GUIDELINES FOR THE MONITORING OF PV SYSTEMS

Summary of questionnaire

COST ACTION PEARL PV: CA16235

Working Group 1, Task 1.1

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GUIDELINES – SUMMARY OF QUESTIONNAIRE

The following is a brief summary of findings from the questionnaire in T1.1. The responses show a large variation in the requirements for monitored data, and generally answers follow an approach 'the more, the better'. Hence, extracting exact results from the questionnaire is difficult. For a given question some may have responded "absolutely necessary" and others "not required", reflecting the large variation in the user group applications.

Due to the spread in answers, only the trend is given in the summary and tables below (Table 1 - Table 17). **The trend is here defined as the answer given by 50 % or more of the total respondents of each question**. Answers have been lumped into three categories: **Required** (referring to "absolutely necessary"), **Desired** (combining the two categories "highly desired" and "nice to have"), and **No need** (referring to "not required").

In most cases, all answers fall within the required/desired categories and the "no need" category is empty. This shows that it is difficult to move away from the traditional "laboratory monitoring", which typically involve a high degree of instrumentation and detailed information. For "commercial monitoring", i.e. data collection from real PV system installations, practical and economic constraints usually limit the amount of available data.

This underlines the need for the work planned in the PEARL-PV project: A switch in paradigm from assessing a limited amount of data of high quality (typically lab data) to assessing a very large amount of data of lower quality (monitoring data). New methods, such as the application of machine learning techniques, may be of help to achieve this goal.

Quality Control: In terms of quality control, most respondents require that instrumentation/sensor accuracy should be specified, data quality control processes should be in place, and a minimum requirement for data accuracy should be set.

File Format: Most respondents prefer "csv" file format, with missing datapoints reported as "NaN" and using 1-second time stamp resolution (YYYY-MM-DDTHH:MM:SS). Two respondents require sub-second resolution data (SS.ssss), indicating special applications such as grid interaction analysis. Reporting of missing datapoints (e.g. number or time period of datapoints missing) is desired, not required.

Metadata - PV system and components: Generally, respondents agree that a relatively large amount of metadata should be made available to adequately document the system and technology used. Required information is: Site name and GPS coordinates, type of PV installation (fixed, tracking, BAPV/BIPV, roof/façade, etc), type of PV module technology, PV module characteristics (Impp, Vmpp, Isc, Voc, Pmpp, temperature coefficients), string design (number of modules, number of strings, connections to each inverter), shading (no shading), type of inverter technology (central, string, micro, transformerless, etc), inverter specifications (AC/DC power, frequency, rated efficiency, number of phases, reactive power, number of independent MPP's, total number of inverters, communication protocols). When applicable, the following BOS-components should be specified: Battery-system and own developed hardware/software. Information about other parts of the BOS is desired, not required.

Metadata - Instrumentation and sensors: For the meteorological instrumentation, details and accuracy of pyranometer, air temperature sensor, PV module temperature sensor are required. Wind and other meteorological sensor information is desired, not required. For other instrumentation, the details and accuracy of power meters (DC and AC) and system status information (system downtime, sensor failure, cleaning events) is required. Metadata for IR and EL imaging and specific purpose irradiance sensors is desired, not required.

Monitored data - meteorological: For monitoring of meteorological parameters, the required data is: Global horizontal irradiance, global plane-of-array irradiance, air temperature. The required sample rate is 1 sec and 1 min, with a record rate of 1 min. Other parameters (diffuse/direct/spectral irradiance, albedo, air pressure, wind speed/direction, humidity, precipitation) are desired, not required.

Monitored data - Yield and durability: For monitoring of yield from PV modules/strings, the required data are: Ambient temperature, module temperature, plane-of-array irradiance, module/string Impp, Vmpp, and Pmpp, sampling time. In terms of datalogging, a minimum time series of 1 month and 1 year should be available, with a sample rate of 1 min and 1 hr, and a record rate of 1 min and 1 hr. Sample and record rates less than 1 sec are not required.

For monitoring of degradation of PV modules/strings, the required data is: IV-curves recorded several times a day and once a week, cleaning frequency of PV modules and irradiance sensors (soiling), visual inspection and leakage current detection. Other failure or degradation indicators (corrosion, IR/EL/UV-FL images, or combined methods) are desired, not required.

Monitored data - PV in the built environment: For monitoring of PV in the built environment, the required data is: Technical integration aspects (specification of BIPV module and fastening system, material choices, weatherproofing, installation procedures, operation and maintenance, electrical safety), and thermal considerations (ventilation of modules, temperature of modules, thermal properties, indoor temperatures). Information about architectural integration is desired, not required.

Required data for other aspects are: Hybrid energy system (type of hybrid system, energy share and power share profile of the hybrid system), environmental footprint (energy payback time), and economic considerations (system costs, economic models, economic value of distributed energy production). Life cycle analysis and the added value of building integration is desired, not required.

Monitored data - PV in grids: For monitoring of PV in grids, the required data is: Inverter output power factor, current and voltage on each phase, active power of load, active power to/from grid, net active power and net energy (generation-load matching). For applications with energy storage, required data is: Operating voltage of energy storage, current to/from energy storage, and active power to/from energy storage. The required sample rate is 10 msec (sinewave), 1 sec, 1 min and 15 min, with similar record rates (10 msec, 5 sec, 1 min and 15 min).

Information about reactive power flows, grid frequency and voltage stability, harmonics, and specific load characteristics is desired, not required.

Modelled data - PV simulation: For PV simulation, the required data is: Weather and irradiance input files (synthetic/TMY files, ground recorded data), and datasheets for the components modelled. The components required to be modelled are the inverter and the PV system. Models of PV modules/strings and BOS components (except inverter) are desired, not required. The simulation resolution should be 1 min and 1 hr.

Other aspects, such as modelling the performance, external influences, thermal properties, building integration, and combined models for electrical/thermal/building properties, are desired, not required.

Quality Control

Table 1: Quality control

Required	Specified instrumentation/sensor accuracy. Minimum requirement for data accuracy.
Desired	Calibration procedures. Data quality control processes (inspection, automated, etc). Data handling processes (filtering, interpolation).
No need	

File format

Table 2: File format

	File format	Timestamp (YYYY-MM-DDT)	Reporting missing datapoints	Format of missing datapoints
Required	csv	HH:MM:SS		NaN
Desired	ascii xml combination (MET_IEC)	HH:MM HH:MM:SS:ssss	Period of datapoints missing Number of datapoints missing Hours of missing data per year	-9999.9
No need				

Metadata – PV system and components

Table 3: Metadata – PV system and components: Site, PV installation

	Site	PV installation
Required	Site name GPS coordinates	Fixed installation: Tilt angle (0-90°), azimuth angle (0-360°) Tracking installation: 1-axis (E-W), 1-axis (N-S), 2-axis Building Attached, Building Integrated, Free-standing system Tilted/Flat roof, Façade, Window blinds, Shelters, Sunshading, Semi-transparent, Other
Desired	Site address Site elevation Time zone UTC	Mixed installation (different technologies, combinations)
No need		

Table 4: Metadata – PV system and components: PV module technology and characteristics

	PV module technology	PV module characteristics
Required	PV technology (mono-Si, CIGS, etc)	Pmpp, Impp, Vmpp, Isc, Voc, Efficiency, Temp coeff Pmp, Temp coeff eff, NOCT
Desired	Brand name Manufacture time Installation time	Number of cells per module Number of bypass diodes per module Size of module: outer frame, aperture area Weight of module
No need		

Table 5: Metadata – PV system and components: PV string design, shading from surroundings

	PV string design	Shading from surroundings
Required	Total number of modules in system Combination of different modules in system Number of strings connected to each inverter Total number of strings in system Complex string designs	No shading
Desired	Number of series- / parallel-connected modules in each string Microinverters/optimizers	Near shading Far horizon shading
No need		

Table 6: Metadata – PV system and components: Inverter technology and specifications

	Inverter technology	Inverter specifications
Required	Inverter type: Central, string, microinverter, power optimizer, transformerless /with transformer Combination of different inverters	Max AC output power, AC power frequency, Max DC input power, rated efficiency 1-phase / 3-phase, Reactive power control Number of independent MPP inputs Total number of inverters in system Data exchange/communication protocol (RS485)
Desired	Brand name	Data exchange/communication protocol: RS485, RS232, MODBUS, Bluetooth, Web interface
No need		

Table 7: Metadata – PV system and components: BOS components, battery/storage system, surveillance

	BOS components	Battery/storage system	Surveillance
Required	Battery-connected system		Own developed hardware/ software
Desired	DC cable type DC cabling length AC cable type AC cabling length Number and type of protective devices System grounding Lightening protection Grid-connected system	Type/model, technology Energy storage capacity Charge/discharge capacity Total number of batteries System topology, control Other energy storage devices: Supercapacitor, hydrogen/fuel cell, other.	Proprietary hardware/ software Dedicated personnel for surveillance / No dedicated personnel for surveillance
No need			

Metadata – Instrumentation and sensors

Table 8: Metadata – Instrumentation and sensors: Irradiance, temperature, wind, other MET sensors

	Irradiance	Temperature	Wind	Other MET sensors
Required	Details and accuracy of: • Pyranometer	Details and accuracy of: • Air temp. sensor • PV module temp. sensor		
Desired	Details and accuracy of: • Reference cell • Pyrheliometer • Spectral irradiance instrumentation • Albedo sensor • Combination of irradiance sensors	Details and accuracy of: • Air dewpoint temperature sensor details, accuracy	Details and accuracy of: • Wind sensor (speed and direction)	Details and accuracy of: • Air pressure sensor • Air RH sensor • Liquid precipitation/rain • Solid precipitation/snow • Dust sensor
No need				

Table 9: Metadata – Instrumentation and sensors: Current and voltage, power, IR and EL imaging, system status

	Current and Voltage	Power	IR and EL imaging	System status
Required		Details and accuracy of: • DC power meter • AC power meter		• System downtime • Sensor failures • Cleaning events
Desired	Details and accuracy of: • DC voltage transducer • DC current transducer • AC voltage transducer • AC current transducer	Details and accuracy of: • AMS two-way power meter	• Camera type, model • Parameters used (e.g. emissivity value for IR imaging) • Procedure used (UAV, technicians, etc.)	• System changes • Communication downtime • External influences
No need				

Monitored data – Meteorological

Table 10: Monitored data – Meteorological: Solar radiation, climate and weather, sample rate, record rate

	Solar radiation	**Climate, weather**	**Sample rate (MET data)**	**Record rate (MET data)**
Required	• Global horizontal irradiance • Global plane-of-array irradiance	• Air temperature	• 1 sec • 1 min	• 1 min
Desired	• Diffuse horizontal irradiance • Direct normal irradiance • Spectral irradiance • Ground albedo	• Air pressure • Air RH • Wind speed • Wind gusts, max • Wind direction • Dew point temp. • Liquid precipitation • Solid precipitation	• 15 sec • 15 min • 1 hr • 1 day	• 15 min • 1 hr • 1 day
No need				• Less than 1 sec • 15 sec

Monitored data – Yield and durability

Table 11: Monitored data – Yield and durability: Time series of data, PV module/string yield, sample rate, record rate

	Time series of data (long term yield)	**PV module/string yield**	**Sample rate (yield data)**	**Record rate (yield data)**
Required	• Minimum 1 month • Minimum 1 year	• Ambient temp. • Module temp. • POA irradiance • Module/string Impp • Module/string Vmpp • Module/string Pmpp • Sampling time of yield measurements	• 1 min • 1 hr	• 1 min • 1 hr
Desired	• Minimum 5-10 years • Minimum 15-25 years		• 1 sec • 5 sec • 15 sec • 15 min • 1 day	• 1 sec • 15 sec • 15 min • 1 day
No need			• Less than 1 sec	• Less than 1 sec

Table 12: Monitored data – Yield and durability: PV module/string IV-curve, soiling, other failure or degradation factors

	PV module/string IV-curve characteristics	Soiling	Other failure or degradation indicators
Required	• Recorded several times a day • Recorded once a week	• Cleaning frequency of PV modules • Cleaning frequency of irradiance sensors	• Leakage current • Visual
Desired	• Recorded continuously at 1-min intervals • Recorded once per month • Recorded once per year	• Type of soiling measurement system • Power loss caused by soiling • Performance analysis before/after cleaning • Type of dust causing soiling • Analysis of soiling	• Corrosion • IR-imaging • EL-imaging • UV FL-imaging • Combination of failure detection methods
No need			

Monitored data – PV in the built environment

Table 13: Monitored data – PV in the built environment: Building technical/architectural integration, thermal considerations

	Building technical integration	Architectural integration	Thermal considerations
Required	• BIPV module and fastening system • Material choices • Weatherproofing • Installation procedures • Operation and maintenance • Electrical safety		• Ventilation of modules • Temperature of modules • Thermal properties, insulation • Indoor temperatures
Desired		• Aesthetics, colour, shape • Special designs	
No need			

Table 14: Monitored data – PV in the built environment: Hybrid system, environmental footprint, economic considerations

	Hybrid energy system	Environmental footprint	Economic considerations
Required	• Type of hybrid system combination • Energy share profile of the hybrid system • Power share profile of the hybrid system	• EPBT	• System costs • Economic models • Economic value of distributed energy production
Desired		• LCA	• Added value of building integration • Added value of environmental image
No need			

Monitored data – PV in grids

Table 15: Monitored data – PV in grids: Grid integration, load characteristics, utility grid, generation-load matching

	Grid integration	Load characteristics	Utility grid	Generation-load matching
Required	• Inverter output power factor • Current, Voltage on each phase	• Load active power	• Active power to/from grid	• Net active power • Net energy
Desired	• Inverter active, reactive power • Grid frequency and voltage • Harmonics in Current, Voltage • Max/min variations in grid frequency, voltage	• Load voltage • Load current • Load reactive power • Values on each phase	• Utility voltage • Current to utility grid • Current from utility grid • Active power to/from grid • Reactive power to/from grid	• Net reactive power
No need				

Table 16: Monitored data – PV in grids: Energy storage, other system information, sample rate, record rate

	Energy storage	Other system information	Sample rate (grid data)	Record rate (grid data)
Required	• Energy storage operating voltage • Current to / from energy storage • Active power to / from energy storage		• 10 msec, sinewave • 1 sec • 1 min • 15 min	• 10 msec, sinewave • 5 sec • 1 min • 15 min
Desired		• Alarms, downtime, fault detection • System earth resistance • Ground leakage current • Grid management value of distributed production • Smart grids/home management systems	• 5 sec • 15 sec • 1 hr	• 15 sec • 1 hr
No need				

Modelled data – PV simulation

Table 17: Modelled data – PV simulation: Weather/ irradiance files, model information and purpose, simulation resolution

	Weather and irradiance input files	Available information	What should be modelled?	Simulation resolution
Required	• Synthetic data, TMY data • Ground recorded data	• Datasheets for components	• Components: Inverter, PV system	• 1 min • 1 hr
Desired	• Satellite data	• Type of simulation model used • Comparison of modelled vs measured data	• Components: PV modules, strings, BOS • Performance • External influences • Thermal properties • Building integration • Combining electrical, thermal, building properties • Grid interaction • Forecasting models for PV production	• 1 sec • 15 min
No need				• 1 day

Appendix Compilation of questionnaire results

This appendix is a compilation of answers to the questionnaires sent to experts in PV monitoring domain. In the preliminary work done, the questionnaire was developed on the basis of information available on different documents. Various international standards and guidelines are referred when preparing the questionnaire. This questionnaire mainly addresses three aspects. Collection of the metadata about the site, collection of the monitored data and handling process and file formats.

The participants were asked to provide the feeback on relevant parameters on the numeric basis of 1 to 4, where 1 meant absolutely necessary parameter, 2 meant highly desired parameter, 3 meant good to have parameter and 4 meant not a required parameter.

The most chosen parameters are presented in the tabular form within the report while the responses from the experts are presented in annex in a graphical form, nested within the intial questionnaires provided to the participants. The comments made by the participants is also included in the comments box below the graphs of response. These comments include suggestions, recommendations and experiences from the installations on their institution.

IEC61724-1 presents updated criterias to the monitoring requirement for different capacity system. Inspiration can be taken from the new IEC 61724 series on maintaining a guideline of monitoring the PV systems and thus retreiving the data.

INTRODUCTION

The questionnaire was sent out by email to all members of the PEARL-PV group. The questionnaire contains a list of possible parameters to be logged and stored with options. The purpose of the questionnaire is to discover what kind of data the various groups in the action need for their purposes, i.e., (WG2) Reliability and durability of PV, (WG3) PV simulation, (WG4) PV in the built environment, and (WG5) PV in grids.

WP1 OBJECTIVE:

Develop generally accepted approaches and guidelines for the collection of data about the performance of PV modules and PV systems using advanced monitoring (dataloggers, smart meters, internet scraping, satellite data, visual inspection) in a suitable format for server storage.

T1.1 RECOMMENDATION FOR SCOPE LIMITATION:

The guidelines developed by this COST action should mainly focus on PV system performance data, rather than module performance data, as the IEA PVPS Task 13 expert group has already developed detailed guidelines for outdoor monitoring of PV modules. However, for the purpose of recording the needs of the PEARL-PV members, some questions about PV module monitoring have been included in the questionnaire below.

REFERENCE DOCUMENTS:

Following documents have been referenced during the formulation of questionnaire:

- IEC 61724 standard for «Photovoltaic system performance monitoring guidelines for measurement, data exchange and analysis» (first edition 1998).
- IEC 61724-1: PV Monitoring (2017)
- MET_IEC Data format (IEA SHC Task 46, per Aug-2016).
- DERlab 2011, «DERlab technical guidelines on long-term photovoltaic module outdoor tests».
- Reports from the IEA-PVPS Task 13 «Performance and Reliability of Photovoltaic Systems», available from the website http://www.iea-pvps.org/index.php?id=57 :
    - Report IEA-PVPS Task 13, May-2018, «PV module testing»
    - Report IEA-PVPS T13-12:2018, «Uncertainties in PV System Yield Predictions and Assessments».
    - Report IEA-PVPS T13-09:2017, «Assessment of Photovoltaic Module Failures in the Field».
    - Report IEA-PVPS T13-07:2017, «Improving Efficiency of PV Systems Using Statistical Performance Monitoring».
    - Report IEA-PVPS T13-06:2017, «PV Performance Modelling Methods and Practices».
    - Report IEA-PVPS T13-05:2014, «Analysis of Long-Term Performance of PV Systems».
    - Report IEA-PVPS T13-03:2014, «Analytical Monitoring of Grid-Connected Photovoltaic Systems».

FINDINGS FROM THE SURVEY

The findings from the survey are tabulated below. The total number of participants is 20 but it is not uniform for every option. Some of the experts have chosen to comment on the options and not choose any of the available choices. But, here the most popular options from every category is presented to provide an overview of the response. The detailed responses are presented in the Annex of this document with the graphical plottings and comments from the respective experts.

Table 18: Tabulation of Chosen Parameters

SECTION	SUB-SECTIONS	PARAMETERS CHOSEN
Quality Control	Quality Control	• Instrumentation/sensor accuracy • Minimum data accuracy • Calibration procedures • Data quality control processes • Data handling processes
File Format	• File Format • Date and Time Stamp • Missing Data • Representation of Missing data	• File format: CSV • Time and Date: YYYY-MM-DDTHH:MM:SS • Format for missing data: NaN
Metadata: Site	Site Information	• Site name • GPS Coordinates
Metadata: PV system and Components	• Fixed or tracking system	• Fixed installation, tilt • Fixed installation, azimuth • 1-axis/2-axis tracking
	• Installation Solution: BAPV	• Tilted roof • Flat roof • Facade
	• Installation Solution: BIPV	• Tilted roof • Flat roof • Facade
	• PV Module Technology	• PV technology • Module installation time
	• PV module characteristics	• Pmpp • Impp • Vmpp • Isc • Voc • Efficiency • Temp coeff Pmp/eff • NOCT
	• PV Module: Composition from Cell to System	• Total number of PV modules in system
	• PV String Design	• Number of strings connected to each inverter • Total number of PV strings in system

	• Shading	• Far horizon shading • Near shading • No shading
	• Inverter Technology	• Inverter type
	• Inverter specifications	• Max AC output power • AC power frequency • Max DC input power • Rated max/EU efficiency • 1-phase/3-phase • Reactive power control • Number of independent MPP inputs • Total number of inverters in system
	• Data exchange protocol	• RS485 • MODBUS • Web interface/company specific
	• BOS Components: Cables and System protection	• Cabling, Grounding and Lightening Protections
	• Energy Storage Systems	• Battery Connected System • Other Energy Storage Systems
	• Surveillance of system operation	• Proprietary hardware/software • Own developed hardware/software
	• Irradiance sensors	• Pyranometer Details • Pyranometer accuracy • Reference cell details • Reference cell accuracy
	• Temperature sensors	• Air temperature sensor details • Air temperature sensor accuracy • PV module temperature sensor details • PV module temperature sensor accuracy
	• Wind sensor	• Wind sensor details • Wind speed and direction accuracy
	• Other meteorological / environmental sensors	• Air RH sensor accuracy • Liquid precipitation/rain sensor details • Liquid precipitation/rain sensor accuracy • Solid precipitation/snow sensor details • Solid precipitation/snow sensor accuracy
	• Current and voltage transducers	• DC current transducer details • DC voltage transducer details • AC current transducer details • AC voltage transducer details
	• Power meters	• DC power meter details • AC power meter details
	• IR and EL imaging	• Camera type, model • Emissivity value used for IR imaging

	• System status	• System changes • System downtime • Sensor failures • Cleaning events
Monitored data: Meteorological	• Irradiance Parameters • Meteorological Parameters • Sampling interval of Meteorological data • Recording interval of Meteorological data	• Global Horizontal Irradiance • Global tilted Plane of Array irradiance • Air temperature • Wind speed • Sampling time 1sec-1min • Recording time 1 min
Monitored data: Yield and Durability	• Time Series of Available data • PV module/string yield • Sample rate of Yield data • Record rate of Yield data • PV module/string degradation: I-V Curve Characteristics • Soiling • Other degradation or failure indicators	• Minimum 1 year • Ambient temperature • Module temperature • POA irradiance • Module/string Impp • Module/string Vmpp • Module/string Pmpp • Sampling time of Yield measurement: 5sec to 1min • Record time of Yield easurement : 1min • Cleaning data pf modules and sensors • I-V curve recorded continuously in a day to week • Visual inspection
Monitored Data: PV in the Built Environment	• Building Technical Integration • Architectural integration • Thermal considerations • Hybrid energy systems • Environmental footprint • Economic considerations	• BIPV module and fastening system • Material choices • Electrical safety • Ventilation of modules • Temperature of modules • Thermal properties, insulation • System costs
Monitored Data: PV in Grids	• Inverter Details • Load characteristics • Utility grid • Generation-load matching • Energy storage • Possible downtime and leakages • Sample rate of grid interaction data • Recording rate of grid interaction data	• Inverter output power factor • Current, Voltage on each phase • Load voltage • Load current • Load active power • Utility voltage • Current to utility grid • Current from utility grid • Active power to/from grid • Net active power • Energy storage operating voltage • Current to energy storage • Current from energy storage • Active power to energy storage • Active power from energy storage • Sampling time 1 min, recording time 1 min

Modelled Data: PV Simulation	• Weather and irradiance files • Simulation and Modelling • Modelling components of PV system • Modelling • Required resolution for PV simulation	• Type of simulation model used • Comparison modelled vs measured data • Datasheets for components • Modelling Components PV modules PV strings PV system Inverter • Modeling performance • Modeling thermal properties • Forecasting models for PV production • Required resolution for PV simulation 1 min to 1 day

ANNEX- QUESTIONNAIRE: PV MONITORING GUIDELINES

COST ACTION 16235 PEARL-PV «Performance and Reliability of Photovoltaic Systems: Evaluations of Large-Scale Monitoring Data», WG1, T1.1

INSTRUCTIONS:

For each data entry point in the questionnaire below, please give a rating from 1 to 4 according to your own research needs. The rating represent the following statements:

1. «Absolutely necessary», minimum requirement for data collection.
2. «Highly desired».
3. «Nice to have».
4. «Not required».

If you have other parameter suggestions or comments to the questions in each section, please write in the comment field box.

The questionnaire addresses several categories:

- The data handling process and file format.
- Collection of metadata (information/text).
- Collection of monitored data (numerical).

The difference between sample rate and record rate is defined in the attached information.

NOTE – YOU ONLY HAVE TO RESPOND TO THE CATEGORIES OF RELEVANCE FOR YOUR WORK. (Categories left blank are assumed to be «Not required».)

Please return the form to: Anne Gerd Imenes, anne.g.imenes@uia.no

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QUALITY CONTROL (QC):

Requirements to equipment and data quality (mark relevant option):

- Instrumentation/sensor accuracy: ___
- Minimum data accuracy: ___
- Calibration procedures: ___
- Data quality control processes (inspection, automated, etc.): ___
- Data handling processes (filtering, interpolation): ___

Comment field:

Jonathan, Francesco and Emilio: *Raw data quality is our priority. All data processing is dependent on application.*

Karl Berger: *Yes, all absolutely necessary to care about, but to what extent for which application is the more appropriate question: A multi MW PV plant needs mroe detailed and accurate monitoring* *system than 5 kW rooftop system, and monitoring of single modules for energy rating (IEC 61853 series) in research and certification testing also has different requirements. Within IEC 61724-1 monitoring classes A, B, C are defined.*

The guideline how monitoring of PV system shall look like was also part of FP7 PERFORMANCE project, and within this project an interactive website at JRC/ESTI was created, but now I am unable to find it. @Nicola: do you know if that website is still active, or do you have a copy?

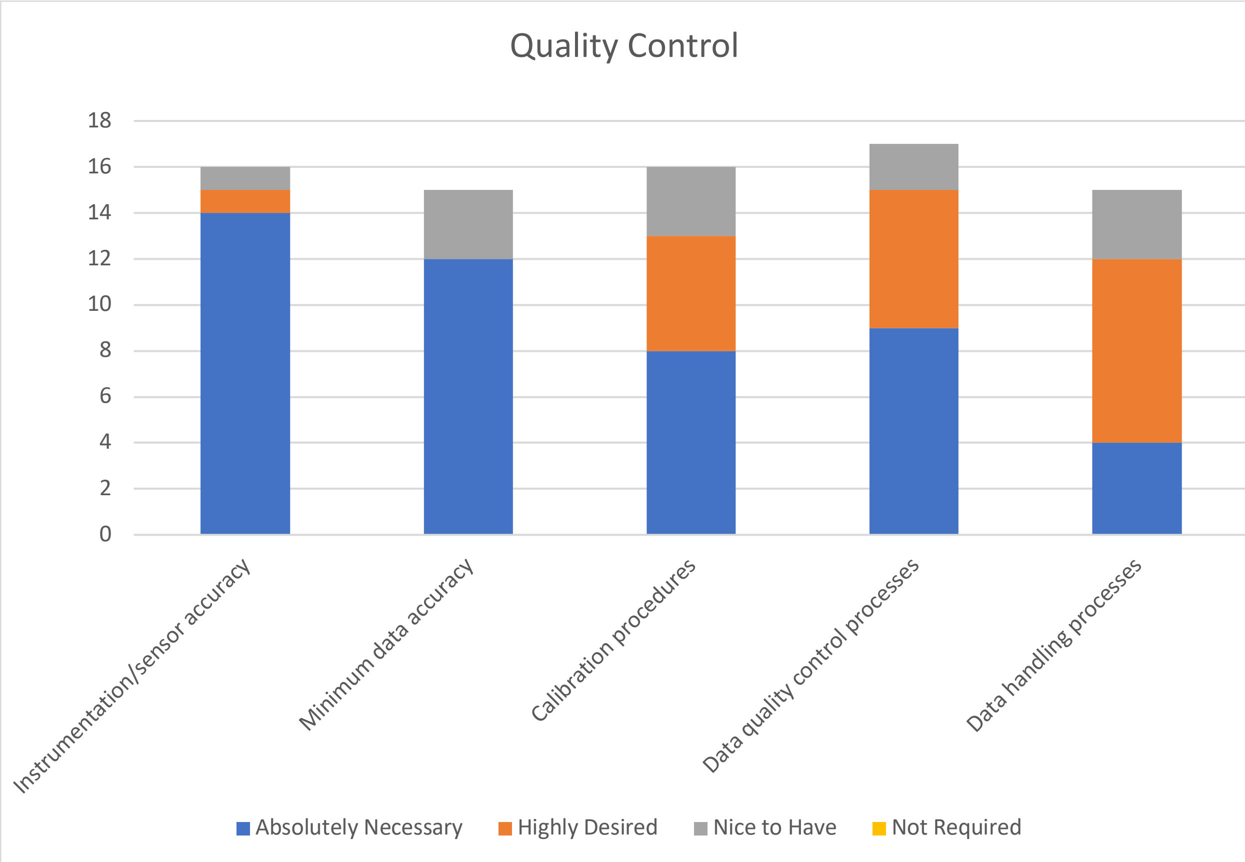

Figure 1: Quality Control

FILE FORMAT

File format (mark relevant option):

XML format: *Most industry data standards, common use for interchange of data over internet.*
ASCII format: *Simple text file, delimiter-separated ASCII 28-31, each line representing one point in time.*
CSV format: *Simple text file, Comma Separated Values.*
CSV format: Combination, ref. MET_IEC format: *Data stored in simple ASCII but includes header that contains all information, can easily be converted into XML for standard web-protocol exchange.*

- XML format: ___
- ASCII format: ___
- CSV format: ___
- Combination, ref MET_IEC: ___

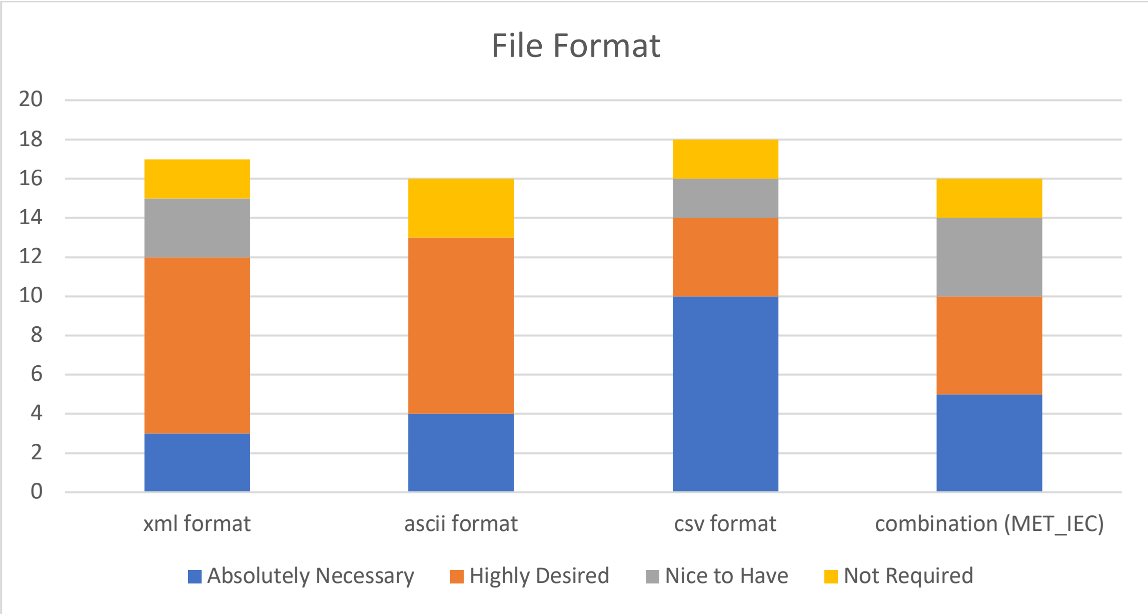

Figure 2: File Format

Date and time stamp format definition: (ref. ISO 8601 (mark relevant accuracy, HH:MM:SS.ssss))

Time stamps for temporally averaged data refer to the end of the integration period, and to the complete time interval, including sunrise/sunset point when sun is at or already below horizon.

Example: 2015-01-01T12:45:00.0000

- Format: YYYY-MM-DDTHH:MM:SS.ssss :___
- Format: YYYY-MM-DDTHH:MM:SS :___
- Format: YYYY-MM-DDTHH:MM :___

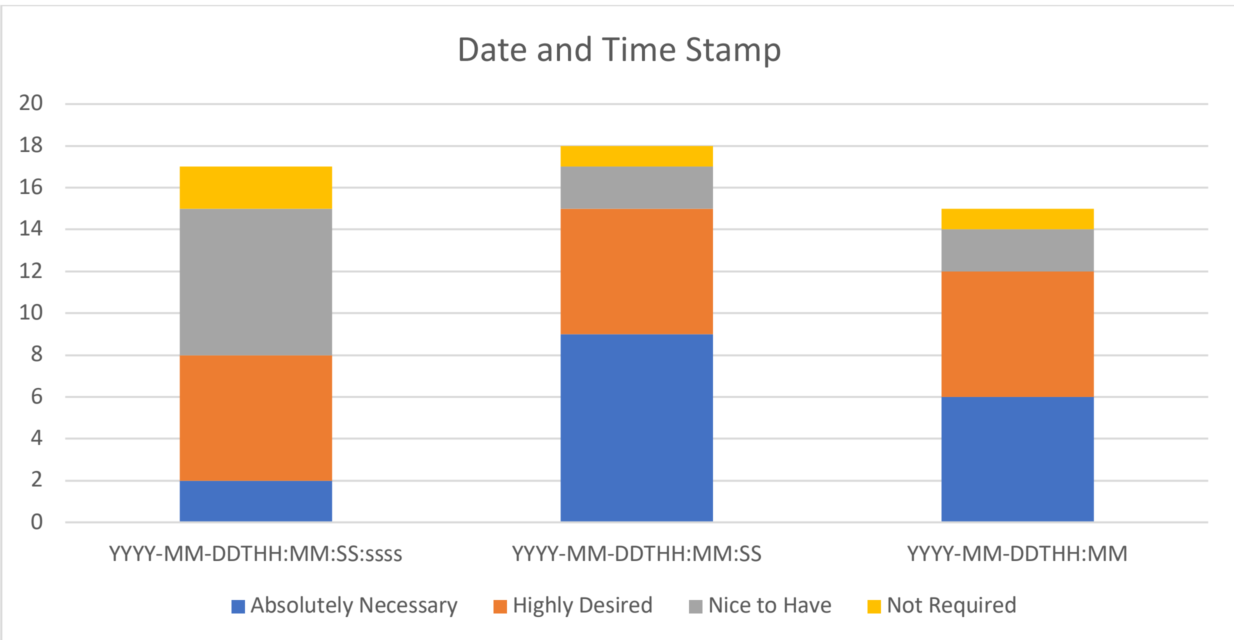

Figure 3: Date and Time Stamp

Reporting of missing data (mark relevant option):

- Number of datapoints missing: ___
- Period of datapoints missing (from-to): ___
- Hours of missing data per year (0-8760 hr): ___

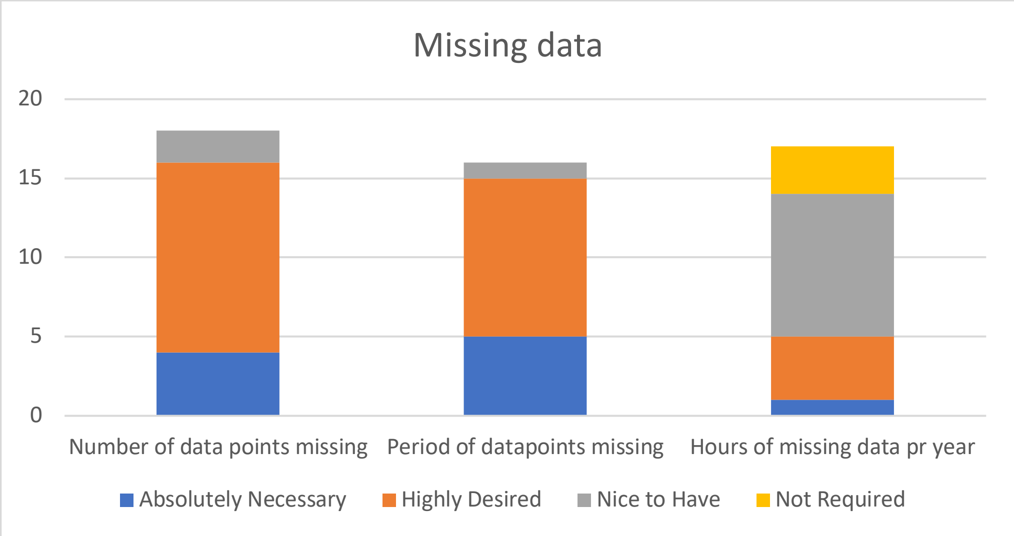

Figure 4: Missing data

Format for missing datapoints (mark relevant option):

- NaN: ___
- -9999.9: ___
- Empty space: ___

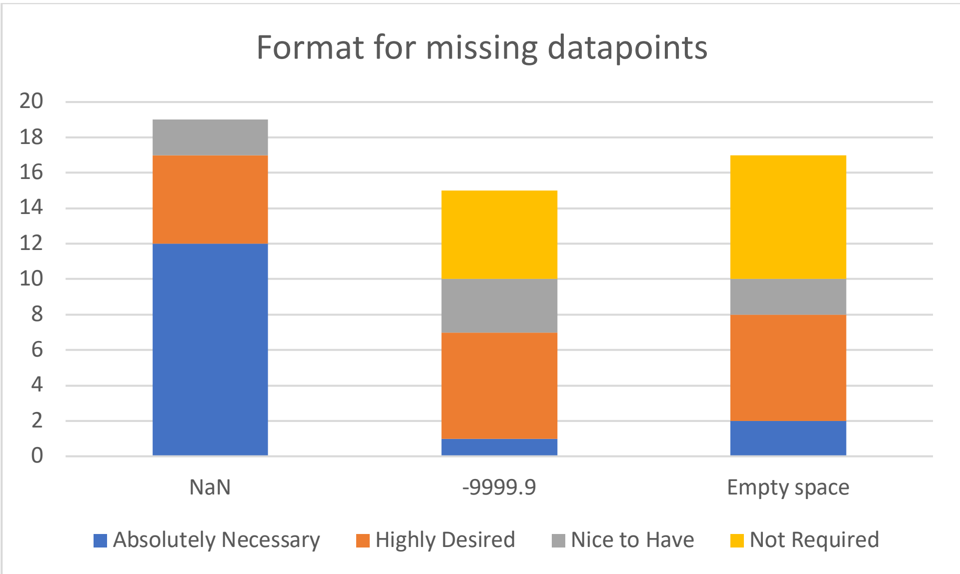

Figure 5: Format for missing datapoints

Comment field:

Aghaei: *File format can differ in various datasets, we should define a protocol to have similar range. However, it is difficult to have same format for all available data, so we should consider typical formats.*

Karl Berger: *XML, even if not so widely used today, will be essential for future applications.*

Exact timestamp essential if data has to be aggregated. Problem if data from eg. Imp, Vmp, GI are taken every 1 minute, but at different time within this minute, especially if weather conditions are non-stable. Better to run the monitoring 24/7 instead of nightly downtimes, making it more complicated to find missing data.

Formatting of missing data depends on software used for the data evaluation.

Simon: *Long term monitoring is performed at CSTB; we only consider number (or period) of missing data.*

Emilio: *Data monitoring on long period is performed at CSTB. We take into account only number or missing data or eventually period of time.*

Francesco: *Error or missing data have different format at SUPSI according to the occurred event (i.e., -999, -888, -777, …)*

Fialho: *The grid interaction variables can have the value -9999.9 in normal operating conditions.*

METADATA: SITE

Site name: ___

Site address: ___

GPS coordinates (°N, °E positive; °S,°E negative): ___

Decimal number (00.0000°N, 00.0000°E) or DMS (degrees, minutes, seconds, 00°00'00.0"N 0°00'00.0"E)

Site elevation (meter above mean sea level): ___

Time zone UTC (no daylight saving): ___

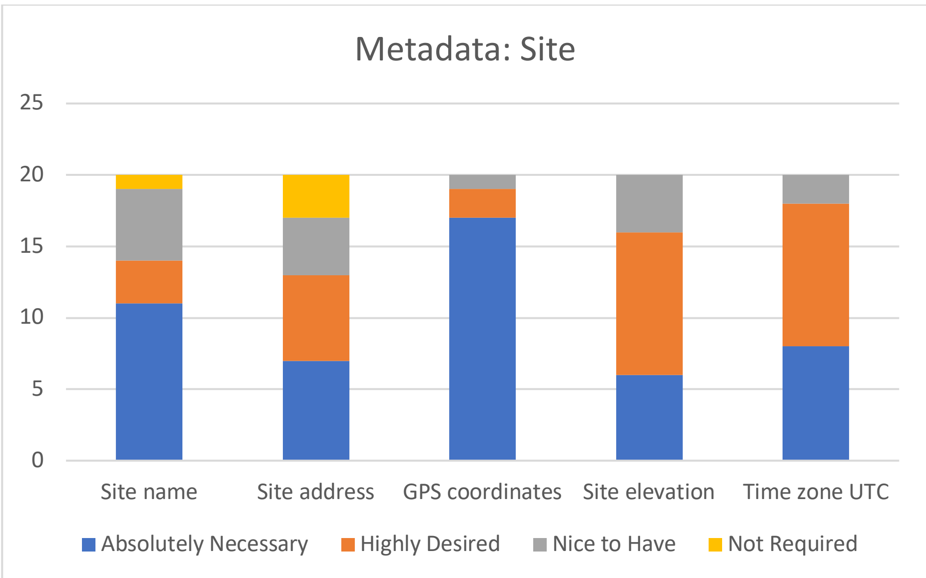

Figure 6: Metadata-Site

Comment field:

Simon: *Geography is main parameter for simulation and comparison withdata; elevantion and time zone play a second role.*

Aghaei: *Sometimes difficult to get all info about the site due to confidentiality. Better to skip less important info like address, name.*

Emilio: *Geographical situation is the main parameter for simulation and calculation comparison with on-site measurements (elevation play a second role as timing zone; just take the good one.)*

Karl Berger*: Name, there shall be an identifier for each system, but not necessarily the 'clear name', and further infos, as the address may be referenced via the identifier.*

Site location and coordinates for clustered analysis of systems, with protection of data privacy, the postal number, and/or the rough longitude, but more exact latitude (and altitude) may be an option.

Daylight time changes disturb the system, but some inverter based monitoring systems do not give option to choose betweeen UTC and actual time zone, using summer/wintertime.

METADATA: PV SYSTEM AND COMPONENTS

Fixed or tracking installation (enter data / mark relevant options):

- Fixed installation, tilt angle (0-90°, zero is horizontal): ___
- Fixed installation, azimuth angle (0-360°, zero is North): ___
- 1-axis tracking E-W: ___
- 1-axis tracking N-S: ___
- 2-axis tracking: ___
- For mixed installation, please use comment field below to specify: ___

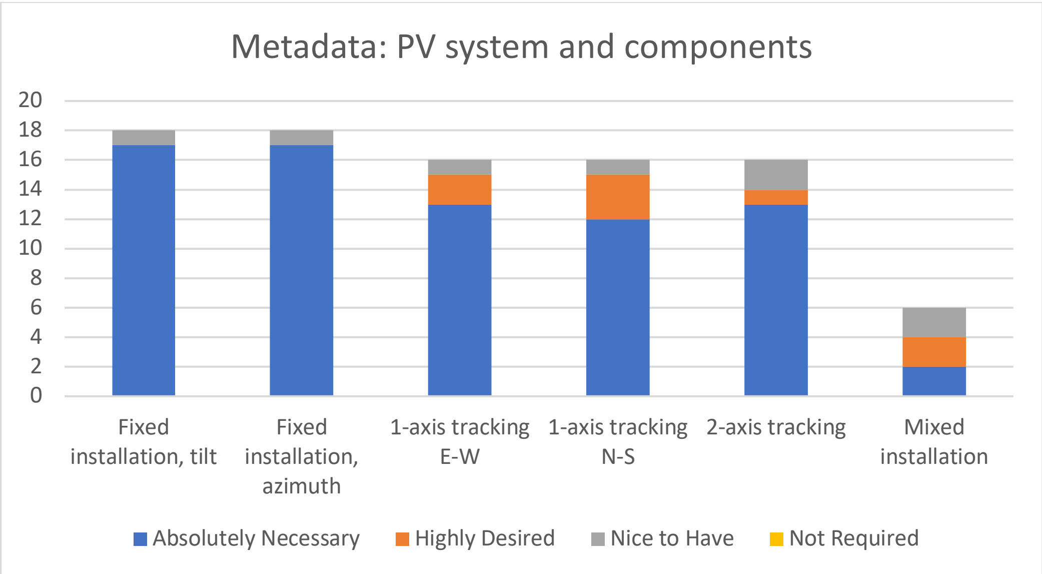

Figure 7: Fixed or Tracking solutions

Comment field:

Karl Berger: *Azimuth: missing definition if clockwise (from N to E) or counter-clockwise (from N to W) for positive values. PVGIS uses zero S (instead of N), positive values from S to W instead.*

Installation solution (mark relevant options):

- **Building-attached (BAPV): ___**
  - Tilted roof: ___
  - Flat roof: ___
  - Facade: ___
  - Window blinds: ___
  - Shelters: ___
  - Other: ___

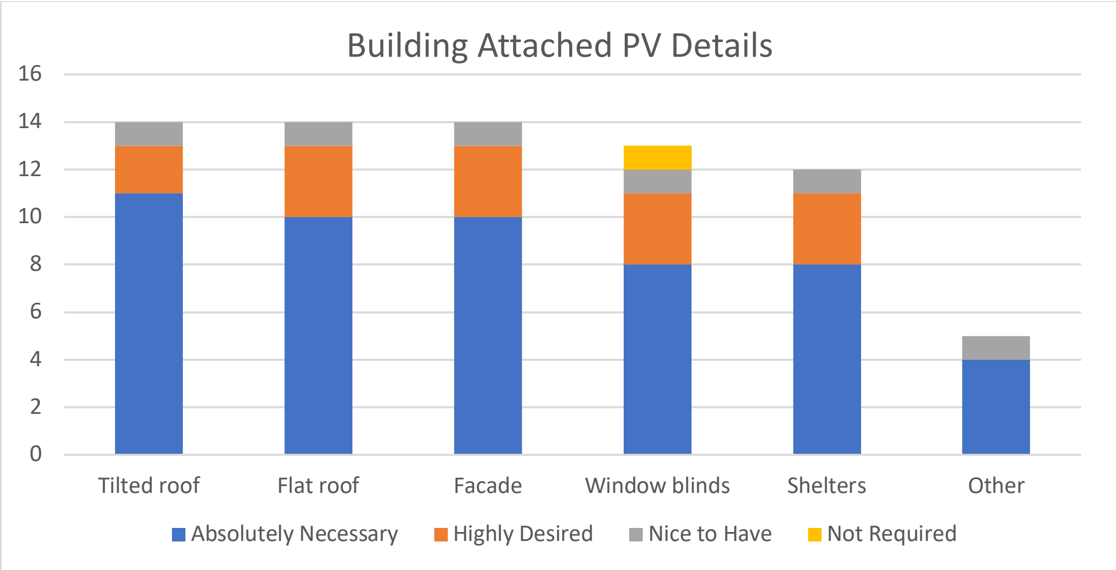

Figure 8: BAPV Details

- **Building-integrated (BIPV): ___**
  - Tilted roof: ___
  - Flat roof: ___
  - Facade: ___
  - Sunshading: ___
  - Shelters: ___
  - (Semi-)Transparent systems, percentage of transparency: ___
  - Other: ___

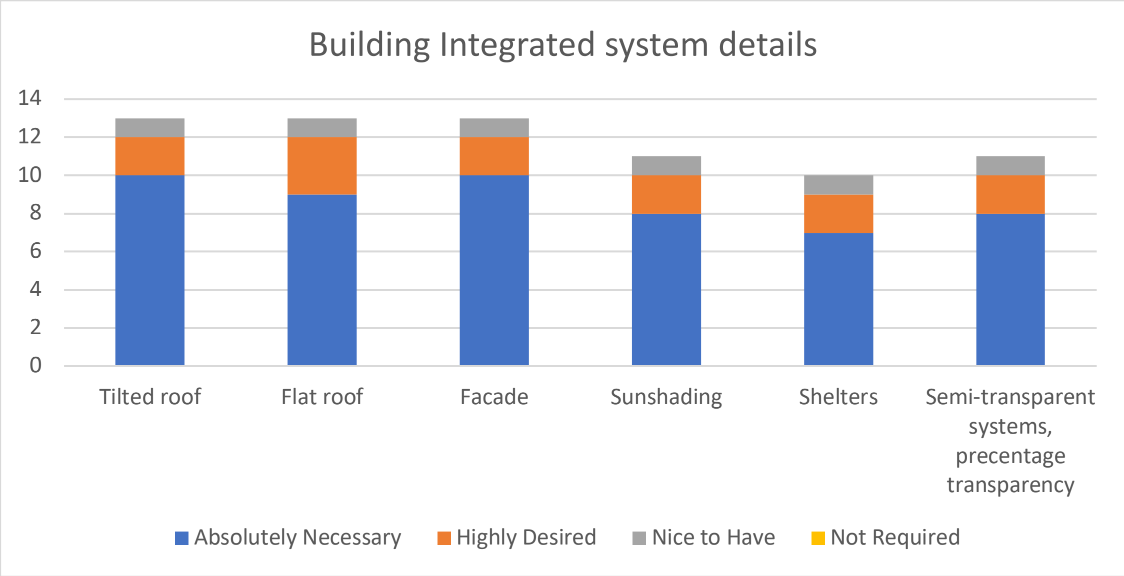

Figure 9: BIPV Details

- **Free-standing system: ___**
- **For combinations of installation solutions, please use comment field below to specify: ___**

Comment field:

Karl Berger: *IPV or BAPV (as derived from EN50583) – does not help at all, because BIPV is basically undefined in a technical sense: e.g. the operating temperatures for roof or facade integration are strongly dependent on thermal boundary conditions, like thermal insulation, radiative properties, etc. not covered by / directly linked to the application list from "BAPV, tilted roof" ... "BIPV, Other".*

So, this categories may be widely misleading – e.g. the same bill of materials for roof integration/application may be ticked as BAPV flat roof or BIPV flat roof, if for one system the active PV is glued at the roof or in the company to the roofing membrane. Or: semi transparent may be used as outer part of a triple glass window system with high thermal insulation properties, or as outer layer of a courtain wall facade before a wide back ventilated area. Multiple ticks for one application?

As this is not easily specified upfront in a meaningful way, the monitoring data has to tell (in combination with azimut and tilt), if a system runs under good or bad thermal operating conditions, influenced from the building or widely decoupled, or this may be derived from a calculation (ranging from using simple approximations like U0 and U1 for the Feyman model, or a full 3D CFD analysis of including the buildings operation, coupled to an electrical inner model of the modules, the circuitry and grid operating conditions.

By the way, "Open rack mounted" (here: "free-standing") is used, but also undefined in IEC 61215 and 61730.

PV module technology:

- Brand name: ___
- PV technology (mono-Si, multi-Si, CIGS, ..., PERC, bifacial, ...): ___

- Module manufacture time (month-year): ___
- Module installation time (month-year): ___

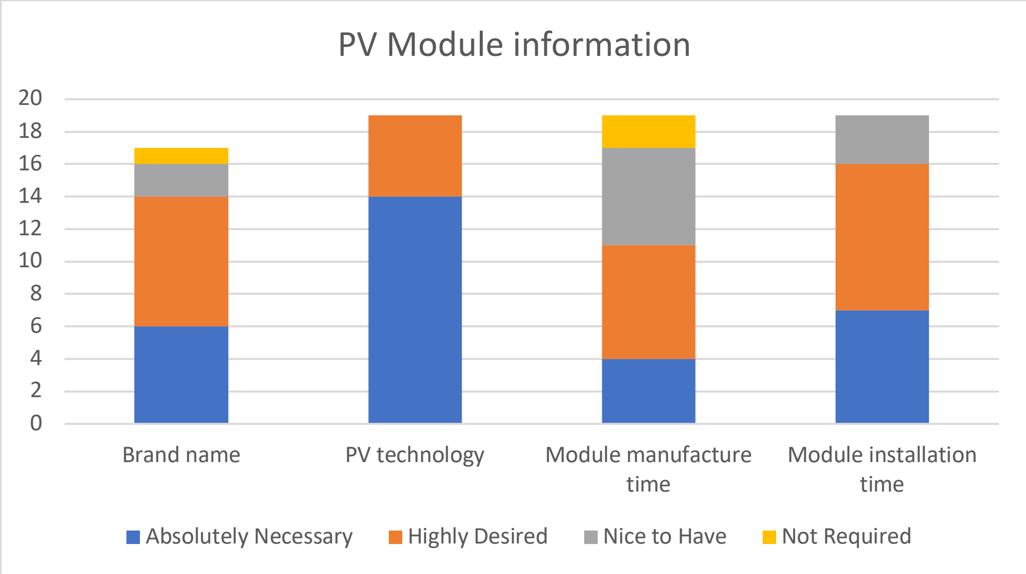

Figure 10: PV Module information

PV module characteristics:

- P_{mpp} at STC (W_p): ___
- I_{mpp} at STC (A): ___
- V_{mpp} at STC (V): ___
- I_{sc} at STC (A): ___
- V_{oc} at STC (V): ___
- Efficiency at STC (%): ___
- Temperature coefficient of P_{mp} or eff (%/degree): ___
- NOCT value (degrees C): ___

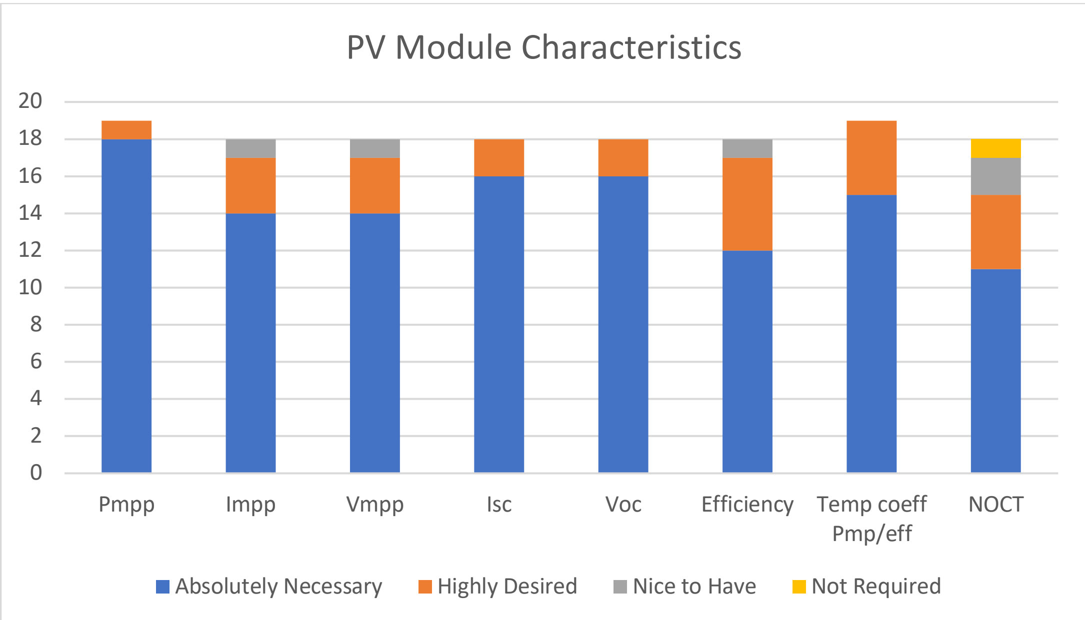

Figure 11: PV Module Characteristics

- Number of cells per PV module: ___
- Number of bypass diodes per PV module: ___
- Size of PV module (m x m, outer frame dimensions): ___
- Size of PV module (m x m, aperture area): ___
- Weight of PV module (kg): ___
- Total number of PV modules in system: ___
- For combination of different module sizes or types in the same system, please use comment field below to specify: ___

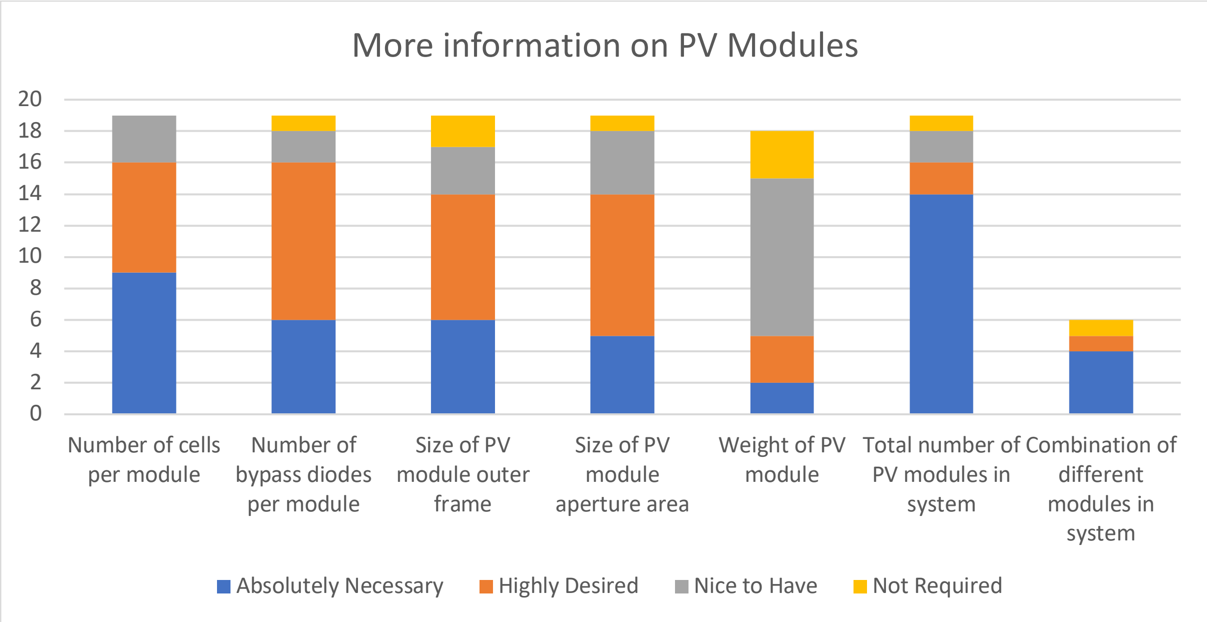

Figure 12: More information on PV Modules

Comment field:

Simon and Emilio: *Take into account surrounding construction components, to evaluate optical and thermal effects on PV.*

Francesco: *Important to define the meaning of each type of installation, and also consider the surroundings (shadows, urban, albedo, …)*

PV string design (mark relevant options):

- Number of PV modules series-connected in a string: ___
- Number of PV modules parallell-connected in a string: ___
- Number of strings connected to each inverter (ref. number of inverter inputs): ___
- Total number of PV strings in the system: ___
- Not relevant (microinverters): ___
- For complex string designs, please use comment field below to specify: ___

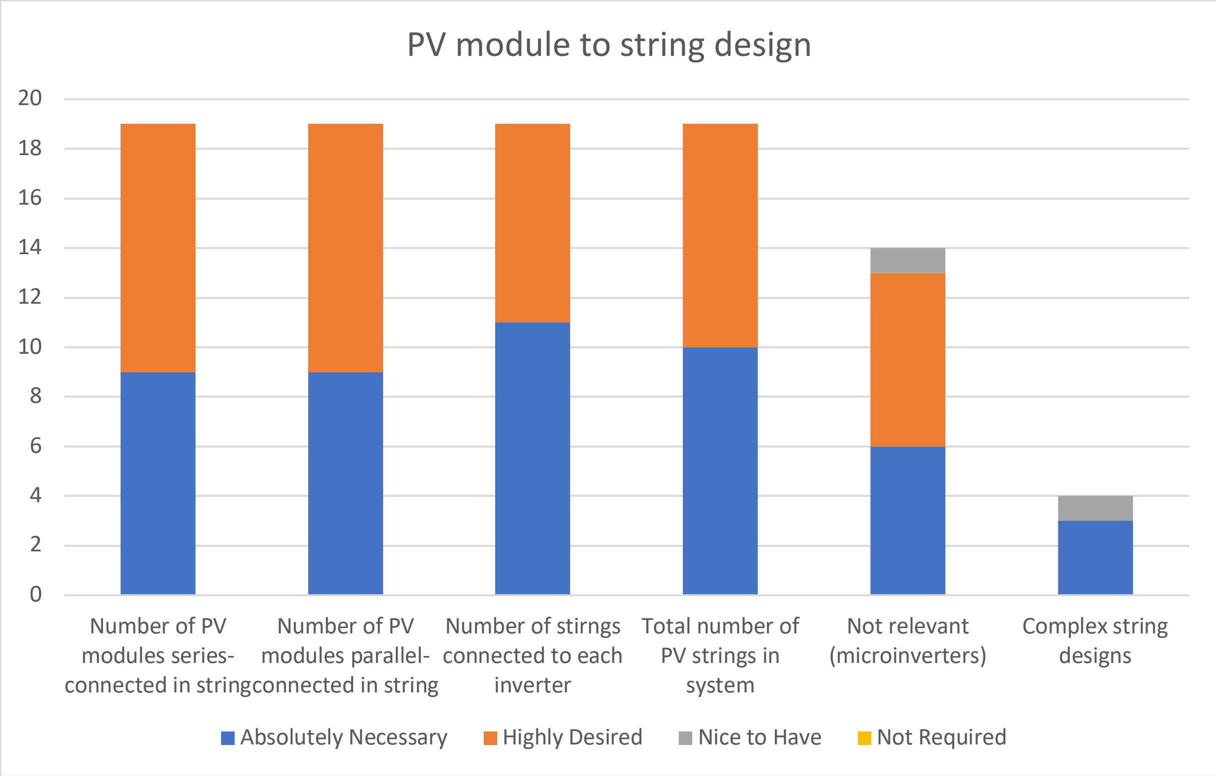

Figure 13: Module to string design

Comment field:

Aghaei: *Weight is sometimes important to calculate max mechanical load of structure.*

Emilio: *For bifacial modules, coefficient of bifaciality (module bifacial factor) and rating used for rear side. Also rear mismatch losses can be very valuable. If flash list report is available, it can also be very valuable.*

Francesco: *Are the PV module data taken from datasheet or measured by certified lab? We normally use both.*

Betti: *Number of each size/type of PV modules in a series-connected string, number of strings in parallel.*

Karl Berger: *Always nice to have the full data sheet information, but some of the data have high (and not/seldom reported uncertainty), e.g. the NMOT value (replacing NOCT) in the 2016 Ed. of the IEC 61215 series, as defined in 61853, or the temperature coefficients.*

Mixed systems: Shall be clarified in the PV-string design data.

Number of bypass diodes also relevant, and missing, if inner module-strings bridged by the diodes are vertically or horizontally (portrait vs. landscape) arranged, giving different shading conditions and losses.

Missing option: DC/DC converting string optimizers here, but included as inverter technology below.

Microinverters: AC-interconnection may also have an influence on the system performance (& safety).

Shading from surroundings on PV modules (mark relevant options):

- Far-horizon shading: ___
- Near-horizon shading: ___
- No shading: ___

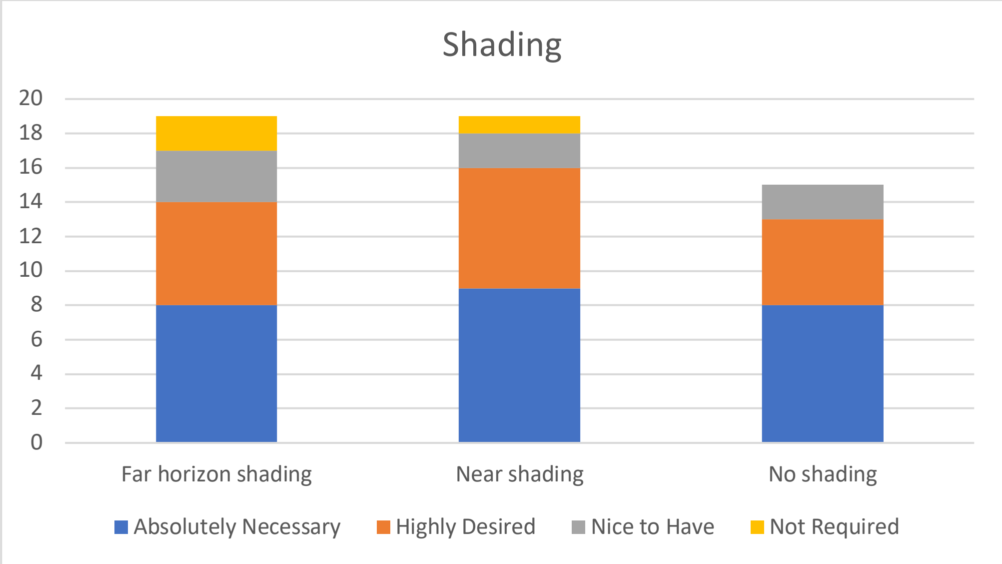

Figure 14:Shading

Comment field:

Karl Berger: *Would be nice to know about, but: Near shading is relevant on sub-string level too, and "No shading" means self shading only? Around summer solstice in the morning and evening the sun is behind south oriented, tilted modules.* **Todorovic:** *Mapping of shading on a polar diagram.*

Inverter technology (mark relevant options):

- Brand name: ___
- Inverter type: ___
  - Central inverter: ___
  - String inverter: ___
  - Microinverter: ___
  - Power optimizer: ___
  - Transformerless: ___
  - With transformer: ___

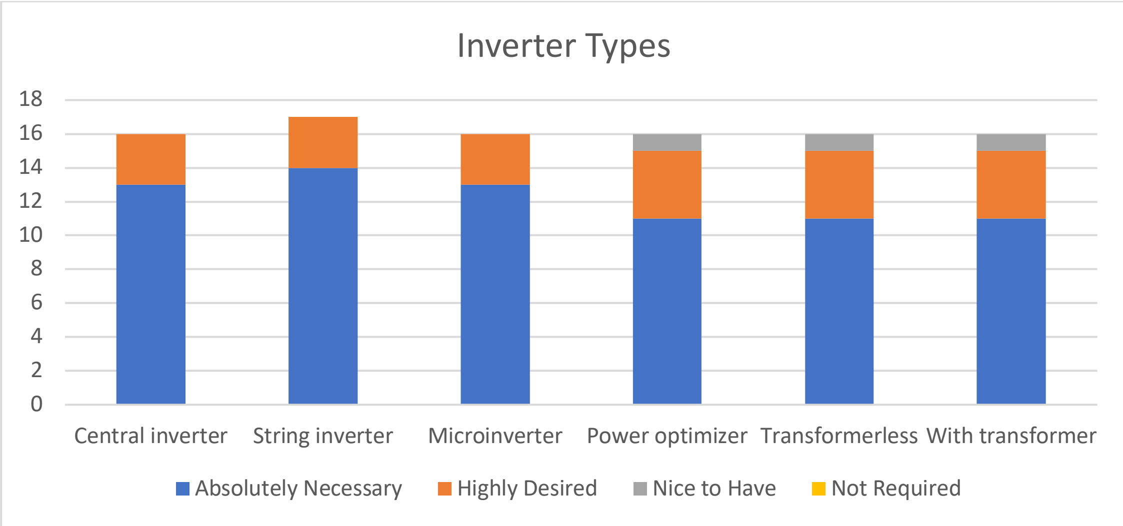

Figure 15: Inverter Types

- **Inverter specifications:**
  - Max AC output power (W): ___
  - AC power frequency (Hz): ___
  - Max DC input power (W): ___
  - Rated max/EU efficiency (%): ___

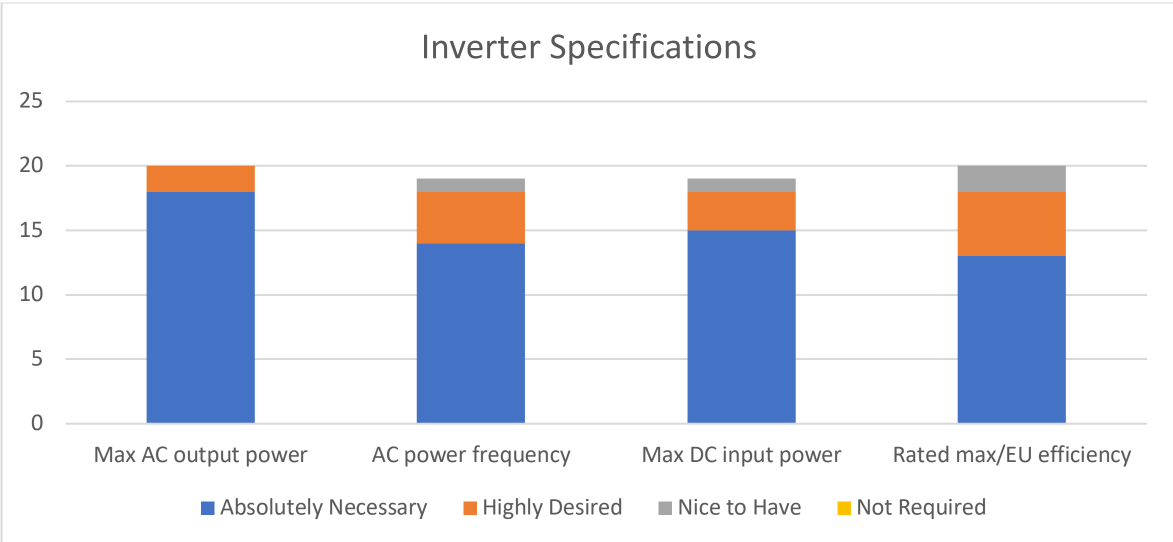

Figure 16: Inverter Specifications

- **1-phase/3-phase: ___**
- **Reactive power control: ___**
- **Number of independent MPP inputs per inverter: ___**
- **Total number of inverters in system: ___**

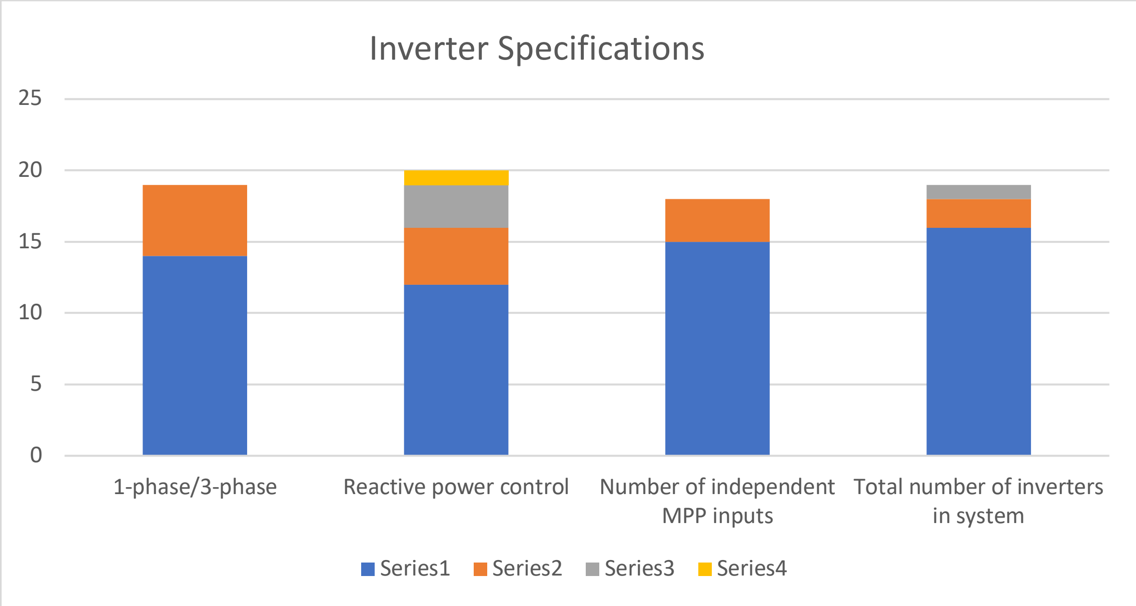

Figure 17: Inverter Specifications

- **Data exchange / communication protocol: ___**
    - RS232: ___
    - RS485: ___
    - MODBUS: ___
    - Bluetooth: ___
    - Web interface (company specific): ___

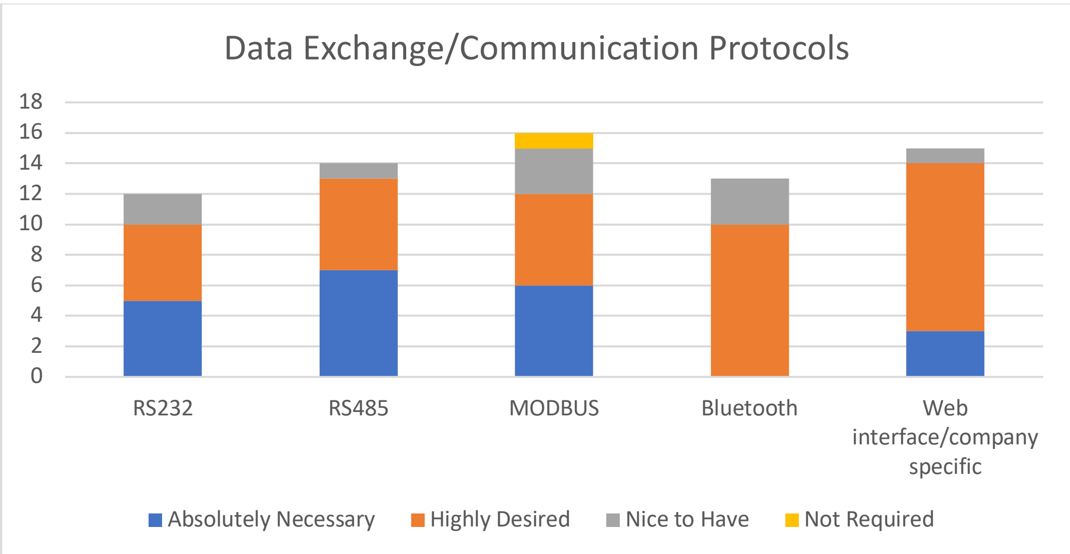

Figure 18:Data Exchange and Communication Protocols

- **For combination of different inverter sizes or types in the same system, please use comment field below to specify: ___**

Comment field:

Karl Berger: *For tripping and malfunctions the inverter specs the min/max. DC and AC voltages are relevant too*

1/3 phase: other types exist with switching – depending on actual DC-power – between 1, 2, and 3 phase AC-operation.

For AC implications on the DC-side (e.g. PID effects) the inner inverter concept allowing/blocking leakage currents is also relevant (flying inductor or capacitor, vs. direct interconnect from DC to AC side). Add to list, or lookup from brand name & type?

Betti: *Connection of PV modules to each inverter.*

Balance-of-system BOS components (mark relevant options):

- DC cable type (e.g. copper, 4 mm^2): ___
- DC cabling, total length module-inverter (m): ___
- AC cable type: ___
- AC cabling, total length inverter-AC cabinet (m): ___
- Number and type of protective devices (fuses, switches): ___
- System grounding: ___
- Lightening protection: ___
- Grid-connected system: ___

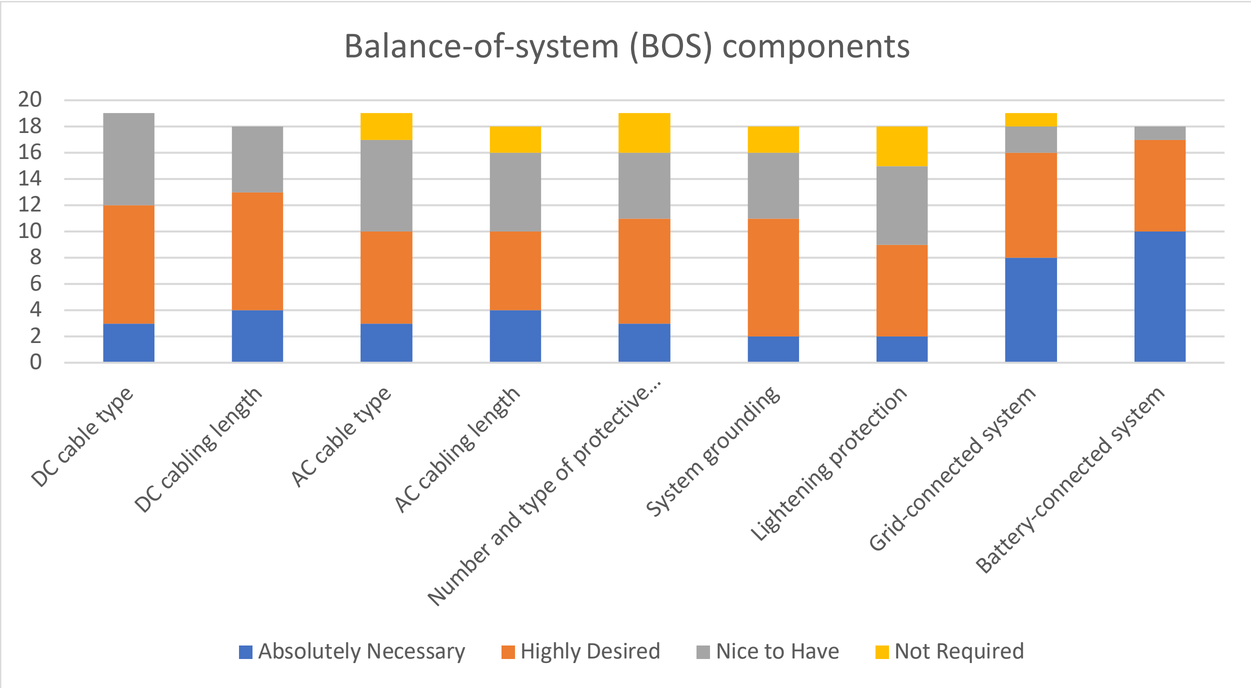

Figure 19: Balance of system (BOS) components

- **Battery-connected system: ___**
  - Type/model and technology: ___
  - Energy storage capacity: ___

- Charge/discharge capacity: ___
- Total number of batteries: ___
- System topology & control strategy: ___

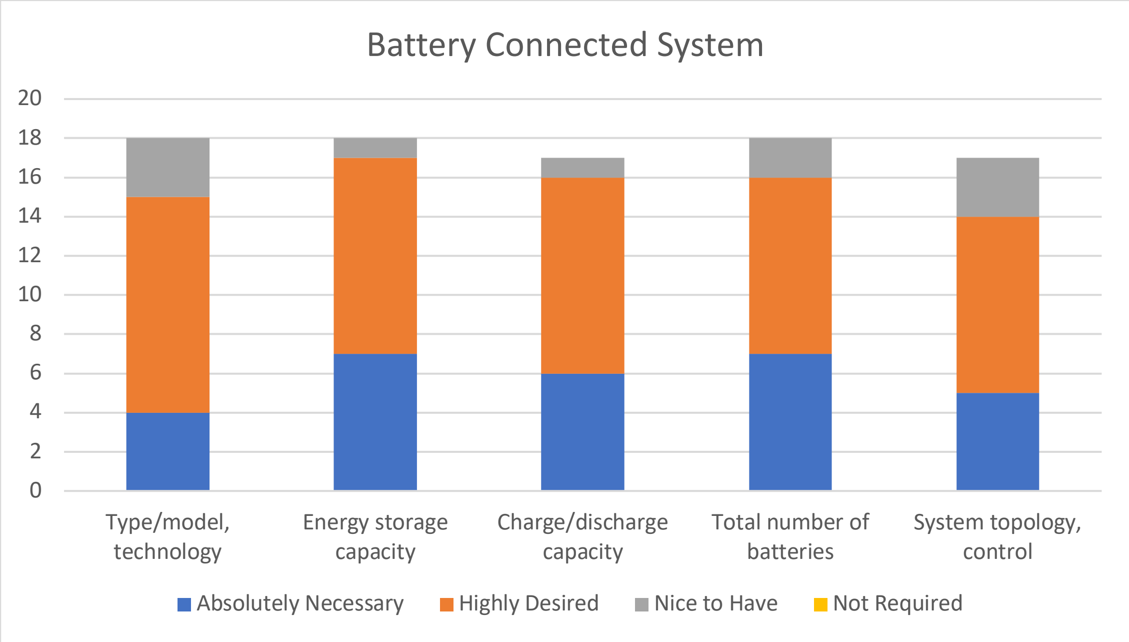

Figure 20:Battery connected system

- **Other energy storage devices: ___**
  - Supercapacitor: ___
  - Hydrogen/fuel cell: ___

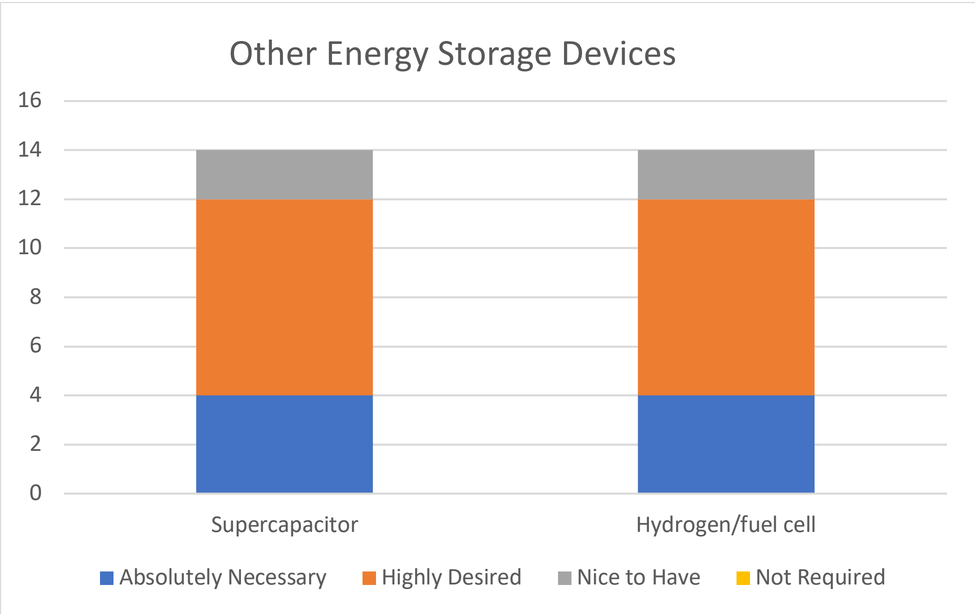

Figure 21: Other Energy Storage Devices

- **Surveillance of system operation:**
  - Proprietary hardware/software: ___
  - Own developed hardware/software: ___
  - Dedicated personell for system surveillance and follow-up: ___

- No dedicated personell for system surveillance and follow-up: ___

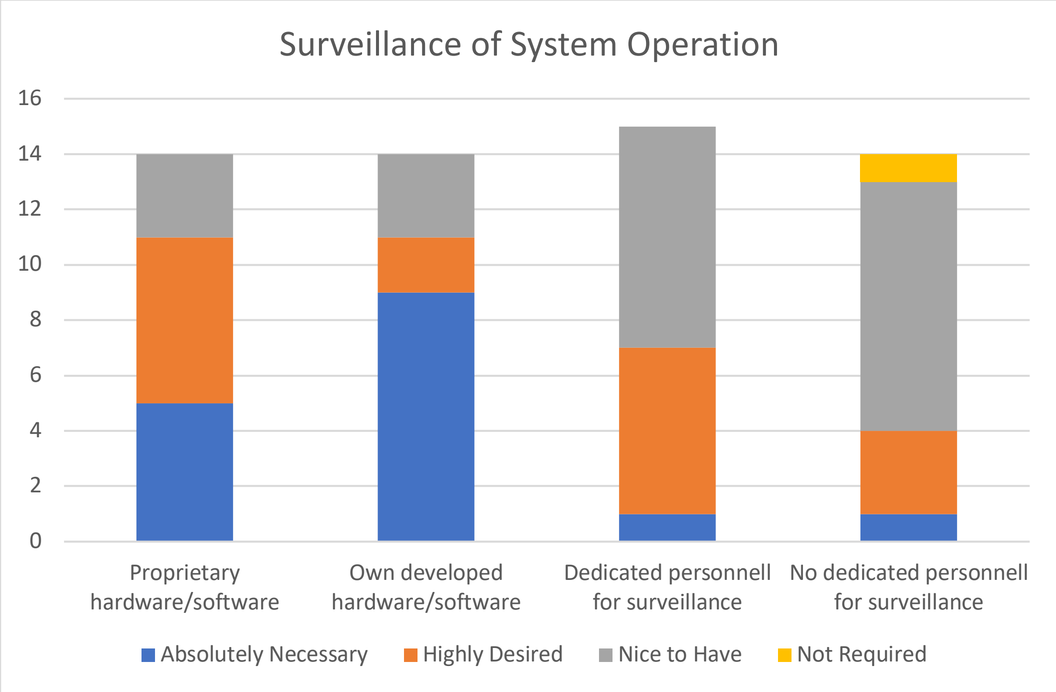

Figure 22: Surveillance of system operation

Comment field:

Karl Berger: Instead of cable type and length, a value / measurement of the total loop resistance?

Instrumentation, sensors, datalogging (mark relevant options):

Irradiance sensors:

The DERlab guidelines for long-term PV yield measurement recommend a secondary standard pyranometer in the module plane (ISO 9060), or a reference cell of the same PV technology as the modules (IEC 60904-2 or IEC 60904-6).

- Pyranometer, brand/model and classification (e.g. secondary standard): ___
- Pyranometer accuracy (%, combined uncertainty for datapoint): ___
- Reference cell, brand/model and technology (e.g. mono-Si): ___
- Reference cell accuracy (%, combined uncertainty for datapoint): ___
- Pyrheliometer, brand/model and classification (e.g. secondary standard): ___
- Pyrheliometer accuracy (%, combined uncertainty for datapoint): ___
- Spectral irradiance sensor, brand/model and technology (e.g. UV/VIS): ___
- Spectral irradiance accuracy (%, combined uncertainty for datapoint): ___
- Albedo sensor, brand/model and classification (e.g.): ___
- Albedo accuracy (%, combined uncertainty for datapoint): ___
- For combination of different irradiance sensors, please use comment field below to specify: _

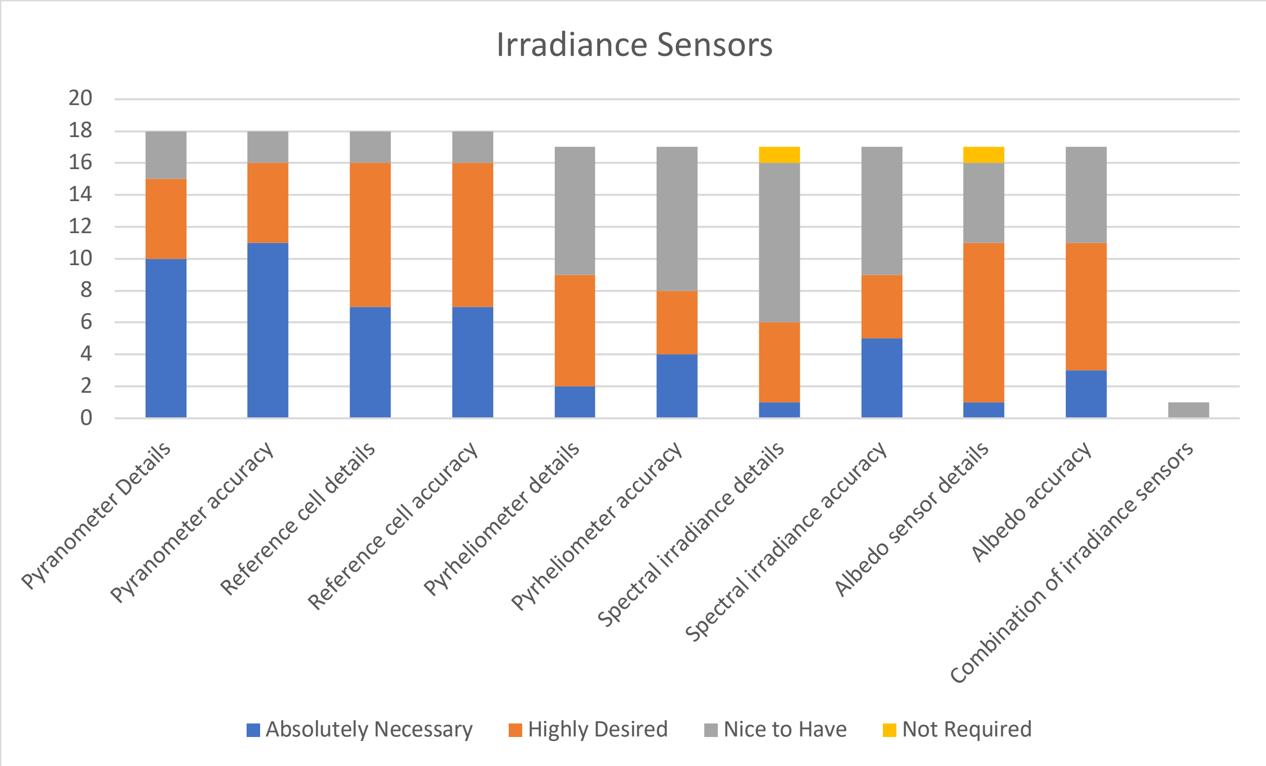

Figure 23: Irradiance sensors

Temperature sensors:

- Air temperature sensor, brand/model and type (e.g. thermocouple): ___
- Air temperature sensor accuracy (degrees C): ___
- PV module temperature sensor, brand/model and type (e.g. thermocouple): ___
- PV module temperature sensor accuracy (degrees C): ___
- Air dewpoint temperature sensor, brand/model and type: ___
- Air dewpoint temperature accuracy (degrees C): ___

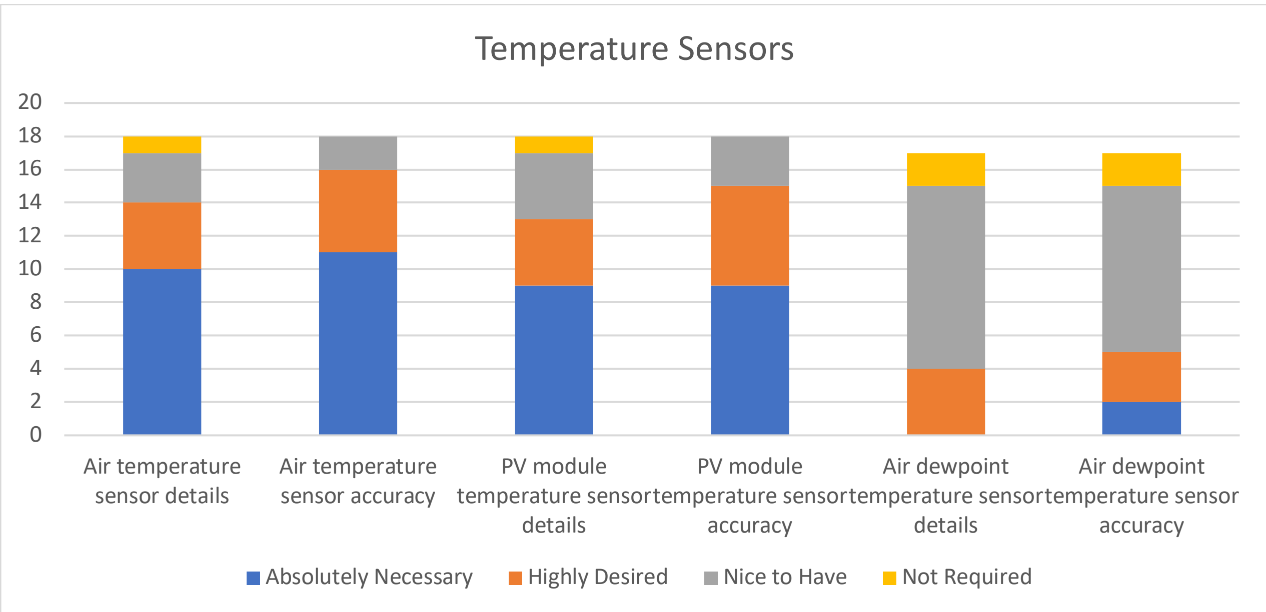

Figure 24: Temperature Sensors

Wind sensors:

- Wind sensor brand/model and type (e.g. cup anemometer): ___
- Wind speed accuracy (m/s): ___
- Wind direction accuracy (degrees): ___

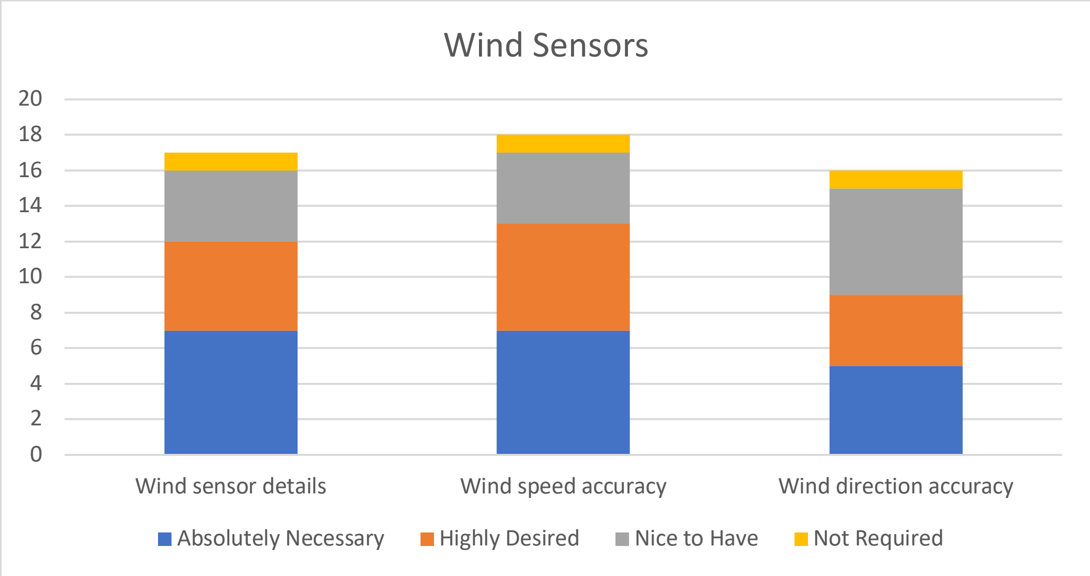

Figure 25: Wind Sensors

Other meteorological/environmental sensors:

- Air pressure sensor, brand/model and type: ___
- Air pressure accuracy (Pa): ___
- Air relative humidity sensor, brand/model and type: ___
- Air relative humidity accuracy (%): ___
- Liquid precipitation (rain) sensor, brand/model and type: ___
- Liquid precipitation (rain) accuracy (m): ___
- Solid precipitation (snow) sensor, brand/model and type: ___
- Solid precipitation (snow) accuracy (m): ___
- Dust sensors (soiling): ___

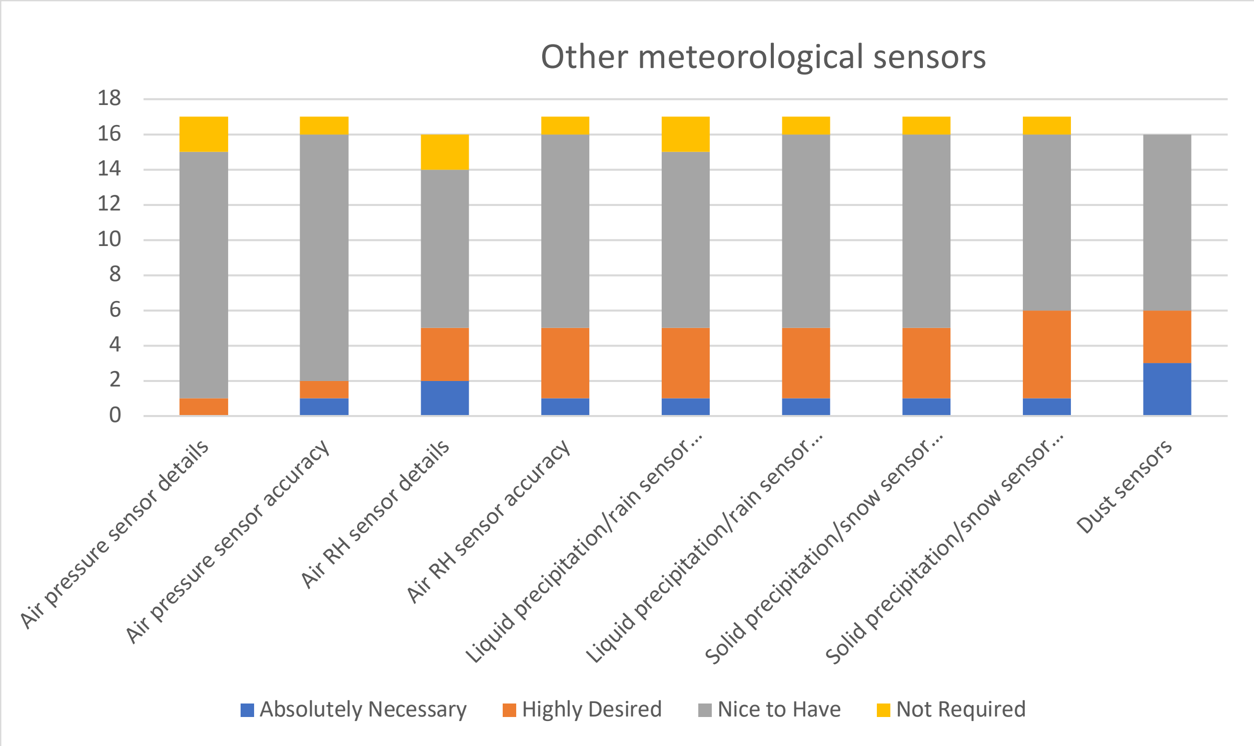

Figure 26: Other Meteorological Sensors

Current and voltage transducers:

- DC current transducer, type/model and range/uncertainty: ___
- DC voltage transducer, type/model and range/uncertainty: ___
- AC current transducer, type/model and range/uncertainty: ___
- AC voltage transducer, type/model and range/uncertainty: ___

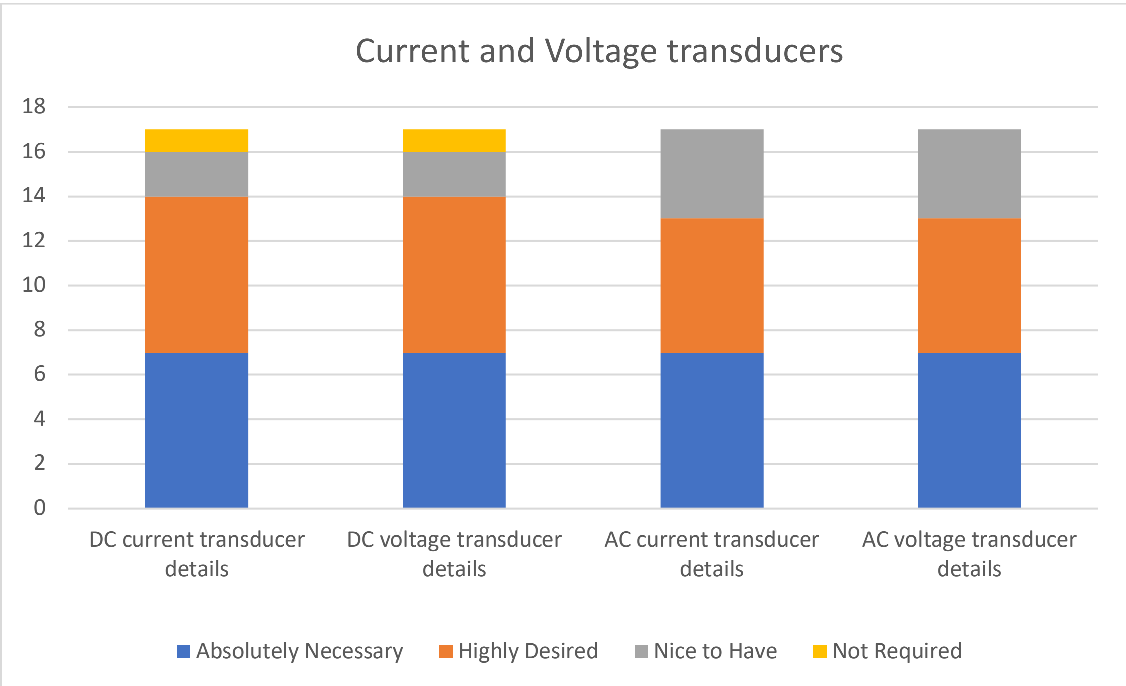

Figure 27: Current and Voltage Transducers

Power meters:

- DC power meter, type/model and class/uncertainty: ___
- AC power meter, type/model and class/uncertainty: ___
- AMS two-way power meter, type/model and class/uncertainty: ___

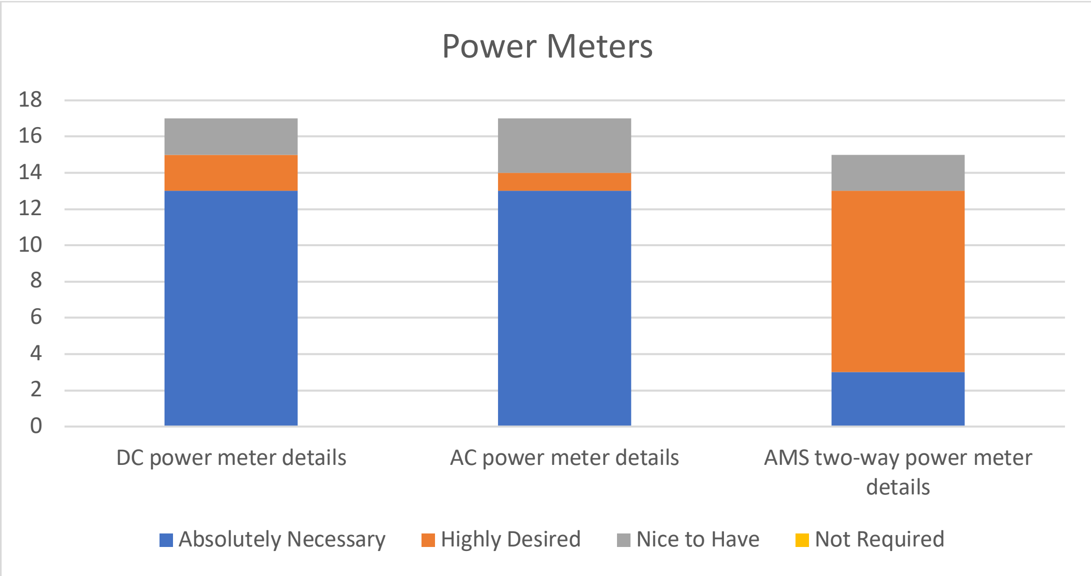

Figure 28: Power Meters

Infrared (IR) and Electroluminescence (EL) imaging:

- Camera type/model: ___
- Emissivity value used during IR imaging: ___
- Procedure used for imaging (UAVs, drones, technician on-site): ___

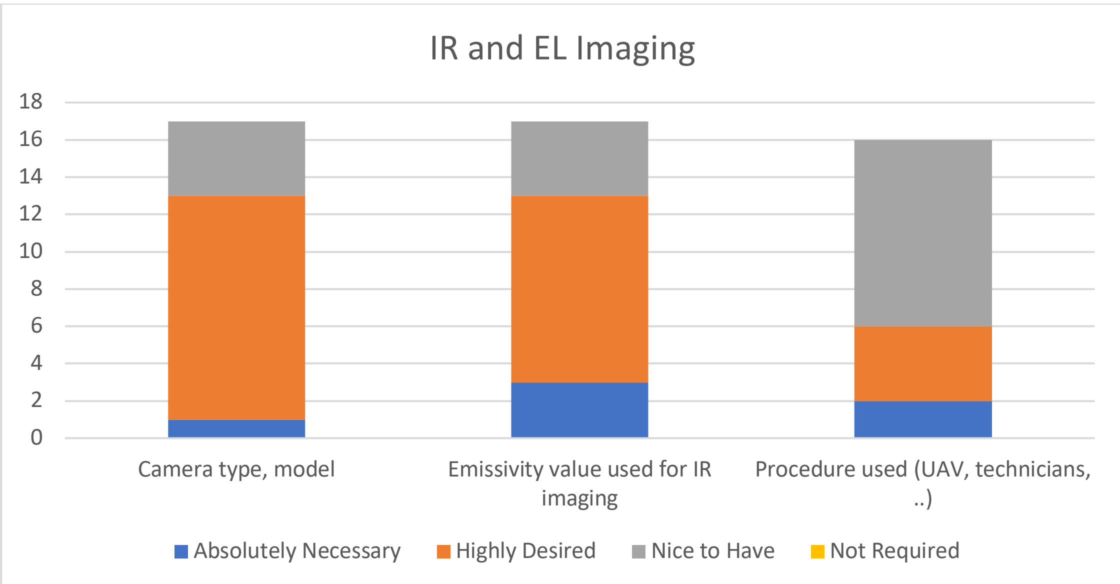

Figure 29: IR and EL Imaging

Comment field:

Francesco: *Minimum wind speed limit (m/s)*

Aghaei: *Sensors for PV soiling, like DustIQ, should be considered.*

For IR analysis we should know if it is performed by UAV or on site.

System status (mark relevant options):

- System changes: ___
- System downtime: ___
- Sensor failures: ___
- Communication downtime: ___
- Cleaning events: ___
- External influences: ___

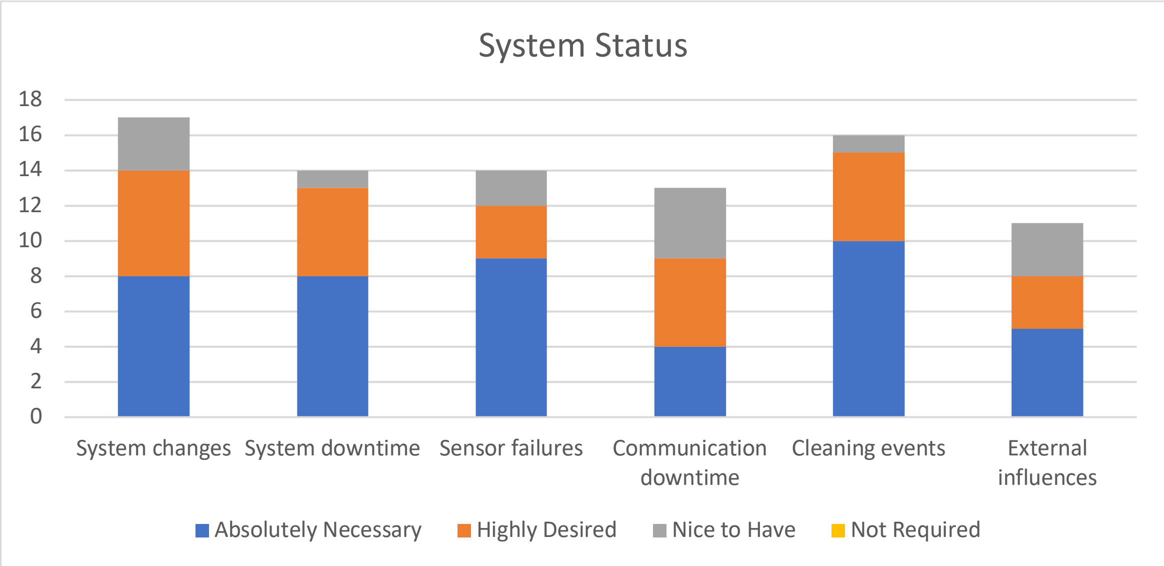

Figure 30: System Status

Comment field:

MONITORED DATA: METEOROLOGICAL

Solar radiation (mark relevant options):

- Global horizontal irradiance, GHI (W/m^2): ___
- Diffuse horizontal irradiance, DHI (W/m^2): ___
- Direct normal irradiance , DNI (W/m^2): ___
- Global tilted plane of array irradiance, POA (W/m^2): ___
- Spectral irradiance ($W/m^2/nm$): ___
- Ground reflection, albedo (-): ___

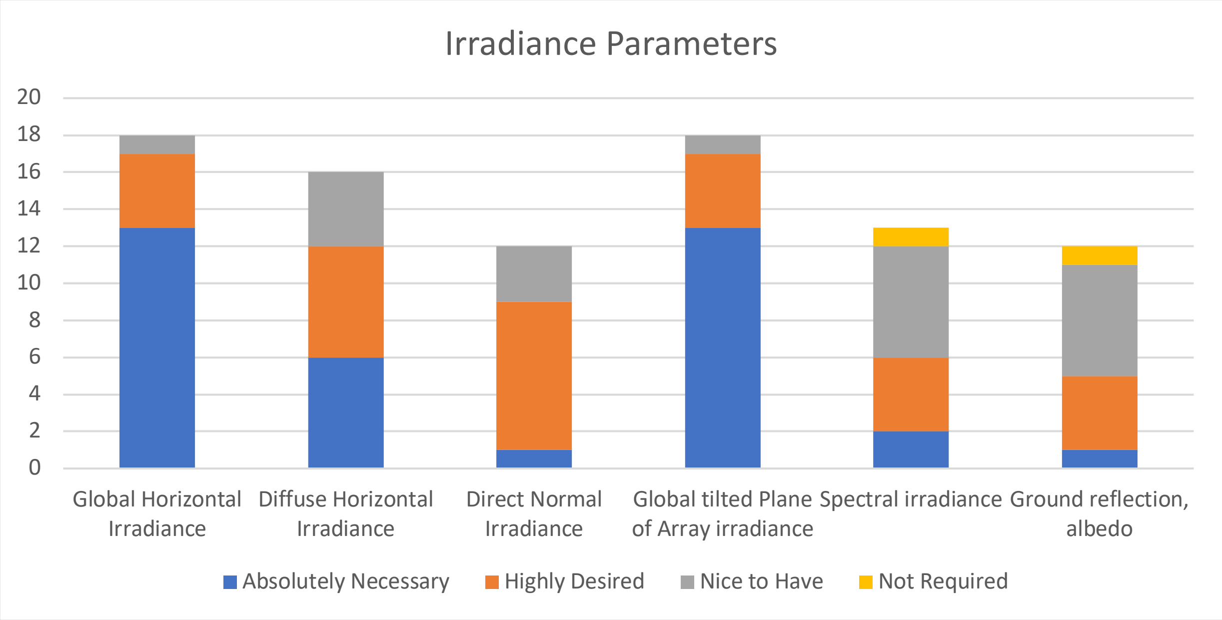

Figure 31: Solar Radiation

Climate and weather (mark relevant options):

- Air temperature (degrees C): ___
- Air pressure (Pa): ___
- Air relative humidity (0-100 %): ___
- Wind speed (m/s): ___
- Wind gusts, maximum wind speed within integration interval (m/s): ___
- Wind direction (0-360°, zero is North): ___
- Dew point temperature (degrees C): ___
- Liquid precipitation, rain (m): ___
- Solid precipitation, snow (m): ___

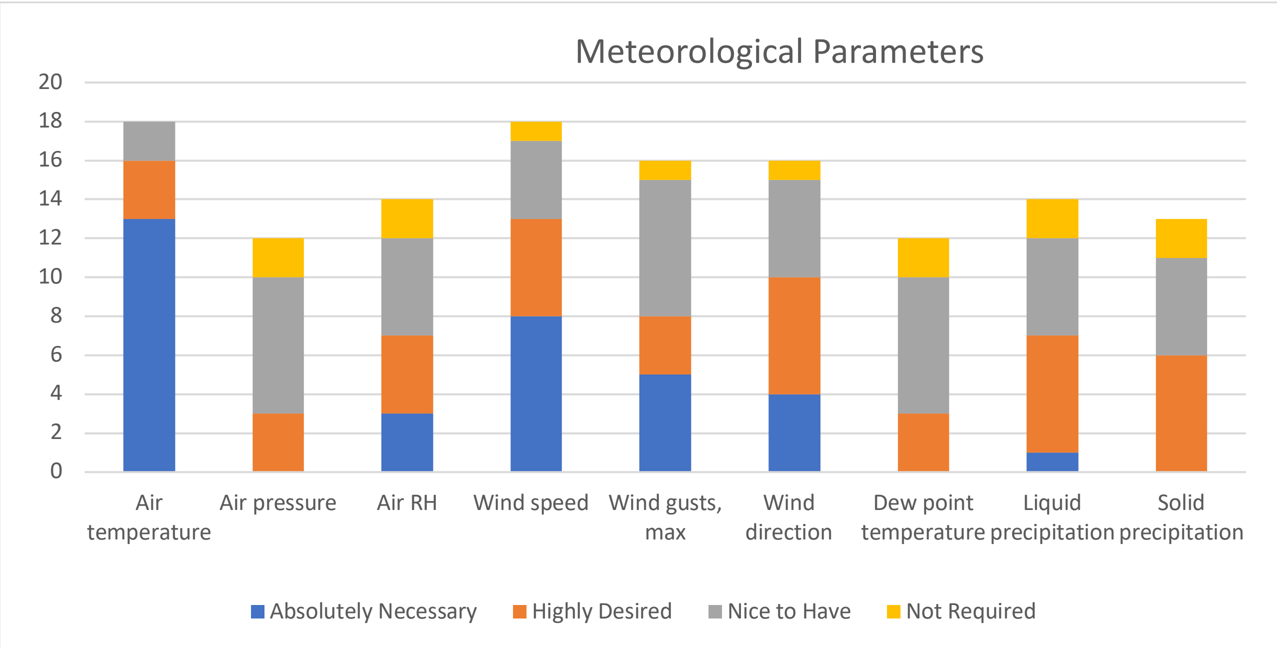

Figure 32:Climate and Weather

Sample rate of meteorological data (mark relevant option):

- <1 sec: ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

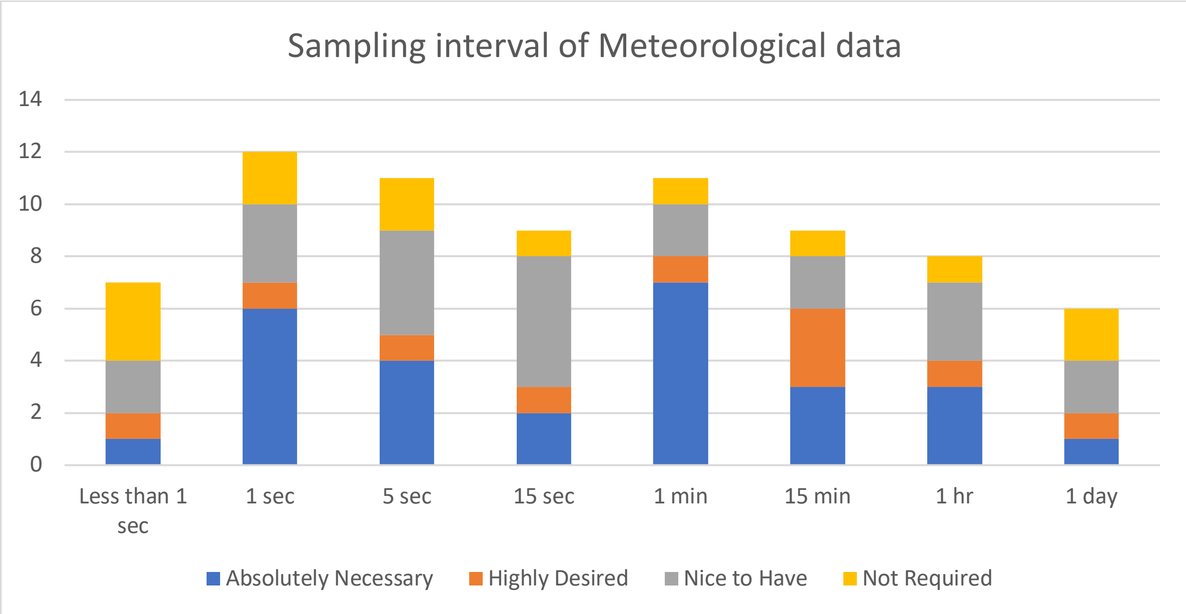

Figure 33:Sampling interval

Record rate of meteorological data (mark relevant option):

- <1 sec: ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

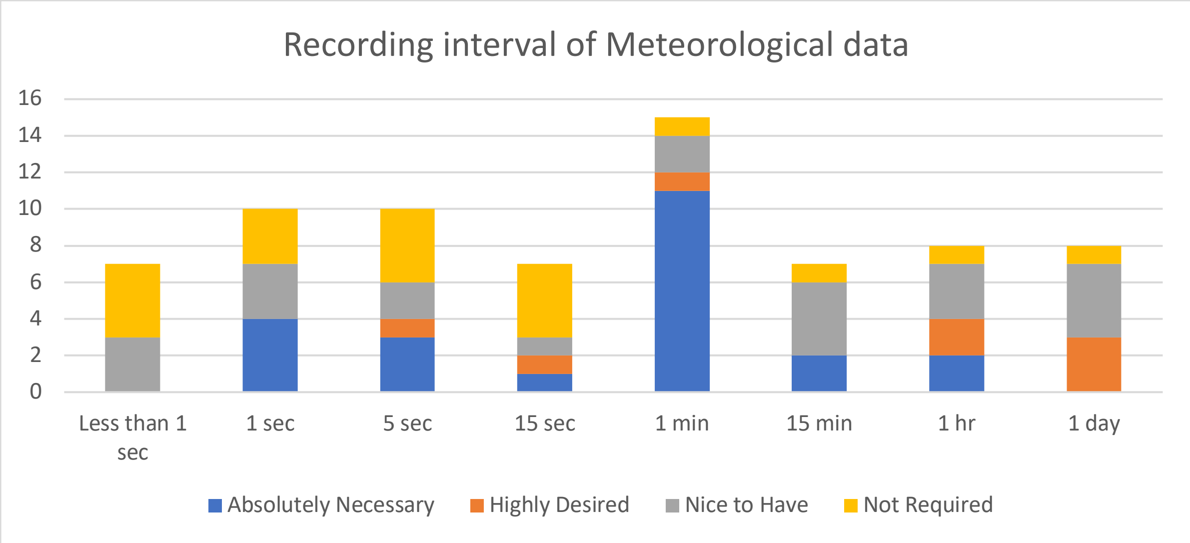

Figure 34: Recording rate

Comment field:

Emilio*: In the last version of IEC61724 for class A, sampling rate has to be max 3 sec, record rate max 1 min.*

MONITORED DATA: YIELD AND DURABILITY

Time series of available data (mark relevant options):

The DERlab guidelines for long-term PV yield measurement recommend at least one year of data, and an availability of at least 98 % to 99 % of the potential operation time per year.

- Minimum 1 month: ___
- Minimum 1 year: ___
- Minimum 5-10 years: ___
- Minimum 15-25 years: ___

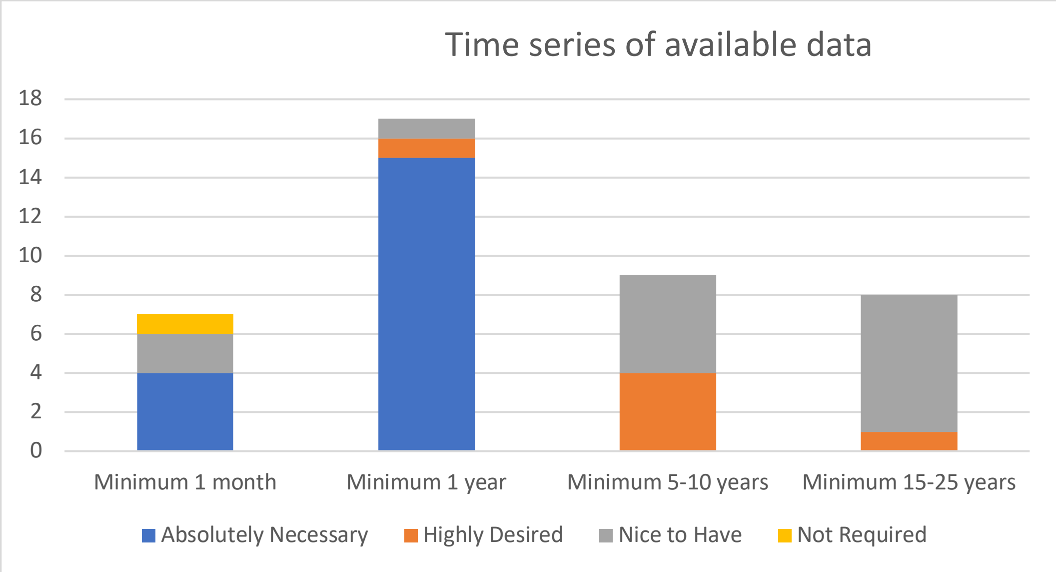

Figure 35:Time Series of available data

PV module/string yield (mark relevant options):

- Ambient temperature (degrees C): ___
- Module temperature (degrees C): ___
- POA irradiance (W/m^2): ___
- Module/string MPP DC current, I_{mpp} (A): ___
- Module/string MPP DC voltage, V_{mpp} (V): ___
- Module/string MPP DC power, P_{mpp} (W): ___

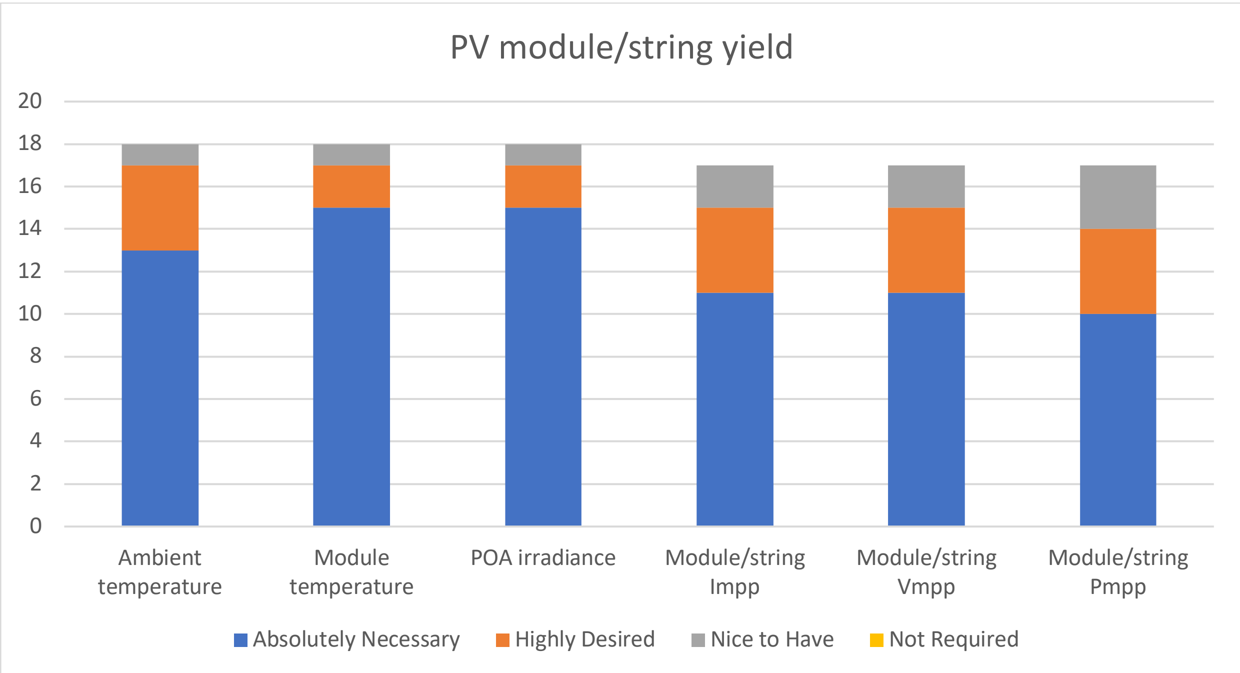

Figure 36: PV Module/String Yield

Sample rate of yield data (mark relevant option):

- <1 sec: ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

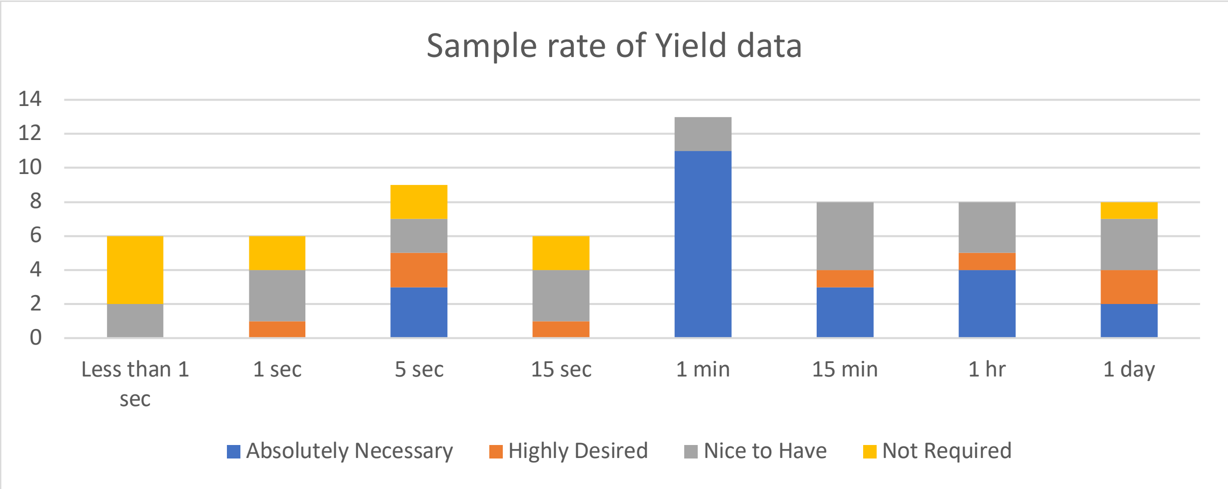

Figure 37: Sample rate of yield data

Record rate of yield data (mark relevant option):

- <1 sec: ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

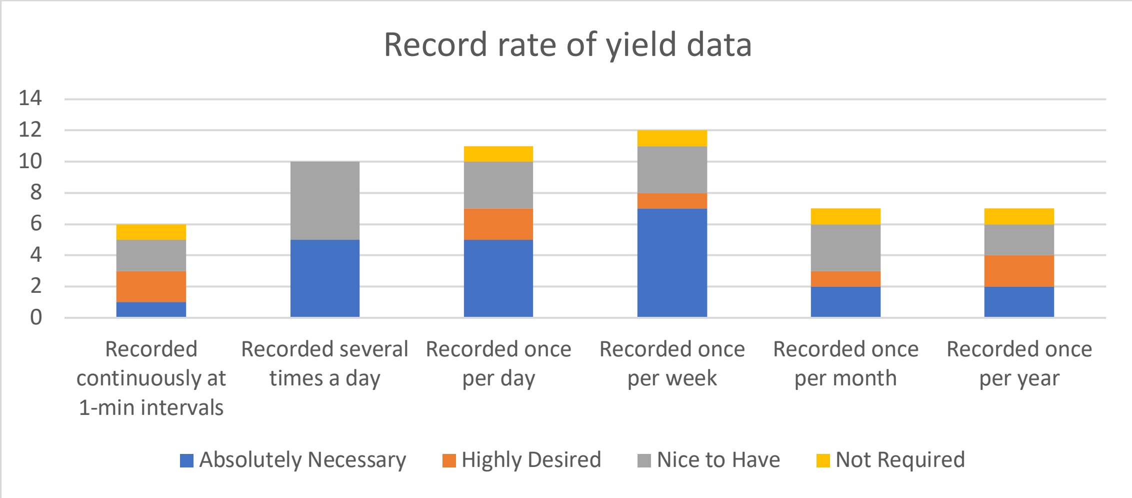

Figure 38: Record rate of yield data

PV module/string degradation (mark relevant options):

The DERlab guidelines for long-term PV yield measurement propose that an IV-curve is retrieved once each month, on a clear day with light wind and corrected for STC (ref IEC 60891), to analyse PV module degradation over time. Irradiance sensors and modules must be cleaned prior to measurements. The guidelines state that even with high-accuracy measurement equipment, it is challenging to determine degradation rates over periods of less than three years.

PV module/string IV-curve characteristics:

- Recorded continuously at 1-min intervals: ___
- Recorded several times per day: ___
- Recorded once per day: ___
- Recorded once per week: ___
- Recorded once per month: ___
- Recorded once per year: ___

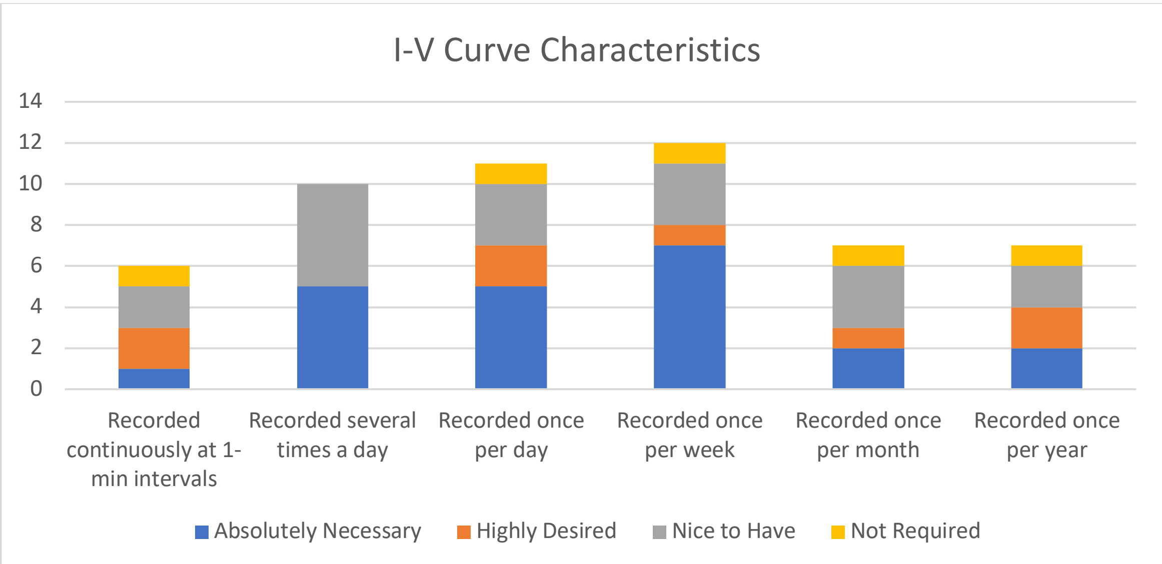

Figure 39: I-V Curve Characteristics

Soiling:

The DERlab guidelines for long-term PV yield measurement propose a maintenance plan consisting of a general survey of the apparatus, cleaning of measuring instruments and tested modules, and calibration intervals for the various sensors used.

- Cleaning freqency of PV modules: ___
- Cleaning frequency of irradiance sensors: ___
- Type of soiling measurement system: ___
- Power loss caused by soiling: ___
- Performance analysis before and after cleaning (e.g. IV-curves): ___
- Type of dust causing the majority of soiling: ___
- Analysis of soiling (grain size, colour, air humidity, aerosols, etc.): ___

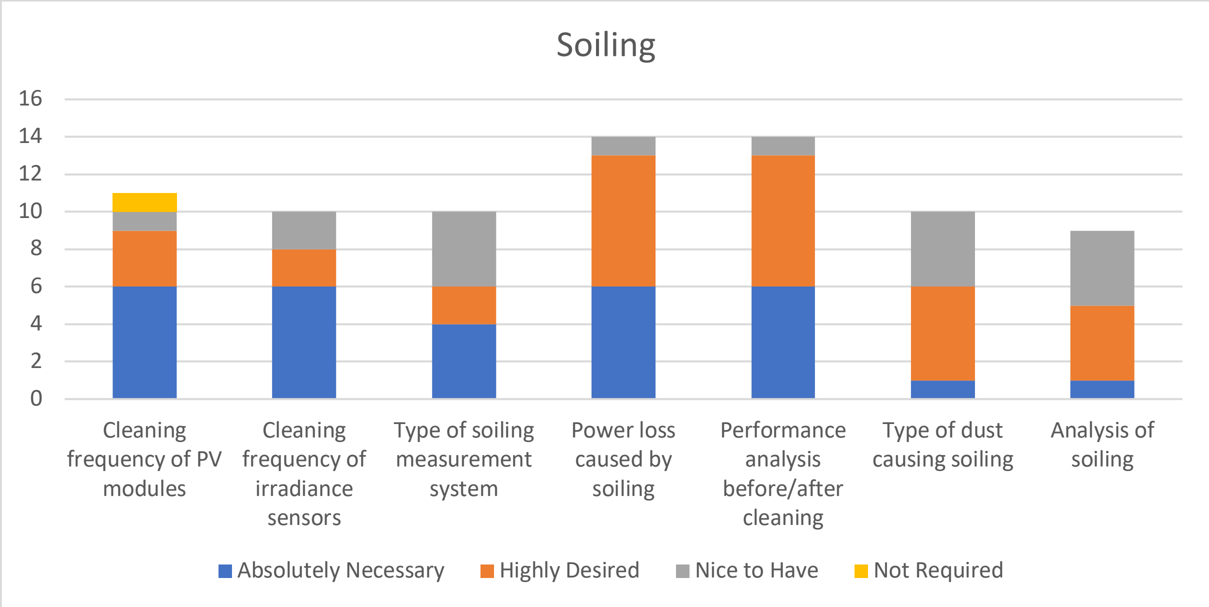

Figure 40: Soiling

Other degradation or failure indicators:

- Leakage current: ___
- Corrosion: ___
- Visual: ___
- IR imaging: ___
- EL imaging: ___
- UV FL imaging: ___
- Combination of failure detection methods (visual, IR, EL, UV FL): ___

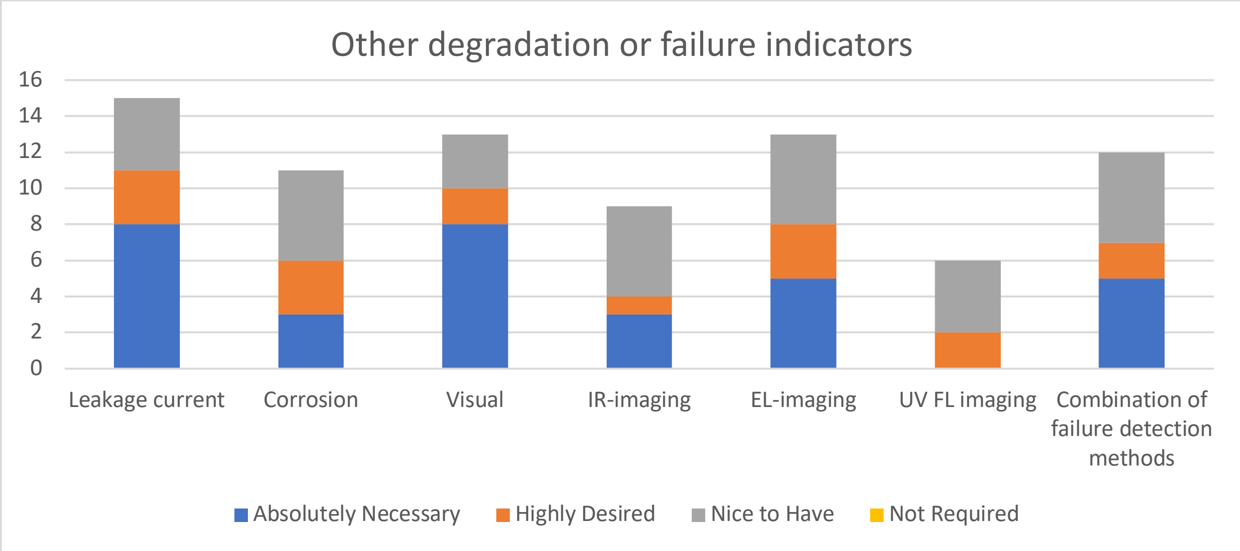

Figure 41: Other degradation or failure indicators

Comment field:

Emilio*:* *In the last version of IEC61724 for class A, sampling rate has to be max 3 sec, record rate max 1 min.*

Karl Berger: *Cleaning frequency of sensors- Minimum once per month, more often in highly soiled areas*

MONITORED DATA: PV IN THE BUILT ENVIRONMENT

Building-technical integration:

- BIPV module and fastening system: ___
- Material choices: ___
- Weatherproofing: ___
- Installation procedures: ___
- Operation and maintenance: ___
- Electrical safety: ___

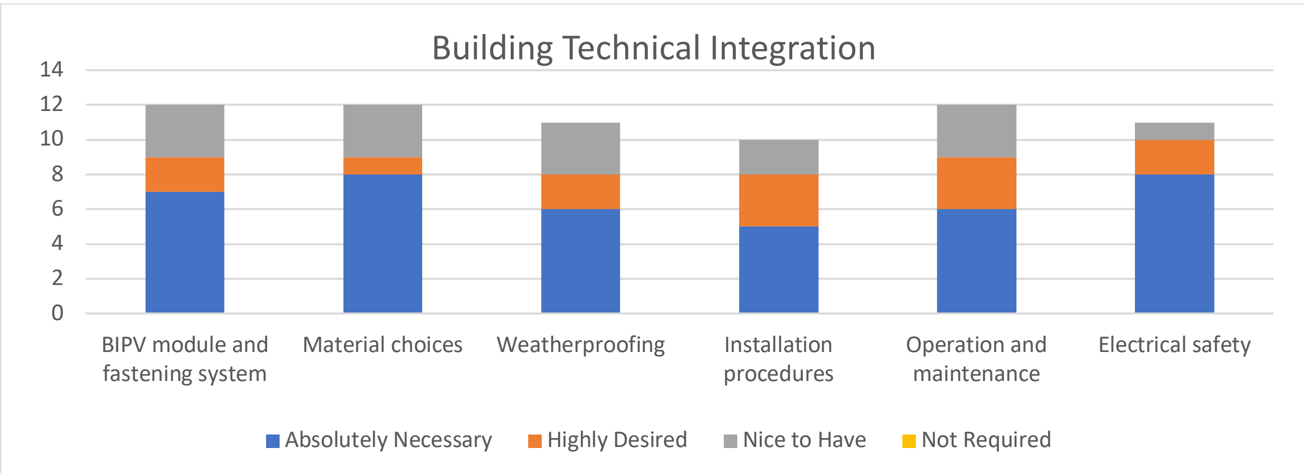

Figure 42: Building Integration

Architectural integration:

- Aesthetics, colour and shape: ___
- Special designs: ___

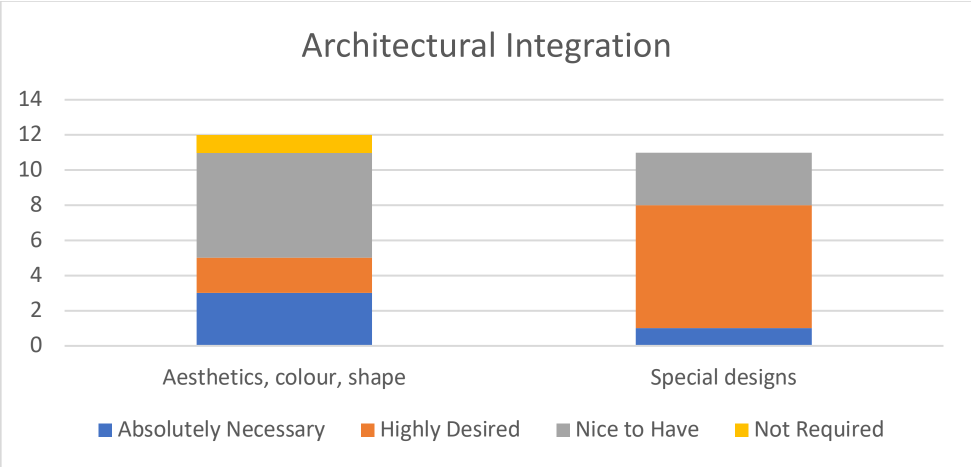

Figure 43:Architectural Integration

Thermal considerations:

- Ventilation of modules: ___
- Temperature of modules: ___
- Thermal properties, insulation, U-values: ___
- Indoor temperatures: ___

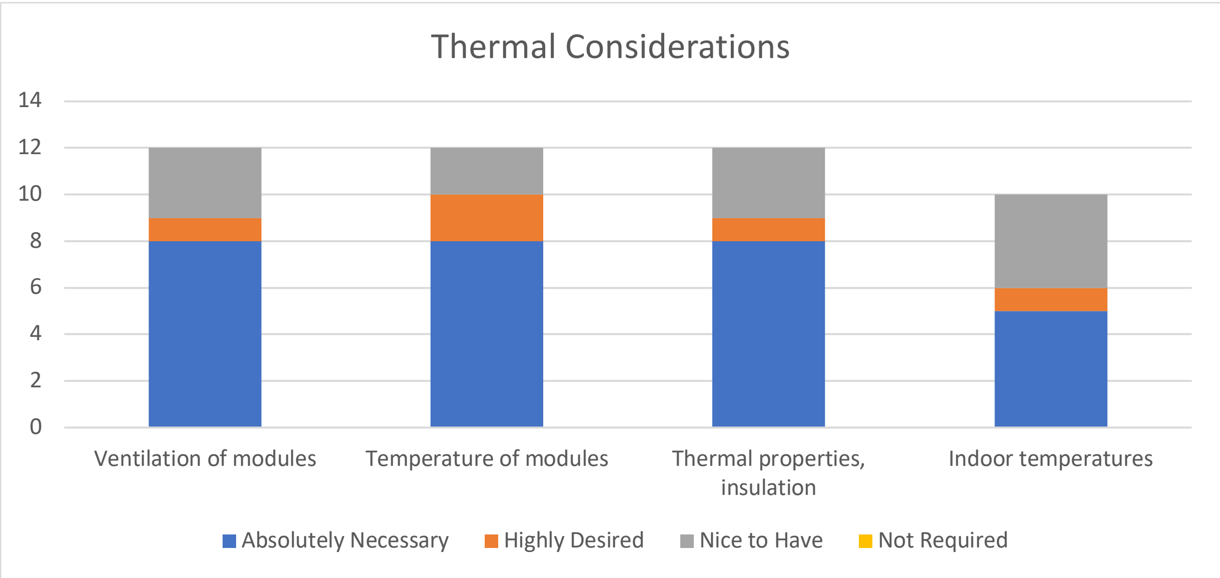

Figure 44: Thermal considerations

Hybrid energy systems:

- Type of hybrid system combination: ___
- Energy share profile of the hybrid system: ___
- Power share profile of the hybrid system: ___

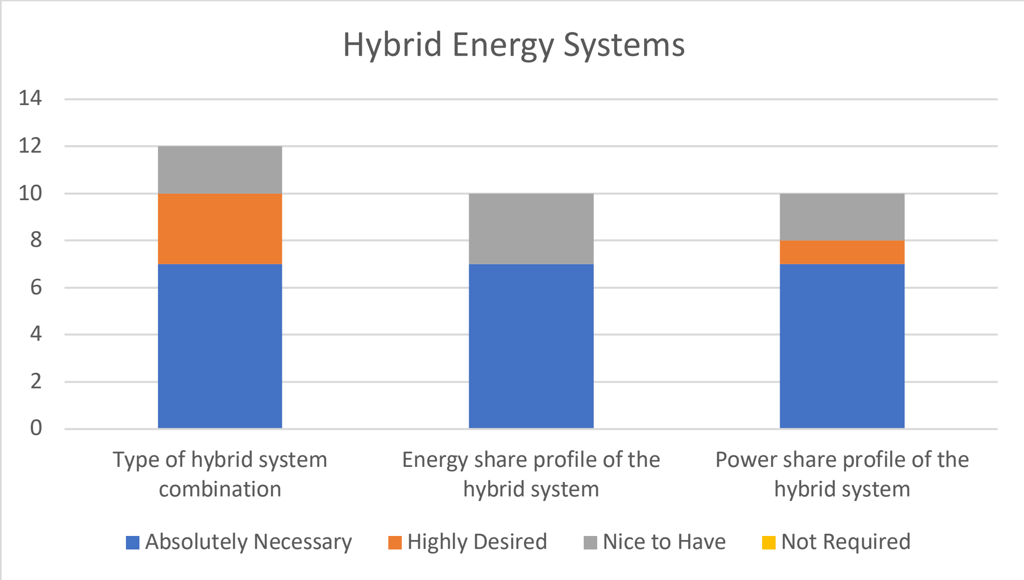

Figure 45: Hybrid Energy Systems

Environmental footprint:

- LCA: ___
- Energy payback time: ___

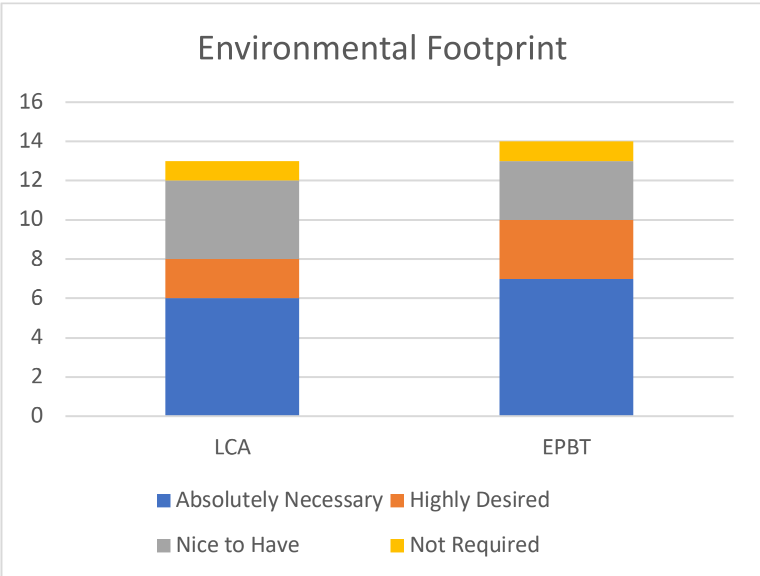

Figure 46: Environmental Footprint

Economical considerations:

- System costs: ___
- Added value of building integration: ___
- Added value of environmental image (e.g. facades): ___
- Economic models: ___
- Economic value of distributed/local energy production: ___

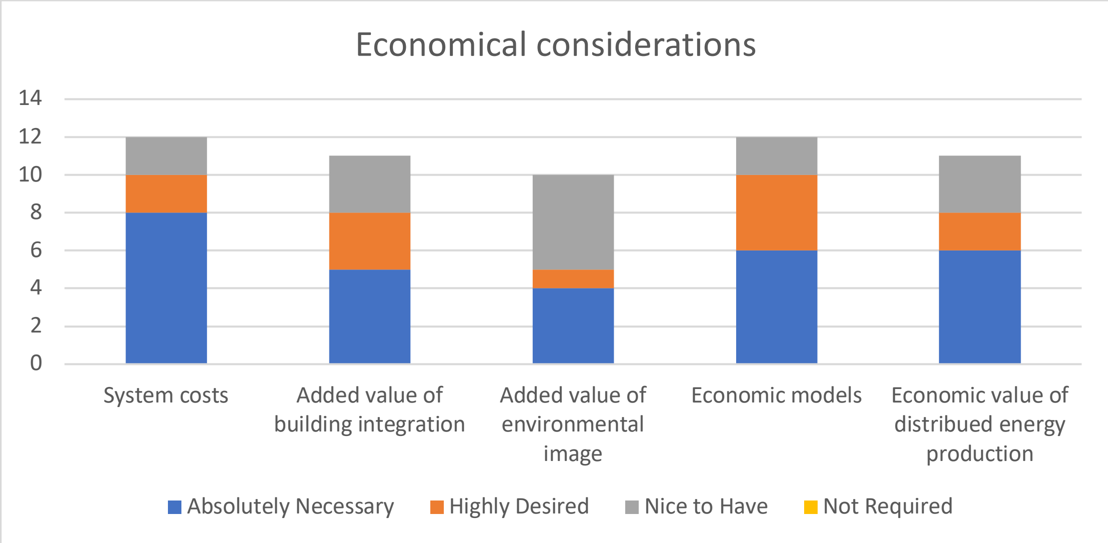

Figure 47: Economical considerations

Comment field:

Karl Berger: *How exact / practicable is it to have and report all these data: seldom constant, widely depending on numerous parameters.*

MONITORED DATA: PV IN GRIDS

- Inverter active (W) and reactive (VAr) power: ___
- Inverter output power factor: ___
- Currents (A) and voltages (V) on each phase (3P+N): ___
- Grid frequency (Hz) and voltage (V): ___
- Harmonics in current, voltage: ___
- Max/min variations in grid frequency (Hz) and voltage (V): ___

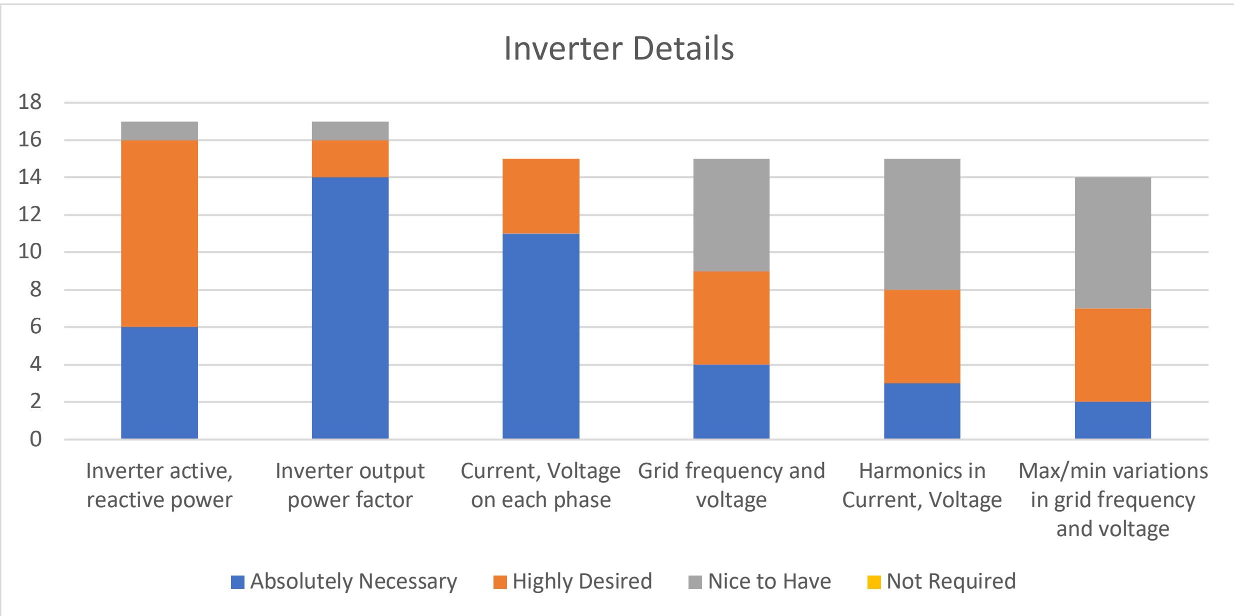

Figure 48: Inverter details

Load characteristics:

- Load voltage (V): ___
- Load current (A): ___
- Load active power (W): ___
- Load reactive power (VAr): ___
- Values on each phase (3P+N): ___

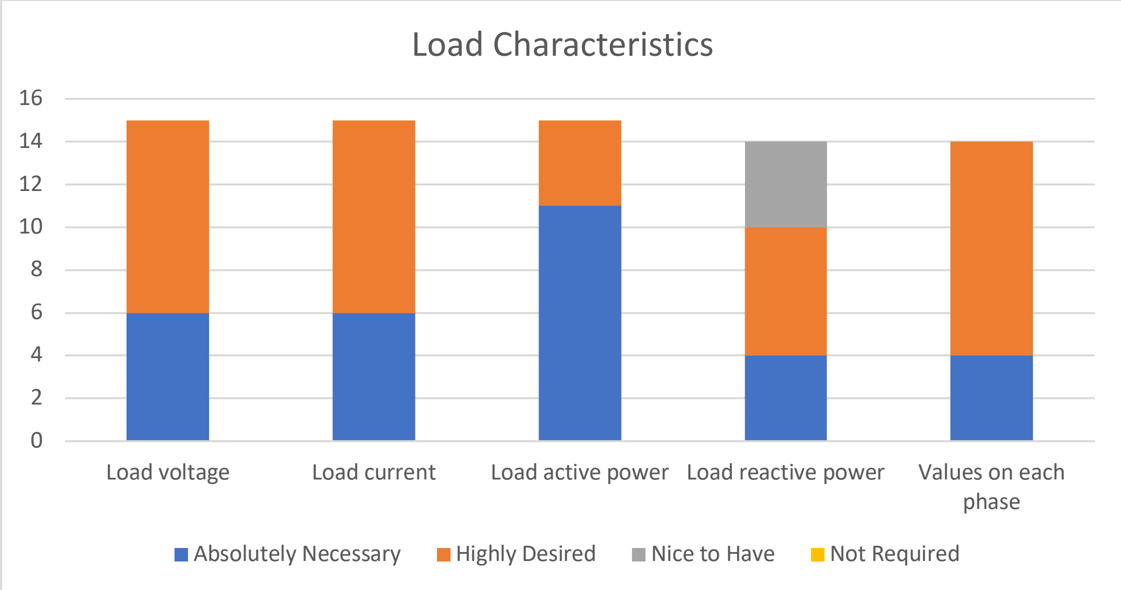

Figure 49: Load Characteristics

Utility grid:

- Utility voltage (V): ___
- Current to utility grid (A): ___
- Current from utility grid (A): ___
- Active power to/from utility grid (W): ___
- Reactive power to/from utility grid (VAr): ___

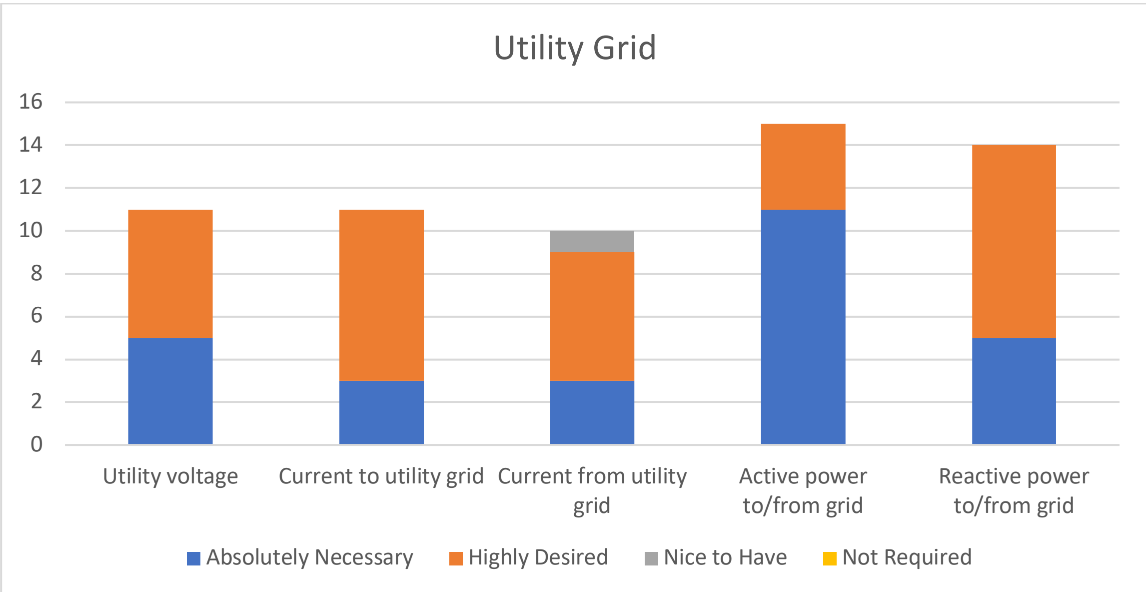

Figure 50: Utility Grid

Generation-load matching/balance:

- Net active power (W): ___
- Net reactive power (VAr): ___
- Net energy (kWh): ___

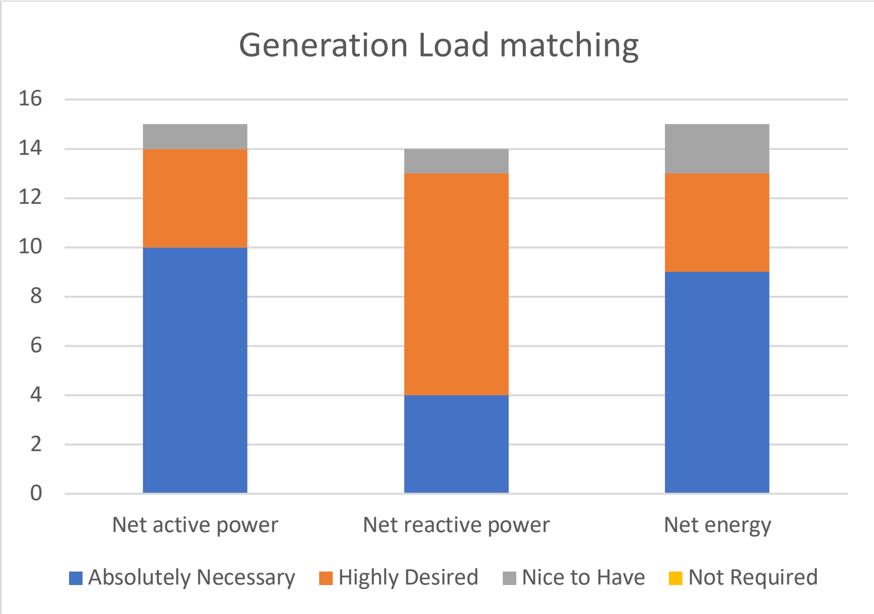

Figure 51: Generation Load Matching

Energy storage:

- Energy storage operating voltage (V): ___
- Current to energy storage (A): ___
- Current from energy storage (A): ___
- Active power to energy storage (W): ___
- Active power from energy storage (W): ___

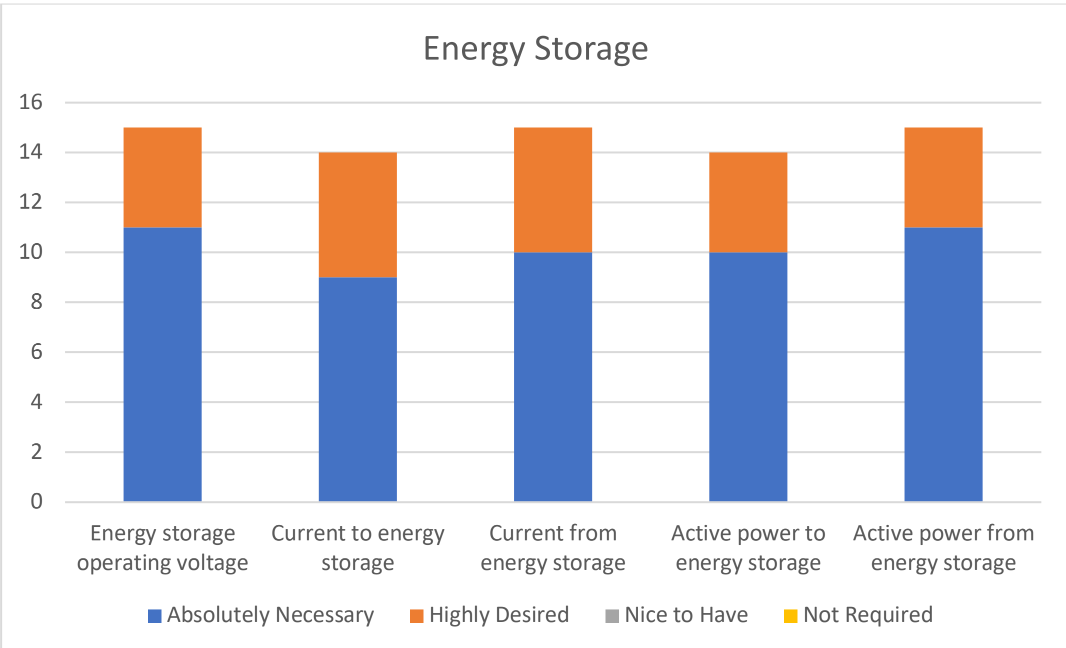

Figure 52: Energy Storage

- Alarms, downtime, fault detection: ___
- System earth resistance: ___
- Ground leakage current: ___
- Grid-management value of distributed/local energy production: ___
- Smart grids/home management systems: ___

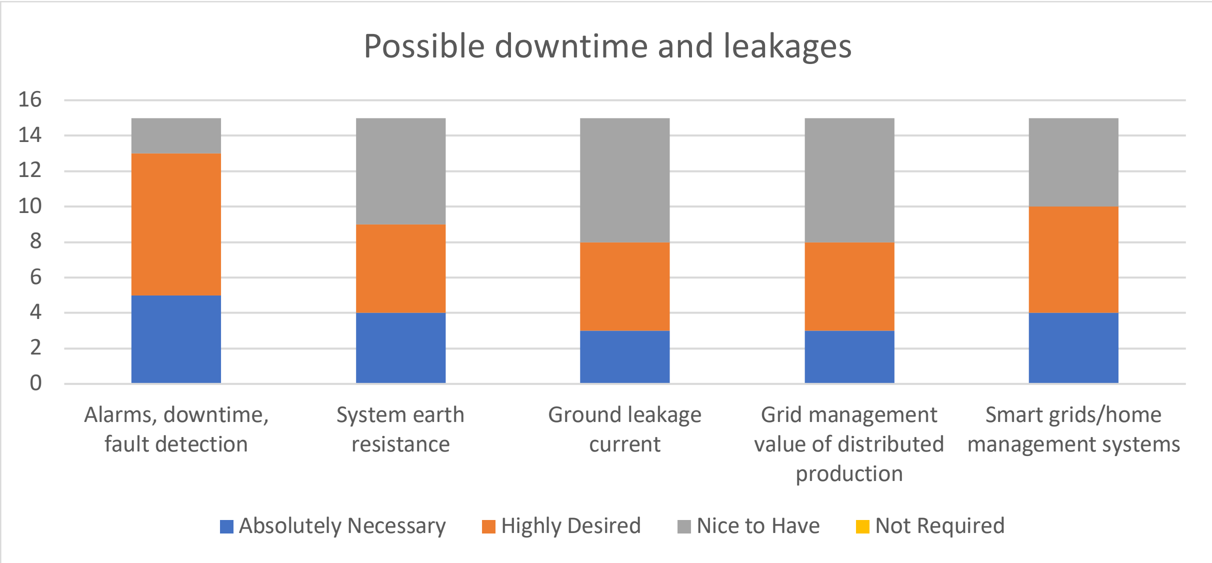

Figure 53: Downtimes and Leakages

<u>Sample</u> rate of grid interaction data (mark relevant option):

- 10 millisec (sine-period of signal): ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

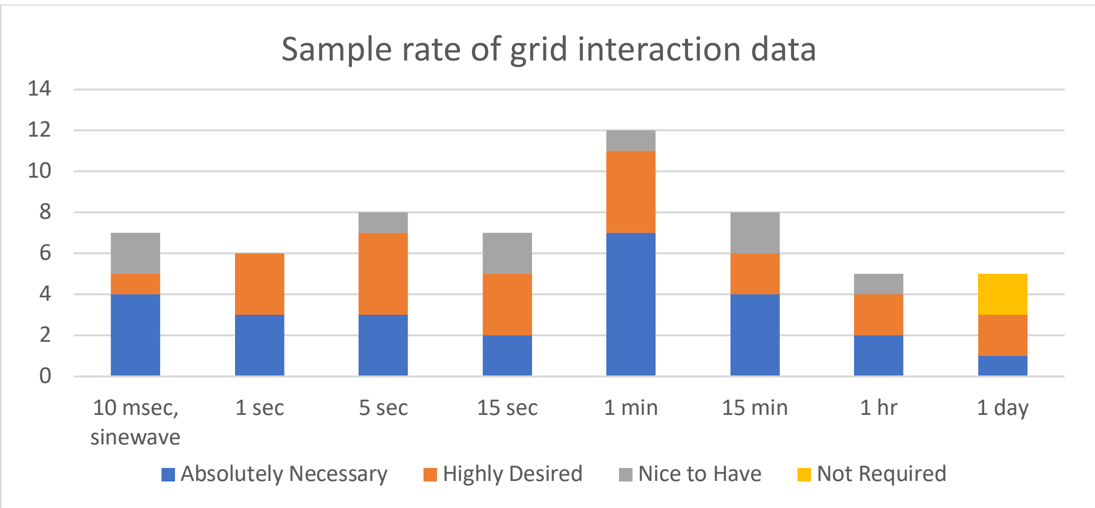

Figure 54: Sampling rate

Record rate of grid interaction data (mark relevant option):

- 10 millisec: ___
- 1 sec: ___
- 5 sec: ___
- 15 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

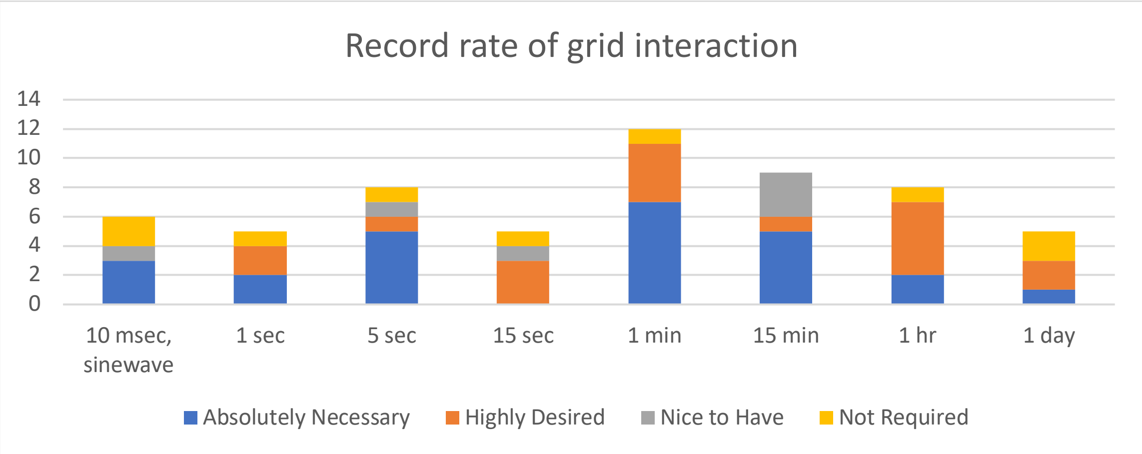

Figure 55: Record rate of grid interaction

Comment field:

Sonia Pinto: *Additionally, it would be important to know the short circuit power in the point of connection of the PV systems to the grid.*

MODELLED DATA: PV SIMULATION

The DERlab guidelines for long-term PV yield measurement recommend to regularly compare measured outdoor data with the outdoor performance prediction tools to identify problems.

Weather & irradiance files:

- Synthetic data, TMY data: ___
- Ground recorded data: ___
- Satellite data: ___

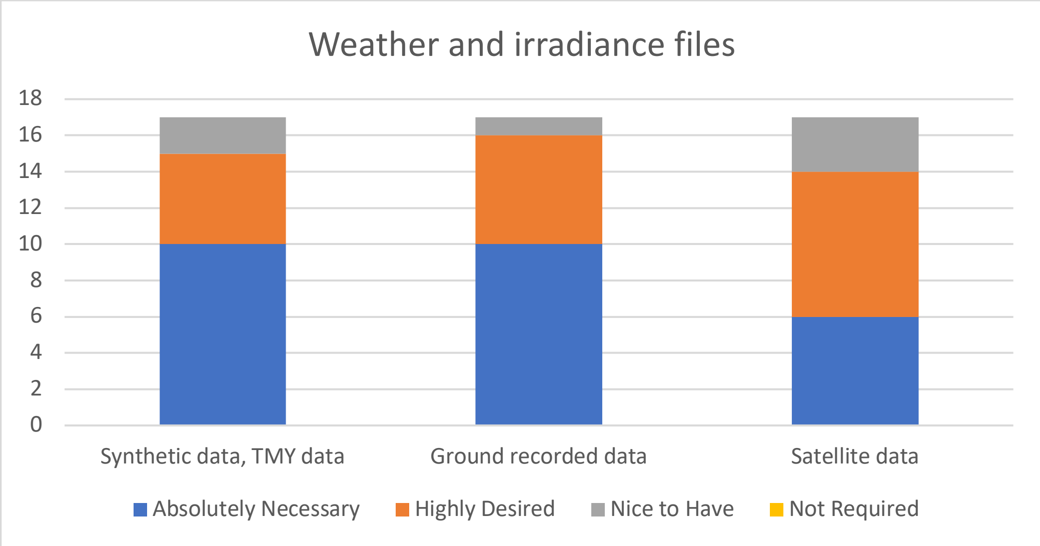

Figure 56: Weather and Irradiance files

- Type of simulation model used, documentation: ___
- Comparison of modelled vs measured data: ___
- Datasheets (modeling parameters for components): ___

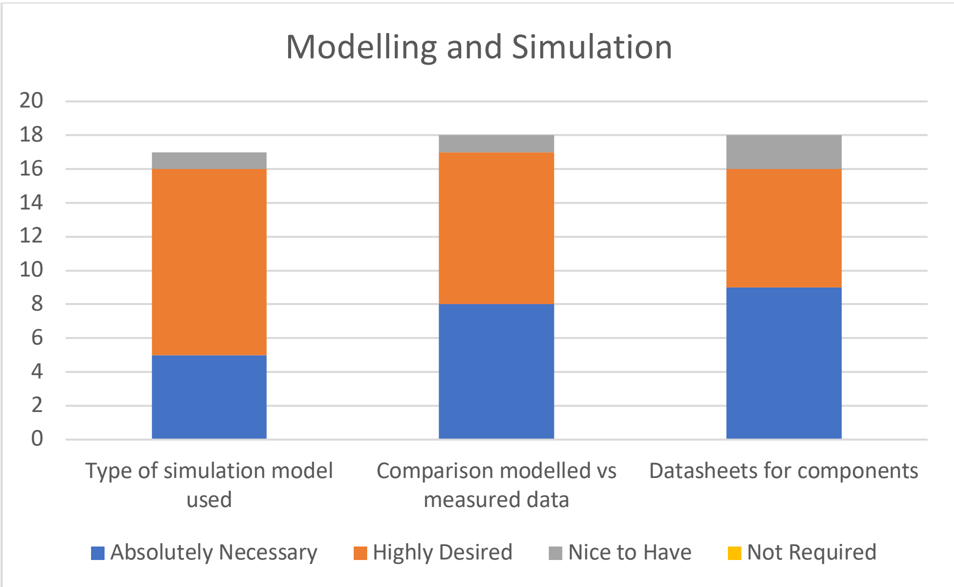

Figure 57: Modelling and Simulation

Modeling components/parts of PV system:

- PV modules: ___
- PV strings: ___
- PV system: ___
- Inverter: ___
- Other BOS components: ___

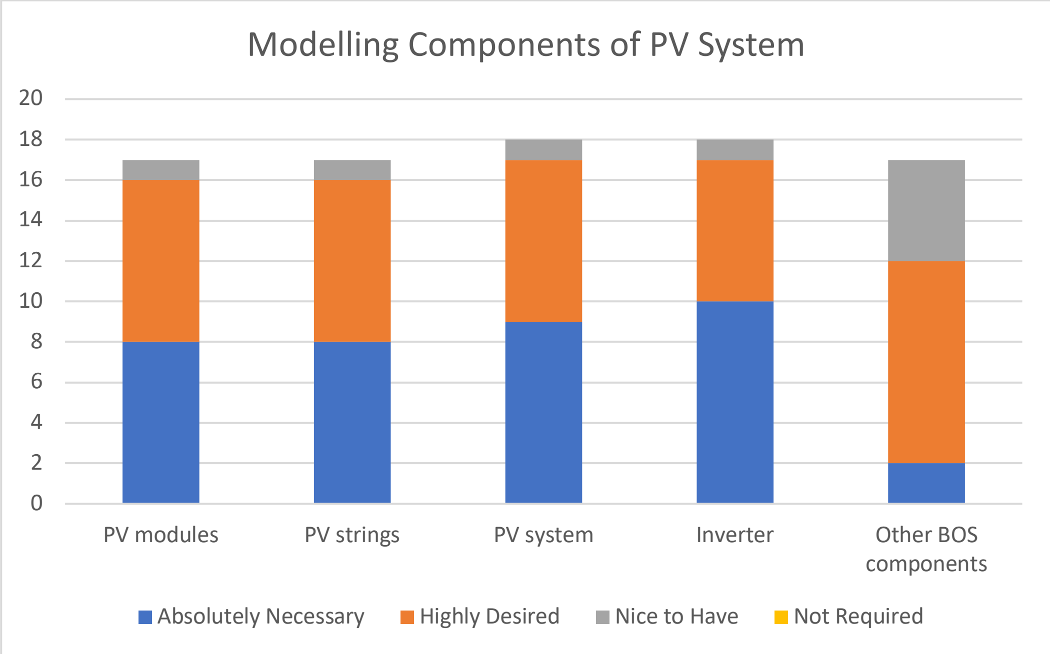

Figure 58: Modelling components of PV System

- Modeling performance (yield, PR, efficiency, degradation loss, BOS loss): ___
- Modeling external influences (shading, snow, soiling): ___
- Modeling thermal properties (air flow, cooling, insulation): ___
- Modeling building integration (BIPV, building properties): ___
- Combining electrical, thermal and building properties (e.g. BIPV): ___
- Modeling grid interaction (ref PV in grids, above): ___
- Forecasting models for PV production: ___

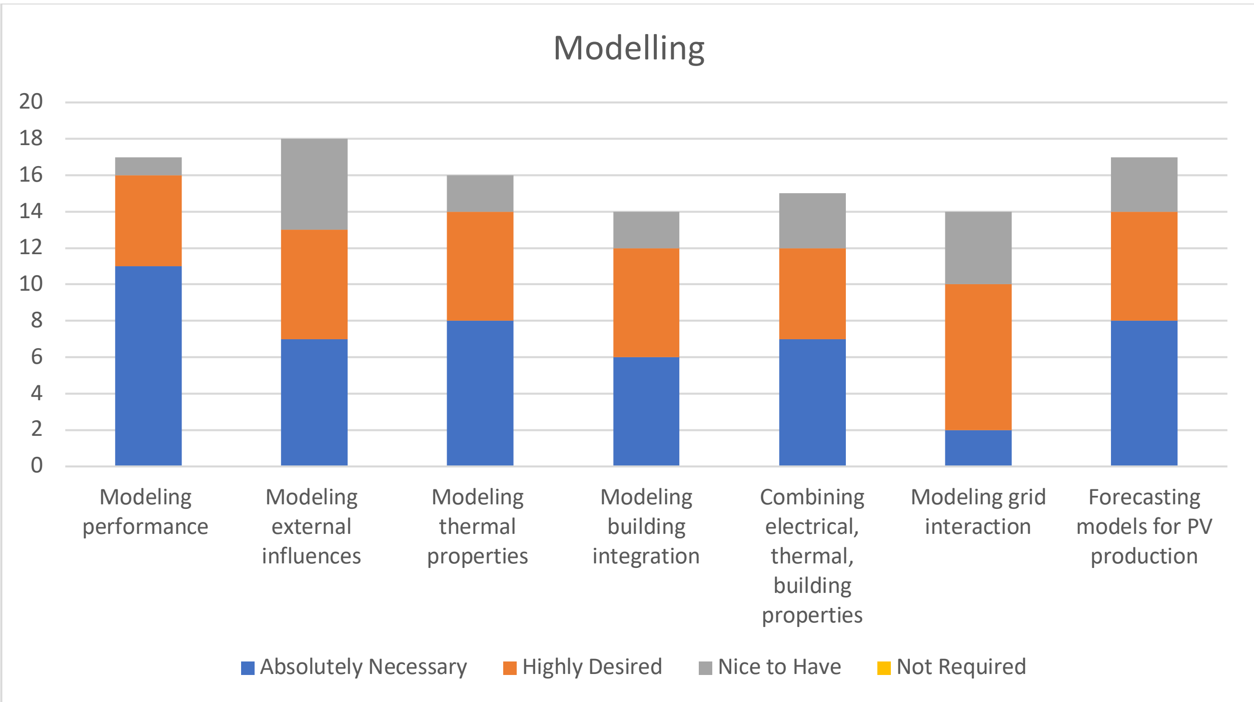

Figure 59: Modelling

Resolution required for PV simulation data (mark relevant option):

- 1 sec: ___
- 1 min: ___
- 15 min: ___
- 1 hr: ___
- 1 day: ___

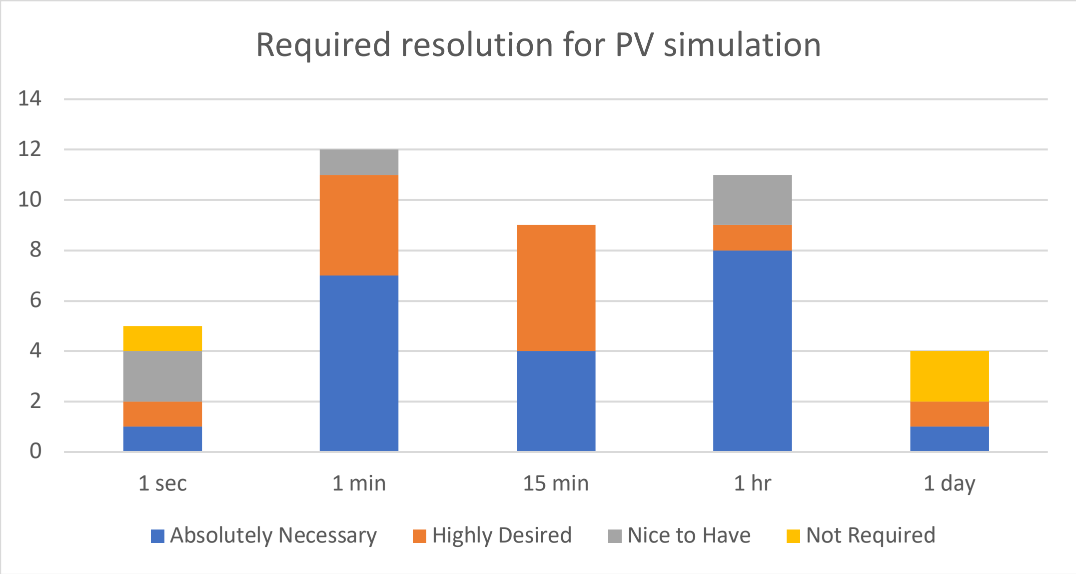

Figure 60: Required resolution for PV Simulation

Comment field:

ANNEX: List of Participants

SN	Name of Participants	Affiliation
1	Bodgan G. Burduhos	Univ Brasov, Romania
2	Simon Boddaert	CSTB France
3	Jonathan Leloux	NA
4	Mohammadreza Aghaei	Politecnico di Milano, Italy
5	Christian Braun	Fraunhofer ISE
6	Nicholas Riedel	DTU, Denmark
7	Emilio Munoz Ceron	Univ.Jaen UJA, Spain
8	Michaela Girtan	Angers Univ., France
9	Emilio Gomez Lazaro	Univ.de Castilla La Mancha, Spain
10	Karl Berger	AIT Austrian Inst.for Technology
11	Francesco Frontini,	SUPSI, Univ.of Applied Sciences and Arts of Southern Switzerland
12	Kristjan Brecl	Univ.of Ljubljana, Slovenia
13	Sonia Pinto	AC Energia, Portugal
14	Sean Erik Foss/Josefine Selj	Inst.for Energy Technology IFE, Norway
15	Tihomir Betti	Univ.of Split, Croatia
16	Petru Cotfas	Univ.of Transilvania Brasov UniTBv, Romania
17	John Gialelis	Univ.of Patras, Greece
18	Luis Fialho	Univ.de Evora, Portugal
19	Brian Norton	Dublin Inst.of Technology, Ireland
20	Jovan Todorovic	Elektrprenos BiH, Bosnia and Herzegovina