffusion of renewables are in great evidence in the Recovery and Resilience National Plan, named "Next Generation Italy", which, among other high-impact objectives, intends to give significant support and acceleration to the green transition. The plan, approved by the Council of Ministers, is divided into six specific Missions and places important resources on Mission 2 "Green revolution and ecological transition", which is based on the four clusters shown in Table 3.

TABLE 3 – RESOURCES OF RECOVERY AND RESILIENCE NATIONAL PLAN – MISSION 2

MISSION: GREEN REVOLUTION AND ECOLOGICAL TRANSITION	
Clusters	Allocated Resources (BEUR)
1) Sustainable agriculture and circular economy	6,30
2) Renewable energy, hydrogen and sustainable mobility	18,22
3) Energy efficiency and building renovation	29,35
4) Territory and water resource protection	15,03
Total	**68,90**

This is the Mission with the highest absolute value of resources, equal to the 31% of the total envisaged by the Plan.

The use of renewable sources is mentioned in almost all the above clusters, but the specific actions are obviously structured in Cluster 2 which commits resources for 18,22 BEUR, of which 8,66 BEUR are dedicated to the renewable energy production and distribution and to the connected industrial sectors.

The plan intends to boost PV industry in the technological sectors with the aim of rising at significant values the national production of photovoltaic modules. The other measures implemented in this cluster should allow for an increase of 4,5-5 GW of new RES capacity by 2026. The actions will support the objectives already set by the PNIEC, with a prevalent role for photovoltaic and wind power. The floating photovoltaic system will be the subject of large-scale demonstration plants (100 MW).

Finally, not to be overlooked is the synergy between photovoltaics and agriculture referred to in cluster 1, in which incentives are provided for the revamping of roofs of buildings in the agricultural, zoo-technical and agro-industrial sectors.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS

MITSUHIRO YAMAZAKI, NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)
OSAMU IKKI, RTS CORPORATION

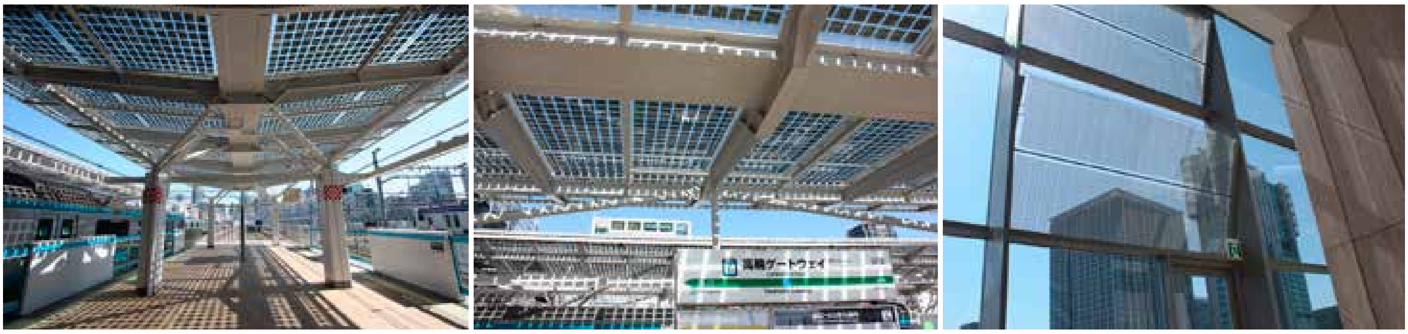


Fig. 1 - Roof and Window Glass-integrated PV System at Station Platform (Takanawa Gateway Station PV System) (Minato Ward, Tokyo). Power generation capacity: 43,8 kW (roof of platform), 1,1 kW (window glass). PV modules: Bifacial single-crystalline silicon PV modules (SUNJOULE® glass-integrated PV modules by AGC).

GENERAL FRAMEWORK

Following the enactment of the Acts for Establishing Resilient and Sustainable Electricity Supply Systems in June 2020, which covers the drastic revision of the current Renewable Energy Act so called Feed-in Tariff (FIT) Act and the revision of the Electricity Business Act, the dissemination of renewable energy in Japan has now shifted from full dependence on the FIT program to the phase of integrating with the market. The Acts are set to take effect in April 2022 and the Ministry of Economy, Trade and Industry (METI) started designing a new framework with regard to promoting utilization of electricity from renewable energy, supporting introduction linked with the market, grid management that takes advantage of the potential of renewable energy, as well as appropriate disposal of renewable energy power generation facilities including recycling of PV modules, toward making renewable energy a mainstream power source early. METI set out a new direction of "creating a renewable energy-oriented economic society", focusing on the following as the main pillars: 1) evolving into a competitive renewable energy industry; 2) establishment of social infrastructure to support renewable energy such as networks and 3) establishment of local communities harmonized with renewable energy. As for 1) evolving into a competitive renewable energy industry, deliberations are underway on the introduction of the Feed-in Premium (FIP) program and vitalization of the aggregator business, the acceleration of distributed power sources introduction focusing on "integration with supply and demand", the reform of consumers' awareness, the expansion of dissemination of storage batteries which support the new energy system, as well as the enhancement of competitiveness of offshore power generation, which is a key to making renewable energy a mainstream power source. As for 2) establishment of social infrastructure to support renewable energy such as networks, deliberations are underway on the review of rules for utilizing bulk power transmission lines, the formation of push-type grids based on the potential of future power sources, as well as improvement of industrial infrastructure which supports renewable energy (R&D on innovative technology, etc.). As for 3) establishment of local communities harmonized with renewable energy, deliberations are underway on realizing appropriate business disciplines to gain understanding and trust by local communities, a mechanism to secure implementation of renewable energy projects for transaction at timely prices and effective use of grids (a scheme to cancel approval), as well as promotion of efforts to realize sustainable expansion of installations in response to the requests of the local communities.

Furthermore, in the third year of the Fifth Strategic Energy Plan formulated in 2018, which indicates that Japan will make renewable energy a mainstream power source, METI started working on the review of the plan to formulate the Sixth Strategic Energy Plan, looking to the future global circumstances and energy and environmental measures.

In September 2020, Prime Minister Yoshihide Suga declared Japan will achieve "net zero greenhouse gas emissions by 2050," aiming to achieve a decarbonized society. At the same time, Prime Minister Suga presented specific technologies such as the next generation PV cells and modules as well as carbon recycle technology, etc., and expressed that groundbreaking innovation will become the key and green investment through regulatory reform will be promoted. Hereafter, Japan will aim to realize a carbon neutral green society through a virtuous cycle of economy and environment as the pillar of the growth strategy. In response to the PM's declaration, METI formulated the "Green growth strategy following carbon neutral by 2050" which makes renewable energy the main axis of mainstream power source. This growth strategy estimates that the power demand will increase by 30% to 50% by 2050, compared to today due to the promotion of electrification, and that 50% to 60% of all power will be covered by renewable energy. Ambitious targets were set for 14 industries that are expected to grow from the perspective of industrial policies that create the "Virtuous Circle of Environment and Economy", and a full-scale mobilization of all policies will be conducted. PV is positioned as the next generation industry in the home and office-related industry, and will play a new role to promote cooperation with the user industries in addition to its role as an energy source.

Regarding the approved and the commissioned capacities of PV systems under the FIT program which took effect in July 2012, a total of 74,3 GWAC (as of the end of June 2020, including cancelled and revoked projects) of PV systems have been approved, of which 51,9 GWAC started operation. Japan's annual PV installed capacity in 2020 is estimated to be 8,2 GWDC, and its cumulative PV installed capacity is expected to reach the 70 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 2020, the FIT levels for PV systems were set lower than those of the previous fiscal year and the tariff for PV systems with a capacity of below 10 kW for FY 2020 was set at 21 JPY/kWh as a uniform tariff nationwide, for the period of 10 years. The tariffs for excess electricity were set as a uniform category irrespective of the devices to respond to output curtailment. As for 10 to < 50 kW PV systems, the requirements for approving power sources as locally-used power sources for self-consumption were newly set and the tariff of 13 JPY/kWh was set. The requirements such as 30% or more self-consumption ratio were also imposed. The tariff for 50 to < 250 kW PV systems was set at 12 JPY/kWh. In the period from July 2012 when the FIT program started to the end of June 2020, 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 7,3 GWAC, 32,4 GWAC and 34,6 GWAC, respectively, amounting to 74,3 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 issues such as development permission and grid connection. Only 51,9 GWAC of FIT-approved PV systems started operation, of which approximately 3,6 GWAC started operation between January and June 2020, a 38% increase year on year. METI's data on commissioned capacity as of the end of June 2020 are the latest data available (as of January 20, 2021). METI amended the FIT Act and shifted the approval scheme from the facility approval to the approval of 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 disclosed. As of September 30, 2020, capacity of approval of PV project business plans for PV systems with a capacity of 20 kW or more reached about 430 000 projects totaling 62,2 GWAC, including commissioned projects. Acts for Establishing Resilient and Sustainable Electricity Supply Systems were enacted in June 2020, based on which the Feed-in Premium (FIP) program, a market-linked support scheme, is scheduled to take effect from April 2022, in addition to the FIT program.

In FY 2020, the scope of the tender was widened to include 250 kWAC or larger PV projects, changed from 500 kWAC or larger PV projects, and the sixth and the seventh 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 sixth tender was 750 MWAC and the ceiling price was not disclosed. 255 PV projects totaling 369 MWAC, which was below the tender target capacity, applied for participating in the tender. According to the tender results released, the ceiling price was 12,0 JPY/kWh and 254 projects (368 MWAC) won the bid. The lowest winning bid price was 10,0 JPY/kWh. Same as the sixth tender, the tender target capacity for the seventh tender was 750 MWAC and the ceiling price was not disclosed. 92 PV projects totaling 79 MWAC, which was below the tender target capacity, participated in the tender. According to the tender results released, the ceiling price was 11,5 JPY/kWh and 83 projects (69 MWAC) won the bid. The lowest winning bid price was 10,48 JPY/kWh.

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 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. 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 certificates issued for the FIT electricity were traded on the "non-fossil fuel energy value trading market" in the form of tender. The results of the tender were released. For example, in August 2020, 33 companies purchased the non-fossil fuel energy certificates with a total contracted electricity amount of 151,17 GWh, whereas in November 2020, 59 companies purchased the non-fossil fuel energy certificates with a total contracted electricity amount of 508,81 GWh. The weighted average price of the contracted amount was 1,30 JPY/kWh for both tenders, 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 Non-fossil 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, and a tender of non-FIT non-fossil fuel energy certificate was also 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) Acceleration of reconstruction of Fukushima; 2) Promotion of energy transition and decarbonization; and 3) Enhancement of energy security and resilience. The amounts of budget regarding technology development and installation support of PV systems and related fields vary largely. While many of the budget items of the FY 2019 budget remained in the FY 2020 budget, there are several new items including the following: "Technology development project to expand possible PV installed capacity, etc." (3,0 BJPY), "Subsidy for the expenses of projects for comprehensive utilization of energy using regional grid lines" (1,73 BJPY) and "Project for international joint R&D on innovative technologies in the clean energy sector" (0,90 BJPY). All of them were established in accordance with the progress of deployment of renewable energy. With regard to technology development, the objective has shifted from cost reduction and improvement of reliability to technology development to expand possible PV installed capacity. Major continued projects related to technology development and demonstration include the following: "Project of research and development on new energy technology for discovering technology seeds and commercializing developed technologies" (1,88 BJPY), "Project to develop next-generation power control technology toward large-volume introduction of renewable energy" (3,19 BJPY), "Subsidy for expenses of demonstrative projects to establish virtual power plants using consumer-side energy resources" (5,0 BJPY) and "Demonstration project to establish supply chain of hydrogen derived from unused energy (14,12 BJPY). As for dissemination support, the budget amount for "Subsidy for projects to support promotion of renewable energy introduction in Fukushima Prefecture" was halved to 4,0 BJPY. For international projects related to PV power generation, the budget has been appropriated for the following projects: "Project to promote energy transition and decarbonization in Japan and abroad through establishing international alliance, etc. in the field of energy conservation and new and renewable energy" (10,5 BJPY), "Projects for feasibility study on overseas deployment of high-quality energy infrastructure" (0,9 BJPY), and "Projects to cultivate emerging markets through utilization of technology cooperation" (4,27 BJPY). Furthermore, with regard to local communities, small- and medium-sized enterprises (SMEs), development and support of human resources, the budget has been appropriated to the following projects: "Project to support seeds development and commercialization of renewable energy technologies by companies, etc. in disaster-stricken areas" (0,79 BJPY), "Project for supporting R&D startups" (2,75 BJPY), "Project to enhance the eco system for global startups" (1,3 BJPY), and "Project expenses to promote future investment in communities" (14,27 BJPY). For safety and security of PV and other renewable energy sources, 0,54 BJPY has been appropriated for "Consignment expenses for projects to improve safety regulations for new and renewable energy, etc." Among the FY 2019 supplementary budget items, "Subsidy for projects to enhance resilience using net zero energy house (2,0 BJPY) and "Establishment of zero emission international joint research center" (9,0 BJPY) have been newly added.

(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 dissemination of renewable energy from wide perspectives of supporting introduction, CO_2 reduction, supporting with the initiative of local communities, as well as providing finance and support for developing countries. Among the major continued budget items related to PV power generation, 3,926 BJPY for "Project to promote self-sustainable dissemination of renewable energy-based electricity and thermal energy", 6,35 BJPY for "Project to support establishment of net zero energy houses (ZEH) at detached houses", 8,0 BJPY for "Project to establish symbiotic and recycling-based community with innovation for decarbonization", 9,85 BJPY for "Project to promote decarbonization and enhancement of resilience of buildings, etc. (integration of "Program to promote introduction of net zero energy building (ZEB) and saving of CO_2 emissions in commercial facilities, etc." and "Project to promote CO_2 saving in newly-built collective housing and existing houses)", 11,6 BJPY for "Project to promote installation of independent and distributed energy facilities which realizes disaster prevention and reduction as well as low carbonization of local communities in parallel", 4,8 BJPY for "Project of fund to promote investment in decarbonization of local communities", 9,687 BJPY for "Subsidy for projects under the Project to support funds for the Joint Crediting Mechanism (JCM)", and 6,5 BJPY for "Technology development and demonstration projects to encourage enhancement of measures to reduce CO_2 emissions have been appropriated. Based on the necessity for new development toward FY 2020, 4,0 BJPY has been allocated for the new project, "Project to promote making renewable energy a mainstream power source and enhancing resilience in local communities".

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" (13,5 BJPY).

The **Ministry of Agriculture, Forestry and Fisheries (MAFF)** is continuously implementing a subsidy program to support the 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 2,586 BJPY) for "Introduction and utilization of renewable energy," MAFF is supporting efforts, etc. to utilize the advantages of the renewable energy projects for the development of regional agriculture, forestry and fisheries.

The **Ministry of Education, Culture, Sports, Science and Technology (MEXT)** has been actively promoting the introduction of renewable energy in relation to promoting measures to improve quake resistance of educational facilities and measures against aging facilities. MEXT has been continuously committed to "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 "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 0,854 BJPY to 8,31 BJPY.

Among **local authorities**, an invitation of applications for subsidy programs to support introduction of residential PV systems and storage batteries as well as joint purchase programs in which participants were invited to participate were conducted. Efforts were made to promote local production and local consumption of electricity including the establishment of Power Producer and Supplier (PPS) in cooperation with the private companies and the development of microgrids. In addition to the issuance of green bonds that will be used to introduce PV systems, etc. into the facilities of local authorities, there is also a growing trend to switch to renewable energy-sourced electricity to cover the electricity consumption at their facilities. In order to make renewable energy a mainstream power source, the ordinances and the guidelines for the proper installation of PV systems were formulated along with long-term strategies and policies.

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 started a new five-year plan program, "Development of Technologies to Promote Photovoltaic Power Generation as a Primary Power Source" from FY 2020, which started in April 2020. This program consists of four development items: 1) development of technology to create a new market for PV; 2) development of technology to make PV a long-term stable power source; 3) development of advanced common basic technologies and 4) investigation of trends. In this program, NEDO selected a total of 50 themes for implementation in July 2020. Development of film-type ultra-lightweight solar cells, solar cells for mobility, wall-mounted PV modules and PV systems to overcome the restrictions of locations, formulation of guidelines and technology development to ensure reliability and safety of PV power generation facilities, development of material recycling technology and technological research to mitigate the impacts on the grid. Moreover, NEDO is conducting the "Project of research and development on new energy technology for discovering technology seeds and commercializing developed technologies" (from FY 2007) to support R&D-based small and medium-sized enterprises (SMEs) as well as venture businesses. In FY 2020, the establishment of a test facility of inverters for distributed power sources and the development and the large-scale demonstration of PV module cleaning robots were selected as new research themes in the field of PV power generation.

NEDO announced "NEDO PV Challenges 2020", a new PV technology development guideline. As new fields to realize the large-volume introduction of PV power generation by 2050, six markets of PV installation, walls of buildings, rooftops with weight restrictions, mobility (PV systems mounted on vehicles), detached houses, floating PV, and PV on farmland, etc., were identified as the markets of new applications where technology development should be especially promoted. The Japanese government announced that it would establish a fund of 2 TJPY (10 years) in NEDO for the development of decarbonization technologies, including the next-generation PV technologies such as perovskite, and research and development for social implementation towards the realization of carbon neutrality by 2050.

JST supports research activities mainly by universities and research institutes. Under the "Advanced Low Carbon Technology Research and Development Program (ALCA)", etc. of the "Strategic Creation Research Promotion Program", development of PV-related technologies is continued, focusing on perovskite PV, semiconductor polymer-based PV and organic thin-film PV technologies.

The National Institute of Advanced Industrial Science and Technology (AIST) dissolved the PV research center in March 2020; but established the "Global Zero Emission Research Center (GZR)" in January 2020. The center collaborates with the world's leading national research institutes, etc., mainly in the G20 countries to conduct research on innovative environmental and energy technologies aimed at realizing a low-carbon society. AIST continues research and development on renewable energy including PV mainly through the GZR and the Fukushima Renewable Energy Institute (FREA).

DEMONSTRATION

Demonstration research is mainly promoted by NEDO. NEDO and Sharp have jointly fabricated PV modules for EVs which use the world's highest-level efficiency III-V compound semiconductor solar cells. These PV modules are mounted on a plug-in hybrid vehicle of Toyota Motor and an EV of Nissan Motor, and the demonstration of driving on public roads is underway. In the program "Development of Technologies to Promote Photovoltaic Power Generation as a Primary Power Source" which started in FY 2020, demonstrations of BIPV systems and PV systems aimed at achieving ZEB are planned. A demonstration of low environmental impact material recycling technology for PV modules will also be conducted.

Demonstration activities on technologies for utilization of PV systems are conducted by METI, NEDO and MoE. NEDO continued to conduct the "International demonstration project on Japan's energy-efficient technologies". Demonstrations of power transmission and distribution operations of storage batteries to respond to surplus electricity from renewable energy, etc. in the USA and Indonesia, as well as demonstrations of automated demand response and energy management technologies to expand the introduction of renewable energy and energy conservation in Slovenia, Poland and China were continued in 2020. Furthermore, NEDO opened the "Fukushima Hydrogen Energy Research Field (FH2R)", one of the world's largest hydrogen production facilities, in Namie Town, Fukushima Prefecture, as a demonstration project to produce hydrogen from renewable energy. Using electricity generated from a 20-MW PV system installed on the site, the hydrogen is produced by a 10-MW hydrogen production plant that is one of the largest of its kind in the world. The produced hydrogen is used for power generation to be stored in stationary fuel cells and for mobility applications.

METI conducts demonstration projects on electric grid control including PV power generation. In the demonstration to establish a virtual power plant (VPP), a demonstration to utilize a VPP for adjusting supply and demand of electricity, in the form of a large-scale consortium, with a number of companies participating as aggregators. In the Project to establish regional microgrids, two projects were selected in FY 2020, which will make use of the dispatching abilities of PV systems and storage batteries, and the existing facilities of grid lines. Both projects are scheduled to start demonstration tests in 2021 in the form of consortium.

MoE conducts demonstration projects of CO_2-free hydrogen production technology using PV and other renewable energy-sourced electricity at ten locations in Japan with the goal of establishing a low-carbon hydrogen supply chain. Of these projects, two model development and demonstration projects aimed at lowering the cost of hydrogen supply using existing renewable energy were selected in FY 2020.

Demonstration of peer-to-peer (P2P) power trading also made progress. TRENDE, in collaboration with The University of Tokyo and Toyota Motor, conducted a P2P power trading demonstration experiment using PV and plug-in hybrid electric vehicles (PHEV) and confirmed its economic efficiency. ENERES started the "Project to demonstrate establishment of P2P power trading platform in the next generation power system" with the support from the Tokyo Metropolitan Government (TMG). Looop has successfully conducted a demonstration experiment to supply electricity to general households using "DIGITAL GRID Platform" in which power sources can be identified using P2P. Moreover, Kyocera started a self-wheeling demonstration experiment of renewable energy using PV and storage batteries for the first time in Japan, aiming for new business development through demonstration at its own facilities.

INDUSTRY STATUS AND MARKET DEVELOPMENT

In the PV cell/ module and PV system business in Japan, the ratio of imported PV cells and modules increased further and foreign manufacturers ranked the top manufacturers in the PV module shipment in Japan the same as in the previous year, mainly for large-scale FIT projects. Major Japanese PV manufacturers reduced their production and shifted their PV-related business strategies from "manufacturing of equipment" to provision of "comprehensive power solution services". While business collaborations have been increasing in Japan and overseas, there were also moves to optimize and restructure businesses, such as Panasonic's dissolution of its partnerships with Tesla of the USA and GS-Solar of China. In terms of sales, proposals of Third-party ownership (TPO) models, power purchase agreements (PPA) models, as well as self-consumption type PV systems increased and a number of demonstrations as well as business partnerships towards establishment of VPP technology and P2P power trading system were also conducted. Solar Frontier plans to build a recycling facility of PV modules to address the mass disposal of PV modules in the future and propose the continuation of the power generation business by replacing them with PV modules with higher performance. Japan Photovoltaic Energy Association (JPEA) announced the PV industry vision by 2050 and indicated the estimated installed capacity towards achieving the CO_2 emission reduction target as well as costs and benefits of PV power generation.

New products and proposals of new applications are increasing as new added value. INFINI and AIST developed a PV module with a snow melting function, and Solar Frontier and HAYAMIZU installed pavement-type PV modules in Tokyo Big Sight in Tokyo. As for building-integrated PV (BIPV) products, Kaneka's high efficiency crystalline silicon see-through PV modules were selected to be installed at the New National Stadium and AGC's SUNJOULE series of laminated glass PV modules were adopted for installation at the Takanawa Gateway Station in Tokyo. NTT Advanced Technology (NTT-AT) announced high-performance glass products using the colorless and transparent photovoltaic device technology. In the field of organic solar cells, Ricoh commercialized solid-state dye-sensitized PV modules for use under indoor lighting and Toray Industries proposed organic thin-film PV (OPV) modules as a battery-less solution. EneCoat Technologies developed an IoT environment sensor system with an independent power source using perovskite solar cells. Suminoe Textile aims to commercialize a fiber-type solar cell made from organic materials.

In the material and equipment areas, the trend of business transfer to overseas is continuing, with the production of aluminum paste and glass being shifted to China, Southeast Asia and the USA where the manufacturing bases of PV cells and modules are located. Efforts such as the development of materials for new-type solar cells including OPV are also gaining momentum.

In the area of PV inverters, various types of inverters were introduced including hybrid-type inverters designed to be connected with storage systems and inverters for industrial applications were launched for overseas markets. Omron introduced small-sized inverters for self-consumption and multi-functional storage platform, etc. Toshiba Mitsubishi-Electric Industrial Systems (TMEIC) aims to expand its services for the users of its inverters, as well as to introduce the inverters for large-scale PV power plants by acquiring international certifications. Fuji Electric is also planning to expand sales of inverters for large-scale PV power plants in overseas markets.

In the housing industry, the main focus is on the construction of houses with PV systems and the promotion of smart towns and renovation businesses. Products equipped with PV systems as standard equipment are being introduced as before and HEMS and storage systems are also being launched one after another. Major homebuilders and other companies are selling condominiums with all ZEH dwelling units, launching energy creation and storage system products for renovation, and introducing products that strengthen resilience (disaster prevention and mitigation) and products designed to prevent COVID-19 infection, etc. As a new business development, strengthening of energy business models (post-FIT measures, PPA (TPO models), purchase of surplus electricity, power generation and retailing business, V2H, sharing of electricity sales revenue in housing complexes for sale, utilization of the environmental value within group companies, etc.) are promoted.

In the area of electricity storage, in addition to stationary storage systems for residential use, new types of storage batteries were developed for PV systems for self-consumption and a number of new products of storage systems were released. Manufacturers of storage batteries are working to increase their production capacity. For residential applications, noteworthy activities were seen such as the launch of "Powerwall" by Tesla Motors Japan and the commercialization of a clay type lithium-ion secondary battery (LiB) by Kyocera. For industrial applications, the sales expansion of redox flow batteries by Sumitomo Electric Industries and the sales plan of reused large-capacity storage batteries by Itochu and BYD attracted attention.

In the area of the PV power generation business, construction and operation of PV systems under the FIT program continue to be active. Trading of operating PV power plants (secondary) under the FIT program has been robust and the conventional energy business operators are actively acquiring assets. Behind this trend is a shift in focus from the coal-fired thermal power generation business to the renewable energy-related business in an effort to achieve decarbonization. As to the post-FIT businesses, in addition to the utilization of TPO model, the installation of non-FIT and self-consumption type PV systems is making progress. Overseas market cultivation that includes partnerships with and acquisitions of overseas businesses is advancing as well. Renewable Energy Association for Sustainable Power supply (REASP), a group led by renewable energy power producers, was established and is conducting various studies and making proposals for the expansion of the introduction of wind and PV power generation systems.

In the area of the PV power generation business support service, efforts are being made to improve the efficiency, automate and sophisticate the inspection, remote monitoring, maintenance and power generation forecasting of PV systems. Efforts on improving efficiency of operation and maintenance (O&M) service through utilization of drones, AI and weather forecasting etc. are progressing and partnerships with overseas companies are increasing, aiming for acquisition of know-how. Other activities such as support for the adjustment of electricity supply and demand, joint purchase of PV systems, energy storage systems and renewable energy electricity and the development of automatic operation systems for self-wheeling were also reported. There were also efforts to strengthen the diagnosis service for end-of-life PV modules and the recycling business.

In the area of PPS, in addition to the conventional energy companies, new entrants are developing new customers and offering new services and TPO models is also expanding. With the background of RE100 and RE Action - Declaring 100% Renewable, the number of contracts to procure electricity from 100% renewable energy sources is increasing and the cases of partnerships between PPS and users in and outside the region are accumulating. Electricity trading using blockchain is becoming more and more active and its effectiveness is being verified in a demonstration project to build a P2P electricity trading platform. Moreover, the announcements of the full-scale start of VPP establishment and aggregator business plans were also made one after another.

As for the finance-related business, public and private financial institutions are contributing to the funding for renewable energy development, including large-scale PV projects in Japan and abroad. The issuance of green bonds to be used for PV projects increased, and a variety of measures such as establishing funds, lease utilization, and syndicated loans are used to promote the dissemination of renewable energy. Financial institutions are increasingly aiming for specialization in ESG (environment, society, governance) investment and focusing on investment and finance in the renewable energy-related business to support the mitigation of climate change and the achievement of the SDGs (Sustainable Development Goals).

REPUBLIC OF KOREA

TECHNOLOGY STATUS AND PROSPECTS

DONGGUN LIM, KOREA NATIONAL UNIVERSITY OF TRANSPORTATION

Fig. 1 - 98 MW PV system at Haenam-gun, Jeollanam-do, Korea.

GENERAL FRAMEWORK AND IMPLEMENTATION

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.

In 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. Simultaneously, 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.

In July 2020, the Korean government plans it will spend 73,4 trillion KRW (Korean Won, 1 100 KRW/USD) in the energy sector in line with the "Korean-type Green New Deal plan" to transform its fossil fuel-dependent economy into an eco-friendly economy. The projects could create around 659 000 jobs and also help to cut 12,2 million tons of carbon emission by 2025. Korea will also expand the power generation capacity of solar and wind power to 42,7 GW in 2025, more than three times growth from that of 2019.

In December 2020, the Korean government announced the 9th Basic Plan for Electricity Supply and Demand. Renewable energy will take up nearly 42% of South Korea's power generation capacity by 2034, according to the 9th Basic Plan for Electricity Supply and Demand.

TABLE 1 – ENERGY MIX ACCORDING TO THE "9TH BASIC PLAN FOR ELECTRICTIY SUPPLY AND DEMAND"

	2020	2022	2030	2034
Coal	35,8 GW	38,3 GW	32,6 GW	29,0 GW (6,8 GW↓)
LNG	41,3 GW	43,3 GW	55,5 GW	59,1 GW (17,8 GW↑)
Nuclear	23,3 GW	26,1 GW	20,4 GW	19,4 GW (3,9 GW↓)
Renewables	20,1 GW	29,4 GW	58,0 GW	77,8 GW (57,7 GW↑)

In 2020, the Korean government announced the "5th Basic Plan on New and Renewable Energy (NRE)" to accelerate Korea's transition to a low-carbon economy and society based on renewable energy innovations in supply, market, demand, industry, and infrastructure. The main content of the policy includes increasing the share of renewable energy among the total power generation by 4,2% (up from 21,6% by 2030 to 25,8% by 2034) and creating 65,1 GW of renewable energy facilities by 2034.

Fig. 2 - 94 MW PV system at Yeongam-gun, Jeollanam-do, Korea.

NATIONAL PROGRAMME

In July 2020, the Korean government announced "Korean-type Green New Deal Plan" to recover the Korean economy which suffered from COVID-19 and to move toward a carbon-neutral society. The Government also declared the leapfrog toward a low-carbon and eco-friendly nation by disseminating 42,7 GW of PV and wind by 2025, which is one step ahead of "NRE 3020 plan" announced in 2017. Electricity generation targets for 2034 were determined by the "9th Basic Plan for Electricity Supply and Demand" and the "5th Basic Plan on NRE".

RPS PROGRAMME

The Renewable Portfolio Standard (RPS) is a system that enforces power producers to supply a certain amount of total power generation by renewable energy. Since 2012, RPS has been introduced as a main renewable energy program to replace FIT. 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 renewable energy sources by 2023, up from 2% in 2012. Thanks to the 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, 2 985 MW in 2019, and 3 970 MW in 2020, respectively. At the end of 2020, the total installed capacity was 13 258 MW. The RPS is expected to be the major driving force for PV installations in the next few years in Korea with improved details; such as boosting the small-scale installations (less than 100 kW) by adjusting the REC and multipliers, and unifying the PV and non-PV markets. To further enhance the predictability of profit (to attract project financing entities), the Ministry of Trade, Industry and Energy (MOTIE) launched a new long-term (max. 20 years) fixed price (SMP+REC) RPS scheme in 2017. This scheme has an advantage of guaranteeing 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, the MOTIE also launched a new REC weighting scheme, in which a maximum 20% increase in REC weighting when community residents are involved in the projects. The grid connection of PV systems is guaranteed up to 1 MW by the Government since 2017. REC weighting scheme is summarized below.

TABLE 2 – REC WEIGHTING SCHEME IN RPS

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

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 projects were to install PV systems on residential houses, the one million green homes plan focuses on a various resource such as PV, solar thermal, geo-thermal, and small wind. 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 2020, 69,8 MW were 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 on schools, public facilities and welfare facilities, as well as universities. In 2020, 30,7 MW were 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 systems that are friendly to the environment,

Fig. 3 - 25 MW Floating PV system at Goheung-gun, Jeollanam-do, Korea.

the government has been promoting the regional deployment subsidy programme designed to support various projects conducted by local government. The government supports up to 50% of the installation cost for NRE (including PV) systems owned and operated by local authorities. In 2020, 13,3 MW were 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 (unconnected 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 2020, 73,9 MW were installed under this programme.

PV RENTAL PROGRAMME

Household owners who use more than 350 kWh of electricity can apply for this programme. Owners pay a PV system rental fee (maximum monthly 70 000 KRW that, on average, is less than 80% of the electricity bill) for a minimum of seven years and can use the PV system with no initial investment and no maintenance cost for the rental period. PV rental companies recover the investment by earning PV rental fees and selling REP (Renewable Energy Point) having no multiplier. In 2020, 8,9 MW were installed under this programme.

PUBLIC BUILDING OBLIGATION PROGRAMME

The new buildings of public institutions, the floor area that 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 2020, 30,3 MW were 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 the total 72,0 BKRW in 2020. In the PV R&D budget, about 45% was invested for c-Si area and about 28% for the Perovskite area.

TABLE 3 – ANALYSIS OF PV R&D BUDGET IN KOREA IN 2020

TYPE	2020	
	BUDGET (BILLION KRW)	SHARE (%)
C-Si	32,5	45,1
Organic	2,3	3,2
Compound	7,8	10,8
Perovskite	19,9	27,7
Others	9,5	13,2
Total	72,0	100,0

For the PV sector in particular, a Common-use PV Research Centre will be established by 2023, to fortify competitiveness of domestic PV-manufacturing enterprises. The Centre will also assist PV companies in quality evaluation and performance certification of the developed products.

INDUSTRY AND MARKET DEVELOPMENT

OCI and Hanwha shut down all polysilicon plants in Korea. Woongjin Energy has a capacity of the ingot of 2 000 MW and wafer of 2 000 MW. Hanwha Solutions has a capacity of 4 300 MW in both c-Si solar cells and modules. LG Electronics has a capacity of 2 000 MW and 1 680 MW in the c-Si solar cells and modules, respectively. Hyundai Energy Solutions has a capacity of 700 MW and 1 800 MW in the c-Si solar cells and modules, respectively.

TABLE 4 – CAPACITY OF PV PRODUCTION CHAIN IN 2020

WAFERS (MW)	CELLS (MW)	MODULES (MW)
2 000	7 410	9 892

About 4 197 MW were installed in Korea during 2020. The RPS scheme was the main driver for the PV installation in 2020, and a remarkable size of 3 970 MW was recorded. At the end of 2020, the total installed PV capacity was about 15 965 MW.

MALAYSIA

PHOTOVOLTAIC TECHNOLOGY UPDATES AND PROSPECTS

SUSTAINABLE ENERGY DEVELOPMENT AUTHORITY, MALAYSIA
MR HAZRIL IZAN BAHARI & MR KHAIRUL IZZUDDIN SULAIMAN
MR IBRAHIM ARIFFIN & MR STEVE ANTHONY LOJUNTIN

Fig. 1 - The 50 MW UiTM Solar Park I in Gambang, Pahang also houses a research centre on Renewable Energy, the first university in Malaysia to operate two LSS plants (Photo: UiTM Energy & Facilities Sdn. Bhd.).

GENERAL FRAMEWORK AND IMPLEMENTATION

Under Malaysia's Ministry of Energy and Natural Resources, two statutory bodies are responsible to monitor all PV programs in Malaysia; the Energy Commission is the custodian for all Large Scale Solar (LSS) and SELCO programs, and the Sustainable Energy Development Authority (SEDA) oversees the Feed-in-Tariff (FIT) and Net Energy Metering (NEM) programs. These programs, however, are not applicable to the state of Sarawak, as it is governed by the state's own electricity supply ordinance.

Following the COVID-19 pandemic that hit the country in early 2020, the government has pushed for initiatives to lower the cost of doing business through generation surplus utilisation. The third NEM program (NEM 3.0) was announced in 2020 in which another 500 MW is to be offered between 2021 and 2023 in addition to the 500 MW offered in NEM 1.0 and 2.0 in which the quota has been fully subscribed in December 2020. Focus is given to commercial and industrial users through the Net Offset Virtual Aggregation (NOVA) Program to benefit from generation excess sold at market price or System Marginal Price (SMP). Virtual NEM is also featured under this program where generation surplus can be shared by distributing it through virtual aggregation up to three different electricity bill accounts under the same name.

One-to-one credit offset is also extended for a special quota allocated for the residential sector under NEM Rakyat (the word *Rakyat* is translated to 'people/citizen' in Malay), targeted to benefit 10 000 to 25 000 domestic users or 40 000 to 100 000 residential users in Peninsular Malaysia. Growth of rooftop PV generation is also expected to increase in 2021, through the one-to-one NEM GoMEn, a program targeting rooftop PV installation on government entity/agency buildings with estimated total savings through sale of electricity generation to up to 6 MMYR (1,5 MUSD) per month.

NATIONAL PROGRAMME & MARKET DEVELOPMENT

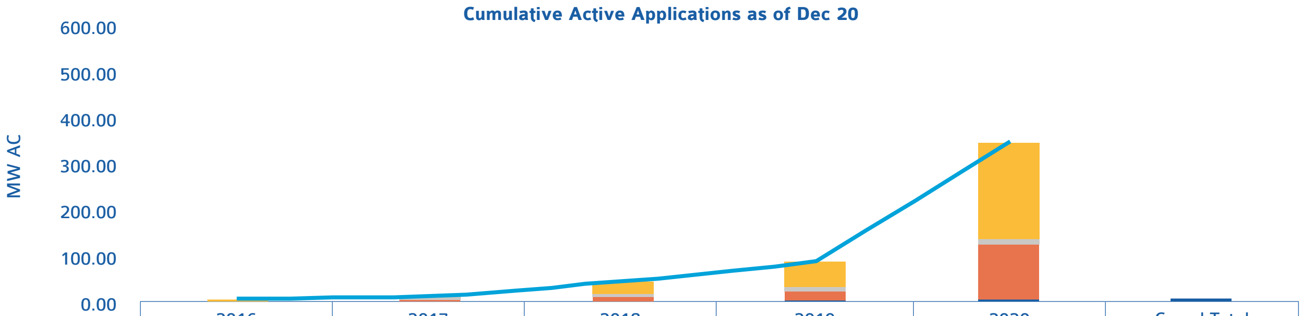
FiT Update: Under the Malaysia's Renewable Energy Act 2011, a 1,6% surcharge is imposed on the electricity bill of all users in Malaysia, which goes to the RE Fund. Since 2012, the FIT program has been funded through this scheme; 322,7 MW of PV installations have been fully operational in 2020 where non-individual PV projects constitute the largest portion at 244,94 MW, 68,63 MW of individual installations, 8,29 MW from the community sector, and 0,83 MW are from MySuria, a program for feed-in approval holders from the B40 category. In total, this program has benefited 10 276 feed-in holders with 86,6% from the individual category. All PV quotas under FiT have been fully subscribed, new PV projects in Malaysia will mainly be driven by the three other programs – LSS, NEM and SELCO.

LSS Update: The Large Scale Solar (LSS) program, which was implemented in 2016, has seen a total of 1 634,21 MW_{ac} cumulative capacity awarded with 801,76 MW_{ac} and was fully operational at the end of 2020; while another 832,45 MW_{ac} is expected to operate between 2021 and 2023. This program, in which there has been an organic progression following the FiT scheme, has seen another 1 000 MW quota to be awarded through the fourth tranche of competitive biddings last held in August 2020 and is expected to achieve commercial operation by 2023. Offered levelized tariffs throughout the four bidding cycles has also dropped significantly from 0,49 MYR per kWh for LSS1 (first bidding cycle in September 2016) to 0,21 MYR per kWh for LSS4 (average bid price).

In 2020, the new PV capacity added under LSS projects was 173,4 MW_{ac} in which 119,92 MW_{ac} was connected to the transmission line and the rest to the distribution line. All new operational plants are located in Peninsular Malaysia, with one 9,98 MW_{ac} plant being a floating solar type.

NEM Update: The NEM is implemented since November 2016 but the take-up rate has been slow, up to 2018. Effective from January 1, 2019, the Government has improved the NEM scheme from the previous net-billing scheme to the true net energy metering scheme, one-to-one energy offset. The enhancement of the NEM policy has improved the take-up rate as compared to 2016-2018.

TABLE 1 – CUMULATIVE ACTIVE APPLICATIONS FOR NEM IN MALAYSIA AS OF DECEMBER 2020



	2016	2017	2018	2019	2020	Grand Total
Industrial	0.59	4.06	28.97	55.79	212.72	302.13
Domestic	0.42	0.92	4.56	6.35	12.81	25.06
Commercial	0.90	4.49	11.21	25.53	117.94	160.07
Agriculture	0.00	0.00	0.00	0.56	6.89	7.45
Grand Total	1.91	9.47	44.74	88.23	350.36	494.72

NEMCD Year

(Source: SEDA Malaysia)

Agriculture Commercial Domestic Industrial Grand Total

The number of active applications spiked from 2019 to 2020; despite the pandemic hitting the country in early 2020, while a number of applications soared as the year ended until the quotas allocated were fully taken up in December 2020 before the expiration of NEM 2.0 in the same month. As of end 2020, the cumulative capacity approved was 494,72 MW_{ac}. In 2020, the cumulative operational capacity under the NEM was 136,10 MW_{ac} with an addition of 98,54 MW_{ac}; 65,75 MW_{ac} are from the industrial sector, 25,06 MW_{ac} are from commercial sector, 7,24 MW_{ac} and 0,48 MW_{ac} are from the domestic and agriculture sectors, respectively.

Cumulative SELCO installation in 2020 is 48,20 MW_{ac} with the biggest portion being the industrial sector at 39,11 MW_{ac}. Off-grid installations on the other hand is totalled at 35,93 MW_{ac} with residential sector tops the table at 27,00 MW_{ac}.

R&D, D

In January 2021, the Minister of Energy and Natural Resources of Malaysia announced the latest renewable energy target for Malaysia to be 31% by 2025 and 40% in 2035, a statement expected to push more initiatives and strategies by the authorities and related bodies/agencies to achieve this target. Malaysia has a vast solar potential to support the initiatives to reach the target. According to a study conducted by SEDA Malaysia it has been shown that Malaysia has vast solar PV technical potential, able to support at least 269 GW_{ac} of solar PV installations in the country. This technical potential is dominated by ground mounted configurations as the major portion of the pool at 210 GW_{ac}, followed by rooftop space and floating solar at 42 GW_{ac} and 17 GW_{ac}, respectively. A study will also be conducted by the Grid System Operator (GSO) of Malaysia to determine the grid solar penetration limit so that the higher solar capacity can be deployed successfully in future.

Following the new RE target announcement, the Renewable Energy Transition Roadmap (RETR) 2035 which was mandated to SEDA is also currently being finalized. Action plans to achieve the new target hve been outlined to cover all initiatives and strategies aimed at striking a balance between environmental targets, preserving affordability and economic benefits, and maintaining system stability by mitigating the impact of variable renewable energy (VRE) sources.

A peer-to-peer (P2P) Energy Trading pilot project has also been conducted in 2019-2020 to allow prosumers to sell excess energy generated from PV on an energy trading platform to another consumer at a rate competitive to the retailer's tariff. In total, 680,644 MW cumulative energy has been exported and 469,586 MW was traded.

INDUSTRY DEVELOPMENT

Following the pandemic that hit the globe in 2020, Malaysia has not been spared from the impact that hits local PV manufacturers and assemblers (LMA) and service providers. In 2020, the total metallurgical grade silicon (MGS) and polysilicon manufacturing nameplate capacity remained at 27 kilotonnes with employment of 585. For ingot, wafer, solar cells and PV modules manufacturing, the total estimated nameplate capacity was 18 886,43 MW with an employment of 14 595. The total number of jobs in Malaysia's PV industry dropped from 18 343 to 15 180 with a significant number of LMA's having ceased production. Table 2 shows the major PV manufacturing statistics in Malaysia classified under four categories - metal silicon/polycrystalline silicon feedstock, cell, ingot and wafer, solar cells and PV modules between 2019 and 2020, with a projection for 2021.

Within the PV industry, there were 164 PV service providers active in the market in 2020. The list of these registered PV service providers for 2019 can be found in www.seda.gov.my.

TABLE 2 – STATISTICS OF MAJOR PV MANUFACTIURING IN MALAYSIA 2019-2021 (SOURCE: SEDA MALAYSIA)

METAL SI/ POLY SI FEEDSTOCK			2019 (FOR COMPARISON)		2020		2021 (ESTIMATE)	
No.	Company Name	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS	Capacity (kilo metric tonnes)	Jobs	Capacity (kilo metric tonnes)	Jobs	Capacity (kilo metric tonnes)	Jobs
1	OCIM SDN BHD	Polycrystalline Silicon	27	612	27	585	27	557
Total			27	612	27	585	27	557
CELL			**2019 (FOR COMPARISON)**		**2020**		**2021 (ESTIMATE)**	
No.	Company Name	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS	Capacity (MW)	Jobs	Capacity (MW)	Jobs	Capacity (MW)	Jobs
1	Jinko Solar Technology Sdn Bhd	sc-Si	3 450	2 117	4 110	2 004	4 250	2 287
2	Hanwha Q CELLS Malaysia	(P-type Multi-Si)	2 000	2 263	2 200	2 200	2 400	2 400
3	LONGI (KUCHING) SDN BHD	Monocrystalline Silicon (Mono c-Si)	880	597	900	552	3 100	1 300
4	LONGI TECHNOLOGY (KUCHING) SDN BHD	Monocrystalline Silicon (Mono c-Si)	1 250	1 373	2 750	1 683	2 750	1 906
5	Sun Everywhere Sdn Bhd	Silicon Heterojunction (HJT)	229,5	226	166.43	222	102,62	222
6	SunPower Malaysia Manufacturing Sdn Bhd	–	773	1 600	0	0	0	0
Total			8 583	8 176	9 960	6 661	12 602,62	8 115
MODULE			**2019 (FOR COMPARISON)**		**2020**		**2021 (ESTIMATE)**	
No.	Company Name	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS	Capacity (MW)	Jobs	Capacity (MW)	Jobs	Capacity (MW)	Jobs
1	Jinko Solar Technology Sdn Bhd	sc-Si	2 480	3 113	3 500	2 467	3 780	2 611
2	LONGI (KUCHING) SDN BHD	Monocrystalline Silicon (Mono c-Si)	900	744	900	618	0	0
3	Hanwha Q CELLS Malaysia	–	2 000	2 263	2 200	2 200	2 400	2 400
4	Sun Everywhere Sdn Bhd	Silicon Heterojunction (HJT)	318,2	515	265,9	456	252,74	455
Total			5 698	6 635	6 865,9	5 741	6 432,74	5 466
INGOT/WAFER			**2019 (FOR COMPARISON)**		**2020**		**2021 (ESTIMATE)**	
No.	Company Name	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS	Capacity (MW)	Jobs	Capacity (MW)	Jobs	Capacity (MW)	Jobs
1	LONGI (KUCHING) SDN BHD	Monocrystalline Silicon (Mono c-Si)	500	344	550	361	550	340
2	Sun Everywhere Sdn Bhd	Silicon Heterojunction (HJT)	49,80	45	10,53	32	9,58	32
Total			500	389	560,53	393	559,58	372
THIN FILM			**2019 (FOR COMPARISON)**		**2020**		**2021 (ESTIMATE)**	
No.	Company Name	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS	Capacity (MW)	Jobs	Capacity (MW)	Jobs	Capacity (MW)	Jobs
1	First Solar Malaysia Sdn. Bhd.	CdTe	3 200	2 531	1 500	1 800	2 500	1 800
Total		CdTe	3 200	2 531	1 500	1 800	2 500	1 800

MOROCCO

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

ZAKARIA NAIMI, GENERAL MANAGER, GREEN ENERGY PARK PLATFORM (GEP)
AHMED BENLARABI, RESPONSIBLE FOR PV SYSTEMS, IRESEN

GENERAL FRAMEWORK AND IMPLEMENTATION

Since 2009, Morocco has developed an ambitious renewable energy program aimed at increasing the share of renewable energies in the national energy network to 52 percent by 2030. In 2020, Morocco reached a share of 34% of renewable energy, translated by the general capacity of 3 950 MW, where solar energy has a capacity of 750 MWp. Of which 210 MWp is from photovoltaic plants [1]. This major deployment of renewables is backed with a huge potential in terms of solar energy and wind energy, totalizing a potential of 500 TWh [2]. These numbers are translated through 47 renewable projects with a total investment of 52.2 Billion Dirhams [3].

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). On the other hand, many institutions with converging missions toward the deployment of the national energy strategy have been created:

- **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'Ingénierie Energétique)**

As for the SIE, formerly known as the Society of Energy Investments, it has become the Society of Energy Engineering, with a main mission to become a super ESCO for the deployment of the energy efficiency program.

NATIONAL PROGRAM

The MASEN is developing national programs aiming to achieve 52% of renewable energy share by 2030. So far, 53 renewable energy projects are under development aiming to achieve more than 1 760 MWp of solar energy where more than 1 500 MWp will be photovoltaic. The Moroccan government, through MASEN, is launching a new program dedicated to mainly national SMEs, by the launching of different tenders for small and medium size PV plants with capacities varying between 5 and 40 MWp. This program will, from one hand, contribute to the setup of a 400 MWp additional capacity based on solar photovoltaics, and on the other hand, will enhance the development for Moroccan SMEs in the field of photovoltaics. It will also support the creation of new job opportunities, as well as the diversification of the Moroccan industrial fabric. 47 companies have already manifested their interest to participate. The future PV plants are expected to be commissioned by 2022. The Moroccan government is projecting to achieve 100% of the scheduled planned capacity by the horizon 2023.

The MEME is also launching a program aiming at the upgrade of public buildings in terms of energy performances, by equipping them with renewable energy sources, mainly being photovoltaic systems. This program, focused solely on public buildings, seeks also to encourage the private sector on a similar approach.

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 to 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 started, as well since 2018, the label "Taqa-pro" for the certification of EPCs based in Morocco.

[1] Ministry of Energy, Mines and Environment
[2] Bulletin Officiel 6914 of the 03/09/2020
[3] https://fnh.ma/article/developpement-durable/le-maroc-avance-avec-serenite-dans-sa-transition-energetique

The MEME is also leading a study to establish the national grid codes as well as a new process for the certification of electricity provided from renewable sources and injected into the grid, that will ease and reinforce the penetration of smaller scale solar installations 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 the middle voltage grid. This law will allow the injection of around 10% of the produced capacity in the 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, the IRESEN is at the heart of the national energy strategy in The Kingdom of Morocco, by its position in the fields of applied research and innovation. Its funding agency strives to meet the priorities defined within the framework of the national energy strategy. Thus, all the topics addressed are aligned with renewable energy and energy efficiency sectors in Morocco with a need for applied R&D.

IRESEN and UM6P initiated, since 2016, the creation of a research platform network throughout the kingdom, Green Energy Park being the first one. Dedicated to solar energy, this platform, that is a unique model of its kind in Africa, allows, on the one hand, the creation of synergies and the pooling of infrastructures of several Moroccan research institutes in order to create a critical mass and achieve excellence, and to on the other hand, the acquisition of knowledge and know-how by the various partner universities as well as by Moroccan industries.

In the same approach, The "Green & Smart Building Park" testing, training and research platform has been created in the framework of the network initiated by IRESEN and UM6P. It is an innovative platform dedicated to research and development in the field of green buildings, energy efficiency and smart grids with the aim of creating the ecosystem in which future sustainable Moroccan and African cities will develop, thanks to the integration of renewable energies and digitalization which will enrich the value chain of the building sector.

Another platform specialized in Power-to-X and the production of Green Hydrogen and Green Ammonia is under study. Green H2A is a research platform that aims to be a national, regional and continental (Africa) reference for R&D and Innovation, dealing with topics related to the "Power-To-X" (PtX) sector, in particular Power-to-Hydrogen and Power-To-Ammonia. The objective of this platform is to offer capacity building and to stimulate the use of green raw materials in fertilizer production in particular, and in the industry more generally.

INDUSTRY AND MARKET DEVELOPMENT

Three PV modules manufacturers have set up their facilities in Morocco as photovoltaic module assembly lines. The biggest production line capacity being held by Almaden Morocco with a 250 MW, the largest production line in North Africa. Nonetheless, different modules producers ranked among the tier one 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 more than 40 EPCs are already in the EnF solar database.

On the other hand, the MEME is launching program aimed at providing industrial areas with renewable energy projects, particularly solar energy, to promote clean production, in the framework of which many companies have started to lay down the foundations for an energy transition to renewable energy, aiming to achieve high percentages of solar integration in their energy mix. Many Gigawatts are planned to be installed before 2030 by those actors and the electricity generated will serve from one side to contribute to the energy consumption in the industrial processes but also, with application of the injection law, will be able to contribute to the national energy mix.

Finally, the Ministry of Industry, Trade and Investment and the Digital Economy, has launched the Acceleration Plan to enhance the investment in high potential production lines, some of them being dedicated to the following:

- Solar Photovoltaic modules assembly
- Inverters
- Batteries
- Solar Heaters

This new step will support the diversification of the industrial fabric, as well as the creation of new job opportunities for the local citizens.

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS 2020

OTTO BERNSEN, NETHERLANDS ENTERPRISE AGENCY (RVO), TEAM ENERGY INNOVATION

GENERAL FRAMEWORK

In 2020, the Dutch solar PV market continued growing with just over 3 GWp installed (preliminary figures CBS news 24-02-2021) which leads to a total cumulative installed capacity of 10 GWp. The COVID-19 lockdown has led to a relatively small delay in some projects.

The estimated cumulative installed capacity now reaches over 10 GWp which is an increase of 44% against increases over 50% during the previous two years. These figures (see Table 1), are frequently corrected for the last years by the CBS (central agency statistics) as late figures over realised projects trickle in.

to keep pace with more ambitious European goals. In addition, a separate national goal is the replacement of the natural gas resources in the North of the country as the main (over 70%) energy source and increased electrification will be a major part of this trajectory. Solar PV will form the bulk of this amount of RES and its share is steadily rising (see Table 2). With a total production of 8,1 TWh in 2020, solar takes up 26% of the RES and 6,75% of the total electricity generation in the Netherlands.

The implementation of RES in general has been placed by the National Regional Energy Strategy at the regional level in 30 so called RES Regions. These 30 regions will finalise their plans over the course of 2021, while some already have.

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

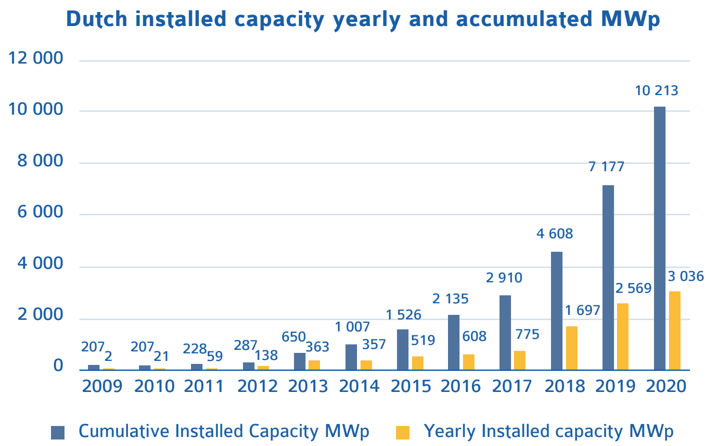
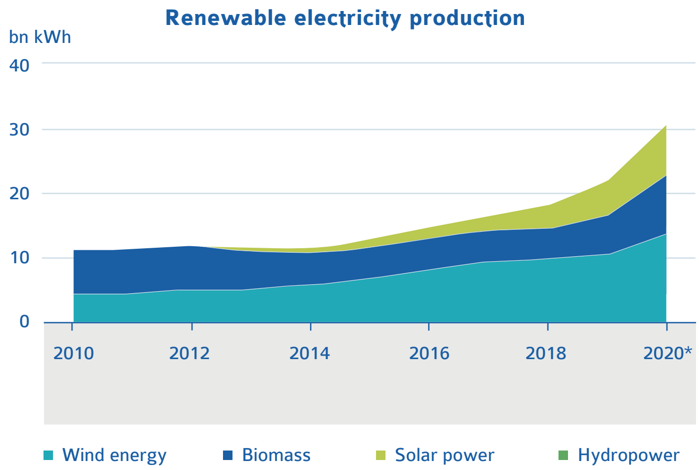


TABLE 2 – RES PRODUCTION 2020 IN THE NETHERLANDS



*Provisional figures

The Netherlands have shown to be a reliable growth markets for solar, even while congestion on the electricity grid is increasing and its full potential is not realised. Another limitation on the growth of solar in the Netherlands is the limited available space and relatively high ground prices. Therefore, integration of solar PV in the infrastructure, land use, buildings and the energy system is paramount in order to reach the necessary high percentages in the energy mix to reach the climate goals. At the same time, a new perspective looms in the near future for the usage of the solar (peak) power in (the summer) for the production of green hydrogen.

The national climate goals are set on 16% renewable energy sources (RES) in 2023, 49% less emissions in 2030 and close to no emissions in 2050. These national goals are dependent on the communal agreed goals in the European area and could be raised

NATIONAL PROGRAMMES

In 2020, the first national call was closed with a mission oriented approach and a clear focus for solar on the integration in the grid, the implementation on land, at sea, in the infrastructure, buildings and on the social acceptability of solar in a broad sense. 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/).

There exists a wide range of supporting schemes for the development and implementation of solar power in the Netherlands. For small roof top systems, a net metering scheme

Fig. 1 - Floating Solar Park Lingewaard, Netherlands. Source RVO Image database.

is in place until 2023, after which it will gradually be scaled down. In order to maintain the present return on investment of approximately six years, a large percentage (at least 60%) of self-consumption is needed which requires smart demand side management and/or additional investments in local storage capacity. For small systems, the VAT taxes can also be returned when applied for.

For larger systems over 15 KWp the SDE+ scheme is available which is basically a reversed auction system. There are now several different categories in place:

- > 15 KWp < 1 MWp
- > 1 MWp ground mounted
- > 1 MWp floating
- > 1 MWp solar tracking

The SDE+ scheme is monitored on the RVO website: Feiten en cijfers SDE(+) Algemeen | RVO.nl | Rijksdienst

The renewable energy subsidy (HE) is related to the SDE+ scheme and consists of a generic innovation scheme for all renewable energy sources 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.

For collective PV systems, a tax reduction scheme is in place called the "Postcoderoos", covering members with a similar postal codes. This scheme is increasingly used by energy cooperatives alongside other schemes.

An energy label is mandatory (the EPC) for new build houses coming on the market, which stimulates the installation of roof top PV panels but not so much its integration into the buildings.

As of 2020, all new buildings will need to be almost "energy neutral".

RESEARCH AND DEVELOPMENT ACTIVITIES

In 2020, there exists a R&D budget for solar technologies divided over the already mentioned missions for the built environment and RES on land. These are usually larger and integrated projects.

A relatively large budget is available in the DEI scheme for demonstration and pilot projects that aim to accelerate market introduction, see https://www.rvo.nl/subsidie-en-financieringswijzer/demonstratie-energie-en-klimaatinnovatie-dei

In addition, there are separate programs for fundamental research (NWO and STW), for renewable energy and technical innovation in general and specific programs for SMEs.

Solar research activities are dispersed in the Netherlands over several universities including; Utrecht, Leiden, Amsterdam, Delft, Nijmegen, Groningen, Eindhoven, Twente. Specific fundamental research is conducted also at the institutes AMOLF in various groups like Nanoscale Solar Cells, Photonic Materials and Hybrid Solar Cells; http://www.amolf.nl/research/nanoscale-solar-cells/ and DIFFER https://www.differ.nl/research/solar-fuels.

INDUSTRY STATUS

The Dutch solar sector is varied and complementary with an established international market position and new start-ups every year. New technologies are developed and introduced, such as the start-up Lightyear, which successfully integrated a solar PV roof on state of the art electrical vehicles.

More information about the activities and examples can be found in the RVO publication Solar Guide 2020 https://english.rvo.nl/news/dutch-solar-energy-industry-nl-solar-guide

DEMONSTRATION PROJECTS

As said, new market segments are being explored and notably the integration of solar panels in buildings, infrastructure and vehicles. For these specific niche markets, dedicated national platforms are formed by industry and the universities together.

Fig 2 - Floating Solar, ZOGRUNN project (Photo: RVO).

In the Netherlands, the waters (sea, rivers, lakes and canals) are an integral part of the infrastructure and perform multiple functions. Therefore, floating solar systems on water are developed, tested and brought to the market. The national platform started in 2017 with ambitious GW goals and provides an overview of the current state of affairs: https://www.zonopwater.nl/.

These projects are managed and tested carefully in different circumstances and under different conditions. The university of Utrecht has developed new evaluations methods and models for solar at sea that simulate the effects of wind, waves and temperature: Floating solar panels at sea: higher yields, better for the landscape - News - Universiteit Utrecht (uu.nl).

Other test sites for brackish and sweet water include the Hanzehogeschool Groningen and the ZOGRUNN project, see Figure 2.

IMPLEMENTATION AND MARKET DEVELOPMENT

The PV market showed sustained growth in 2020 with an estimated added amount of 3,3 GWp installed capacity (see Table 1 and Table 2, CBS 24-02-2021). The percentage of RES has risen to 26% and is likely to continue to grow in the following years if intelligent solutions can be found and agreed upon to avoid congestion on the grid, sufficient surface is found and enough professionals are educated to sustain this pace and the Dutch industry. With a total production of 8,1 TWh in 2020, solar PV takes up 6,75% of the total electricity generation in the Netherlands.

An increased emphasis is noticeable on the different niche markets which are carefully being prepared with new products but also to fit into the multi-functional land use in the Netherlands.

The implementation of RES in the 30 RES regions could have a major positive effect for solar PV deployment as the planning process could improve and the integrated roll out speeds up. However, the first results still have to come in and the regions face challenges in scale up efforts and knowledge in order to design and implement these regional plans.

The expectations for 2021 are that the growth of solar PV in the Netherlands will continue in both the residential segment and the larger (SDE+ category) projects. New perspectives loom for tailor made applications in, up till now, niche markets and the production of clean hydrogen for different uses.

The challenge remains to keep more people involved and raise the percentage of local ownership of the solar resources. For the existing and future solar prosumers, an additional challenge will be to raise the level of self-consumption in order to maintain a healthy business case after subsidies and tax incentives have ceased in the near future.

NORWAY

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

TROND INGE WESTGAARD, THE RESEARCH COUNCIL OF NORWAY

Fig. 1 - Powerhouse Telemark. This building's energy efficiency is due to a combination of architecture and technology. It has solar panels as façade and roof-top elements and uses innovative technologies for ventilation and heating (Photo: R8 Property/Tor Helge Thorsen).

GENERAL FRAMEWORK

Norway's electricity production is already based on renewable energy due to the availability of hydropower. In normal years the electricity production from hydropower exceeds the domestic electricity consumption. In 2020, hydropower generated 92% of the total electricity production of 154 TWh, which was the highest production level recorded. The gross domestic electricity consumption was 134 TWh. The generation from wind power is increasing from year to year due to increased installed capacity, and it contributed 6,4% of the total electricity generation in 2020. 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 into 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.

Fig. 2 - Solar panels on the roof of Powerhouse Telemark (Photo: R8 Property/ Tor Helge Thorsen).

NATIONAL PROGRAMMES

Norway's programmes in the energy sector are generally aiming for promoting renewable energy and increasing energy efficiency. Support for PV implementation 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 (to be reduced to 7 500 NOK from July 1, 2021) and 1 250 NOK per installed kW rated 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 program 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. Powerhouse Telemark (Figure 1 and Figure 2), in the town of Porsgrunn in southern Norway, was completed in 2020 and is an example of how Enova can support innovative projects.

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 2020. The portfolio consists of R&D projects on the silicon chain from feedstock to solar cells research, on novel solar cell concepts, innovative applications, 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 (28 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 Nanotechology (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.
- SINTEF Trondheim and Oslo: Focuses 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 pumps, 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 is a provider of utility scale solar (PV) power plants and is also 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 1,6 GW, consisting of power plants in Africa, Asia, South America, and Europe.

In recent years, new companies have been formed for developing new services or solutions for the PV markets. One example is companies offering technology for floating solar power plants.

MARKET DEVELOPMENT

The Norwegian PV market is small on an international scale, but the growth rate has been high. The rate of new commercial installations was reduced in 2020, compared to 2019, due to uncertainty caused by the COVID-19 pandemic. It is estimated that 40 MW of PV capacity was installed in 2020, while the total PV generation capacity installed before 2020 was approximately 120 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 homeowners. 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. During most of 2020, electricity prices were exceptionally low due to abundant precipitation.

The Norwegian Energy Regulatory Authority (NVE-RME) has proposed new tariffs for grid fees. This proposal aims at a fairer distribution of grid costs compared to the existing tariffs. NVE-RME's proposal will affect the economics of PV installations negatively when the owner requires relatively high peak power from the conventional grid. On the other hand, PV installations that reduce peak power demand will potentially benefit from the new tariffs. A revised proposal was subject to public review in 2020, but this proposal was also criticized for being unpredictable for consumers.

PORTUGAL

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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

Fig. 1 - PV plant Mogadouro, in northern Portugal, with an installed peak power of 48,9 MW (Photo: Smartenergy).

GENERAL FRAMEWORK AND IMPLEMENTATION

Portugal has the ambition to reach the carbon neutrality in 2050 supported by well-defined trajectories for the different economy sectors. The National Carbon Neutrality Roadmap for 2050 (RNC 2050), approved by the Portuguese government (RCM No. 107/2019), includes the new strategies for renewable policies, setting the country targets from 2030 to 2050.

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, and constitute 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.

The Portuguese National H2 Strategy for Portugal (EN-H2) was also approved by the Portuguese government (RCM No. 63/2020, 14th August 2020) and defines a set of public policies to promote an industrial policy focused on the H2 value chain. The national strategy sets the target of installing up to 2,5 GW of electrolysers for green H2 production up to 2030. Moreover, the also recent legislation on the National Gas System (Decree-Law No. 62/2020, 28th August 2020) states that renewable gases (such as biomethane and H2) produced from RES have an important role to play in the decarbonisation of the Portuguese natural gas grid. Given the low prices of electricity produced by PV plants, a significant increase in PV installed capacity is expected in the supply of energy for hydrogen production.

TABLE 1 – TARGETS OF DECARBONIZATION UNTIL 2050

	2030	2040	2050
GHGs Reduction (without LULUCF) (% relative to 2005)	-45% to -55%	-65% to -75%	-85% to -90%
Renewable Energy Sources (RES)	47%	71% to 72%	86% to 88%
RES – Electricity	80%	97%	100%
RES - Transports (without aviation and navigation)	20%	58% to 61%	94% to 96%
RES – Heating and Cooling	49%	58% to 60%	66% to 68%
Energy Efficiency	35%	n.d.	n.d.

Source: NECP 2030 and RNC 2050

At the end of 2020, Portugal had an accumulated PV installed capacity of **1 030 MW** including a total capacity of 15 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 **124 MW** in 2020:

- Decentralized PV was responsible for an increase of **45 MW**;
- New utility scale power plants had an increase of capacity of **79 MW**.

The total PV electricity produced reached 1 705 GWh, which represents about 3,3% of the total electricity production in Portugal in 2020.

(Source of data: DGEG, "Estatísticas rápidas - n° 193 - dezembro de 2020")

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 those targets, for which the solar PV contribution is of paramount relevance.

In the framework of the new 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 important capacity auctions to install large-scale PV projects with very good results. A total photovoltaic capacity of 1 400 MW was auctioned in July 2019 and 670 MW in August 2020. Both auctions broke world records by reaching minimum values under the guaranteed remuneration scheme of 14,76 EUR/MWh in 2019 and under the variable premium for differences of 11,14 EUR/MWh in 2020. These auctions are part of Portugal's efforts to speed up the increase of installed PV capacity.

On the decentralized side, a new legal framework for self-consumption units, or UPACs, came into force in January 2020 (DL No. 162/2019, 25th October 2019). According to this new Decree-Law, the production surplus from the self-consumption units or UPACs can be sold through: a) an organized or bilateral market; b) participation in the wholesale electricity market (MIBEL), against the payment of a price agreed between the different parties; c) the market facilitator. This Decree-Law transposes partially the RED II Directive, namely introducing the legal framework for jointly acting renewables self-consumers and renewable energy communities.

The legal regime applicable to the production of electricity sold in its entirety to the public service electricity network from renewable resources through small production facilities (UPP) is now regulated by DL No. 172/2006, 23rd August (actual version). The production should be done by a single RES technology with an installed capacity until 1 MW and allows the producer to sell all the electricity produced, based on market revenue or a model of discount offer to the reference tariff of 0,045 EUR/kWh (Ordinance DGEG No. 80/2020, 25th March 2020). The proposed tariff will be effective for 15 years.

In the following years, it is expected that solar PV will continue to increase its share in decentralized production, in particular, with its integration into 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 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.

PV R&D

In the last years, PV R&D in Portugal has had strong development with an important scientific community, comprised of 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 the following:
University of Minho is 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) is working on solar fuel production; inorganic-organic hybrid solar cells, sensitized solar cells, perovskite solar cells, Cu_2O, Cu(In, Ga)Se_2 solar cell devices and materials, quantum dot solar cells, thin-film Si, encapsulation barrier, and Si-NW solar cells.

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

University of Aveiro is working on semiconductor physics; growth and characterization of thin-films for photovoltaic applications.

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

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

University of Lisbon (Instituto Superior Técnico) is working on organic cells.

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

LNEG (Laboratório Nacional de Energia e Geologia) is 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 is working on modeling the contribution of PV technologies for the national energy system up to 2030, namely supporting the NECP.

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

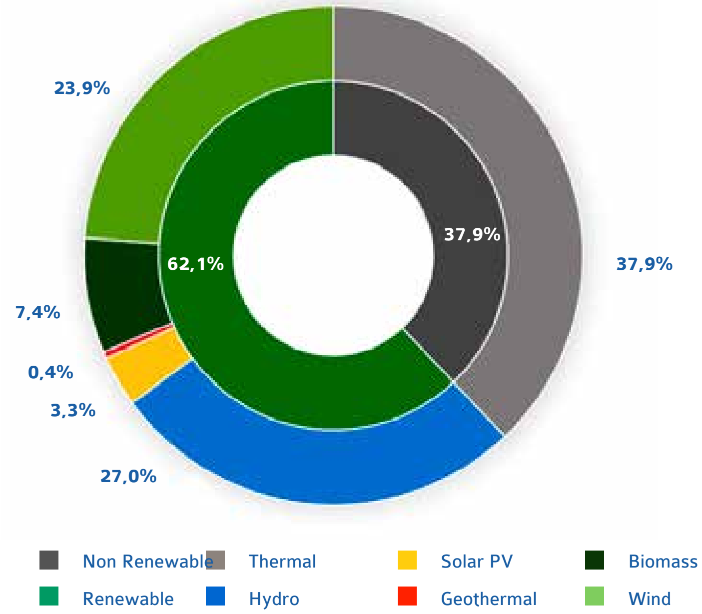


Fig. 2 - Electricity generation by energy source in Portugal 2020 (Data from DGEG, provisional).

INDUSTRY AND MARKET DEVELOPMENT

Provisional data for 2020 registered an incorporation rate for RES into the electricity production mix of about **62,1%** (32,0 TWh), as shown in Figure 2, within an annual total gross electricity production of **51,5 TWh**. The remaining **37,9%** (19,4 TWh) were produced by fossil fuels. Solar PV accounted for **3,3%** of the total electricity generation in Portugal.

The 2020 annual average daily market price of the Iberian Electricity Market (MIBEL) where Portugal operates was of **34,0 EUR/MWh**, which represents a decrease of around 29% related to the 2019 value.

Figure 3 shows the evolution of monthly electricity market prices for 2019 and 2020 in Portugal, reflecting the positive impact of renewables related to electricity consumption for the same period. It is worth noting that in April 2020, a lowest monthly average electricity market price of 17,8 EUR/MWh was reached, representing a 65,9% decrease in comparison to the same month in 2019. This reduction in the electricity prices was not only a result of moderate renewable penetration, but also, and more significantly, due to the huge drop in electricity demand verified in that period, a result of the state of emergency decreed by the national government to tackle the COVID-19 pandemic.

The power sector in Mainland Portugal was responsible for a total of 8,0 million tonnes of CO_2 emissions which represents a specific CO_2 emission of 159 g/kWh.

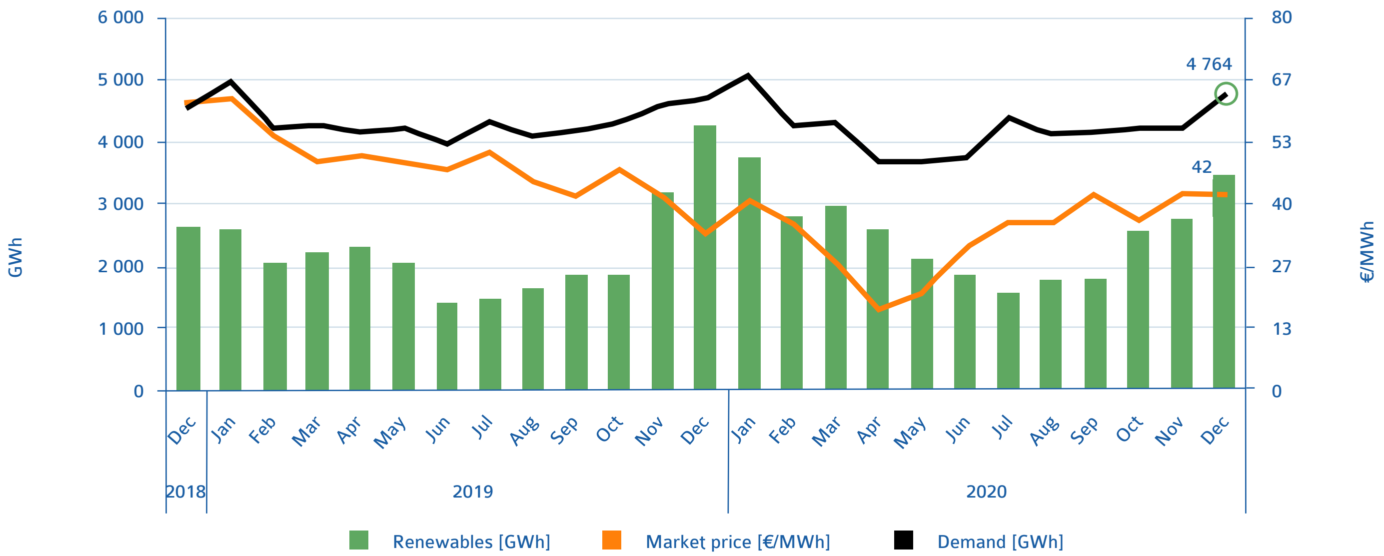


Fig. 3 - Renewable Electricity Production and Iberian Wholesale Electricity Market Price (December 2018 to December 2019) (Source: OMIE, REN; APREN's analysis).

SOLARPOWER EUROPE

SOLARPOWER EUROPE'S ACTIVITIES

AURELIE BEAUVAIS, POLICY DIRECTOR, SOLARPOWER EUROPE

Fig. 1 - SolarPower Europe CEO Walburga Hemetsberger and EU Energy Commissioner Kadri Simson at the Solar Power Summit 2020 (Photo: © SolarPower Europe).

AN UNPRECEDENTED YET SUCCESSFUL YEAR: LOOKING BACK ON SOLARPOWER EUROPE'S POLICY ACHIEVEMENTS IN 2020

In Europe and around the world, the year 2020 was unlike any other year. Despite the dramatic impacts of the COVID-19 pandemic, there is more hope than ever that the European Union can recover quickly from this crisis, and build back better, placing clean energy technologies at the core of its economic renaissance. The solar sector has demonstrated that it can be a key ally to turn this ambition into reality.

In 2020, SolarPower Europe witnessed the incredible resilience of solar PV. EU Solar installations grew by 11%, bringing new capacity additions to a level that marks the second-best year ever in EU solar history. SolarPower Europe worked relentlessly to shape the best possible policy and business environment, which will enable our sector to grow even further, and contribute to a green recovery for the EU. Only one month into 2021, it is a good time to look back on the association's achievements.

In 2020, SolarPower Europe made a prominent entry into a new and promising area: Renewable Hydrogen. SolarPower Europe has been leading this topic since May 2020, with the successful "Choose Renewable Hydrogen Campaign", which secured the prioritisation of renewable-based solutions within the European Hydrogen Strategy. The success of this campaign led to the creation of the "Renewable Hydrogen Coalition" in November 2020, in collaboration with Wind Europe and Breakthrough Energy. SolarPower Europe is also proud to coordinate the European Clean Hydrogen Alliance's "Low-carbon and renewable hydrogen production Roundtable". On 18 February 2021, SolarPower Europe will kick-off the Renewable Hydrogen Workstream that will channel the contributions from members to these exciting activities.

On top of this, SolarPower Europe created three new workstreams covering priority areas for membership: Grids, AgriSolar, and Financing.

The AgriSolar Workstream was launched in April 2020, to support the clean energy transition in rural communities, and has since achieved many great successes. In June 2020, investing in solar was recognised as a priority within the European Commission Farm to Fork Strategy. During the SolarPower Summit, the workstream launched a briefing paper: Agri-PV: How Solar Enables the Clean Energy Transition in Rural Areas.

In June 2020, SolarPower Europe also launched the new Grids Workstream, tasked with the critical mission of removing current barriers to grid access and connection, which hampers the deployment of solar in Europe. The workstream hosted a successful launch webinar, "Decentralised, Smarter, Greener: the 2030 European Grid" and is working full speed to deliver its first report on Grid Integration.

Finally, the Finance Workstream spent 2020 providing key recommendations to leverage private and public finance towards achieving energy and climate goals. This included advising the European Investment Bank (EIB) Climate Roadmap 2021-2025, the EU Sustainable Finance Strategy, the EU Taxonomy, the EU Non-Financial Reporting Directive, and the EU Renewable Energy Financing Mechanism.

At the same time, SolarPower Europe's existing workstreams kept enriching their activities to keep pace with a fast-changing environment and break new ground.

In 2020, the Solar Buildings Workstream expanded its scope beyond BIPV to include traditional rooftop PV and building decarbonisation technologies. This workstream bore the following fruits: in the Renovation Wave Strategy, the European Commission committed to removing barriers to the development of BIPV in the EU, to develop minimum requirements for the use of renewable energy in buildings, and to revise the State Aid framework for renewable self-consumption. Furthermore, the European Parliament expressed its support for a European solar rooftop programme in the 'Own Initiative Report' on "Maximising the energy efficiency potential of the EU building stock."

The Storage Workstream released the first edition of its new European Market Outlook for Residential Battery Storage, the first report of its kind, analysing the development of residential

Fig. 2 - SolarPower Europe is positioning solar PV as a key clean energy technology to power the European Green Deal and to help reach energy and climate targets (Photo: © FOXBAT).

battery energy storage systems (BESS) in Europe providing an overview of the current status of the market and a five-year forecast of its mid-term evolution. The workstream also published Recommendations on Recovery and Resilience Plans to foster the growth of battery storage through different support policies. It also published a white paper on policies to support the integration of battery energy storage systems.

The Digitalisation Workstream supported the development of the EU Energy System Integration Strategy, contributing to the definition of data access, management, and interoperability standards, which is necessary to create a digital ecosystem that allows smart devices across sectors to interact and enables further innovation. The workstream also provided specific guidance on cybersecurity measures for distributed PV systems and solar parks in the Directive on security of network and information systems (NIS Directive).

The Sustainability Workstream positioned SolarPower Europe as the leading stakeholder on the Sustainable Product Policies initiative by the EU Commission, planning to introduce Ecodesign and Energy Label policy tools to solar modules, inverters, and systems. Bringing together a number of partner associations, the Workstream established a Joint Mission Group to liaise with EU policymakers on the design of the policy tools. Meetings were held with high-level EU institution representatives on the topics of circular economy, EU-ETS reform, and Carbon Border Adjustment Mechanism.

The Emerging Markets Workstream had very productive year with new reports on solar investment opportunities in Latin America (regional), India, and Tunisia. The workstream also actively partnered with international cooperation programs around the world to disseminate industry best practices, support capacity building measures and access to financing, and provide policy and technical advice to enhance conditions for solar in Jordan, India, and Tunisia, working with key international players such as RenewAfrica and the Global Solar Council.

The Lifecycle Quality Workstream published the industry-first best practice guidelines on Engineering, Procurement and Construction (EPC). Building on a successful first guide, the workstream also published version 2.0 of the Asset Management Best Practice Guidelines, incorporating even more industry experience. The workstream further created the Solar Best Practices Mark, a self-certification, voluntary quality label. Along with 20 partners, the workstream is also part of TRUST-PV, a 4-year research project with over 12 MEUR in grant value from the EU's Horizon 2020, aimed at improving the performance and reliability of solar power plants.

The Industrial Strategy Workstream has taken a huge leap forward, with the launch of the Solar Manufacturing Accelerator, which selected and presented 10 leading industrial projects to the European Commission and the European Investment Bank in July 2020. The success of this meeting has enabled the association to reposition solar PV manufacturing on top of the European Agenda, with the upcoming launch of a European Solar Initiative together with EIT InnoEnergy, the architects of the well-known European Battery Alliance.

In parallel to policy activities, SolarPower Europe's market intelligence output has also experienced a substantial increase. In addition to the association's flagship reports, the award-winning Global Market Outlook 2020-2024 and the EU Market Outlook 2020-2024, last year saw the publication of 100% Renewable Europe, a landmark study carried out in collaboration with LUT University, which looks at pathways for achieving a fully RE-based European energy system before 2050 and highlights the crucial role of solar in the energy transition.

Last but not least, 2020 was also a strong year for SolarPower Europe's media and digital presence:
- Over 4 000 mentions in the media in 2020 including coverage in world-leading press such as in Forbes, Politico, Bloomberg, NBC, Reuters, New Statesman, Al Jazeera, Euractiv;
- 131 press releases, blogs, and news articles in 2020, almost doubling its output from the year before;
- 35% average increase in followers across SolarPower Europe's social media channels.

In 2021, SolarPower Europe will continue these activities and more, looking 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

The expansion of installed PV capacity in Spain has continued during 2020. A total of 2 633 MW grid-connected have been added (preliminary data out of the operator Red Eléctrica de España, REE) and 596 MW more as self-consumption (individual and collective). In these circumstances, available data about share of electricity demand coverage positions PV with slightly more than 6%, almost duplicating the prior year's value.

The interest on achieving the goals of decarbonization for the country, together with the good possibilities of the PV technology in this area of the world, make PV the preferred source for renewable electricity; in fact, the recent (01/26/2021) tender for RREE in Spain, based on the LCOE parameter, was mostly won by PV in front of other renewable technologies.

In summary, the total (preliminary) installed PV capacity for the year has been 3 229 MW; accounting for grid connected and isolated power.

With these numbers and having some uncertainty on the electricity generated out of self-consumption, that cannot be easily estimated, the contribution of PV to the electricity demand coverage during 2020 appears in Figure 1, together with the contribution from the other RREE sources, but reflecting only the grid connected generation.

Total percentage value of demand coverage by PV appears the highest ever, although that might be influenced by COVID-19 pandemic circumstances contributing to lower industrial activity and therefore lower use of energy.

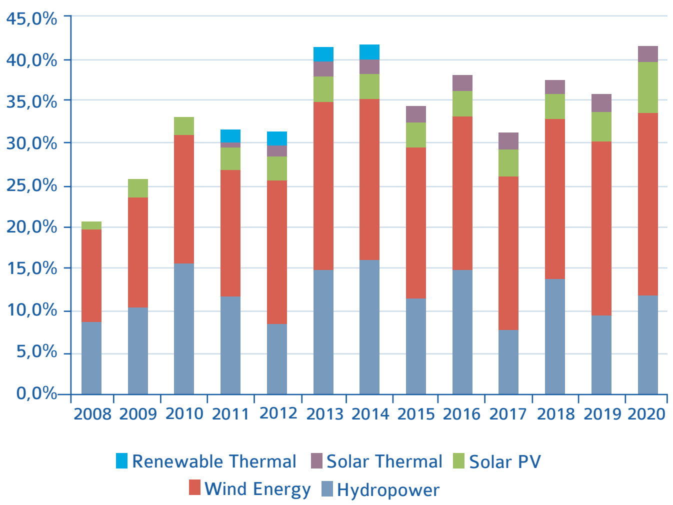


Fig. 1 - Percentage of demand coverage from renewable energies (2008, 2009 data out of CNE, 2010 - 2019 REE, 2020 REE- preliminary information).

Figure 2 shows the yearly evolution of total electricity generation in the country (250 400 GWh) by the different energy sources (grid connected). Wind (54 337 GWh) approaches Nuclear values. Coal goes down to 5 000 GWh. Hydropower increases in opposition to Combined Cycle and PV augments its value up to 15 274 GWh. The impressive growth of PV electricity from previous year (9 136 GWh) is due to the generation of full 3,7 GW installed capacity out of the tenders in 2019, which were fully connected in 2020, plus the new additions in the year.

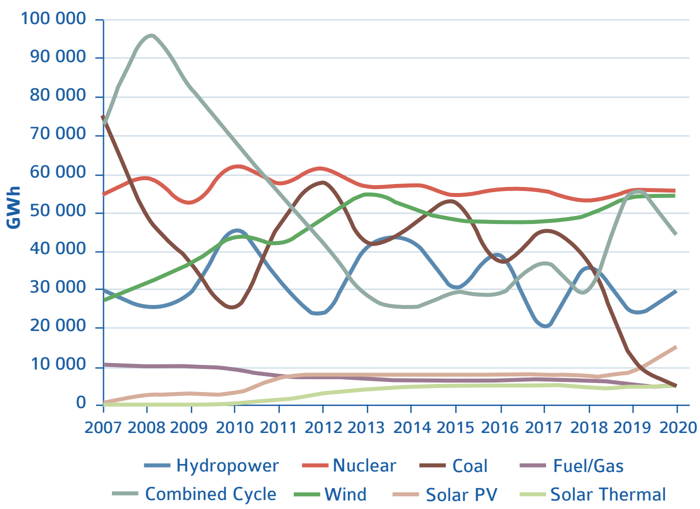


Fig. 2 - Percentage of demand coverage from renewable energies.

The contribution of electricity generated out of PV in 2020 can be seen in Figure 3 where monthly percentage of demand coverage due to PV is represented for the last 11 years. In the case of 2020 (light blue plot line), the big values appear supported by the increase in PV capacity, as well as by the reduction in demand associated to slow down in activity due to COVID-19. Increase in contribution due to new capacity added in the 2019 tender can also be seen in purple plot line from August.

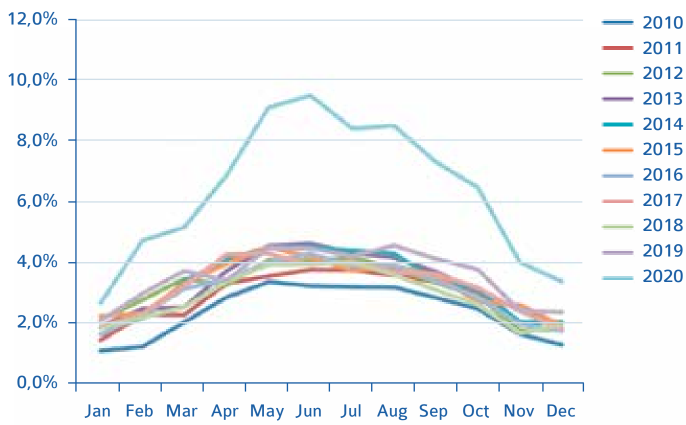


Fig. 3 - Monthly demand coverage by PV (last 11 years).

Information presented corresponds to consolidated values up to 2019, reported by grid operator REE (Red Eléctrica de España). For 2020, data are first estimations as of January 2021 for both peninsular and extra-peninsular territories. Consolidated final information for the year will appear in the July 2021 timeframe. Demand coverage due to off-grid and self-consumption has not been considered at all in these Figures.

With this mixture of generation, the average monthly spot price had a profound decrease for the months from March through June, associated, among other reasons, to low activity those months due to lockdown of the country and low cost generation technologies therefore available for use. However, after some activity was recovered, the value increased towards the end of the year where it achieved its maximum due to higher demand.

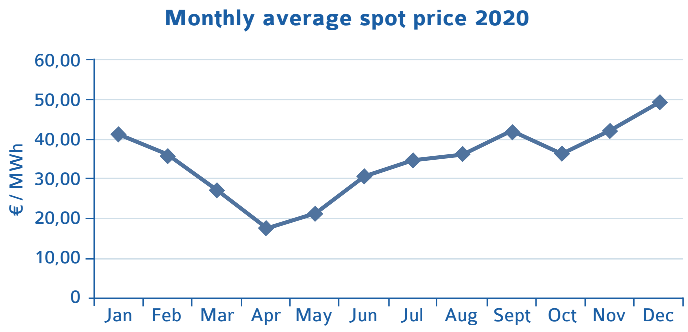


Fig. 4 - Evolution of monthly average MWh spot price (all generation technologies).

NATIONAL PROGRAM

On March 31st, 2020, the Spanish government approved the "Plan nacional Integrado de Energía y Clima" PNIEC-(2021-2030) to be sent to the EC, that positions Spain to achieve climatic neutrality in 2050 and fulfils its commitment to the Paris Agreement. The plan requires the reduction in next 10 years of greenhouse gas emissions (23% respect 1990), 42% RREE in the final use of energy, 39,5% improvement in energy efficiency and 74% presence of RREE in the electrical sector as an intermediate step towards a 100% renewable electricity in the 2050.

In the path to planned goals, the year 2020, has reached a very important milestone for the photovoltaic sector as the development and installation of 2 633 MW, all new projects grid connected, was done without any governmental support mechanisms; opening the possibility of many more PV plants in the same circumstances to come. The total PV capacity installed (not self-consumption) at the end of December 2020 in Spain was 11 547 MW.

Concerning PV self-consumption, no specific national program is established, nevertheless, in some cities and Autonomous Communities, mostly individual roofs but also cooperatives, have been supported through particular programs and tax reductions. As reported by the Spanish Industry Association, UNEF, based on information from its members, the total cumulated self-consumption PV power installed in Spain has gone almost to 1,5 GW due to the addition in 2020 of 596 MW more.

In summary, Figure 5 shows the evolution of installed capacity from 2005 grid-connected and off-grid (2017-2020).

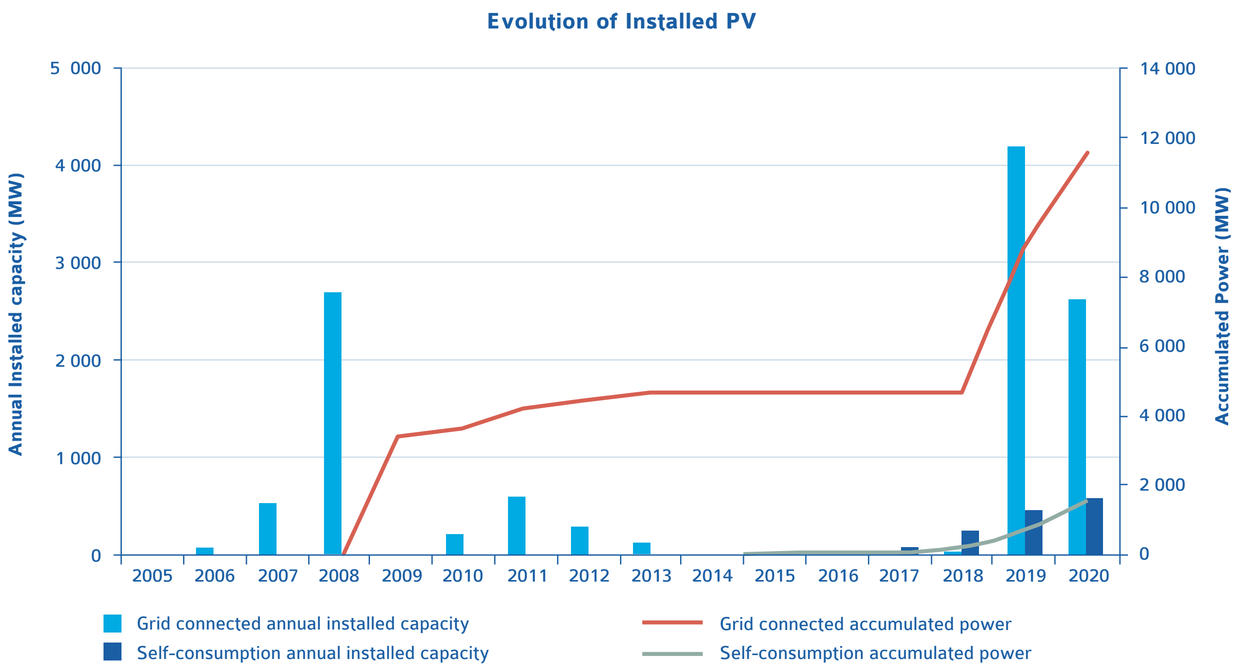


Fig. 5 - Evolution of installed PV 2005 – 2020, including grid-connected and self-consumption.

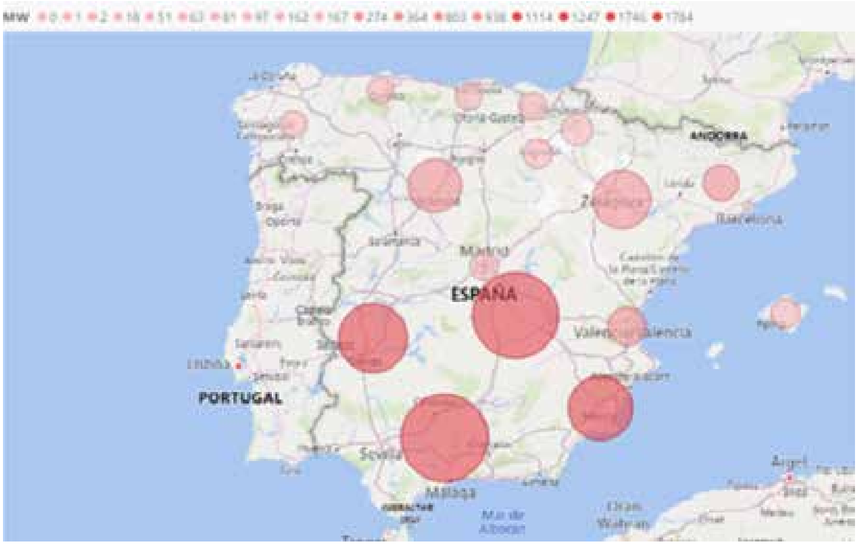


Fig. 6 - Geographical distribution of PV capacity installed in Spain.

When looking at the distribution of new PV capacity added throughout the Spanish territory, it can be seen that the said distribution is not uniform. There are four Autonomous Communities (mostly Central to South Spain) that have more than 1 GW PV each, another two on the central northern area approach the 1 GW and the rest having 2 or 3 hundreds of MW and lower. The distribution is mostly related to solar resource and land availability, and this last point is becoming a subject of discussion in the places where PV plants, situated close to the cities and in some cases using land that had previously had agriculture use, are present in the landscape.

Although real numbers report very low values of terrain occupation, aspects related to integration of PV plants (mostly massive) in the environment are going to be a subject of discussion in the years to come. Figure 6 shows the map of PV capacity distribution in the country among different Autonomous Communities as of 2019.

R&D

R&D activities remain important in Spain and not only related to pure PV technology development but just insisting on possibilities of application. Local (Autonomous Communities Government), National and European calls have participation of Spanish R&D institutions and companies. In that sense, the recently developed concern about increase in land used for PV is driving new approaches for installing PV, not only in the ground, but taking advantage of dual use of spaces as façades, such as the project TECH4WIN, with a consortium where the Spanish companies ONYX and ACCIONA and the technological center IREC participate in the development of PV windows for energy harvesting. Another example of no-land used for PV is being presented in the FRESHER project for direct use on water surfaces, in the role of base for PV plants, by developing sustainable floating PV parks on-shore and off-shore. This project, also from H2020 program, has the Spanish company ISIGENERE's participation in the consortium.

Another important area of application is covered by the project SolAqua, from the call H2020-LC-SC3-2020-RES-IA-CSA lead by IES-UPM (Solar Institute of Polytechnic University of Madrid) for developing materials, tools and methodologies to support the deployment of solar irrigation (SI) with zero-emission energy and at a substantially lower cost. The project consortium includes mostly southern European institutions and Morocco. Also related to optimization of LCOE of PV plants, TECNALIA leads the recently awarded project SERENDY-PV from the H2020-LC-SC3-2020-RES-IA-CSA, with a large consortium of 20 members that includes among them four more Spanish companies (QUALIFYING PHOTOVOLTAICS, COBRA, CEGASA and INGETEAM POWER). The project's goal is the development of advanced PV modelling, simulation and monitoring for fault diagnostics and improved operation and maintenance in PV plants.

On the side of R&D for technology, CIEMAT leads the SCALED project from the national call RETOS (2017-2020) program, for development of materials for selective contacts on heterojunction solar cells and potential application on energy storage. Also concerning new PV technologies development, CENER, together with other 14 European partners, participates in the VIPERLAB project from the H2020-INFRAIA-02-2020 call, lead by Helmholtz Institute Berlin. The project aims to support the European academic and industrial researchers in working together on the research and development at lab-scale and pre-industrial level of the new generation of tandem Si-perovskite solar cells that will support the new activity of PV industrialization in Europe.

Fig. 7a - Construction of "Nuñez de Balboa" PV plant (500 MW in Badajoz, Spain) by the Spanish utility IBERDROLA.

Fig. 7b - Completed construction of "Nuñez de Balboa" PV plant (500 MW in Badajoz, Spain), by the Spanish utility IBERDROLA.

INDUSTRY STATUS

At the beginning of 2020 and just following the tendency of previous years, the expectations about contribution of PV to the Gross Domestic Product (GDP) were very good, however final numbers including the influence of COVID-19 might be less optimistic, but have not been presented at the time of submitting this report.

The main contributors to GDP expected are engineering and EPC companies followed by manufacturers and other distribution activities. PV manufacturing in Spain is mostly in the BOS sector (inverters, supporting structures and trackers) with very competitive companies selling their products around the world. While PV modules fabrication is still residual, new companies with innovative products to support PV deployment have appeared in recent years, as is the case of SMS, the manufacturer of robots for cleaning PV modules installed in the plants or PVH (tracker manufacturer), that also has developed a specific robot for modules onto tracker cleaning. However, manufacturing activity also remains in custom-specific BIPV products, as is the case of the well-known ONYX Solar Company and there have been certain announcements of potential re-activation of some other PV module fabrication plants (ESCELCO) in the near future.

Of special interest to highlight is the successful debut last October 2020, on the Spanish stock market (IBEX 35) of SOLTEC, the solar trackers manufacturer, which joins other firms of RREE already there. In the same direction are the recent notices by OPDEnergy, Ecoener, Capital Energy and Factor Energía. Also, there is news about the negotiations of the GRANSOLAR Company for its sale to an investment fund. Finally, two more initiatives to go to stock market come from the well-known infrastructure company ACCIONA, that could present its Renewable Energies division to go on the IBEX-35 and similar interest in the case of the petrochemical and multi-energy company REPSOL.

In summary, apart from problems which arose from the COVID-19 pandemic, 2020 has been positive and optimism remains in the PV sector for 2021, as well as for the future of PV deployment in the country, together with the large presence of Spanish companies abroad.

SWEDEN

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

JOHAN LINDAL, BECQUEREL SWEDEN
PIERRE-JEAN RIGOLE, SWEDISH ENERGY AGENCY

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 the following targets:

- 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 to 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 above-mentioned target.

INCENTIVES FOR RENEWABLES

Sweden has a technology-neutral, market-based support system for renewable electricity production called "the electricity certificate system". Sweden and Norway have shared a common electricity certificates market since 2012, wherein certificates may be traded between borders.

The original objective of the common Swedish and Norwegian certificates market was to add 28,4 TWh of new renewable electricity production by 2020. This goal was met in the spring of 2019. Additionally, Sweden also has a goal of an additional 18 TWh by 2030. The overall goal within the electricity certificate system is therefore 46,4 TWh of new renewable electricity production by 2030.

Although the incentive has accelerated the current expansion, other factors have played a larger role; such as technology development, good conditions for large wind power projects, low competition for the projects, low interest rates and new financing schemes. Renewable electricity production is therefore built faster than the targets set in the incentive scheme. This has led to large surpluses of electricity certificates being created, which cause prices to approach zero. From January 2019, the prices have gone from 0,16 SEK/kWh to being 0,01 SEK/kWh in December 2020.

The electricity certificate system has lost it significance and the certificates are no longer a prerequisite for new investments in, for example, wind power or PV parks.

The electricity certificate system is about to be phased out. The Government has decided on a stop rule for the system. No new power plants will be approved for certificates after 31st of December 2021. The Government expects that the 2030 target of renewable electricity production will be reached as early as 2021. If the goal is not met, the stop date will be moved forward.

SUBSIDY FOR PV INSTALLATIONS

Since the introduction of a capital subsidy for PV installations 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 been higher than available funds in the budget throughout the last few years. The capital subsidy for PV installations was ended for private individuals as of the end of 2020, but companies and organizations that applied for the support before the 7th of July 2020 can, under 2021, receive a 10% coverage for their PV projects as long as the budget of 260 MEUR for 2021 lasts. The application deadline for the investment support as of 7th of July 2020 has been sent, so no new PV projects will be able to receive support through this program.

For private individuals the capital subsidy for PV installations will be replaced by tax deduction incentive as of 2021. Through this tax deduction for installation of green technology incentive, a 15% deduction for labor and material costs can be applied.

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 the owner is not a net electricity consumer. The tax credit is drawn from the income tax and has a cap of 1 900 EUR per year.

Fig. 1 - The largest PV plant in Sweden to date at 14 MWp. The plant lies outside of Strängnäs and was installed by EnergiEngagemang for HSB Sörmland (Photo: © EnergiEngagemang).

Fig. 2 - CIGS thin film research at Uppsala University (Photo: © Uppsala University).

PUBLIC PERCEPTION

There is a strong opinion in favor of PV technology in Sweden, and about 82% of the population thinks that efforts towards implementation should increase [1]. When it comes to the willingness of homeowners to install PV on their house, different surveys have shown that about 60% of the homeowners in Sweden are interested in having a PV system on their roof.

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 [ref]. 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 in 2040 as it is today.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Research, development and demonstration is supported through several national research funding agencies, universities and private institutions in Sweden. However, among the national research funding agencies, the Swedish Energy Agency is specifically responsible for the national research related to energy. With an annual budget of 140 MEUR, some 50 programmes and 1 000 projects running are therefore using this main funding source for research and innovation projects within PV.

[1] Persson, S., & Holmberg, S. (2020). Åsikter om energi och kärnkraft – Den svenska miljö-, energi- och klimatopinionen 1998-2019. Göteborg

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 projects, innovation procurement and expert studies. International projects are conducted in the EU collaboration SOLAR-ERA.NET. In addition to the research programme, the Swedish Energy Agency also provides funding to PV companies though dedicated projects supporting their technology development.

In addition to the research funding distributed by the Swedish Energy Agency, the Swedish Research Council, the Swedish Governmental Agency for Innovation Systems and the Swedish Foundation for Strategic Research also support PV related research. In total, about 150 MSEK was distributed from these four major actors to Swedish PV research in 2019.

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 to 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.

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 cells. 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 cultivates algae (diatoms) to use their shell material to enhance the efficiency of solar panels. The company collaborates 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.

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 PV power has grown from only 250 kW in 2005 to 714 MW in 2019. The annual market for PV in Sweden grew by 83% in 2019, as 289 MW were added. However, PV still accounts for only about 0,34% of the Swedish electricity production (158,6 TWh under 2019), 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 decentralized PV systems and by customers who buy and own their PV systems. However, large centralized PV parks are becoming more common and larger. To date, the largest PV park is a 14 MW PV park outside of Strängnäs, but announcements for plans of bigger PV parks have been made.

A fast-growing number of small to medium-sized enterprises exist, that design, sell and install PV products and systems. At the end of 2019, there were about 315 installers or retailers active on the Swedish PV market. Many of these companies depend almost exclusively on the Swedish market. Some utilities are selling turn-key PV systems, often with assistance from PV installation companies. In past years, some companies also started to offer third-party financing as a method of realizing a PV installation.

Fig. 3 - Example of a typical Swedish decentralized PV installation (Photo © HP SolarTech).

Sun Renewable Energy AB is the only remaining solar cell factory for silicon PV modules in Sweden. The company took over 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 modules, primary for a BIPV market, as well as equipment to manufacture CIGS cells. Exeger AB is offering dye-sensitized solar cells that can harness the energy of ambient light for powering consumer electronics and have their own manufacturing plant in Sweden. 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 which are 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 impacts.

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS

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

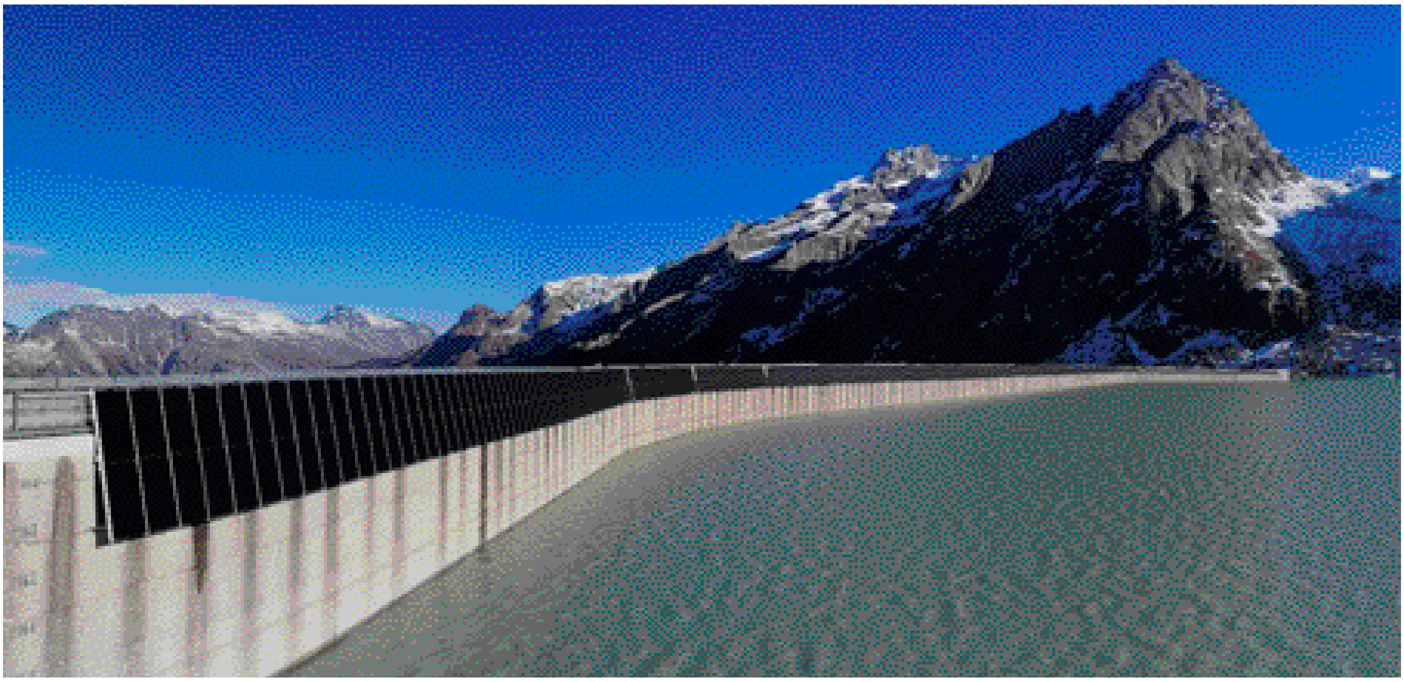


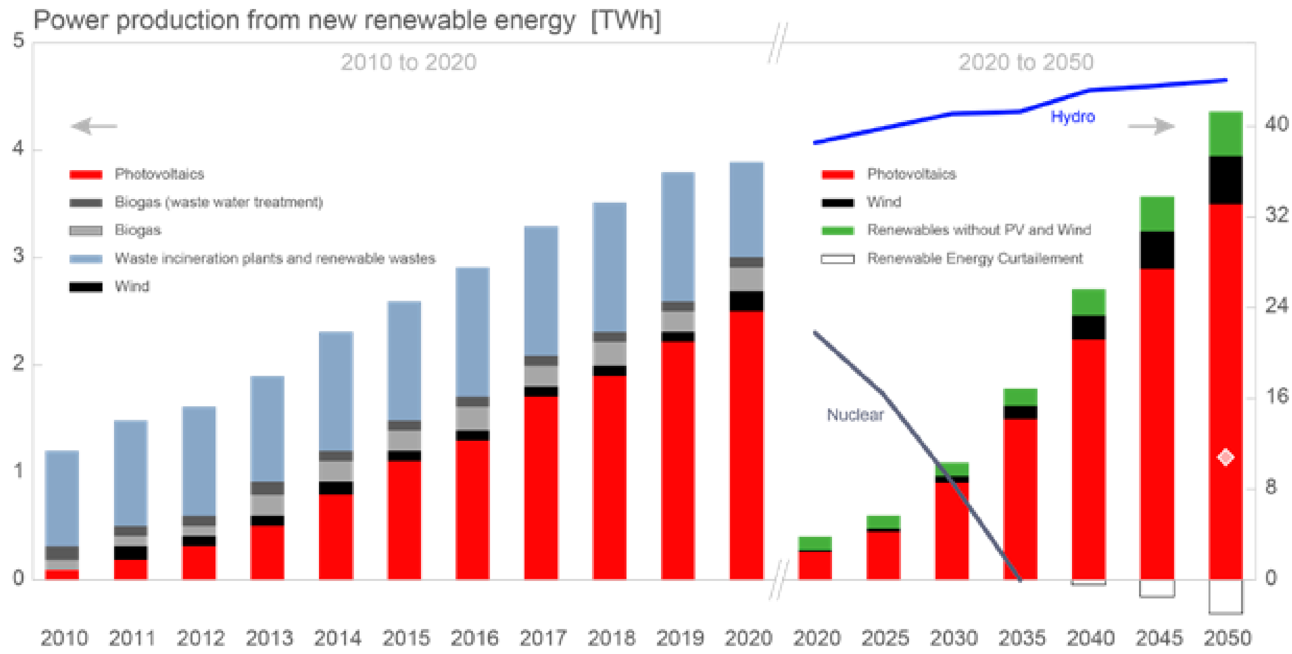
Fig. 1 - In September 2020, a high-alpine 410 kWp PV system was commissioned by the Zurich power utility ewz at the Albigna Dam at 2,165 m. Due to its location the installation is subjected to extreme meteorological conditions. The analysis of the yield data, periodic measurement of the module output, thermal imaging and examination of the general condition of the system will be used to gain insights on the long-term reliability of installations installed at comparable locations (Photo: © Reech GmbH).

GENERAL FRAMEWORK AND IMPLEMENTATION

With the "Energy Strategy 2050" Switzerland has embarked on a path to make its energy system more sustainable and climate-friendly, while at the same time ensuring a high level of security of supply. Since around three quarters of greenhouse gas emissions in Switzerland are caused by the use of fossil fuels, the energy strategy is closely related to climate policy. Here, the focus lies on a total revision of the CO_2 Act, which in 2020 has been adopted by parliament after almost three years of consultation and on which a popular referendum will be held in 2021, with possible entry into force January 2022.

With the revised CO_2 Act as the national implementation of the Paris Climate Agreement, Switzerland aims to halve its greenhouse gas emissions by 2030 compared to 1990 levels. Switzerland's final goal by 2050 is to emit not more greenhouse gases than natural and artificial reservoirs can absorb (net zero emission target). With a reduction of only 15%, the current target of reducing greenhouse gas emissions by 20% by 2020 compared to the 1990 level was missed. With the revised CO_2 Act, various measures are foreseen: in transport, the emission regulations for new cars (including heavy-duty vehicles) will be further tightened; the producers and importers of fossil fuels will have to compensate for a greater proportion of CO_2 emissions; for buildings, the CO_2 tax on fossil fuels is to be continued and if necessary increased to accelerate the switch to renewable forms of heating; in the industrial sector, flexible measures should further reduce emissions; and finally, Switzerland's emissions trading system has been linked to that of the EU.

In November 2020, first results of the updated Swiss Energy Perspectives for 2050 (EP 2050+) have been published. The EP 2050+ analyse a development of the energy system that is compatible with the long-term climate goal of net zero greenhouse gas emissions in 2050 ("net zero") and at the same time ensures a secure energy supply. According to EP 2050+, in 2050, domestic power production will be almost exclusively by hydropower plants and renewable energies including combined heat and power plants (CHP plants). New renewable energies shall supply



(including heavy-duty vehicles) will be further tightened; the producers and importers of fossil fuels

Fig. 2 - Development of power production from new renewable energies 2010 to 2020. Switzerland's most important domestic energy source is hydropower and its exploitation in run-of-river and storage power plants covers around 56% of Switzerland's electricity needs. Today, hydropower accounts for almost the entire share of renewable electricity production, at around 96%. The 2020 target value for supplementary generation from other /new renewable energies such as PV, Wind and others is 4 TWh, what was achieved thanks to continuous increase of PV capacity. The right part shows power production from new renewables in a "net zero" scenario, which is nearly entirely based on a strong increase of PV power production with a smaller contribution from wind energy. The target value for PV in 2050 has tripled (from 11,4 to 34 TWh) compared to the previous perspectives (the diamond in the column 2050 denotes the previous PV target value of 11,4 TWh). Nuclear power production fades out, while production from hydropower will increase only slightly. Electricity consumption (not shown) will also increase due to electrification in mobility (Data Source: https://www.bfe.admin.ch/bfe/de/home/politik/energieperspektiven-2050-plus.html).

39 TWh or 46% of gross electricity generation with 34 TWh from photovoltaics (40% of generation, today around 3%, 2 TWh) [1]. Electricity imports in winter are increasing on a short term and will decrease again approaching 2050, since with increasing PV capacity also the winter share of electricity generation by PV rise to over 30% in 2050. In addition, hydro storage plants can shift their flexible production into the winter depending on demand.

Today, the PV market in Switzerland is driven by self-consumption with an expansion rate of around 0,3 GW/year. In order to achieve the goals formulated in the Energy Perspectives, new market stimuli are needed for new large photovoltaic installations without self-consumption (e.g. on agricultural, commercial and office buildings). Proposals for tenders are discussed as part of the revision of the Energy Act. In the medium term, a rate of capacity expansion in the order of 1 GW/year is required.

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 RD&D from basic research, over applied research, product development, pilot and demonstration projects. On average, the volume of the SFOE programme support (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) (https://pv.energyresearch.ch/projects).

[1] The Swiss PV potential on buildings, analysed from data of a national solar potential cadastre (www.sonnendach.ch) and meteo data, is on the order of 67 TWh. Of these, 50 TWh are from rooftops in combination with an additional potential of 17 TWh from façades. In this potential analysis, only larger surface areas with economically useful insulation are considered.

Fig. 3 - Swiss photovoltaics technology landscape (without claim of completeness). Circles denote academic institutions, squares industrial actors (source https://pv.energyresearch.ch/actors). Actors are classified according to: (1) "Solar cells": Research and development of various solar cell technologies, material supply, process equipment, recycling. (2) "Modules BIPV": Modules and BIPV, activities around the topic of PV modules (materials, process equipment, testing and quality assurance. (3) "System technology": System aspects of photovoltaics, inverters, electrical components, quality assurance, grid integration, storage. (4) "Other (LCA, solar resources)": Life cycle analysis, solar resource analysis and forecasting.

The SFOE photovoltaics programme supports research and pilot & demonstration in different areas of photovoltaic cell technologies (namely c-Si, CIGS and perovskites), 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 Technology Collaboration 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 kind of different aspects of photovoltaics (see Figure 3). 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. Grid integration of photovoltaics, photovoltaics in combination with heat pumps and storage technologies (batteries, thermal storage), photovoltaics and electro-mobility (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.

R&D HIGHLIGHT 2020:

New forecast method on imperfect PV production measurements

A critical element for enabling large-scale penetration of PV generation into the power grid lies in the precicse forecasting of production. Power production by PV is characterized by significant variability since it depends on meteorological conditions. In an R&D project by the Centre Suisse d'Electronique et de Microtechnique (CSEM) and the Swiss utility BKW Energie completed in 2020, a new method for multi-site PV forecasting was developed, starting from the premise that PV systems by themselves provide a dense network of simple weather stations, since PV production data can indirectly provide meteo data.

Based on the outcomes of a first proof-of-concept, the applicability of big-data analytics to forecast of power generation of distributed PV systems all over Switzerland was demonstrated. The developed algorithms have been tested with more than 300 real PV systems spread over Switzerland, and 1 000 synthetic ones that reproduce the statistical distribution of installed PV in the country in terms of size, orientation and location. The new methods outperform state-of-the art techniques which combine numerical weather

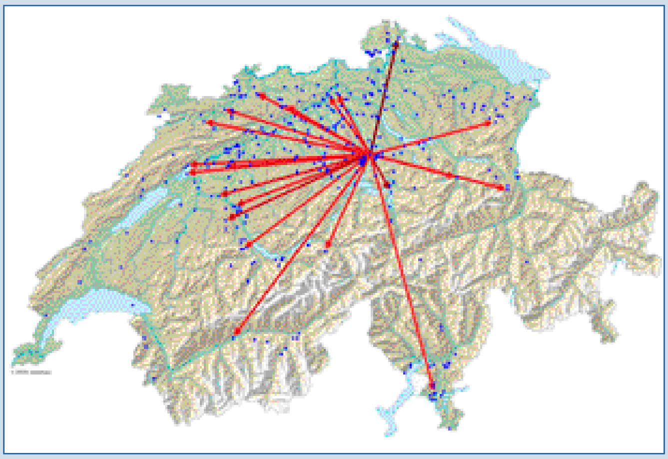


Fig. 4 - PV forecast methods based on the assumption that the current power production can be modelled as a function of the past production data of a subset of nodes over a predefined time interval. The rationale behind is that events in the past production (e.g. clouds) are informative to predict the production in other nodes. Graph-based methods were used to reconstruct missing or faulty data. The figure on the left shows an example of a set of PV production site for the forecasting a a node in central Switzerland (Graphics: CSEM).

Degradation of perovskite solar cells under reverse bias

Partial shading caused by vegetation, building structures, soiling or snow drives the shaded cells in a module into reverse bias as they are required to pass the reverse current of illuminated neighbors. The time spent in reverse bias can have a permanent detrimental impact on the integrity of the cells in a module. That is why there are IEC (International Electrotechnical Commission) protocols to test the partial shading resilience of PV modules that any commercially relevant perovskite technology would have to demonstrate. Researchers in Neuchâtel (at EPFL Neuchâtel and the CSEM PV-Center) combine optical, microstructural, and electrical characterization to understand the degradation mechanisms in perovskite solar cell degradation under reverse bias.

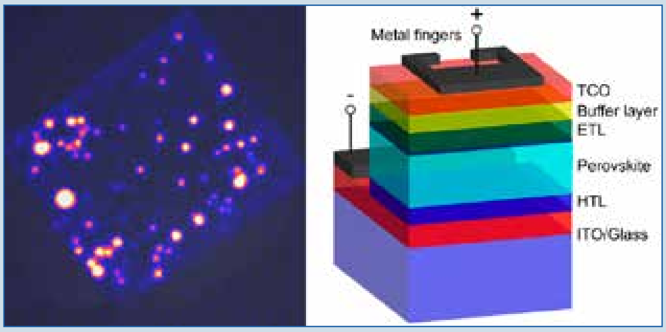
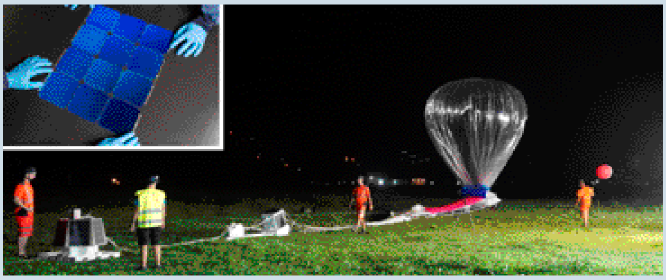


Fig. 5 - (Left) Lock-in thermography image of a semi-transparent perovskite solar cell exposed to a reverse bias of -3V showing hot-spot/shunt formation over the entire cell area. (Right) Schematic of a semi-transparent perovskite solar cell architecture, such as it would be used in a tandem cell configuration (with the Si bottom cell replacing ITO/Glass) (Source: EPFL/CSEM).

Only one of three identified mechanisms on how perovskite solar cells are degrading is reversible to some extent, while the other two are irreversible with the formation of shunts. The results out of this project underline the urgent need to develop cell designs that are far more robust to partial shading conditions compared to current stateof-the-art perovskite solar cell devices. (https://doi.org/10.1039/C9TA12032G)

Weather balloons with flying photovoltaic technology from CSEM

Over the past years, the Centre Suisse d'Electronique et de Microtechnique CSEM has developed ultra-light customised photovoltaic modules. These are now being used in a French research project (STRATEOLE-2) to ensure the energy supply of weather balloons. The project will use balloons to study interactions between the troposphere and stratosphere in the equatorial belt over the Indian Ocean. The specifications for the PV modules are very demanding: maximum weight of about one kilo per square metre, i.e. about ten times less than a standard



module, extreme conditions with low temperatures, huge thermal cycles and high UV radiation in the stratosphere. These modules are especially interesting for PV mobility applications (source: https://www.csem.ch/page.aspx?pid=159509).

Fig. 6 - Leverage for cost reduction lies in increasing efficiency of modules, the reduction of material costs and high module reliability. An industrial R&D project within the framework of a European cooperation (SOLAR-ERA.net) has made significant contributions to these challenges by combining fine-line metallization of solar cells with the cell connection technology from Meyer Burger. On the cell level, silver paste consumption for metallization could be lowered to 5 mg/Watt, which is far ahead in the photovoltaic technology roadmap. With the modules built and tested with this approach, the total module power exceeded by 15 watts compared to commercial 3 busbar modules (Photo: Meyer Burger).

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.

2020 was a year of transformation for the Swiss company Meyer Burger with a complete reorientation from a supplier of equipment to a manufacturer of solar cells and modules based on its own heterojunction/smart-wire technology, developed in Switzerland over the past 13 years in strong collaboration with Swiss research institutions. In order to be able to finance the transformation, the company successfully completed a capital increase of 165 MCHF, following the approval of the shareholders at the extraordinary general meeting in July 2020. Meyer Burger selected the traditional solar locations in Germany (Bitterfeld-Wolfen in Saxony-Anhalt and Freiberg in Saxony) to set up production facilities. Production start is planned for the first half of 2021, with 400 MW solar cells and 400 MW solar module. Expansion of the production up to 5 GW is planned.

THAILAND

PV TECHNOLOGY STATUS AND PROSPECTS
MR. PRASERT SINSUKPRASERT, DIRECTOR GENERAL, DEDE
MR. RUANGDET PANDUANG, DEPUTY DIRECTOR GENERAL, DEDE
MR. SUREE JAROONSAK, DIRECTOR OF SOLAR ENERGY DEVELOPMENT DIVISION, DEDE

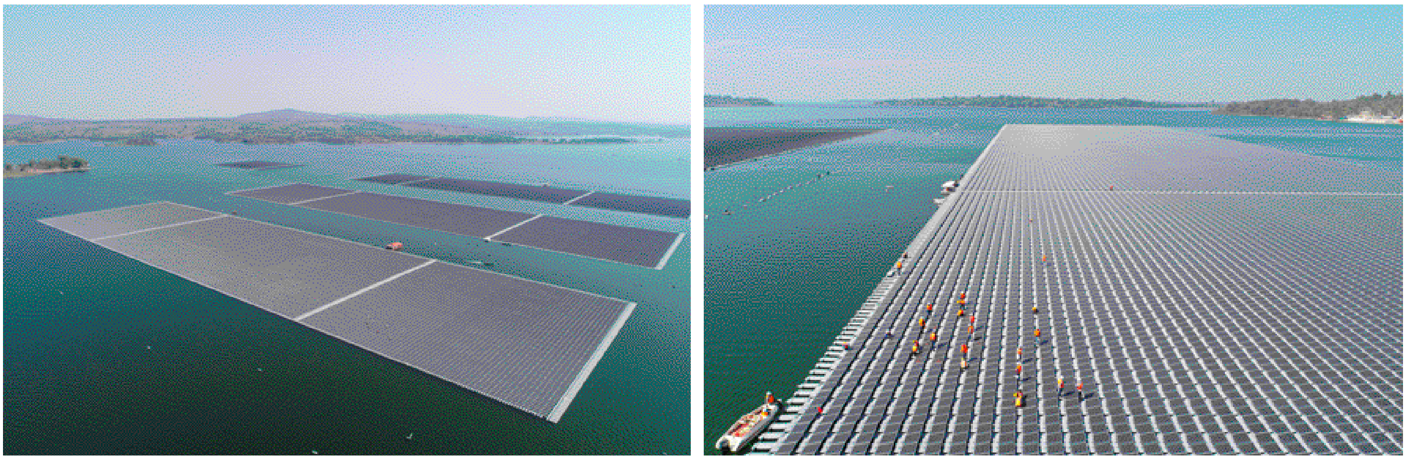


Fig. 1 - The 45 MW world's largest floating PV system, as part of the Hydro-Floating Solar Hybrid Project at Sirindhorn Dam, operated by the Electricity Generating Authority of Thailand (EGAT). This project will hybridize the FPVs with the hydropower dam to increase efficiency of the system (Photo: EGAT).

GENERAL FRAMEWORK AND IMPLEMENTATION

Thailand has continually promoted PV system installation for a long time. For the progress of Thailand PV in 2020, the cabinet resolution had approved both Power Development Plan 2018 Rev.1 (PDP 2018 Rev.1) and Alternative Energy Development Plan 2018 (AEDP 2018) which will set the new installation targets for PV for Thailand to achieve 12 139 MW of solar PV (9 290 MW new AEDP 2018 target + contracted 2 849 MW) and 2 725 MW for floating solar PV by 2037. These targets were significantly increased from AEDP 2015, which set the target of only traditional solar PV installation at 6 000 MW by 2036. 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. According to AEDP 2018, Thailand has contracted a PV installation capacity of 2 849 MW (SPPs + VSPPs), 463,55 MW of Independent Power Supply (IPS or solar rooftop PV), and 4,04 MW off grid PV.

The Electricity Generating Authority of Thailand (EGAT) is also conducting the Hydro-Floating Solar Hybrid Project that will incorporate floating PVs (FPVs) with traditional hydropower plants all over the country to ensure energy security. Progress has been made for the construction of 45 MW floating PVs (FPVs) on Sirindhorn Dam in the northeastern part of Thailand. This system exploits the double-glass PVs installed on food-graded buoys and use the Energy Management System (EMS) to maximize energy security from peak-load and bad weather period.

PTT groups (Petroleum Authority of Thailand) located in Map Ta Phut Industrial Estate in Rayong province, had trialed the country first FPVs (100 kW size) installed over the sea surface and use self-innovated food grade plastic materials from another PTT subsidiaries to reduce barnacles' adhesions on the buoys and ensure safety to the environment.

FPVs on sea surface operated by PTT groups (Photo: PTT)

NATIONAL PROGRAMME

The National Energy Policy Council (NEPC) approved the amendment of ongoing residential solar rooftop projects by increasing the FiT rate of selling the excess electricity from PV installed on household rooftop back to the grid from 1,68 THB/kWh (0,055 USDcents/kWh) to 2,20 THB/kWh (0,073 USDcents/kWh) for a 10 year period, and adjusting the annual target from 100 MW to 50 MW. This is expected to attract more investments from the residential sector owners who want to install PV to reduce their electricity bills. The new phase is expected to have the payback period within 8-9 years.

The concept of this PV rooftop project will also extend towards hospitals (target 20 MW), schools and colleges (target 20 MW), and agricultural water pumping (target 10 MW) with the FiT rate of 1 THB/kWh (0,033 USDcents/kWh).

Fig. 2 - A King Mongkut's University of Technology Thonburi (KMUTT) study on the impact of dust on the performance of solar power systems in Thailand (Photo: KMUTT).

RD&D

According to the Smart Grid Plan, Thailand is now under the 2nd phase that will implement the pilot projects for technical feasibility study and economics of investments. The concepts of studies included energy management system (EMS), demand response (DR), microgrid, and energy storage system. EGAT, MEA (Metropolitan Energy Authority) and PEA (Provincial Energy Authority) are now implementing smart security systems to control and to manage the energy production for both conventional power generators and the renewable energy power plants. For example, EGAT and PEA are cooperating together in establishing the Mae Sariang District micro-grid located in the far north of Thailand, while PEA is also piloting smart energy management in Pattaya city (Chonburi) and Betong city (Yala).

Solar home demonstration wagon (Photo: AEITF)

In order to promote more solar PV market penetration in Thailand, the Energy Regulatory Commission (ERC) and the Alternative Energy Institute of Thailand Foundation (AEITF) launched the Solar Move project, the program that incorporates more than 10 000 households from over 200 villages to participate in the solar PV active learning program via innovative and interactive media and simulation models, including the PV system demonstration wagon.

King Mongkut's University of Technology Thonburi (KMUTT) is also conducting studies on the impact of dust on the performance of a solar power system in Thailand under the Thailand Science Research and Innovation (TSRI) and EGAT cooperation. The findings will have the potential to convince solar power plant owners to move forward to exploit smart services for their maintenance and operations.

Electric boat service with solar PV installed on its roof in Bangkok (Photo: Arkorn Soikaew)

In 2020, Thailand had initiated the first electric boat service line that runs through a canal of Bangkok. Each boat is equipped with two 10 kw motors and a 42 kW Li-on NMC battery, along with 12 solar PV panels that help generate auxiliary powers for motors and lighting. The services will expand to a number of lines throughout Bangkok in the near future.

INDUSTRY AND MARKET DEVELOPMENT

Thailand has been known to home both local and international PV manufacturers that produce a wide range of PV module products including crystalline silicon PV modules for large scale systems and high efficiency PV modules for rooftop PV systems. There are 15 PV manufacturers in Thailand, around half of them are international companies while another half are local manufacturers. The ongoing solar PV rooftop projects for households (and also for hospitals, schools and agricultures) will play an important role in penetrating a new PV market in Thailand. For the local installation project, there are regulations that require the PV panels to obtain the Thai Industrial Standards (TIS) which is regulated by the Thai Industrial Standards Institute (TISI), Ministry of Industry. Since May 2019, the new TIS61215 B.C. 2561 (following IEC 61215: 2016 series) and in October 2019, the TIS 2580 B.C. 2562 (following IEC 61730: 2016) were announced. These two standards for PV modules were announced in the government gazette in which the PV manufacturers must comply to certify the active standards of PV modules.

The PV markets in Thailand are driven by both government projects (such as the PV rooftop program, PV systems for electricity in the communities in rural areas, and the PV solar pumping for agricultures) and the private sector (for both self-consumption purpose and grid connected).

THE UNITED STATES OF AMERICA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS

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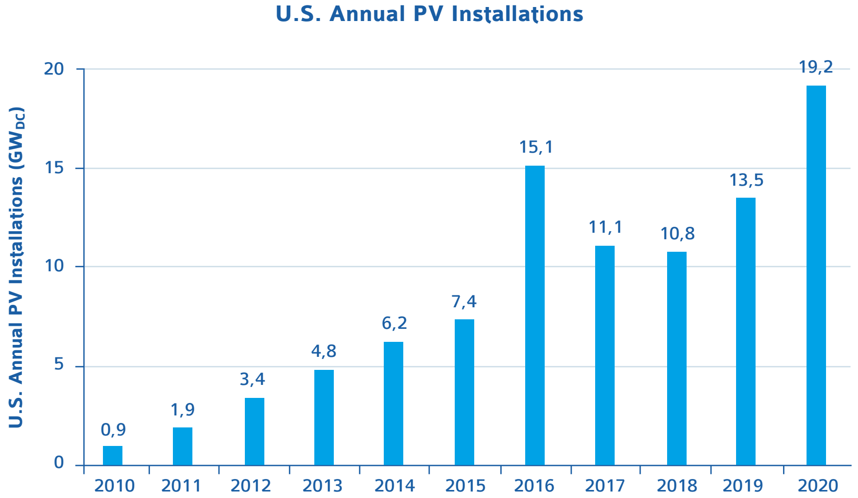

Fig. 1 - U.S. Annual PV Installations. Sources: Wood Mackenzie/SEIA, Latest Quarterly and Annual US PV Historical Data Release: 2020 Year-in-review, February 11, 2021

GENERAL FRAMEWORK AND IMPLEMENTATION

In the United States (U.S.), photovoltaic (PV) market development is supported by both national and state-level financial incentives, though state and local policies vary in form and magnitude. In 2020, there was not a national-level deployment mandate, however individual state mandates have been successfully implemented, with 2020 bringing several new mandates. Existing policy at the national and state level and rapidly declining technology costs have enabled PV to continue to grow rapidly in the U.S. At the end of 2020, the U.S. reached 95,1 GW_{DC} [1] of cumulative installed capacity, an increase from 75,9 GW_{DC} in 2019, and 62,6 GW_{DC} in 2018 [2].

NATIONAL PROGRAM

The U.S. supports the domestic installation and manufacturing of PV generating assets for domestic consumption. Financial incentives for U.S. solar projects are provided by the national government, state and local governments, and some local utilities. Historically, national incentives have been provided primarily through the U.S. tax code, in the form of a 30% Investment Tax Credit (ITC) (which applies to residential, commercial, and utility-scale installations) and accelerated five-year tax depreciation (which applies to all commercial and utility-scale installations and to third-party owned residential, government, or non-profit installations). The 30% ITC expired at the end of 2019. Beginning in 2020, the credits stepped down to 26%, and had been scheduled to drop to 22% beginning in 2021. However, a federal spending package passed in December 2020 extended the ITC at 26% for two additional years, through 2022, at which point it drops to 22% beginning in 2023, before expiring for residential markets and falling to 10% for commercial and utility markets in 2024. For commercial projects, these dates represent the deadline for starting construction of a project, however all projects placed in service after 2025 are only eligible for a 10% ITC.

State incentives in the U.S. have been driven in large part by the passage of Renewable Portfolio Standards (RPS). An RPS, also called a renewable electricity standard (RES), requires electricity suppliers to purchase or generate a targeted amount of renewable energy by a certain date. Although design details vary considerably, RPS policies typically enforce compliance through penalties, and many include the trading of renewable energy certificates (RECs). Alternatively, a clean energy standard (CES) is similar to an RPS, but allows a broader range of electricity generation (e.g., nuclear) resources to qualify for the target. As of September 2020, thirty states, four territories, and Washington D.C., had RPS policies or goals with specific solar or customer-sited provisions, while five states had CES policies [3]. A number of states have recently adopted increasingly aggressive RPS and carbon-free generation goals. As of February

[1] Wood Mackenzie/SEIA, U.S. Solar Market Insight, Q4 2020. December 2020.
[2] Id.
[3] North Carolina Clean Energy Technology Center. Renewable Portfolio Standard Policies. Accessed February 2021. http://www.dsireusa.org/resources/detailed-summary-maps/

2021, ten states, Washington D.C., Puerto Rico, and over one hundred municipalities had passed legislation requiring 100% clean energy by 2050, or sooner, and a growing number of cities and states are poised to implement similarly stringent standards. While these RPS and CES markets are expected to increase installations to meet new requirements, in 2020, a majority of utility-scale procurements were voluntary and occurred outside of RPS structures [4]. In addition to RPS and CES, many states also require utilities to offer net metering, a billing mechanism which credits electricity produced by a solar energy system fed back to the grid. Use of net metering is declining, as some states, including California, plan to transition to value-based compensation mechanisms for customer-connected PV systems. Seven states also offer incentives for storage [5]. California significantly bolstered its lead in front-of-the-meter storage deployment through the addition of over 250 MW in Q3 2020 alone, putting 2020 on track to see a tripling of total U.S. storage capacity [6].

The U.S. government also provides support for PV research through its work at the National Science Foundation, the Department of Defense, the National Aeronautics and Space Administration, and the Department of Energy's (DOE) Office of Science, Advanced Research Projects Agency - Energy (ARPA-E), and the Solar Energy Technologies Office (SETO). In addition to the U.S. government, states such as California, New York, Florida and Hawaii, as well as public and private companies also fund solar R&D.

RESEARCH, DEVELOPMENT & DEMONSTRATION

The DOE is one of the primary bodies that supports research, development, and demonstration (RD&D) of solar energy technologies. In 2017, DOE announced that it had met its benchmark utility-scale 2020 goal of 6 USD cents per kilowatt-hour and increased its focus on addressing the challenges of integrating increasing amounts of solar energy into the electricity grid by introducing a target of 3 USD cents per kilowatt-hour by 2030 [7]. However, to meet the urgency of the climate crisis and accelerate solar deployment by three to five times, costs need to fall faster. Recognizing this need, SETO has accelerated this goal to 2 USD cents per kilowatt-hour by 2030.

By funding a portfolio of complementary RD&D concepts, SETO promotes transformation in the way the U.S. generates, stores, and utilizes solar energy. These RD&D activities fall into five broad categories, which in fiscal year 2020 were funded at the levels found in Table 1:

1. Photovoltaic (PV) Research and Development, which supports the research and development of PV technologies to improve efficiency, durability, and reliability, as well as lower material and process costs to reduce the levelized cost of solar generated electricity.
2. Concentrating Solar Power (CSP), which supports research and development of CSP technologies that incorporate thermal energy storage to supply solar power on demand, as well as heat for direct use in industrial processes.
3. Systems Integration, which develops technologies to enable improved integration of solar power with the power grid including power electronics and systems-level research on renewables integration.
4. Balance of Systems Soft Cost Reduction, which works with a diverse set of stakeholders to cut red tape, streamline processes, and increase access to solar.
5. Innovations in Manufacturing Competitiveness, which supports U.S. businesses with innovative solar products to develop prototypes and validate their technologies.

TABLE 1 – BREAKDOWN OF SOLAR ENERGY TECHNOLOGIES PROGRAM FY 20 ENACTED FUNDING

Photovoltaic Research & Development	72,0 MUSD
Concentrating Solar Power	60,0 MUSD
Systems Integration	53,0 MUSD
Balance of Systems Soft Cost Reduction	35,0 MUSD
Innovations in Manufacturing Competitiveness	60,0 MUSD
Total	**280,0 MUSD**

INDUSTRY AND MARKET DEVELOPMENT

Despite installation slowdowns in the first half of 2020 due to the COVID-19 pandemic, significant growth during the second half of the year led to a record amount of annual installed solar capacity in the U.S., increasing from 13,5 GW_{DC} in 2019 to 19,2 GW_{DC} in 2020. 2020 also marked the second-largest single-year increase in U.S. installed electric generation capacity [8], with PV accounting for a record-setting (for solar) 43% of all new electricity generation capacity.

[4] Wood Mackenzie and SEIA: Solar Market Insight, Q4 2020. December 2020.

[5] North Carolina Clean Energy Technology Center. Renewable Portfolio Standard Policies. Accessed February 2021. http://www.dsireusa.org/resources/detailed-summary-maps/

[6] "Wood Mackenzie Power & Renewables/ESA U.S. energy storage monitor, December 2020.

[7] Since solar energy does not match demand at higher penetrations, even lower prices are needed to spur development. More information on the SunShot 2030 Goal of 3¢/kWh can be found here: https://www.energy.gov/eere/solar/sunshot-2030

[8] 2016 saw the largest single year increase in installed capacity due to expectations from developers and utilities that the ITC would expire at the beginning of 2017, accelerating many planned installations to meet the expected deadline and contributing to the subsequent lull in 2017. GTM Research/SEIA, Q4 2016: U.S. Solar Market Insight. December 2016.

Fig. 2 - UMass Crop Animal Research and Education Center in South Deerfield, MA, USA (Photo: Dennis Schroeder / NREL).

At the beginning of 2020, in an attempt to mitigate economic damage caused by pandemic lockdowns, the U.S. Federal Reserve lowered interest rates twice, decreasing annual rates from 1,75% at the beginning of the year to 0,25% by mid-March, where they remained through year end [9]. U.S. interest rates are historically low, generally favoring solar installation economics. In January 2018, the previous presidential administration placed a tariff [10] for a period of four years on imported cells and modules. The tariff was set at 30% in the first year and fell to 20% in 2020, from where it was scheduled to be further reduced by five percent in each of the next two years. The first 2,5 GW of cells imported each year were excluded, as well as certain other modules, such as ones with IBC cells (starting in September 2018) and bifacial cells (starting in June 2019). At the end of 2020 the President increased the tariff beginning in February 2021 to 18% from the scheduled 15% and, at around the same time, the U.S. Court of International Trade repealed the exclusion on bifacial cells.

Several solar market segment trends changed in 2020. After experiencing a major contraction during Q2, the residential market rebounded in the second half of the year, buoyed by virtual and online sales innovations and increased online permitting processes at the municipal level. Overall, the residential market experienced a slight slowdown in annual growth, from 17,6% in 2019 to 11,5% in 2020, but still saw its highest levels of overall installed capacity to date [11].

New non-residential, or commercial, installations decreased again in 2020, attributable at least in part to decreases in the availability of tax equity financing brought on by uncertainties caused by the pandemic. An increasing percentage of non-residential installation capacity came through community solar projects, a majority of which were driven by incentive programs in New York, Minnesota, and Massachusetts [12].

Utility sector installations increased 65% over 2019 levels, to 13,95 GW_{DC} in 2020. The ITC step down in 2021 contributed to an increase in Q4, which saw nearly 6,4 GW_{DC} of utility-scale capacity installed. The utility sector wasn't significantly affected by pandemic supply or installation disruptions and benefited from decreased tariffs and growing RPS structures.

U.S. PV module manufacturing production grew in 2020, due to ramping up of production from c-Si manufacturing facilities and an increase in production and capacity from First Solar's new production facility in Ohio. The U.S. produced a record 3,2 GW of modules in the first nine months of 2020 compared to 2,4 GW in the first nine months of 2019 [13]. The U.S. has a significant presence in other parts of the PV manufacturing value chain, including racking, polysilicon, encapsulants, wiring, and fasteners.

[9] https://www.federalreserve.gov/monetarypolicy/openmarket.htm

[10] Tariffs resulted from a case brought by two U.S. based PV manufacturers to the U.S. International Trade Commission under Section 201, Trade Act of 1974, accusing foreign governments of implementing policies supporting their domestic manufacturing in violation of WTO rules and the GATT agreement.

[11] Wood Mackenzie and SEIA: Solar Market Insight, Q4 2020. December 2020.

[12] Id.

[13] Wood Mackenzie and SEIA: Solar Market Insight, Q4 2020. December 2020.

IEA PVPS COMPLETED TASKS

DELIVERABLES – WHERE TO GET THEM?

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TASK 2 - PERFORMANCE, RELIABILITY AND ANALYSIS OF PHOTOVOLTAIC SYSTEMS (1995-2007)

Task 2 Reports & Database

1. Analysis of Photovoltaic Systems, T2-01:2000
2. IEA PVPS Database Task 2, T2-02:2001
3. Operational Performance, Reliability and Promotion of Photovoltaic Systems, T2-03:2002
4. The Availability of Irradiation Data, T2-04:2004
5. Country Reports on PV System Performance, T2-05:2008
6. Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies, T2-06:2007
7. Performance Prediction of Grid-Connected Photovoltaic Systems Using Remote Sensing, T2-07:2008

TASK 3 – USE OF PHOTOVOLTAIC POWER SYSTEMS IN STAND ALONE AND ISLAND APPLICATIONS (1993-2004)

Task 3 Reports

1. Recommended Practices for Charge Controllers, T3-04:1998
2. Stand Alone PV Systems in Developing Countries, T3-05:1999
3. Lead-acid Battery Guide for Stand-alone Photovoltaic Systems, T3-06:1999,
4. Survey of National and International Standards, Guidelines and QA Procedures for Stand-Alone PV Systems, T3-07:2000
5. Recommended Practices for Charge Controllers, T3-08:2000
6. Use of appliances in stand-alone PV power supply systems: problems and solutions, T3-09:2002
7. Management of Lead-Acid Batteries used in Stand-Alone Photovoltaic Power Systems, T3-10:2002
8. Testing of Lead-Acid Batteries used in Stand-Alone PV Power Systems – Guidelines, T3-11:2002
9. Selecting Stand-Alone Photovoltaic Systems – Guidelines, T3-12:2002
10. Monitoring Stand-Alone Photovoltaic Systems: Methodology and Equipment - Recommended Practices, T3-13:2003
11. Protection against the Effects of Lightning on Stand-Alone Photovoltaic Systems - Common Practices, T3-14:2003
12. Managing the Quality of Stand-Alone Photovoltaic Systems- Recommended Practices, T3-15:2003
13. Demand Side Management for Stand-Alone Photovoltaic Systems, T3-16:2003
14. Selecting Lead-Acid Batteries Used in Stand-Alone Photovoltaic Power Systems – Guidelines, T3-17:2004
15. Alternative to Lead-Acid Batteries in Stand-Alone Photovoltaic Systems, T3-18:2004

TASK 5 – GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC SYSTEMS (1993-2003)

Task 5 Reports

1. Utility Aspects of Grid Interconnected PV Systems, T5-01:1998
2. Demonstration Tests of Grid Connected Photovoltaic Power Systems, T5-02:1999
3. Grid-connected Photovoltaic Power Systems: Summary of Task 5 Activities from 1993 to 1998, T5-03:1999
4. PV System Installation and Grid-interconnection Guideline in Selected IEA Countries, T5-04: 2001
5. Grid-connected Photovoltaic Power Systems: Survey of Inverter and Related Protection Equipment, T5-05: 2002
6. International Guideline for the Certification of PV System Components and Grid-connected Systems, T5-06:2002
7. Probability of Islanding in Utility Networks due to Grid Connected Photovoltaic Power Systems, T5-07: 2002
8. Risk Analysis of Islanding of Photovoltaic Power Systems within Low Voltage Distribution Networks, T5-08: 2002
9. Evaluation of Islanding Detection Methods for Photovoltaic Utility-interactive Power Systems, T5-09: 2002
10. Impacts of Power Penetration from Photovoltaic Power Systems in Distribution Networks, T5-10: 2002
11. Grid-connected Photovoltaic Power Systems: Power Value and Capacity Value of PV Systems, T5-11: 2002

TASK 6 – DESIGN AND OPERATION OF MODULAR PHOTOVOLTAIC PLANTS FOR LARGE SCALE POWER GENERATION (1993-1998)

Task 6 Reports, Papers & Documents

1. The Proceedings of the Paestrum Workshop
2. A PV Plant Comparison of 15 plants
3. The State of the Art of: High Efficiency, High Voltage, Easily Installed Modules for the Japanese Market
4. A Document on "Criteria and Recommendations for Acceptance Test"
5 A Paper, entitled: "Methods to Reduce Mismatch Losses."
6. Report of questionnaires in the form of a small book containing organized information collected through questionnaires integrated with statistical data of the main system parameters and of the main performance indices
7. The "Guidebook for Practical Design of Large Scale Power Generation Plant"
8 The "Review of Medium to Large Scale Modular PV Plants Worldwide"
9. Proceedings of the Madrid Workshop

TASK 7 – PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT (1997-2001)

Task 7 Reports

1. Literature Survey and Analysis of Non-technical Problems for the Introduction of BIPV Systems, T7-01:1999
2. PV in Non-Building Structures - A Design Guide, T7-02:2001
3. Potential for Building Integrated Photovoltaics, T7-04:2001
4. Guidelines for the Economic Evaluation of Building Integrated Photovoltaics, T7-05:2002
5. Market Deployment Strategies for Photovoltaics in the Built Environment, T7-06:2002
6. Innovative electric concepts, T7-07:2002
7. Reliability of Photovoltaic Systems, T7-08:2002
8. Book: "Designing with Solar Power - A Source Book for Building Integrated Photovoltaics (BIPV)", Edited By Deo Prasad and Mark Snow, Images Publishing, 2005 (ISBN 9781844071470)

TASK 8 – STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM (1999-2014)

Task 8 Reports

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

TASK 9 – DEPLOYMENT PV SERVICES FOR REGIONAL DEVELOPMENT (1998-2018)

Task 9 Reports

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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

ANNEX A

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ISBN 978-3-907281-16-1