P A R L P V

COST Action CA16235 - PEARL PV

Performance and Reliability of Photovoltaic Systems: Evaluations of Large-Scale Monitoring Data

Workplan 2021-2022

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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1. Introduction to Pearl PV's Workplan

Chair: Angèle Reinders, University of Twente and TU/e, The Netherlands

Vice Chair: David Moser, Eurac Research, Italy

This document presents COST Action PEARL PV's workplan for the period of April 2021 until the end of the Action in April 2022. It is the result of a collaborative effort of all PV experts that volunteer in the PEARL PV network and will be fully implemented in the forthcoming years. This workplan will also be available as a living document that will be periodically revised by the website of PEARL PV at https://www.pearlpv-cost.eu/.

COST Action PEARL-PV aims are:
i) to improve the energy performance and reliability of photovoltaic (PV) solar energy systems in Europe leading to lower costs of electricity produced by PV systems by a higher energy yield,
ii) a longer life time eventually beyond the guaranteed 20 years as specified by manufacturers, and
iii) a reduction in the perceived risk in investments in PV projects.

These objectives will be achieved by a solid collaboration between five Working Groups (WGs), see Figure 1, which will be using a shared data bank and joint simulation tools to analyze big data of the actual monitored long-term performance, defects and failures in PV systems installed all over Europe. The 5 Working Groups are focused on (WG1) PV monitoring, (WG2) Reliability and durability of PV, (WG3) PV simulation, (WG4) PV in the built environment and (WG5) PV in grids.

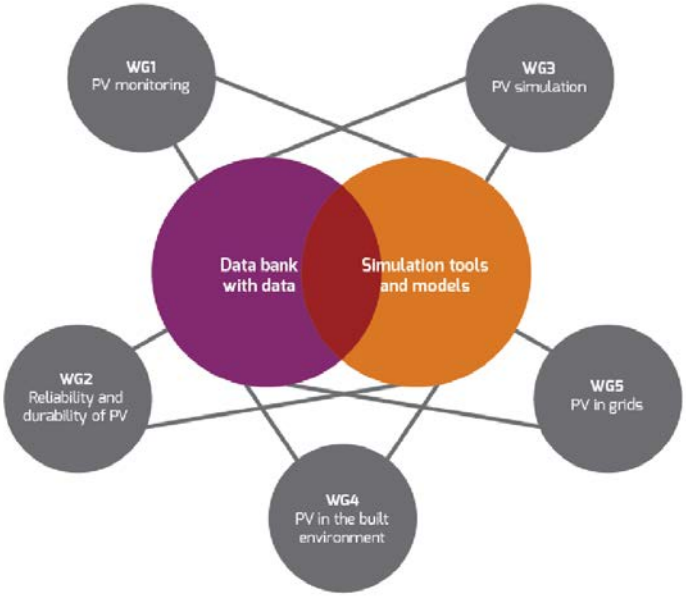

Figure 1: The 5 Working Groups of COST Action PEARL-PV in relation to a shared data bank and simulation tools.

By data analyses and simulations it will be possible to quantitatively determine the absolute influences of components rated performance, key design of systems, installation, operation,

maintenance practice, geographic location and weather factors on the performance, performance degradation over time and failure modes of installed PV systems.

In this document the workplans of the five Working Groups are presented in the context of the wider Action. The background for workplan is the MoU of the Action which provides information about the objectives, the research field of PV performance analyses and the expected research program at the start of the Action in October 2017. However because of interactions between researchers in combination with new insights resulting from ongoing research in the field, these objectives and related research programs can change in any COST Action. Moreover from March 2020 onwards COVID-19 has been causing significant changes in the work situation of almost all participants of PEARL PV, and in the end resulted in the extension of the Action of half a year, until April 2022.

Therefore the Action's workplan for 2018 to 2021. has been updated to this new Action workplan for the period of April 2021 to April 2022. in relation to the internal progress made in this Action and the external developments in the fields of PV performance, durability and reliability research.

To give the reader an insight in the wider scope and activities of the last year of this Action, Table 1 shows the global planning of PEARL PV for 2021 to 2022 including all scheduled MC meetings, many networking events such as Seminars, Workshops, Training Schools and a final Conference as well as expected reporting for the COST Association, the Action's participants and external parties. Please notice that due to positive experiences with online workshops held during the COVID-19 lockdowns, this type of meeting will stay as a significant networking event for the remainder of COST Action PEARL PV.

In August 2021, COST Action PEARL PV consisted of 38 countries: that is to say 35 European COST Member countries (including Israel), 2 International Partner Countries (IPC), namely the USA and Australia and 1 Near Neighbor Country (NNC) which is Armenia. The map in Figure 2, shows all the with PEARL PV affiliated countries.

Since its start at 5 October 2017, COST Action PEARL PV has acquired more than 250 members among which above 65 MC members, more than 50 MC Substitutes and 4 MC Observers. Since it is required that in this COST Action all members actively contribute to the execution of the workplan, new members will be kindly invited to accept a role in this Action, ranging from being a member of a Working Group to having a managerial role to being part of the Core Group.

Two major issues of general concern of this COST Action are indicated below. They will be addressed in the following ways:

i) Limited interest in data sharing by means of the CKAN data server. This is a problem that can cause delays of envisioned research ambitions in this Action. To stimulate a broader and more intensive use of the CKAN data server and to enhance the number and quality of data uploads, WG1 in collaboration with the Chair and Vice Chair of this Action will be holding workshops and joint research actions in the period until the end of this Action.

ii) Limited connection with third parties, such as industrial partners and other research networks. This issue is partially related to the recent covid pandemic with a strong decrease of international contacts in general, as well as to the lack of photovoltaic manufacturing industry in Europe. Therefore we aim at solving this issue by connecting to item ii, namely a widespread stimulation of the use of the CKAN data server, which will give reasons to internationally collaborate with the PEARL PV network in a digital manner.

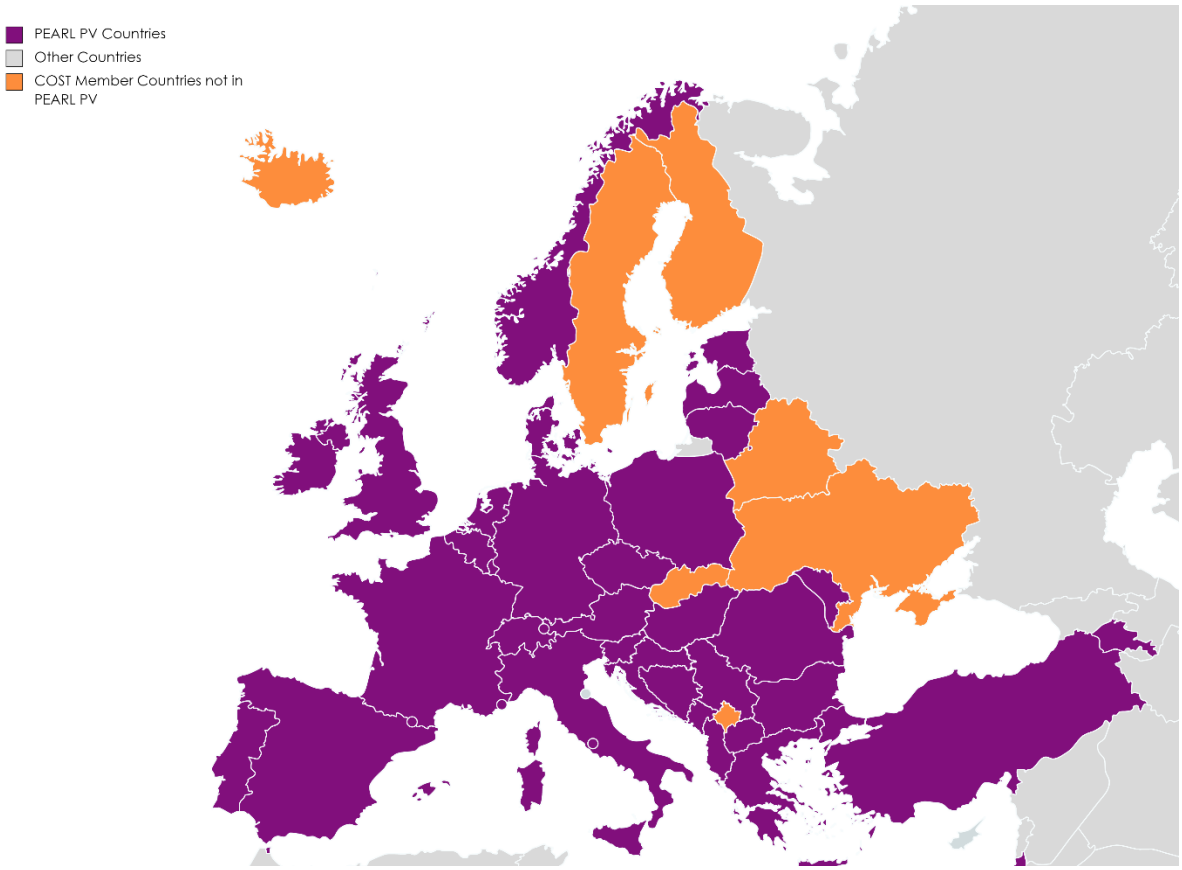

Figure 2: Countries involved in COST Action PEARL-PV in purple by April 2021 except Israel, Australia and the USA.In orange, EU COST Member countries which have not joined PEARL PV yet for various reasons.

Table 1: Planning of COST Action PEARL PV for the period of 2021 until 2022, GP: Grant Period, N: Newsletter, OW: Online Workshop, MC: Management Committee meeting, CG: Core Group meetings (please notice that GP4 continues until 4 October 2021, and GP5 until 4 April 2022)

Year	2021												2022			
Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Grant Periods	GP4				GP4- extended						GP5					
Reports & Newsletter					**N**					**N**					M48 - PR3 Final report for COST Final Newsletter	
Meetings	**OW**	**OW**	**OW**	**OW**			Seminar Training School 5-9, Brasov Romania		MC5 Workshops 22-24, online		**OW**	**OW**	**CG & OW**	**OW**	MC6 Final conference Training School 4 Date: tbdl, the Netherlands	
Data bank	First round analyses						Final round analyses, data uploads and information supply to users on how to use the facility									
Working Groups	Revise workplan		Implementation of revised work plan													

2. Workplan of WG1: PV Monitoring

WG1 Chair: Wilfried van Sark, Utrecht University, the Netherlands

WG1 Vice Chair: Christian Braun, Fraunhofer ISE

'PV Monitoring' is focused on the identification of relevant data to be collected to properly assess PV performance of installed PV systems in the field and on rooftops. Activities cover both defining guidelines for collection and analysis, as well as designing a data bank with appropriate access options. A strong connection to all other Working Groups in the PEARL-PV project is envisioned as data requirements will differ per Working Group.

The overall objective of WG1 is to **investigate long-term PV performance.** This will be achieved by analyzing data of the actual monitored long-term performance, defects and failures in PV systems installed all over Europe to quantitatively determine the absolute influences of components rated performance, key design of systems including BIPV, residential, field-based and floating systems, installation, operation, maintenance practice, geographic location and weather factors on the performance, performance degradation over time and failure modes of these PV systems.

In order to reach this overall objective, the following detailed objectives are defined as:

1. To develop generally accepted approaches and guidelines for the collection of data on performance of PV modules and PV systems
2. To set-up a data bank for data collection and sharing
3. To develop generally accepted approaches and guidelines for the use and/or analysis of data
4. To define a strategy for data bank access

WG1 Description of Tasks

WG1 has four major tasks, as described below.

Task 1.1: Development of generally accepted approaches and guidelines for the collection of data.

In this task a study of published approaches and existing guidelines on data collection has been performed, and discussed in a WG1 workshop. Existing IEC standards and IEA-PVPS-Task13 reports are used as basis, while a distinction is made between need-to-have and nice-to-have data taking into account that data availability can be flexible. Obviously, power and energy data from systems are essential as well as irradiation data. The combined outcomes have been used to design a questionnaire on data needs and requirements, that has been used for consultation of all PEARL-PV participants in all working groups. The results of the questionnaire have been discussed at a WG1 seminar, which provided input to the design of the the data structure of the data bank (T1.2).

This task has been completed at the end of Grant Period 2, while updates may be made if new data is available. This task contributes to Objective 1.

Task leader: Anne Gerd Imenes, Norway

Subtasks:
T1.1.1: Preparation of data requirement questionnaire

T1.1.2: Distribution of questionnaire

T1.1.3: Analysis of questionnaire responses and summary of results

Task 1.2: Compilation of a data bank on a server.

Based on required data, statistical (meta)data and dynamical data, data types and time resolutions, a system for data collection and sharing will be identified. Options using SQL and non-SQL, HDFS, and others will be investigated. A decision has been made in Grant Period 2, after consultation with PEARL-PV data experts during a WG1 seminar. A first version of the data bank has been set-up using a CKAN environment, hosted by University of Twente. CKAN has been selected as it allows for inclusion of different data and formats.

Though originally it was assumed that the data bank would be fully available by the end of 2018, due to the complexity of implementation, it was completed at the end of Grant Period 3, while updates may be made if new data is available. This task contributes to Objective 2.

Task leaders: Dijana Capeska Bogatinoska, fYR Macedonia, Anton Driesse, PV Performance Labs, Germany

Subtasks:
T1.2.1: Investigation of data bank structure options

T1.2.2: Selection of data bank structure

T1.2.3: First realization of data bank structure

T1.2.4: Assess necessity for updates of data bank structure

Task 1.3: Development of guidelines for use and analysis of data.

This task has targeted the development of generally accepted approaches and guidelines for the use, analysis and/or interpretation of meteorological data and data about the performance of PV modules and systems. Existing scientific documentation, guidelines and standards, as well as meetings with PV monitoring experts has been used to set this up. A link with Working Group 3 ensures harmonization of data and procedures regarding simulation algorithms and software. Also, PEARL-PV data experts assisted in co-developing scripts to access the data bank. The guidelines contain advantages and disadvantages, relevance, accuracy and complexity of application as well as data requirements. Finally, using the guidelines on collected data is providing information on the performance of PV

systems. The guidelines have been completed at the end of Grant Period 3, while updates may be made if new data is available.

This task contributes to Objective 3.

Task leaders: Carolin Ulbrich, HZB, Germany, Atse Louwen, Eurac, Italy

Subtasks:
T1.3.1: Collect state-of-the-art data use and analysis guidelines

T1.3.2: Discuss state-of-the-art guidelines among PV experts

T1.3.3: Compile updated guidelines

T1.3.4: Perform analyses on collected data

Task 1.4: Development of a strategy for data bank access

In this task an access strategy to data stored on a server is be developed in the form of a data management plan, which will include non-disclosure agreements for participants that supply data that may contain privacy sensitive information. The EU General Data Protection Regulation is used to guide this. Also, a policy for use of these data taking into consideration costs, publishing and IP for COST Action participants and external parties will be developed. This has been implemented in the CKAN server, at the end Grant Period 3, while updates may be necessary if new data is available.

This task contributes to Objective 4.

Task leader: Carolin Ulbrich, HZB, Germany, Wilfried van Sark, UU, Netherlands

Subtasks:
T1.4.1: Draft a data management plan

T1.4.2: Prepare a Non-Disclosure Agreement

T1.4.3: Develop data bank access strategy and policy for use

WG1 Deliverables Plan

Within the project specification, three main deliverables were identified for WG1 (D1 to D10 detailed below). This deliverables plan links the main deliverables to their respective Tasks and identifies the path to those deliverables, according to the current workplan.

D1. Publications of findings originating from WG1 in high-impact scientific journals, conference proceedings and via the COST Action's website

D2. Reports of the WG 1 activities (annually), including the organization of one workshop per year and one seminar per year on PV monitoring.

D3. A data bank to be realized on one of the MC members' server.

D4. Publication of findings originating from WG3 in high impact journals, conference proceedings and a book.

Pathway to D1: All tasks will contribute to the preparation of reports, specifically Task 1.1 and Task 1.3. These will be assessed in terms of their suitability for the preparation of journal or conference papers, with a specific target of the specialist journals and conferences relating to the PV community. Since the first reports are due to be prepared in the third quarter of GP2, the initial plan is to target abstract submission for the PV conferences taking place from April to September 2019 (such as IEEE PVSC and EU PVSEC). WG1 will also contribute to papers submitted in relation to the overall PEARL PV project, as appropriate. Specifically, subtask 1.3.4, in which actual PV system data analysis will be performed based on the data collected will lead to several publications in high-impact journal. It is expected that the work of WG3 will allow a contribution of several specialist chapters to the projected book arising from the COST Action.

During the execution of the Action, it appeared to be difficult to collect sufficient amount of data for analysis. In various workshops, webinars and meetings, it was decided to attempt to steer this by focusing on specific research questions, with volunteers to lead this:

- Assessment of solar spectral variations across Europe using spectral measurements of various participants, and average photon energy as proxy (Lead: Anne Gerd Imenes, University of Agder)
- Climate dependent degradation of PV systems (Lead: Steve Ransome)
- Uncertainties in determination of degradation, satellite base data and recorded data (Lead: Alessandro Virtuani)
- Geographic locations of installations, factors to influence stability across Europe (Lead: Jeff Kettle)
- PV data analysis for performance assessments of roof top PV systems in relation to losses due to system failures, soiling and maintenance schemes (Lead: Carolin Ulbrich)
- Variation of floating PV performance across Europe (Lead: Wilfried van Sark)
- Performance analysis in Agrivoltaics (Lead: Tareq Abu Hamed)
- Effect of fast power fluctuation of PV systems on the grid? (Lead: Jovan Todorovic)

D2. Annual reports of the WG 1 activities, including the organization of one workshop per year and one seminar per year on PV monitoring.

Pathway to D2: Annual reports will be produced as required. The first annual report, in autumn 2018, will report on Tasks 1.1 and 1.2, both of which will be well advanced at that time, and on Tasks 1.3 and 1.4 that just will have started. WG1 is organizing a seminar in October 2018 on "Matching PV data and PV performance research questions" as part of Task 1.1. WG1 is also contributing to the training workshop to be held in October 2018 on "Monitoring and simulation of the performance and reliability

of photovoltaics in the built environment". WG1 will contribute to other workshops, always focusing on PV system performance aspects.

D3. A data bank to be realized on one of the MC members' server.

Pathway to D3: The activities of Tasks 1.1 have provided input to Task 1.2, which was about setting up the data bank itself. It was planned that a first version of the data bank is available in December 2018, and data access (Task 1.4) is defined at that time as well. However, due to the complexity of the task, this has been finalized at the end of Grant Period 3, and is hosted by University of Twente. Collection of data as well as the use and analysis of data (Task 1.3) has been used to set-up data bank structure, which has led to the choice for a flexible data bank structure.

WG1 Timeline of Actions

Deliverables by the end of Grant Period 1 (30 April 2018):

- Workshop on data needs (Brussel, 22 January 2018)
- Questionnaire on data needs and PV monitoring guidelines defined and send out to all PEARL-PV participants (completed 26.04.2018)

Deliverables by the end of Grant Period 2 (30 April 2019)

- Report "Results from questionnaire on data needs and PV monitoring guidelines" (November 2018) (Task 1.1.1)
- Report D1.1 First annual report of WG1 activities (November 2018)
- Seminar S1.1 Matching PV data and PV performance research questions (Nicosia, Cyprus, 22 October 2018)
- Contribution to training school "Monitoring and Simulation of the Performance and Reliability of PV in the Built Environment" (Nicosia, Cyprus, 23-26 October 2018)
- Contribution to joint conference paper for 35th EU PVSEC (September 2018)
- Realization of first data bank at MC member server (Task 1.2.1, 1.2.2, 1.2.3)
- Report on state-of-the-art in data use and analysis guidelines (Task 1.3.1), potentially in the form of a paper
- Report on data access (Q2-2019)

Deliverables by the end of Grant Period 3 (30 April 2020)

- Contribution to training school "Evaluation of the performance degradation of PV-systems – influence factors, failure modes and their detectability and affect on economic viability" (Q3-2019)
- Realization of updated data bank at MC member server (Task 1.2.4)

- Contribution to (joint) conference paper for 36th EU PVSEC (September 2019)
- Report D1.2 Second annual report of WG1 activities (November 2019)
- Report on updated state-of-the-art in data use and analysis guidelines (Task 1.3.2, 1.3.3), potentially in the form of a paper
- First paper on analysis of data on PV system performance using data collected (Task 1.3.4)

Deliverables by the end of Grant Period 4 (4 October 2021)

- Realization of updated data bank at MC member server (Task 1.2.4)
- Scientific paper on overall performance of PV systems in Europe, focus on energy yields (Q2-2020, Task 1.3.4)
- Contribution to (joint) conference paper for 37th EU PVSEC (September 2020)
- Session about the functioning and use of the CKAN data server at 38th EU PVSEC (September 2021)
- Report D1.3 Third annual report of WG1 activities (November 2020)
- Contribution to training school "Simulation tools and models for the forecast of system efficiencies of PV plants – with focus on environmental and integration aspects (Q3-2021)

Deliverables by the end of Grant Period 5 (4 April 2022)

- Scientific paper on detailed analysis of performance of PV systems in Europe, identifying causes for malfunction (Q4-2021, Task 1.3.4)
- Contribution to final report of this Action for the COST Association (Q2-2022).
- Contribution to training school "Potential of monitoring tools and advanced operation and maintenance practice for security and predictability of PV performance (Q1-2022)
- Report D1.3 Fourth annual report of WG1 activities (31 October 2021)

3. Workplan of WG2: Reliability and Durability of PV

WG2 Chair: Jeff Kettle, James Watt School of Engineering, University of Glasgow, Scotland

WG2 Vice Chair: Reza Aghaei, TU Eindhoven, Netherlands

The main objectives of WG 2 are defined as follows:

1. Definition of reliability and durability metrics for PV modules, components and systems
2. Identification of relevant data to be collected to measure reliability and durability
3. Sharing knowledge via workshops, seminars and joint publications originating from WG2 with a wider community of PV experts solar electricity and other experts working for insurers, investors and banks.

WG2 Description of Tasks

The work in WG2 is divided in two Tasks. The Deliverables and Task Leaders are summarized in Table 2 on the next page.

Task 2.1: Development of a common description of reliability and durability of PV modules and PV systems by meetings and communications with PV researchers and other experts leading to a shared document to be published on this COST Action's website.

Task 2.2 (modified): Identification of required data and measurement methodology to be used in the framework of understanding reliability and durability given the challenges of (i) the often long elapsed duration before occurrence of both defects and degradation of PV modules in the field (ii) the climate dependency of these effects and (iii) relationships between the manufactured quality of PV module and observed reliability and durability in practice.

Task 2.3 (new): Understand how advancements in big data analytics (BDA) approaches can be used to assess reliability. Make use of the CKAN (and other) repositories to understand how key factors in performance degradation to be identified and explore how the installation, operation, maintenance practice, geographic location or test conditions affect degradation over time. In addition, this task will initiate a new research framework on how BDA can be used to improve advancing technologies such as perovskite and organic solar cells.

Table 2: Overview on Tasks, Task leaders and deliverables for WG2

TASK 2.1: Development of a common description of reliability and durability of PV modules and PV systems LEADER: Jeff Kettle **Task 2.2:** Identification of required data to be used in the framework of understanding reliability and durability LEADER: Reza Aghaei **Task 2.3:** Identification of required data to be used in the framework of understanding reliability and durability LEADERS: Jeff kettle/Shazada Ahmad
DELIVERABLES AT THE END OF THE 1ST GRANT PERIOD (30.04.2018)
Work Plan (done)
Deliverables at month 12 (01.11.2018)
WG2 report #1 (done)
Deliverables at month 24 (01.11.2019)
WG2 report #2 (done) Workshop #1: Reliability metrics for PV (done)
Deliverables at month 36 (01.11.2020)
WG2 report #3 (done) Workshop #2 (done) Deliverable 5: White paper on definition of reliability and durability of different PV technologies (done and converted to a review paper for submission to a journal)
Deliverables at month 48 (01.11.2021)

WG2 report #4

Deliverable 7: Report on using BDA analytics for 3rd generation PVs

Task 2.1: Development of a common description of reliability and durability of PV modules and PV systems

The main objective of Task 2.1 is the definition of reliability and durability metrics for PV modules, components and systems. One the one hand properties describing reliability & durability from different views of PV stakeholders (Consumers, investors, manufacturers, researchers, utilities) are defined. One the other hand also different metrics for different PV technologies (c-Si, thin film, organic….) are considered. Also metrics dependent on different applications like PV for consumer products, utility-scale power production, mobility, building integration etc. will be evaluated. Finally also discrepancies between high durability and easy end-of-life management will be addressed.

The main outcome of Task 2.1 is Deliverable 5 mentioned in the MoU: White paper on definition of reliability and durability of different PV technologies, which is planned to be published Autumn 2021. The tentative paper structure has been discussed with the work group members via email, a conference call in July 2018, bilateral talks and a personal meeting at the PVSEC 2018 in Brussels, meetings in Lisbon/Utrecht (COST workshops), three conference calls. There are around 109 contributing authors (as of June 2021) from 10 different COST country members. The paper is to be submitted in June 2021.

Task 2.2 (modified): Identification of required data and measurement methodology to be used in the framework of understanding reliability and durability

The work plan of Task 2.2 had to be adapted in order to avoid overlaps and duplications with parallel running activities. For example, simulation models for certain PV module degradation modes are already summarized in IEA Task 13 report on “Assessment of PV module failures in the field” (published 2017). Also, there are strong overlaps between original Task 2.2 description and recent IEA PVPS Task 13 work program (2018-2021), which runs in parallel to Pearl PV. Moreover, several proposals of WG2 members are already covered within Task 13, such as description of reliability and failure modes of new module technologies and new system designs. Therefore, the new objectives for Task 2.2 are as follows.

The main objective of this work is to collect relevant information on how measure reliability and durability. This includes the description of mass PV data analysis methods - output power over time and multi-faceted analysis to gauge output decrease, the identification of issue causing decrease in power output (e.g. shading, physical degradation…) and a correlation of failure modes with climatic conditions

The planned output of Task 2.2 has been adjusted to a published paper reviewing specific failures modes in PV modules. These can then be used for more accurate identification of failure modes within BDA

Task 2.3 (new): Identification of required BDA approaches to be used in the framework of understanding reliability and durability

The use of BDA to analyse solar cell performance is a rapidly growing area, especially for material discovery. Fast advances have been developed in software, hardware, and also platforms for large data acquisition, storage, and communication for PV. Subsequently, many methods have been developed for BDA such as statistical analysis, artificial intelligence, data mining, and machine learning, and advanced data visualization. PVBDA aims to increase the reliability and service life of PV systems through developing the methods for automating the monitoring procedure, failures detection, and analyzing the degradation mechanism systematically, predict the performance and real-time decision-making for remedial action during PV systems' operation. PVBDA also contributes to enhancing the performance of emerging PV technologies.

The particular focus of T2.3 is upon how reliability metrics and reliability analytical techniques are changing within PV modules and systems and how advancements in big data analytics (BDA) approaches can be used to assess reliability. As a result of to the CKAN repository, that will enable the key factors in performance degradation to be identified and explore how the installation, operation, maintenance practice, geographic location affect degradation over time. This task will focus on all generations of PV technology and it is envisaged that lessons learned from mature PV technologies (e.g. c-Si) can be transferred to researchers and businesses in 3rd or next-generation PVs. In addition, this task will initiate a new research framework on how BDA can be used to improve advancing technologies such as perovskite solar cells.

WG2 Deliverables Plan

Within the project specification, three main deliverables were identified for WG2 (D5 to D7 detailed below). This deliverables plan links the main deliverables to their respective Tasks and identifies the path to those deliverables, according to the current workplan.

D5. Publications of findings originating from WG2 in high-impact journals, conference proceedings and a special issue of an international peer reviewed journal. *(D5 complete)*

D6. Reports of the WG2 activities (month 12, 24, 36, 48), including the organisation of one workshop per year on reliability and durability of PV modules, components and systems. (D6 complete in September 2021)

D7. Review article on durability and reliability aspects of PV modules (D7 complete)

D8. Joint paper submitted to high impact journal on use of BDA to improve perovskite solar cell performance (expected Q1 2022)

4. Workplan of WG3: PV Simulation

WG3 Chair: Nicola Pearsall, Northumbria University, UK

WG3 Vice Chair: João Serra, Universidade de Lisboa, Portugal

The 'PV Simulation' Working Group considers the use of modelling tools to simulate the performance of photovoltaic devices and systems. This covers both the prediction and the assessment of performance and complements the activities of the other Working Groups in the PEARL PV project, especially those considering specific PV applications. The objectives of WG3 are:

1. Classification of PV simulation models by content ranging from (i) fundamental solar cell research, (ii) PV irradiance modelling including forecasting and cloud formation, (iii) PV systems (grid-connected, stand alone and hybrid), (iv) PV in the built environment and (v) PV grid interactions. Distinction will be determined between simulation models that can predict performance on short and long timescales as well as different approaches to prediction of the durability of PV modules and systems.
2. Identification of PV simulation tools and models by category.
3. Provision of access to information about PV solar electricity simulation models.
4. Comparison of various PV solar electricity simulation models.
5. Sharing knowledge originating from WG3 with a wider community of PV and other renewable energy experts by internet, workshops, seminars and joint publications about the topic of PV simulation.

WG3 Description of Tasks

WG3 has three major tasks. Tasks 3.1 and 3.2 were completed by the end of Grant Period 2 and are therefore only summarized here. The following description concentrates on Task 3.3, which forms the main part of the remaining work. Some additional activities, which relate to the collation and dissemination of information on PV simulation are also described.

Task 3.1: Development of a common description of PV simulation

Task Leader: Tihomir Betti, Croatia

The description of simulation has been expressed in terms of the categories outlined in Objective 1. This task included the initial identification of software, the categorization of that software and the specification of the information requirements for the inventory (ST 3.1.1). The results were used in the development of the questionnaire in Task 3.2 and in the definition of the simulation comparison in Task 3.3. The three subtasks were completed by the end of Grant Period 2, retaining an option to repeat subtasks if considered necessary. This task contributed mainly to Objectives 1, 2, 3 and 5.

Subtasks:

ST 3.1.1	Identification of the simulation categories and inventory requirements
ST 3.1.2	Determination of the scope of modelling currently undertaken
ST 3.1.3	Recommendations for testing of models and development of new models

Task 3.2: Identification of PV simulation tools and models

Task Leader: Jesús Robledo Bueno, Spain

The PV simulation tools and models currently in use and/or available to the PV community were identified, together with information on scope and ease of use. This was achieved via the distribution of a questionnaire that investigated the current usage of software by the COST Action participants and others, determined the main reasons for that usage and sought to identify perceived gaps in provision. The distribution and analysis of the questionnaire was completed by the end of Grant Period 2 and has led to a conference presentation as well as feeding into the definition of Task 3.3. This task contributed mainly to Objectives 2, 3 and 5.

Subtasks:

ST 3.2.1	Preparation of simulation questionnaire (including delivery method)
ST 3.2.2	Distribution of questionnaire
ST 3.2.3	Analysis of questionnaire responses and summary of inventory results

Task 3.3: Assessment of simulation models

Task Leader: Nicholas Riedel-Lyngskær, Denmark

The results of the usage survey indicated several aspects of PV systems that were of specific interest and not fully addressed in existing simulation packages. It was decided that these could be considered in more detail within a focused assessment, where models are compared using common data sets.

Further topics were identified during a workshop held in December 2020. The simulation topics to be considered are related to either new and/or complex system types (e.g. bifacial systems) or operational issues which are challenging to include on a consistent basis (e.g. shading, soiling). Initially, a series of round robin exercises was proposed, where several different modelling groups would simulate the same system designs with a common data set. However, due to the variety of systems and the difficulty of sourcing open-access data suitable for all the exercises, this approach was modified to more targeted comparisons within a single group or between a few groups.

In Grant Period 3, work commenced on the comparison of existing software for bifacial systems and results were published by Riedel-Lyngskær et al in Applied Sciences (November 2020) at the European PV Solar Energy Conference, September 2020. This work had some delays caused by difficulties with data collection during 2020, due to access restrictions, but will be continued during Grant Period 4. Members of the PEARL network are also developing new software for complex irradiance modelling, suitable for both bifacial PV systems and systems with complex shading (e.g. building integrated systems).

One of the most important aspects being considered in the ongoing model comparisons relates to uncertainty, especially as we move to more complex systems, including the role of the user of the model.

This task contributes mainly to Objectives 3, 4 and 5.

Subtasks:

ST 3.3.1	Definition of software to be tested, together with the test regimes
ST 3.3.2	Comparative software testing
ST 3.3.3	Assessment of test results and recommendations

WG3 Deliverables Plan

Within the project specification, three main deliverables were identified for WG3 (D8 to D10 detailed below). This deliverables plan links the main deliverables to their respective Tasks and identifies the path to those deliverables, according to the current workplan.

D8. Publication of findings originating from WG3 in high impact journals, conference proceedings and books.

Pathway to D8: Whilst the outputs from Tasks 3.1 and 3.2 have mainly been used for identifying the detailed studies of Task 3.3, results have also been published in conference proceedings. Two journal papers have been published on modelling of PV systems and further papers will be published in the remaining period, most of which will be based on the work in Task 3.3. A summary of the work of WG3 was included in the first edition of the PEARL PV Country Reports book and a final summary report will be included in the updated version of the Country Reports at the end of the COST Action.

D9. Annual reports of the WG3 activities, together with the organization of two workshops and two seminars on PV simulation.

Pathway to D9: WG3 is contributed to the training workshop held in Cyprus in October 2018, with a specific set of sessions on the simulation of BIPV systems. The third PEARL PV training workshop, to be held in GP4, is being organized by WG3 and focuses on simulation and modelling. This was originally planned for October 2020, but was postponed due to travel constraints across Europe, and is now scheduled for July 2021. WG3 has held workshops at the annual meetings of PEARL PV throughout the Action, together with an on-line workshop in December 2020. It is planned to hold a further on-line workshop for all PEARL participants in early 2022, to discuss the results of the model comparisons. WG3 will also contribute to the final conference.

D10. Open-source software for the simulation of PV modules and systems.

Pathway to D10: The activities of Tasks 3.1 and 3.2 have identified the current open-source software available for PV modules and systems. Task 3.3 will include the testing of some open-source software alongside proprietary software, leading to recommendations on best use and requirements for future development.

WG3 Timetable of Actions 2021-22

	Grant Period 4
	Grant Period 5

Task	Subtask	2021				2022
		1-4	5-8	9-10	11-12	1-4
3.1 Common description of PV simulation	3.1.1	Task Completed				
	3.1.2					
	3.1.3					
3.2 Identification of PV models	3.2.1	Task Completed				
	3.2.2					
	3.2.3					
3.3 Testing of simulation models	3.3.1					
	3.3.2					
	3.3.3					
Networking Activities (see key below)			NA1	NA2		NA3, NA4

NA1: Training School #3, Simulation tools and models for the analysis of PV system performance, Brasov, Romania, July 2021

NA2: WG3 workshop at annual meeting of PEARL PV

NA3: WG3 on-line workshop, January/February 2022

NA4: PEARL PV Final Conference, April 2022

WG3 Milestones and Deliverables

Deliverables by the end of Grant Period 4 (31 October 2021)

- Report on the organization of the training workshop on PV simulation
- Progress report for GP4

Deliverables by the end of Grant Period 5 (30 April 2022)

- Report on the organization of the second seminar on PV simulation
- Paper on open-source software availability and development needs
- WG3 final report (including contribution to update Country Reports)

5. Workplan of WG4: PV in the Built Environment

WG4 Chair: Bogdan-Gabriel BURDUHOS, Transilvania University of Brașov, Romania

WG4 Vice Chair: Mirjana Devetakovic, University of Belgrade, Serbia

For many years PV systems have been used with the unique objective to produce renewable energy from the sun, by installing modules on large fields and on large industrial or commercial flat roofs. Since the cost of photovoltaic technologies was drastically reduced in the last years and the *net Zero Energy Buildings* were defined as a target for new buildings starting with 2020, the idea to integrate PV modules in the built environment (mainly as façade or roof element) became more feasible and important for building designers. This has been defined as Building Integrated Photovoltaic (BIPV) meaning that PV modules will serve not only as renewable energy producers but also as elements of the building, having also other functions such as weather protection or shading.

If integrated in the built environment, PV modules have to withstand often variable outdoor conditions leading to complex situations which are difficult to be predicted with SoA simulation models and existing standards that are representing “conventional” conditions. For these reasons the main goals of WG4 are:

1. Collect information about the applications of PV solar electricity in the built environment using both information from other WGs and by communications with PV experts, architects, installers, construction / building service engineers and city / urban planners.

2. Identify monitored data from existing systems and appropriate simulation models that can be used in the framework of PVs installed in the built environment.

3. Sharing knowledge originating from WG4 with a wider community of PV experts and other experts in the building sector by internet, workshops, seminars and joint publications.

WG4 Description of Tasks

WG4 has two major tasks, as described below.

Task 4.1: Collection of information for the database server

The aim of this task is the collection of relevant and useful information about realized PV projects in the built environment (such as exemplary public founded research or Pilot and Demonstration

projects) for the database server developed in the frame of this COST Action, from different WG partners, from other stakeholders and from scientific publications / internet articles.

Also, in order to enlarge the scope of the task and increase the echo of the Action, information related to the PV cost can be obtained from PV experts (architects that already experienced PV installation in their building project, installers, construction / building services engineers and city / urban planners) and added to the database server of the Action.

Subtasks:

ST 4.1.1 Characterisation of the built environment and PV related issues

- Definition of different built environments
- Identification of the main PV related issues
- Identification of the main possibilities of use of PV in the built environment

ST participants: Aleksandra Krstić, Mirjana Devetaković, Gabriele Lobaccaro

ST 4.1.2 Simulation models

- State of the art
- What models are used for predicting the PV energy performance in the built environment
- Characteristics, parameters, need for other functions

ST participants: Gabriele Lobaccaro, Georgios Martinopoulos, Nikolina Shutinoska, Mircea Neagoe

ST 4.1.3 Energy performance norms that apply to buildings

- State of the art, based also on different country perspectives (translation on national documents in English when necessary).

ST participants: Georgios Martinopoulos

Task 4.2: Identification of required data and appropriate simulation models to be used in the framework of PV systems in the built environment

The aim of this task, which is complementary to Task 3.1, is to identify useful relevant data from real case studies and to assess / simulate the performances and the behaviours of PV systems in the built environment. This will be done based on the archetypes definition of *BIPV* and *PV in built environment*; afterwards the physical, technological and architectural parameters related to integration into the building (e.g. shading, temperature, non-optimal cabling, etc.) will be described in order to identify in the last stage the specific and appropriate simulation models that best fit the planning needs and the designer requirements.

Subtasks:

ST 4.2.1 Definition of BIPV and PV in built environment archetypes (product and system)
ST participants: Aleksandra Krstić, Mirjana Devetaković

ST 4.2.2 Identification of issues and parameters related to integration into building (e.g. shading, temperature, non-optimal cabling …)

ST participants: Georgios Martinopoulos, Patrick Hendrick

ST 4.2.3 PV and the urban mobility
ST participants: Bogdan Burduhos, Mircea Neagoe, Alonzo Sierra

WG4 Deliverables Plan

Within the project specification, three main deliverables were identified for WG4. This deliverables plan links the main deliverables to their respective Tasks and identifies the path to those deliverables, according to the current work plan.

D11. Publications of findings originating from WG4 in high-impact journals, conference proceedings and a special issue of an international peer reviewed journal.

Pathway to D11: Both tasks will result in the preparation of reports which will be assessed in terms of their suitability for the preparation of journals or conference papers related to the BiPV community (photovoltaic and construction domain experts). The exact content will depend on the advances that will be achieved in the WG4.

Results

WG4 has produced several publications in high-impact scientific journals and conferences.

Paper at Places and Technologies Conference 2018 (published in the proceedings)
Title: Trends in integration of photovoltaic facilities into the built environment
Authors: Aleksandra Krstić-Furundžić, Alessandra Scognamiglio, Mirjana Devetaković, Francesco Frontini, Budimir Sudimac

Paper at ESCC - Energy Sustainability and Climate Change 2018 (abstract published in the proceedings)
Title: International experiences ongoing on the use of photovoltaics in the built environment. Starting points for new research development
Authors: Alessandra Scognamiglio, Francesco Frontini

Paper at EUPVSEC (visual presentation)
Title: The Use of Photovoltaic Technologies in the Built Environment: Open Issues and Research Perspectives
Authors: A. Scognamiglio, F. Frontini, A. Krstić-Furundžić, M. Devetaković, B. Sudimac

Paper in FME Transactions Journal 2019, vol. 47(2), pp. 387-397. ISSN: 1451-2092 (print), ISSN: 2406-128X (online), UDC: 62. https://doi.org/10.5937/fmet1902387D, https://www.mas.bg.ac.rs/istrazivanje/fme/start)
Title: Design of Solar Systems for Buildings and Use of BIM Tools: Overview of Relevant Geometric Aspects
Authors: Mirjana Devetaković, Đorđe Đorđević, Gordana Đukanović, Aleksandra Krstić Furundžić, Budimir Sudimac, Alessandra Scognamiglio

Paper in Energies Journal 2019, vol. 12(18), pp. 1-28
Title: A Methodological Analysis Approach to Assess Solar Energy Potential at the Neighborhood Scale
Authors: Gabriele Lobaccaro, Malgorzata Maria Lisowska, Erika Saretta, Pierluigi Bonomo, Francesco Frontini

Paper at 3rd International Forum for Architecture and Urbanism, Modernisation and Globalization Conference
Title: Modernization of Built Environment by Integration of PV Technology - The Case Of Street Light Systems
Authors: Mirjana Devetakovic, Florian Nepravishta, Goran Radovic, Milan Radojevic

Paper in Open House International Journal, Vol. 45 No. 1/2, pp. 195-207, ISSN: 0168-2601 (2020), https://doi.org/10.1108/OHI-04-2020-0015
Title: Trends in the integration of photovoltaic facilities into the built environment
Authors: Aleksandra Krstić-Furundžić , Alessandra Scognamiglio , Mirjana Devetakovic, Francesco Frontini , Budimir Sudimac

Paper in Applied Sciences Journal 2020, 10(19), 6696; https://doi.org/10.3390/app10196696
Title: Photovoltaics on Landmark Buildings with Distinctive Geometries
Authors: Mirjana Devetaković, Djordje Djordjević, Milan Radojević, Aleksandra Krstić-Furundžić, Bogdan-Gabriel Burduhos, Georgios Martinopoulos, Mircea Neagoe and Gabriele Lobaccaro

Paper in Solar Energy Conversion in Communities. Springer Proceedings in Energy, https://doi.org/10.1007/978-3-030-55757-7_9, pp. 125-139
Title: Comparative Analysis of Software Accuracy in Photovoltaic Energy Estimation for a Temperate Mountain Climate
Authors: Bogdan-Gabriel Burduhos, Mirjana Devetaković, Mircea Neagoe, Nadia Ramona Cretescu

Members of WG4 also coordinated 2 special issues of international peer reviewed journals:

- Modeling and Forecasting for Energy Production of Photovoltaic (PV) Systems, https://www.hindawi.com/journals/ijp/si/430386/
- Photovoltaic Systems in the Built Environment, https://www.mdpi.com/journal/energies/special_issues/PV_Built_Environment

D12. Reports of the WG 4 activities, including the organization of two workshops ~~and two seminars~~ about PV in the built environment.

Pathway to D12: Annual reports will be produced as required. Workshops ~~and seminars~~ will be held during the project presenting the main findings obtained in WG4.

Results

- Organizing of a Workshop in Lisbon, Portugal, 2019
- Organizing of a Workshop in Utrecht, Netherlands, 2020 (*BIPV on landmark objects*)
- Organizing with Aleksandra Krstić of 3 training schools related to PV systems in the built environment:
  - *Monitoring and Simulation of the Performance and Reliability of PV in the Built Environment* (Nicosia, Cyprus, 2018)
  - *Evaluation of the performance degradation of PV-systems – influence factors, failure modes and their detectability and effect on economic viability* (Paola, Malta, 2019)
  - *Simulation tools and models for the analysis of PV system performance* (Brasov, Romania, 2021)
- Participation at the Pearl PV seminar organized in Nicosia, Cyprus, 2018
- Participation at the Pearl PV seminar organized in Paola, Malta, 2019
- Participation at the Pearl PV seminar organized in Brasov, Romania, 2021

Also the chair and members of WG4 were actively involved in organizing the COST Pearl PV seminar and training school in Brasov, Romania in July 2021.

D13. List of open source data and software for PV in the built environment

Pathway to D13: Collection of information for the database server of this Action about PV systems in the built environment, from realized projects, publications and information retrieved from internet, and from PV experts, architects, installer, construction and building services engineers and city/urban planners.

6. Workplan of WG5: PV in grids

WG5 Chair: Jonathan Leloux, Polytechnic University of Madrid, Spain

WG5 Vice Chair: Sonia Pinto, University of Lisbon, Portugal

WG5 aims to contribute towards research on PV systems that are better integrated into the grid, that perform better, and whose operation under real-world conditions is better understood. This is done through the exploration of different complementary pathways:

- Objective 1. Collecting information about the application of PV in grids ranging from (i) forecasting of irradiance and hence PV power generation for utilities, (ii) low voltage distributed grids, (iii) smart solar charging of electric vehicles to (iv) domestic uses of PV such as smart appliances. This WG will use information from WG1, WG2 WG3 and WG4 on PV monitoring, reliability and durability and PV simulation respectively and information from communications with PV experts, electrical engineers, utilities, smart grid experts and meteorologists.
- Objective 2. Identification of required data and appropriate simulation models to be used in the framework of PV in grids.
- Objective 3. Sharing knowledge originating from WG5 with a wider community of PV experts and other experts at utilities and smart grid sector by Internet, workshops, seminars and joint publications.

WG5 Description of Tasks

WG5 is currently organized in several Tasks. Three of them have been particularly active and prolific:

- PearlPQ: Power quality at the connection of PV to the LV and MV grids

The high diffusion of photovoltaics plants in medium and low voltage distribution grids might cause different issues in the integration such as reverse load flows, protection settings and power quality. Since a significative number of power quality disturbances can be introduced into the grid by PV inverter, the focus of this task, led by University of Lisbon, Portugal, is to is to carry out an assessment of power quality indicators for various PV inverters topologies (micro-inverters, string and central inverters) and to understand their impact on the utility grid vis-à-vis the EN50160 standard. Some of the inverters' assessment will be carried out in the laboratory (when the inverter is available) where different power operating conditions simulating various irradiance levels can be tested.

- PearlSoil: Mapping annual and seasonal soiling in Western Europe

As part of the effort on soiling, the task, led by University of Jaén, Spain, is working to extract the soiling losses from the sites available on the PearlPV dataset, using standard and novel soiling extraction techniques. The work of the team is currently focused on building a model to automatically calculate the performance index and the soiling ratio of the systems, by integrating the PV power data and various climatic data available on public repositories.

- PearlFault: Fault detection for PV system fleets using machine learning

This task, led by University of Madrid, Spain, is developing fault detection algorithms to improve the energy yield of grid-connected PV systems and reduce their power instability. Several complementary approaches are considered, including parametric and non-parametric models, peer to peer (P2P) approaches, Artificial Neural Networks (ANN), stochastic modeling, etc.

WG5 Deliverables Plan

Within the project specification, three main deliverables were identified for WG5 (D14, D15 and D16 detailed below).

D14. Publications of findings originating from WG5 in high-impact journals, conference proceedings and a special issue of an international peer reviewed journal.

Pathway to D14: Several journal publications will be produced. Their exact nature will depend on the advances that will be achieved in each one of the five tasks.

D15. Reports of the WG5 activities (month 12, 24, 36, 48), including the organization of two workshops and two seminars about PV in grids.

Pathway to D15: Workshops and seminars will be held during the course of the project and they will allow to present the main findings obtain as the results of the work done in WG5.

D16. Open source data and software for PV in grids.

Pathway to D16: Several tools will be developed in WG5, and part of their code will be made open source, to be decided as a function of the interest of the parties and the soundness of the use of open source for these tools.

Publications

WG5 has produced several publications in high-level scientific journals and conferences.

Leonardo Micheli, Eduardo F. Fernández, Matthew Muller, Greg P. Smestad, (2020) Florencia Almonacid, Selection of optimal wavelengths for optical soiling modelling and detection in photovoltaic modules. Solar Energy Materials and Solar Cells, Vol. 212, pp. 110539,

Jonathan Leloux, Luis Narvarte, Adrien Desportes, David Trebosc, (2020) Performance to Peers (P2P): A benchmark approach to fault detections applied to photovoltaic system fleets. Solar Energy, Vol. 202, pp. 522-539.

Leonardo Micheli, Jose A. Caballero, Eduardo F. Fernandez, Greg P. Smestad, Gustavo Nofuentes, Tapas K. Mallick, (2019) Correlating photovoltaic soiling losses to waveband and single-value transmittance measurements, Florencia Almonacid, Energy, Volume 180, 2019, pp. 376-386.

Jonathan Leloux, Eduardo Lorenzo, Christian A. Gueymard, (2019) From video games to solar energy: 3D shading simulation for PV using GPU, Jesús Robledo, Solar Energy, Volume 193, 2019, Pages 962-980.

Greg P. Smestad, Thomas A. Germer, Hameed Alrashidi, Eduardo F. Fernández, Sumon Dey, Honey Brahma, Nabin Sarmah, Aritra Ghosh, Nazmi Sellami, Ibrahim A. I. Hassan, Mai Desouky, Amal Kasry, Bala Pesala, Senthilarasu Sundaram, Florencia Almonacid, K. S. Reddy, Tapas K. Mallick & Leonardo Micheli, (2020) Modelling photovoltaic soiling losses through optical characterization, Sci Rep 10, 58.

Andreas Livera, Marios Theristis, George Makrides, Juergen Sutterlueti, Steve Ransome, and George Elias Georghiou, (2019) Performance analysis of mechanistic and machine learning models for photovoltaic energy yield prediction, EU PVSEC 36.

Álvaro Fernández-Solas, Leonardo Micheli, Matthew Muller, Florencia Almonacid, Eduardo F. Fernández, (2020) Design, characterization and indoor validation of the optical soiling detector “DUSST”, Solar Energy, Volume 211, Pages 1459-1468.

Álvaro Fernández-Solas, Leonardo Micheli, Matthew Muller, Florencia Almonacid, Eduardo F. Fernández, (2020) Novel Model to Estimate Transmittance Soiling Losses Using DUSST, an Innovative Soiling Sensor, EU PVSEC 37.

7. Schedule of Meetings

Event	Dates	Location - LO	Targeted audience	Comments
Online Workshop WG 1	3 – 11 – 2020	Online UT, NL	All participants of the Action	Held
Online Workshop WG 3	1 – 12 – 2020	Online UT, NL	All participants of the Action	Held
Online Workshop WG 5	12 – 1 - 2021	Online UT, NL	All participants of the Action	Held
Online Workshop WG 2	2 – 2 - 2021	Online UT, NL	All participants of the Action	Held
Online Workshop WG 4	2 – 3 - 2021	Online UT, NL	All participants of the Action	Confirmed
Online Workshop TBDL	6 – 4 - 2021	Online UT, NL	All participants of the Action	Not confirmed
Seminar *	5 – 7 - 2021	Romania – University of Brasov	All participants of the Action	Confirmed
Training School 3 **	6 – 7 - 2021 until 9 – 7 - 2021	Romania – University of Brasov	Trainees: PhD students, colleagues from academia, industry partners and all participants of the Action	Confirmed
MC5 meeting	22 – 9 - 2021	Online, EURAC, IT	MC members only	Confirmed
Workshops	22 – 9 – 2021 until 24 – 04 - 2021	Online, by the WG leaders' organizations	All participants of the Action and colleagues from academia, industry partners	Confirmed
Conference	March 2022	The Netherlands, Enschede	All participants of the Action and colleagues from academia, industry partners	Dates not confirmed
Training School 4 * **	March 2022	The Netherlands, Enschede	Trainees: PhD students, colleagues from academia, industry partners	Dates not confirmed

*) *Seminar:* Designing with Photovoltaics.

**) *Training School 3:* Simulation tools and models for the forecast of system efficiencies of PV plants – with focus on environmental and integration aspects.

****) Training School 4:* Potential of monitoring tools and advanced operation and maintenance practice for security and predictability of PV performance.

8. Publication Policy of PEARL PV

Authors of papers are allowed to acknowledge PEARL PV only if at least 2 PEARL PV countries are represented. Please make sure that you circulate the author list and an abstract of the manuscript to the relevant WG leader(s), chair and vice chair:

- 2 weeks before submission in case of submission to a peer-reviewed journal, and
- 1 week before submission in case of submission to a conference.

Once published please send a communication to the Action's Science Communication Manager for further dissemination of the publication through the PEARL PV publication list at the website of PEARL PV: https://www.pearlpv-cost.eu/dissemination/publications/

Please follow the dissemination guidelines and COST corporate identity which can be found here http://www.cost.eu/media/dissemination-corporate-identity

Please include the following standard COST acknowledgment in any publication, poster, book, etc.: " This article/publication is based upon work from COST Action CA16235 PEARL PV supported by COST (European Cooperation in Science and Technology)" as well as further texts shown on page 55 of this workplan. Please also include the COST website as well as the PEARL PV, COST logo and EU logo in any publication. If space is limited then only the COST logo should be shown.

9. Core Group and Special Roles

Core Group Members

Role	Name	Country
Action Chair	Prof.dr. Angèle Reinders	Netherlands
Action Vice Chair	Dr. David Moser	Italy
Grant Holder	Mr. Peter Jansen	Netherlands
Working Group 1 Leader	Prof.dr. Wilfried van Sark	Netherlands
Working Group 2 Leader	Dr. Jeff Kettle	United Kingdom
Working Group 3 Leader	Prof.dr. Nicola Pearsall	United Kingdom
Working Group 4 Leader	Dr. Bogdan Gabriel Burduhos	Romania
Working Group 5 Leader	Mr. Jonathan Leloux	Spain
Science Communication Manager	Dr. Sara Mirbagheri Golroodbari	Netherlands

Special Roles

Role	Name	Country
Training School Manager	Dr. Cedric Caruana	Malta
Training School Manager	Prof.dr. Aleksandra Krstic-Furundzic	Serbia
Newsletter Editor	Dr. Sarah McCormack	Ireland
COST Policy Monitoring Manager	Mr Jonathan Leloux	Spain
Science Communication Support	Mr. Vasileios Tompros	Greece
Web Manager	Mr. Fjodor van Slooten	Netherlands

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Website COST Association: www.cost.eu

Website PEARL PV at COST Association: www.cost.eu/actions/CA16235#tabs|Name:overview

Website PEARL PV of the Core Group: www.pearlpv-cost.eu/