HORIZON EUROPE PROGRAMME

TOPIC HORIZON-CL5-2023-D3-01-02

GA No. **101136094**

Sustainable Photovoltaics Integration in buildings and Infrastructure for multiple applications

SPHINX - Deliverable report

MILESTONE No.7 – Monitoring Procedure for demo-site

Funded by
the European Union

1 Milestone Achievement

1.1 Title of Milestone

This document reports the achievement of SPHINX Milestone 7 concerning the monitoring procedure of the demonstration sites.

1.2 Description of Milestone and means of verification

EPFL, CEA and Fraunhofer-ISE will together define by M6 the general monitoring procedure (in line with IEC 61724-1:2021) for the demonstrators as well as the equipment to be used, including the irradiance sensors, temperature sensors, power output, data logger and data transmission. The data will be stored in an accessible portal (following the data management procedure) developed by EPFL to centralize the data treatment and analyse.
The milestone is validated when the report including all requested procedure is done.

In the work-package 5 (WP5) about "Demonstration and validation of SPHINX technology", monitoring activities on photovoltaics (PV) systems aims to demonstrate the advantage of matrix shingle technology compared to standard PV technology.
The present report gives an overview and a guidance for the outdoor monitoring for the different tasks within WP5. To ensure a high level of quality and reproducibility of the data, the IEC 61724-1: 2021 standard about "Photovoltaic system performance – Part 1: Monitoring" is followed first. Secondly a dedicated monitoring website developed by EPFL and supported by CSEM for SPHINX project collects, brings together raw data from different sites and applies the exact same treatment to ensure a lower risk of data treatment errors and a standard and direct comparison of the various PV systems. The website is a tool to store, consult and treat the data of monitoring for the different PV systems to compare their performances.

The present report specifies the requirements relating to:

- The type of photovoltaic modules and systems to be tested,
- The characteristics of the testing facilities (test configurations),
- The type of tests to be performed,
- The measurements to be done and the associated required monitoring equipment,
- The maintenance on the facilities,
- The data transfer to SPHINX monitoring website and data treatment,
- The key performance indicators to be calculated.

Note: this document was written based on systems with one centralized inverter. If the demonstrations sites present constraints regarding this part, the procedure shall be adapted accordingly.

1.3 Standard for monitoring

The IEC 61724-1:2021 standard about "Photovoltaic system performance – Part 1: Monitoring" is dedicated to similar applications but for large PV systems producing electricity where the minimum PV installation size to be monitored ranges from 0 up to 5 MWp. In Sphinx the monitoring will be done on maximum 100kWp system at VOLTEC carport. One effect of having small systems is that most of the performance parameters will be given at direct current (DC) without the loss induced by the inverter, but as we will compare systems in the same configuration, the comparison is acceptable.

1.4 Monitoring within Sphinx

1.4.1 List of sites

In WP5 about demonstration of SPHINX technology, 3 partners will monitor at least 8 sites as shown in Fig. 1.4.1.1 The sites are located from North to South, in Dinsheim-sur-Bruche, (France), Merdingen (Germany), Colombiers (Switzerland), Lausanne (Switzerland), Rossinière (Switzerland), Arzier-Le-Muids (Switzerland), Founex (Switzerland),, , Saint-Paul-lez-Durance (France). The WP5 is structured in 5 tasks following 5 different PV integration types. First task 5.1 is dedicated to industrial building, then task 5.2 is for PV integration in individual houses including façade, task 5.3 is for PV solar tiles integration in heritage house, task 5.4 is for demonstration of advanced PV technology for parking car-port application, and finally task 5.5 is for demonstration for PV integrated noise barrier.

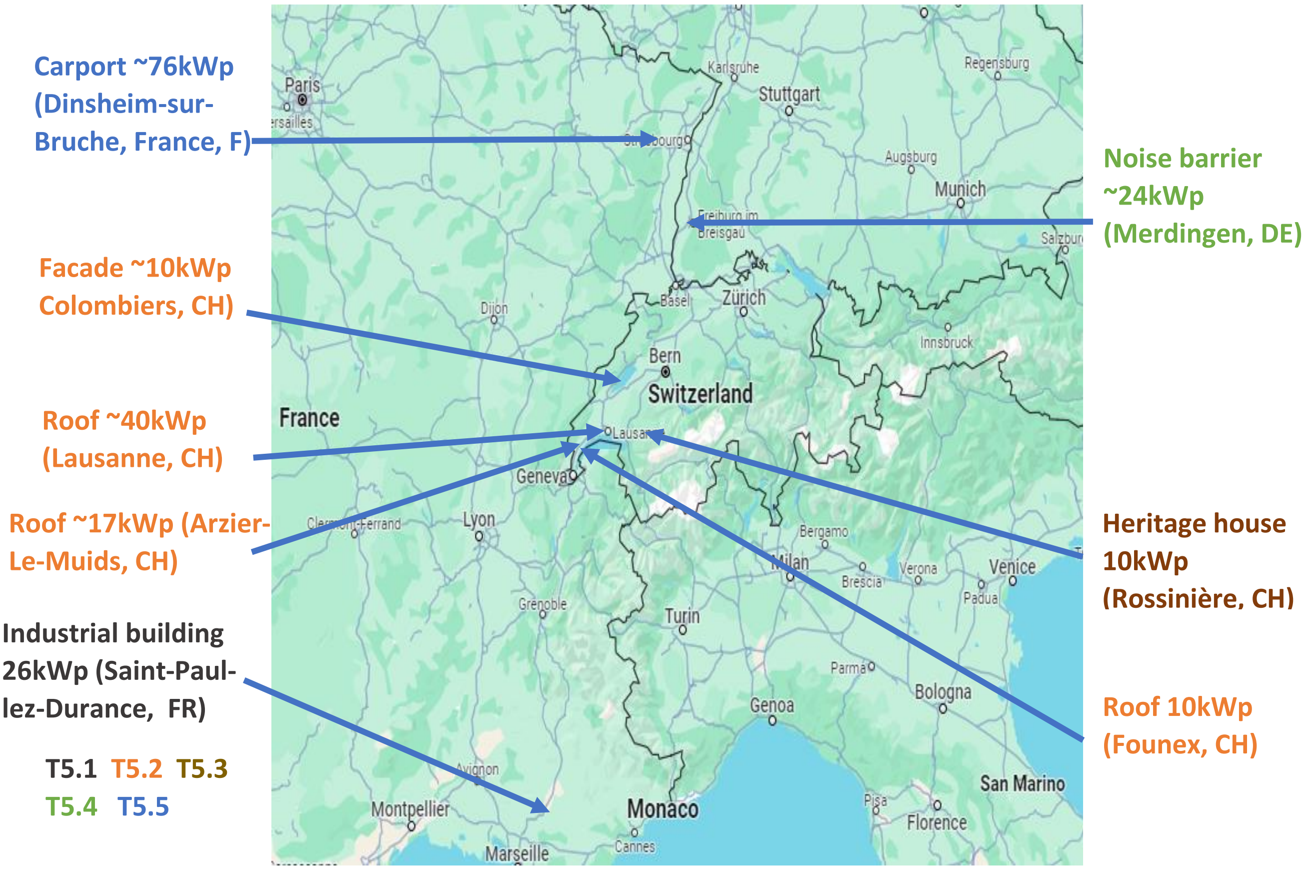


Figure 1.4.1.1 : List of sites for monitoring of SPHINX technology

1.4.2 Characteristic of sites

Demonstrator/Application	Baseline / State-of-art	SPHINX product	SPHINX innovations beyond state-of-art components	SPHINX innovations beyond state-of-art process
Industrial application roof 	Half-cell conventional PV modules	Lightweight PV modules with matrix shingling (HLP)	-matrix shingling Interconnection -antifouling coating - UV selectively absorbing/emitting encapsulant	-equipment and pilot line build up for (flexible) industrialization production focused on matrix shingling with various PV Products -upscaling of encapsulant production with adapted CSEM extrusion line
Heritage application roof 	SOLARISTM Heritage, matt grey, no visible lines, $\leq$138 Wp.m^{-2}	SPHINX tiles for roof with matrix shingling (FSUNS)	-matrix shingling Interconnection -coatings with antiglare properties -shading resilience	
Façade and roof 	Half-cell conventional PV modules	SPHINX (modular) tiles for façade with matrix shingling (FSUNS)		
Parking area carport 	Half-cell conventional PV modules	Customizable semi-transparent PV module (tuneable transparency, colour & wavelength selectivity) (VOL)	- chess patterned matrix shingling concept to adjust light transmission -shading resilience - UV selective absorber & IR-tuned (coloured) encapsulants - coatings with antifouling or antiglare properties	
Noise barrier / PV fence 	Half-cell conventional PV modules	SPHINX semi-transparent bifacial modules (VOL)		

1.4.3 List of modules

The list of modules was initially defined in the proposal and refined during the development phase within WP3. The modules should be produced in WP4 for M18 and send to the various partners within WP5 as soon as the modules are fabricated. For T5.1 about industrial building, lightweight shingle matrix system will be monitored. For T5.2 about PV integration in individual houses including façade, matrix shingle tiles roof and façade system will be monitored. For T5.3 about PV solar tiles integration in heritage house, coloured matrix shingle tiles will be monitored. For T5.4 about demonstration of advanced PV technology for parking car-port application, semi-transparent matrix shingle and standard modules will be monitored. For T5.5 about demonstration for PV integrated noise barrier, custom PV module with current technology, bifacial semi-transparent module with shingle technology and anti-soil module will be monitored.

For the monitoring within WP5, the partners will monitor various benchmark and SPHINX technologies modules (as shown in Table 3.2.1):

- CEA will monitor in Saint-Paul-lez-Durance lightweight matrix shingle modules on industrial building roof in T5.1.
- EPFL will monitor in Colombiers tiles with matrix shingle technologies for individual house facade in T5.2.
- EPFL will monitor in Lausanne, Arzier-Le-Muids and Founex tiles with matrix shingle technologies for individual house roof in T5.2
- EPFL will monitor in Rossinière tiles with matrix shingle technologies for heritage house in T5.3.
- F-ISE will monitor in Dinsheim-sur-Bruche semi-transparent benchmark and matrix shingle modules in T5.4.
- F-ISE will monitor in Merdingen bifacial semi-transparent module with matrix shingle technologies in T5.5.

Tasks	Module type	Azimut h	Tilt	Electrical data	Environmental data	Specific monitoring
T5.1	Lightweight matrix shingle modules (HLP)	0°	Plane tilt ~5° (< max 10°)	- AC current/voltage - DC current - DC voltage at module and system level - IV curves at system level	- Irradiance POA + GHI - Wind - Module temperature - Ambient temperature	- Measurement of thermal behaviour for diagnosis at module and cell level Type: cameras Link: WP3 T3.3 and T5.6 -Measurement of soiling ratio Type: soiling kit Link: WP3 T3.3
T5.2	Matrix shingle roof dans facade tiles	TBD	Depending on demonstrat or	- AC current/voltage - DC current - DC voltage at module and system level	- Irradiance POA + GHI - Wind - Module temperature - Ambient temperature	

T5.3	Matrix shingle heritage tiles	TBD	Roof inclination	- AC current/voltage - DC current - DC voltage at module and system level	- Irradiance POA + GHI - Wind - Module temperature - Ambient temperature	
T5.4	Semi-transparent matrix shingle module	??	??	- AC current/voltage	- Irradiance POA + GHI - Wind - Module temperature - Ambient temperature	
T5.5	Bifacial semi-transparent module	0°	~30° & 90°	- AC current/voltage - DC current - DC voltage at NB segment level	- Irradiance POA + GHI + DNI + DIF - Wind - Module temperature - Ambient temperature	

1.5 Procedures

Each partner from WP5 should follow a list of procedures for the full process of monitoring:

1. System outdoor installation and monitoring (following IEC 61724-1:2021)
2. Weather and site monitoring
3. Data transfer on the SPHINX monitoring website and data check
4. Maintenance

On the side of data storage and data treatment, this will be done on the SPHINX Monitoring Website which will include the following items:

1. Site, systems and modules information
2. Indoor measurement data for each module done in WP4
3. Monitoring data from systems, modules and site
4. Data treatment and data display
5. Monthly score card + ranking (automated procedure, result stored in database)

1.5.1 Indoor measurement

Indoor measurements will be conducted in WP4.

Additionally, for each reference modules should be conducted after stabilization:

- Low light IV curves (200, 400 and 700 $W.m^{-2}$)
- Temperature coefficients for current (α), voltage (β) and power (γ)

- LIV with various angle of incidence (AOI)
- Spectral response and electrical quantum efficiency (EQE)
- For bifacial modules, the bifacialility coefficients φ_{Isc}, φ_{Uoc} and φ_{Pmax}. These are the ratio between I-V characteristic of the rear side and the front side of a bifacial device

1.5.2 Stabilization

Stabilization will be done for the reference modules of each system through outside monitoring. The stabilization procedure is based on MQT 19 of IEC 61215. The stabilization procedure will follow these steps:

1. Record the last indoor P_{max} under 1 000W.m^{-2} -> P_0
2. Put the module outdoor for ~5kWh.m^{-2} of irradiation
3. Measure indoor the Pmax under 1 000W.m^{-2} -> P_1
4. If $|P_1 - P_0| / P_0 < 0.01$, the module is stabilized. Otherwise repeat the steps before by replacing P_0 by P_1

The difference between the first measurements characteristics and the new measurements characteristics will give the coefficients to apply to the system to get its stabilized characteristics.

1.5.3 Monitoring equipment

1.5.3.1 Selection of equipment

Appropriate sensors must be chosen for the parameters to be monitored

- Irradiance is to be measured with a pyranometer or a reference cell, with uncertainty lower than 3% at 1 000 W.m^{-2} and a resolution ≤ 1 W.m^{-2},
- Module temperature is measured with a temperature sensor affixed to the back of one or more modules, with uncertainty lower than ± 1 °C and a measurement resolution ≤ 0,1 °C. Adhesive or interface material between the temperature sensor and the rear surface of the module shall be thermally conductive. The total thermal conductance of the adhesive or interface layer shall be 500 W.m^{-2}.K^{-1} or greater, to keep the maximum temperature difference between the module's rear surface and the temperature sensor on the order of approximately 1 K,
- Ambient air temperature is measured with uncertainty lower than 1°C and a measurement resolution ≤ 0,1 °C,
- Electrical measurements are to be measured at (DC input) and AC output of inverters, with uncertainty as follow:
    - (Input voltage (DC) ±2,0%)
    - (Input current (DC) ±2,0%)
    - (Input power (DC) ±3,0%)
    - Output voltage (AC) (±2,0%) ±3,0%
    - Output current (AC) (±2,0%) ±3,0%
    - Output power (DC) (±3,0%) ±4,5%
- If not possible, do it on the inverters side.
- Wind speed sensor measurement uncertainty shall be ≤ 0.5 m.s^{-1} for wind speeds ≤ 5 m.s^{-1}, and ≤ 10 % of the reading for wind speeds greater than 5 m.s^{-1}. Wind direction shall be measured with an accuracy of 5°.

Here a list of suggested sensors that match these recommendations:

- Pyranometers:
    - SR30-M2-D1 pyranometer

    - SMP10 Pyranometer + CVF4 Ventilation Unit
    - EKO MS-80 Pyranometer
- Reference cell:
    - Si-V-1.5TC-T or **Si-RS485TC-2T (GPOA + Tmod sensor)**
    - See detail list
- Module temperature:
    - CS241DM or **Si-RS485TC-2T (GPOA + Tmod sensor)**
- Ambient air temperature:
    - 3S-AT-PT1000-MB
- Electrical measurements:
    - Depends on system size

1.5.3.2 Installation

- In-plane irradiance is measured with an irradiance sensor oriented parallel to the plane of array (POA),
- Global horizontal irradiance (GHI) is measured with a horizontally oriented irradiance sensor,
- Rear irradiance should be measured with an irradiance sensor placed at mid height of the system. The ratio between the rear side POA irradiance and the front side POA irradiance shall be noted as ρ_i,
- Irradiance sensors placement shall be chosen to avoid shading conditions from sunrise to sunset. Shading should only occur within half hour of sunrise or sunset and any shading shall be documented,
- For class B system, regular cleaning of irradiance sensor is not mandatory, yet sensors shall be maintained according to manufacturer requirements. Maintenance requirements may include, for example, desiccant inspection and/or replacement, where applicable,
- Module temperature sensor should be placed in the middle of a module; for bifacial module, special attention should be paid not to make shadow with the adhesive or interface material,
- Air temperature sensor should be at a location representative of array conditions, and 1 m away from obstacles,
- Wind speed and direction are to be measured at a height and location which are representative of the array conditions.

1.5.4 Data acquisition

The IEC 61724-1:2021 recommend:

- Time between each data sample shall be maximum 1min.
- Time between each data recording shall be maximum 15min. Data recording should be the mean of the data samples during the recording period.
- Time between reports can be 1 day, 1 week, 1 month or 1 year. It is recommended to have all these reports timing available.
- Timestamp record is the ending of interval

Recording interval was set to maximum 5 minutes for SPHINX project.

The timestamp of recordings will be in UTC+00:00.

When multiple data acquisition units are involved that each independently apply timestamps, the clocks of the units must be synchronized, preferably by an automated mechanism such as global positioning system (GPS) or network time protocol (NTP).

1.5.5 Data filtering

Performance of system should be restricted to daylight hours, i.e. excluding measurements referring to an irradiance lower to 20 $W.m^{-2}$. Outliers' data must be filtered out or be replaced.

The following methods will be applied on the online SPHINX platform to clean the data before rendering and report evaluations:

- applying physically reasonable minimum and maximum limits for irradiance and temperature values,
- applying physically reasonable limits on maximum rates of change for irradiance and temperature,
- applying statistical tests (like z score) to identify outlying values, including comparing measurements from multiple sensors,
- applying contract data to identify viable parameter boundaries for certain performance data,
- noting error codes returned by sensors and report them into a database,
- identifying and deleting redundant data entries,
- identifying missing data and replace them by previous or next data when reasonable (less than 5 missing values),
- identifying readings stuck at a single value for an extended time,
- checking timestamps to identify gaps or duplicates in data,
- checking system availability reports.

1.5.6 Monitoring duration

Data will be measured for an entire year during the monitoring phase.

1.5.7 Maintenance

To ensure data acquisition is working correctly, some maintenance must be done such as:

- Regular visual inspection to check the state of modules, of sensors … (weekly inspection),
- Regular inspection of monitoring data quality and acquisition (daily inspection),
- Regular module and irradiance sensor cleaning (monthly, using squeegee with deionized water).

For an easier visual maintenance, cameras can be installed looking directly at the system.

1.6 Monitoring parameters

1.6.1 Monitoring parameters for site

The monitoring parameters for the site are presented in Table 5.1.1. The most important parameters are the module temperature and the in-plane irradiance (in red in the table) as these two parameters will be used later to calculate the performance ratio. Without these parameters the system performance could not be compared to the others and the most important value for system comparison will be unknown. All the other parameters are important for data analysing and to answer special questions when analysing the data.

Parameter – IEC 61724-1:2021	Units	Number sensors	Interval (sec)
Irradiance			
In-plane irradiance (tilt, azimuth)	$W.m^{-2}$	1	3
Global horizontal irradiance	$W.m^{-2}$	1	3
Environmental Factor			
PV module temperature	°C	1	3
Ambient air temperature	°C	1	3
Wind speed	$m.s^{-1}$	1	3
Wind direction	degrees	1	3
Soiling ratio (clean once a week)		1 if concerned	60 (1 per day)
Rainfall	cm	1	60
Extra parameters			
Backside plane irradiance	$W.m^{-2}$	1 if concerned	3
Web-cam module	image	1 if possible	600

1.6.2 Monitoring parameters for array & module

Electrical Output	Units	Number sensors	Interval (sec)
Array voltage (DC)	V		3
Array current (DC)	A		3
Array power (DC)	W		3
Output voltage (AC)	V		3
Output current (AC)	A		3
Output power (AC)	W		3
Output power factor		1	3

1.7 Specific shading monitoring

As matrix shingle technologies shows up to 3 times performance under partial shading condition compared to standard module, it is important to be able to see the actual improvement with partial shading.

1.8 Sphinx monitoring website

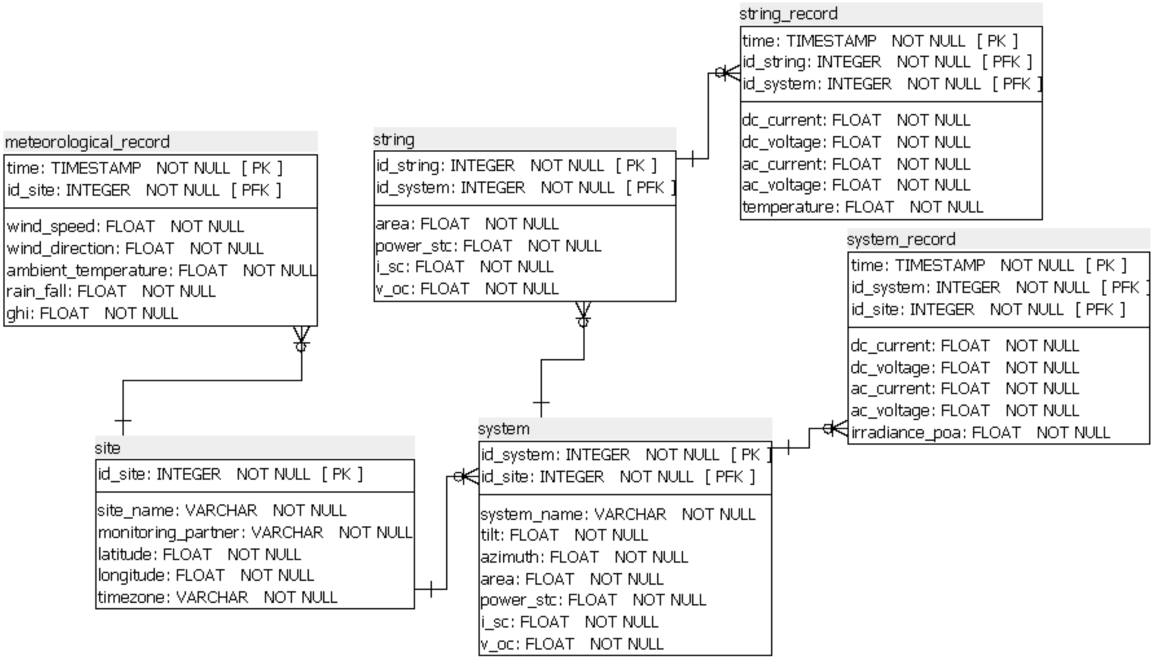
The SPHINX monitoring website was developed by EPFL within SPHINX to enable a centralization of data, a similar data treatment and data analysis, and a simple way to check and compare the monitoring data produced within SPHINX. The website can be accessible on this link. A compete introduction and detailed help to access and the use of the SPHINX monitoring website is described in the Annexe A.

1.8.1 Reference measurement + Indoor measurement

Each module will receive a unique ID from production in WP4 that will be recorded on the SPHINX monitoring website. Each system will be a combination of some produced modules

1.8.2 Data transfer

Data transfer will be done automatically on an hour basis through SFTP csv files sending. These files will fill the following database:



On each data sending to the server, the monitoring site will send 3 csv files :

- string_record_<date>.csv:

time	id_string	dc_current	dc_voltage	ac_current	ac_voltage	temperature
2024-03-26 13:46:57	1	10.5	30.75	10	28.3	12.3
2024-03-26 13:51:57	2	9.5	24.3	9	24.1	12.5
2024-03-26 13:56:57	1	11.1	21	8	20.5	12.8
2024-03-26 14:01:57	3	12.4	17.64	12.1	17.23	13.4

- system_record_<date>.csv :

time	id_system	dc_current	dc_voltage	ac_current	ac_voltage	irradiance
2024-03-26 13:46:57	1	10.5	30.75	10	28.3	752
2024-03-26 13:51:57	2	9.5	24.3	9	24.1	813
2024-03-26 13:56:57	1	11.1	21	8	20.5	860
2024-03-26 14:01:57	3	12.4	17.64	12.1	17.23	950

- meteorological_record_<date>.csv :

time	id_site	wind_speed	wind_direction	ambient_temperature	rain_fall	ghi
2024-03-26 13:46:57	1	7	30.75	10	28.3	752
2024-03-26 13:51:57	2	8	174	9	24.1	813
2024-03-26 13:56:57	1	9	10	8	20.5	860
2024-03-26 14:01:57	3	6	30	12.1	17.23	950

1.8.3 Performance indicator

A comparison of system performance will be conducted based on calculation indicators such as the ones defined in the standard IEC 61724-1:2021.

1.8.3.1 Daily irradiation in the plane of modules

The in-plane daily irradiation H is the sum of the irradiance collected in the plane of modules over the considered time duration:

$$H = \sum G_i \times \tau_i$$

where τ_i is the sampling period. It is expressed in $kWh.m^{-2}$

1.8.3.2 Daily production (energy delivered into the grid)

The daily production E_{out} is the sum of the supplied power over the considered time duration:

$$E_{out} = \sum P_{out} \times \tau_i$$

where τ_i is the sampling period. It is expressed in kWh.

From the powers measured at input and output of the inverter, it is possible to calculate the energy amounts at the output of the PV array E_A and the inverter E_{inv}:

$$E_A = \sum P_A \times \tau_i \quad \text{and} \quad E_{inv} = \sum P_{inv} \times \tau_i$$

1.8.3.3 PV array yield YA, PV system yield Yf, reference yield Yr

- Reference yield:

The **reference yield Y_r** can be calculated by dividing the total in-plane irradiation by the module's reference in-plane irradiance $G_{i,ref}$ ($1\ kW.m^{-2}$):

$$Yr = H / G_{i,ref} = \left(\sum G_i \times \tau_i \right) / G_{i,ref}$$

It is expressed in $kWh.kW^{-1}$.

- Bifacial reference yield:

The **reference yield for a bifacial module Y_r^{bi}** can be calculated by taking the product of the front-side in-plane irradiation and the bifacial irradiance factor and dividing by the module's reference plane-of-array irradiance:

$$Y_r^{bi} = \left(\sum G_{i,k} \times \tau_k \times BIF_k \right) / G_{i,ref}$$

Where $BIF_k = (1 + \varphi_{Pmax} \times \rho_i)$

- Array yield:

The **array yield Y_A** is the daily array energy output (E_A) per kW of installed PV array (P0):

$$Y_A = E_A / P_0 = \left(\sum P_A \times \tau_i \right) / P_0$$

It is expressed in $kWh.kW^{-1}$.

- Final PV system yield:

The final PV system yield, Y_f, is the portion of the net energy output of the PV system (E_{out}) per kWp (front face of modules only) of installed PV array (P0):
It is expressed in $kWh.kW^{-1:}$

$$Y_f = E_{out} / P_0 = (\Sigma P_{out} \times \tau_i) / P_0$$

1.8.3.4 Performance ratio

The performance ratio, PR, is equal to the ratio between Y_f and Y_r yields:

$$PR = Y_f / Y_r$$

It indicates the overall effect of losses on the array's rated output due to array temperature, incomplete utilization of the irradiation, and system component inefficiencies or failures. It can be expressed in %.

As is well known, temperature has a strong effect on performances depending on the season. It is therefore useful to determine the array ratio with a temperature compensation to have a 25°C-array ratio for each day or month (i.e. ratio calculated without considering temperature losses). Temperature coefficients for power (**γ**) stem from datasheets for commercial modules and will be measured in WP3 for all the technologies from SPHINX.

$$P'_{out\_25°C} = P_{out} / [1 + \gamma \times (T-25)]$$

Y_f_25 and $PR'_{25°C}$ are then evaluated based on $P'_{out\_25°C}$.

1.8.3.5 Performance ratio of the array

To compare performance ratios of different systems, it is better to take the DC power as reference instead of the AC power to remove the possible impacts of the inverter.

The **Performance Ratio of the Array PR_a** is equal to the ratio between the array yield Y_a (using DC power) and reference yield Y_r :

$$PR_a = Y_a / Y_r$$

It indicates the overall effect of losses on the array's rated output due to array temperature, incomplete utilization of the irradiation, system component inefficiencies or failures, module mismatch. It can be expressed in %.

A temperature compensated array ratio **PR'_{a_25}** can also be calculated as it is done for PR.

Note: as PR and AR are based on the front face power of modules (P_0), these yields may exceed 100% for bifacial modules, as they include the gain provided by the rear face of modules.

1.8.3.6 Surface energy

The **surface energy production Y_s** is the daily DC array energy output (E_{DC}) per m^2 of installed PV array (S):

It is expressed in $Wh.m^{-2}$.

$$Y_s = E_{DC} / S = (\sum P_{DC} \times \tau_i) / S$$

Then one may calculate the surface ratio as well, which is equal to the ratio between Y_s and Y_r (solar irradiation expressed in hours at 1000 W/m^2) yields:

$$SR = Y_s / Y_r$$

It is expressed in $W.m^{-2}$.

1.8.3.7 Soiling

The soiling ratio SR is calculated by measuring the short-circuit current and the temperature of the clean device and either the max power (method 1) or the short-circuit current (method 2) and the temperature of the soiled device.

The instantaneously measured values shall be integrated to compute a **daily average value**.

1.8.4 Monitoring results presentation

This part will be completed when the SPHINX monitoring web site is finished.

1.9 Comments on completion

The milestone was achieved using the IEC 61724-1:2021 document.

1.10 Other relevant information

Lead beneficiary	Antonin FAES (EPFL)
Linked WP	WP3, WP5
Achievement date in DoA	April - 2024
Actual date	
Achieved	Yes / No
Reference documents	Mention relevant documents (if any)

1.11 Interconnections with deliverables

This document is related to 6 deliverables:

- D5.2 Renovation of industrial buildings
- D5.3 PV integration in individual houses including façade
- D5.4 PV solar tiles integration in heritage house
- D5.5 Demonstration of advanced PV technology for carport application
- D5.6 Demonstration for PV integrated noise barrier
- D5.7 Performance of demonstrators

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Project partners:

#	Partner short name	Partner Full Name
1	VOL	VOLTEC SOLAR
2	ETW	ETWAY S.R.L.
3	HLP	HELIUP
4	M10	M10 INDUSTRIES AG
5	UNR	UNIRESEARCH BV
6	Fraunhofer	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV
7	ICARES	ICARES CONSULTING
7.1	BI	BECQUEREL INSTITUTE FRANCE
7.2	BIE	BECQUEREL INSTITUTE FSPAIN
8	CEA	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
9	FSUNS	Freesuns SA
10	CSEM	CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT
11	EPFL	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE
12	SOP	SOPREMA

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