This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement N952957.
The information reflects only the project's view and the Commission is not responsible for any use that may be made of the information it contains.

TRUST-PV: Performance and reliability of solar PV power plants

14 July 2022

David Moser

Institute for Renewable Energy

eurac research

TRUSTPV
SOLAR PV, PERFORMANCE & RELIABILITY

UNSW SYDNEY

SPREE Talk 14 July 2022

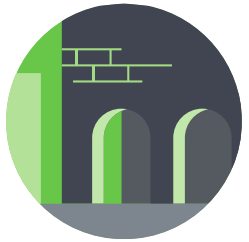
The Institute for Renewable Energy

Credits: M. Gretter/Eurac Research - Institute's collaborators with the Scientific Council 2021

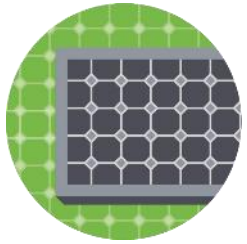
2021: Fact & Figures

Our 6 Research fields

Sustainable
Heating & Cooling Systems



Energy Retrofit
of Historic Buildings



Photovoltaic
Energy Systems

Urban & Regional
Energy Systems

Energy Efficient
Buildings

Overall Energy System
Modelling & E-Mobility

Photovoltaic Energy Systems

Performance and reliability of PV systems, solar resources: exploitation and mitigation of variability, PV integration into buildings and electricity grids.

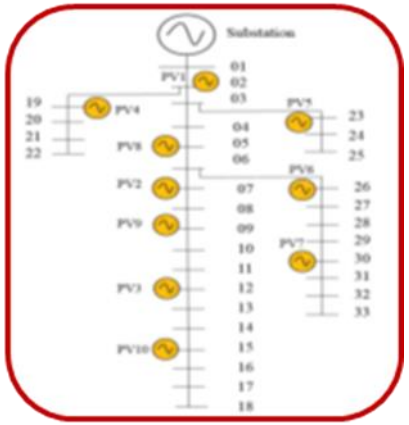
Credits: I. Corrà/Eurac Research

Quality and Sustainability of the PV sector

Performance and reliability

PV integrated in the energy system

PV in buildings



PV in grids

MAIN EFFORTS IN PAST 2 YEARS:

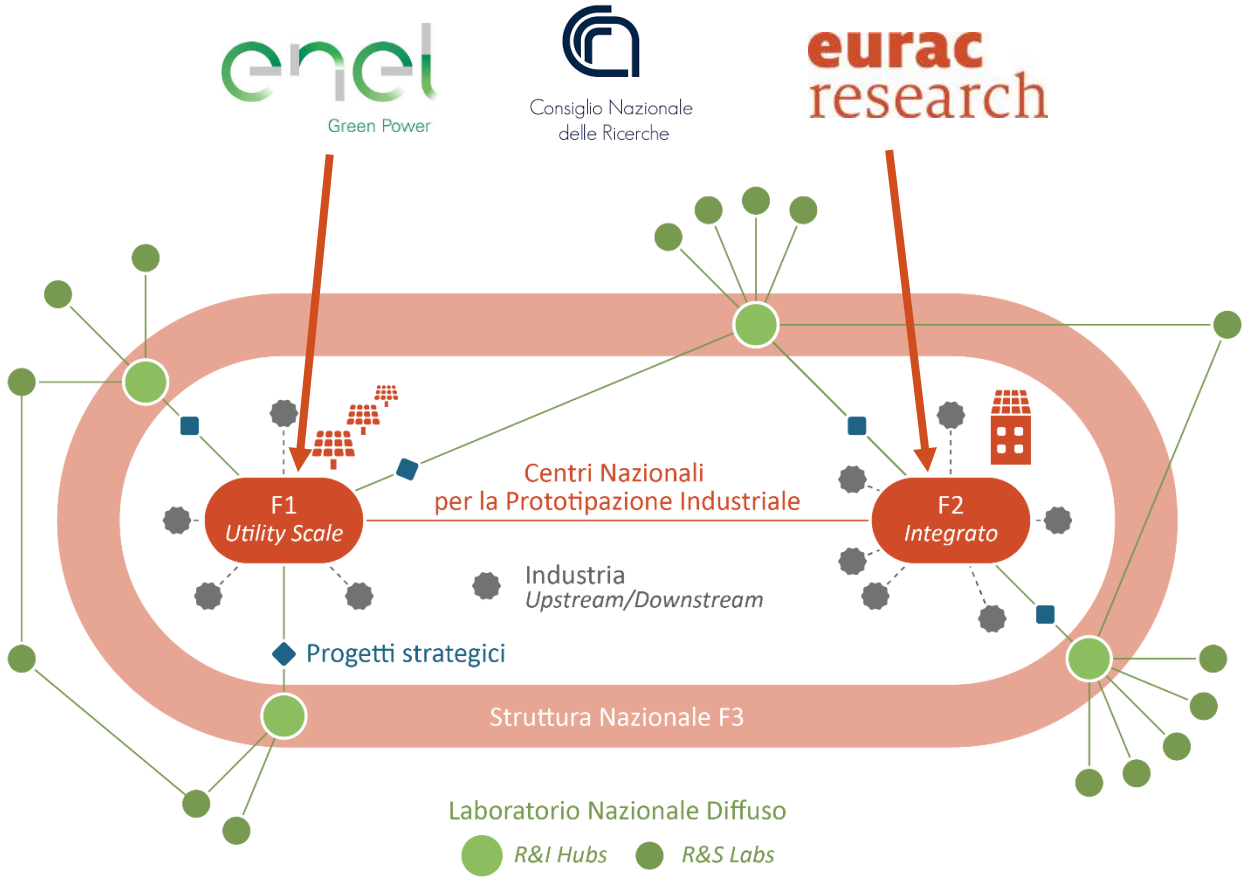
- Become point of reference for reliability and bankability of PV technologies and systems at international level
- Digitalisation of the PV sector
- BREAKING SILOS (facilitate dialogue between stakeholders)
- Collect best practices in BIPV
- Assess impact of PV + BESS + e-mobility + HP in renewable energy communities and in the distribution grid

National strategy and local manufacturing

IAPI: ItaliAn network for Photovoltaic R&I

A Strategic Plan for Research and Innovation to Relaunch the Italian Photovoltaic Sector and Contribute to the Targets of the National Energy and Climate Plan

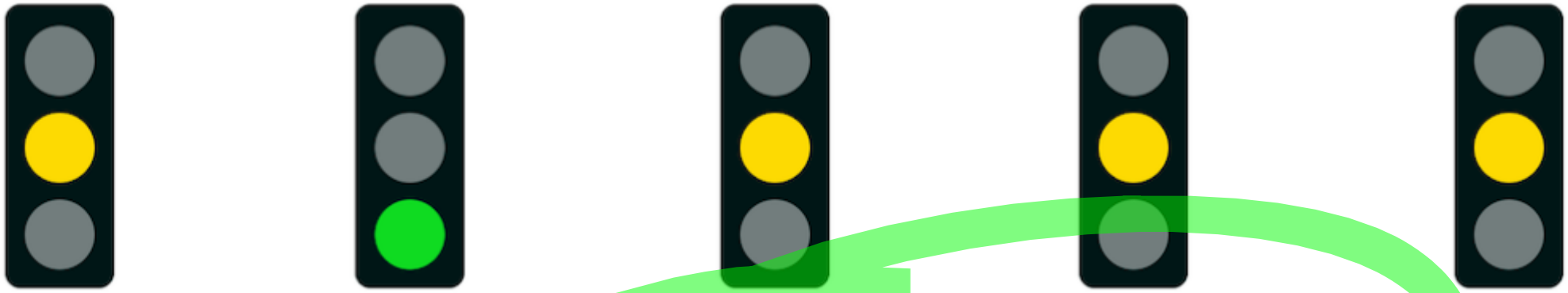
This document is the result of a joint effort of the Italian R&I community operating in the photovoltaic sector. Senior Italian researchers and innovation managers with an active role in European and international organisations (EERA, PV-ETIP, IEA) have worked with the rest of the community to translate the priorities of the PV Implementation Plan of the SET Plan, into a comprehensive action plan with clear objectives and expected economic and strategic impact. This initiative goes hand in hand with the plans of the European PV industry to relaunch large-scale manufacturing in Europe along the whole value chain and is inspired by the R&I "missions" of Horizon Europe.



+ 50 organisations (RTOs, industry)

National strategy: Industrial prototyping center

PhotoVoltaic
EUROPEAN TECHNOLOGY & INNOVATION PLATFORM



CHALLENGE 1	CHALLENGE 2	CHALLENGE 3	CHALLENGE 4	CHALLENGE 5
Performance enhancement and cost reduction (through advanced photovoltaic technologies, manufacturing and applications)	Lifetime, reliability and sustainability enhancements (through advanced photovoltaic technologies, manufacturing and applications)	New applications through integration of photovoltaics (for diversified and dual-use deployment and enhanced value)	Smart energy system integration of photovoltaics (for large-scale deployment and high penetration)	Socio-economic aspects of the transition to high PV contribution
Experts pool	Led by EURAC	Experts pool	Experts pool	

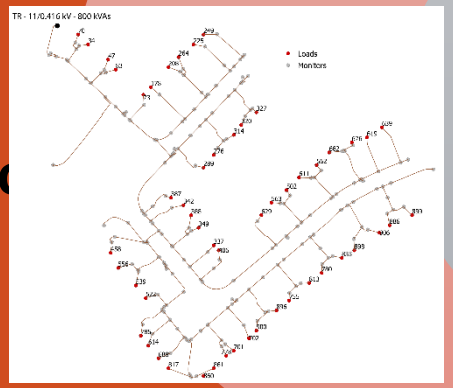
ETIP-PV Strategic and Research Innovation Agenda (https://etip-pv.eu/publications/sria-pv/)

2030 VISION

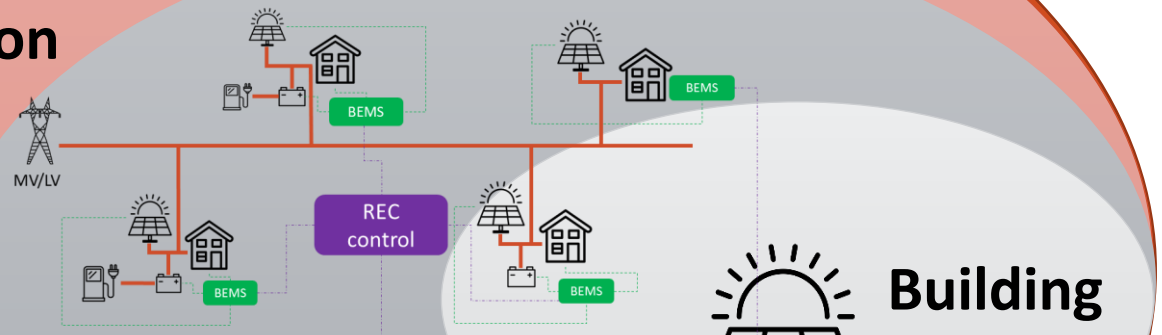
PV integrated in the energy system

MISSION: PV plants must provide ancillary services and ultimately become dispatchable to increase utility friendly integration

Transmissi

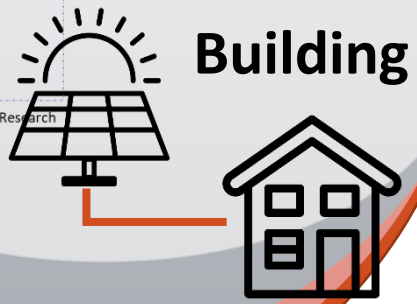


Distribution



Local grid

Building



PV Performance and Reliability

PhotoVoltaic EUROPEAN TECHNOLOGY & INNOVATION PLATFORM

2000… 2010 2015 2020 2022 2024

IEA PVPS IEA PVPS Task 13

PV performance database
Failure review in the field
Uncertainty framework

SOLAR BANKABILITY

Technical risk framework
CPN methodology

Yield assessments
Performance Loss Rates

solartrain

Performance Loss Rates

PEARL PV

PV performance database

PV 4.

Industry4.0 + IoT platform
Big data analytics

TRUSTPV

MISSION: The installed power capacity in GW must also reliably and sustainably generate TWh of electricity for an extended lifetime

The overall objective of the project is to develop a concept for the effective management of the activities of various stakeholders (asset managers, O&M companies, etc) inspired by Industry 4.0 and so to optimise the decision process minimising time and operational costs.

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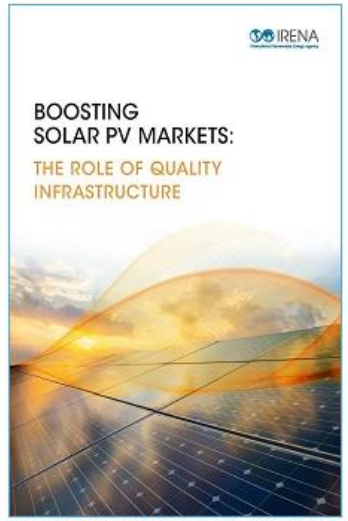
THE QUEST FOR QUALITY



Boosting global PV markets: The role of quality infrastructure

SolarPower Europe

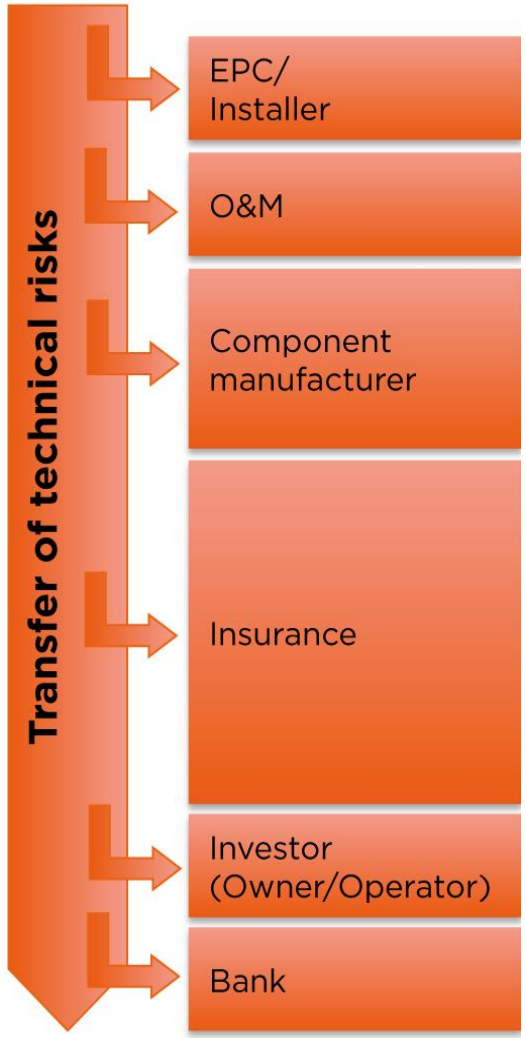
PhotoVoltaic EUROPEAN TECHNOLOGY & INNOVATION PLATFORM

IEA PVPS

IRENA International Renewable Energy Agency

SOLARUNITED

STAKEHOLDERS' NEEDS



short defect warranty periods, minimum of additional guarantees and warranties, high sale price with low OPEX (short time horizon)

manage all the conflicting requirements for a long period of time. The best condition for O&M operators is in fact in the presence of long defect warranty period and low sale price to allow for higher OPEX.

Limit their liability to product guarantees and warranties

limit their liability to failures PV plants, which meet technical market standards and are maintained on a regular basis

long defect warranty periods, performance guarantees, reasonable low CAPEX and OPEX, high long-term plant performance and lifetime (ideally above the initial prediction).

projects with a 10-15 year financing period and PV plant performance which can also be slightly below prediction.

TRUSTPV Proudly powered by the European Union's Horizon 2020 Research and Innovation Programme.

TRUST-PV PROJECT

Start date 1 September 2020
End date 31 August 2024

Funded under
SOCIETAL CHALLENGES - Secure, clean and efficient energy

Total cost
€ 12 984 222,50

EU contribution
€ 9 969 043,63

Coordinated by
ACCADEMIA EUROPEA DI BOLZANO
Italy

Project Coordinator eurac research

3E, above, BayWa r.e., covestro, endurans solar, enel Green Power, eurac research, FOSS Research Centre for Sustainable Energy, HUAWEI, imec, inaccess, INNOSEA An LDC Company, PVcase, Raptech, Reuniwatt, saidea, SolarPower Europe, Solar Monkey, Statkraft, TU Delft, TÜVRheinland® Precisely Right.

Testing

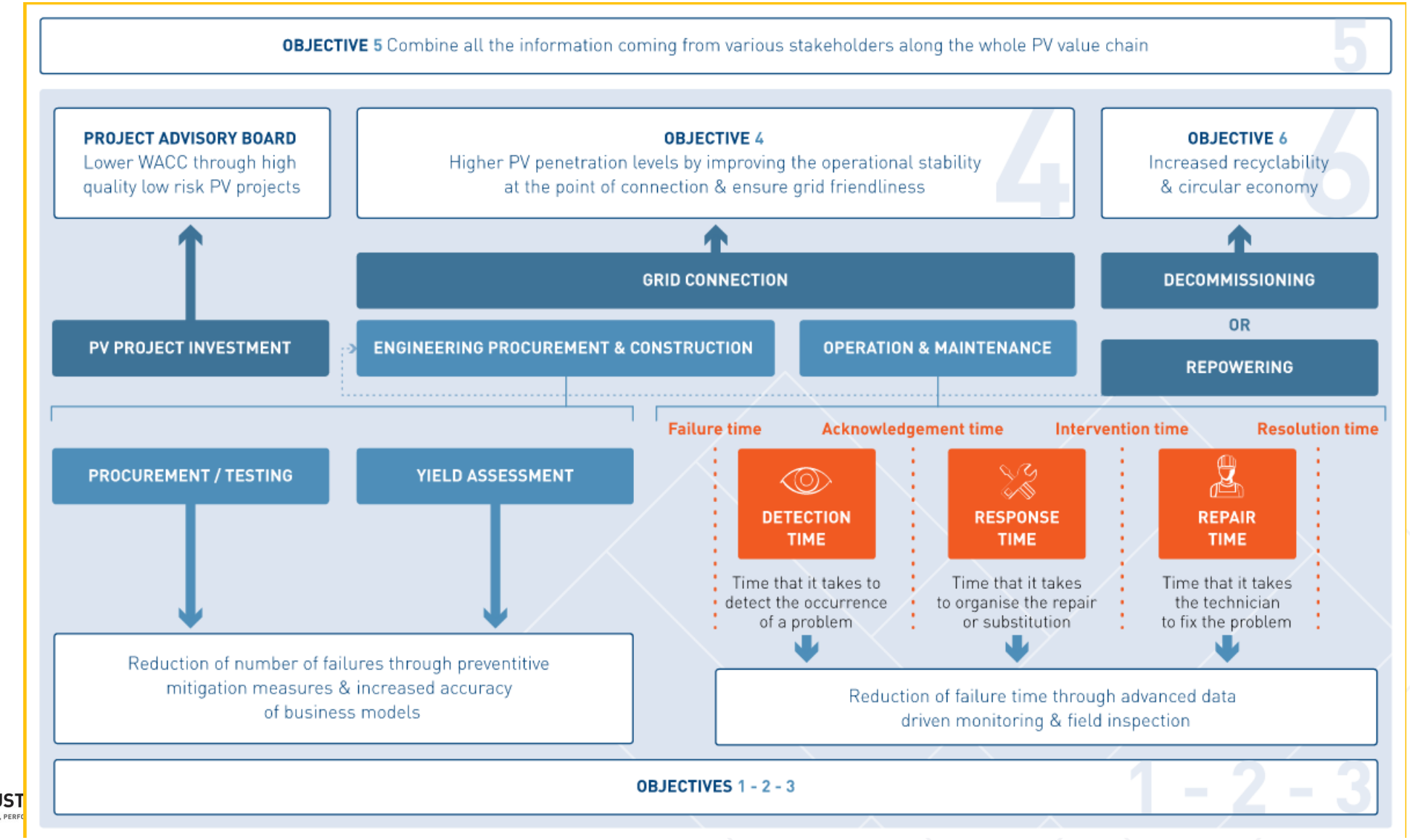
Early Prototype

Advanced Prototype

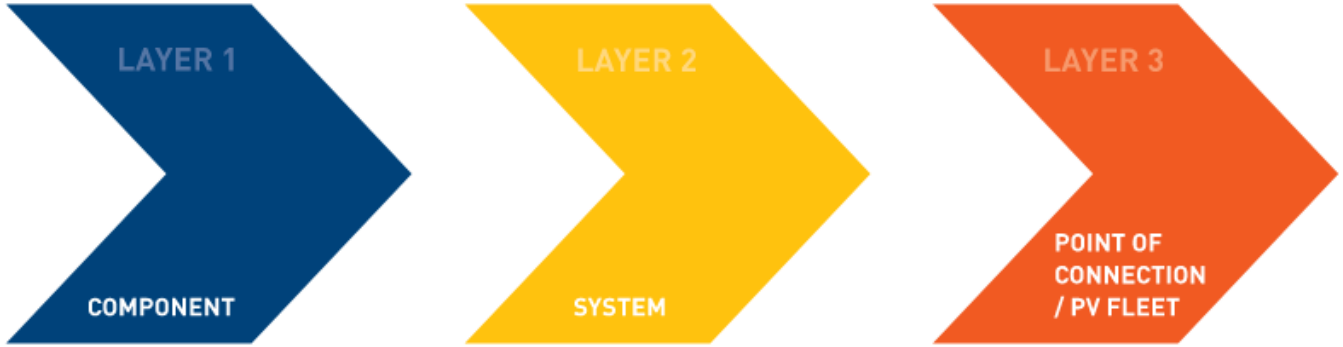
Demo and Pilot sites

M0 M6 M12 M18 M24 M30 M36 M42 M48

TRUST-PV: A VALUE CHAIN APPROACH



EXPECTED RESULTS



RESULTS

R1 Sustainable O&M & grid friendly PV components

R2 Application & climate-tailored testing beyond existing standards

R3 Context-sensitive PV Plant components benchmarking

RESULTS

R4 More accurate energy yield prediction

R5 Progressive repowering

R6 BIM / augmented reality for improved skills of O&M operators

R7 Wireless Sensor Networks

R8 Automated fault diagnostic based on combined image analysis (IR/EL/UV) & electrical signatures

R9 Large database for failure rates calculation, mitigation measures & failure rate reduction based on CPN methodology including grid

R10 Decision support platform from fab to field

RESULTS

R11 Fully felxible & interoperable PV systems

R12 Advanced forecasting

R13 Digital twin concepts

OBJECTIVES

TRUSTPV's RESULTS ENABLE THE ACHIEVEMENT OF OBJECTIVES

1. Increase P&R & lifetime of system components.
2. Increase the knowledge on the performance & establish cost effective fault diagnostic models of medium size commercial-resitential systems.
3. To increase the design accuracy & the reliability & performance of utility – large commercial systems.
4. To combine all the information coming from various stakeholders along the whole PV value chain into a platform for enhanced decision-making.
5. To allow higher PV penetration levels by improving the operational stability at the point of connection and ensure grid friendliness.
6. To increase the sustainability of utility – large commercial systems through progressive repowering interventions.

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LAYER 1 | COMPONENTS

RESULT | 1

O&M and grid-friendly solar PV components.

Read more »

RESULT | 2

Application and climate-tailored testing beyond existing standards

Read more »

RESULT | 3

Context-sensitive PV plant components benchmarking based on monitoring data from over 6 GW of PV plants under operation and Big Data analytics.

Read more »

- Antireflective coatings with improved performance
- O&M-friendly solar PV modules considering the needs of O&M contractors such as reduced weight and reduced number of failures
- Inverter enabling semi-automated field inspection combined with UAV and forecasting
- Innovative PV modules passive cooling
- Power Plant Controller enabling grid friendliness

TESTING

48 bifacial 3SUN (EGP) modules
185 kVA HUAWEI inverter

Inverter enabling semi-automated field inspection - EL

Reverse Power flow on the string is required during EL

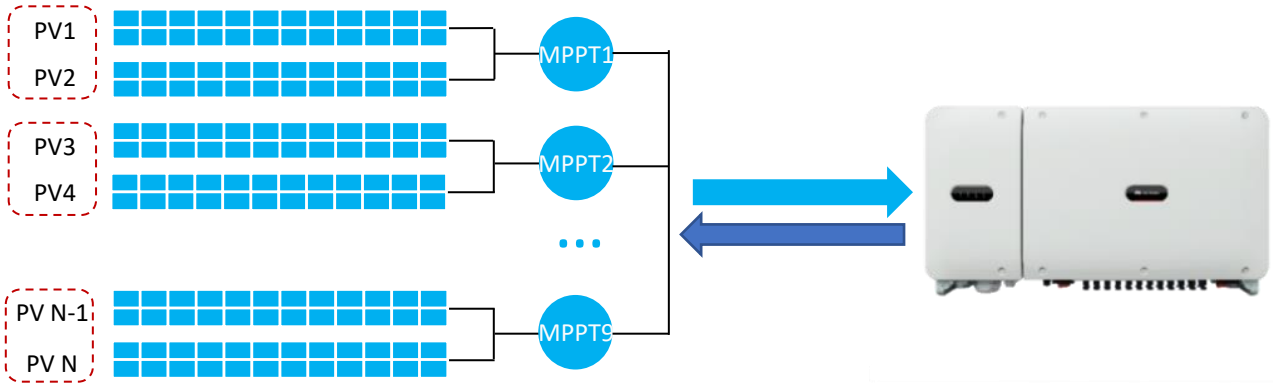
In order to provide the conditions for Electroluminescence (EL) the hardware of the current Huawei's standard string inverters must be upgraded as there is no reverse energy flow possible via the MPPT

TRUST-PV Innovation-enabled Potential

Within H2020 TRUST-PV, Huawei is researching and assessing the best ways to combine EL in an integrated-inverter-level solution (software & hardware based)

EL is enabled without extra/external hardware or cabling reconfiguration – cost-effective and user-friendly

EL Enabled Inverter with Integrated Solution – No extra equipment needed



- **Latest version based on a prototype with embedded hardware for final definition of the EL operating conditions (necessary string voltages, currents and reverse power)**
- **Latest EL software has both APP and MODBUS capabilities to ease the control management**

Inverter enabling semi-automated field inspection - EL

Electroluminescence Functionality tested in the field

- Confirmation of functionality
- Special considerations for Bi-facial modules necessary
- Next steps: combination with UAV and forecasting to find best weather for flying

Inverter enabling semi-automated field inspection - EL

Electroluminescence Functionality tested in the field

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- Special considerations for Bi-facial modules necessary
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LAYER 1 | COMPONENTS

RESULT | 1

O&M and grid-friendly solar PV components.

Read more »

RESULT | 2

Application and climate-tailored testing beyond existing standards

Read more »

RESULT

Context-sensitive PV plant components benchmarking based on monitoring data from over 6 GW of PV plants under operation and Big Data analytics.

Read more »

enel Green Power — PV component failure data, O&M ticketing data

BayWa r.e. r.e.think energy — Monitoring and as-built information, Asset management data

3E — Monitoring and as-built information

Statkraft — PV component failure data, O&M ticketing data

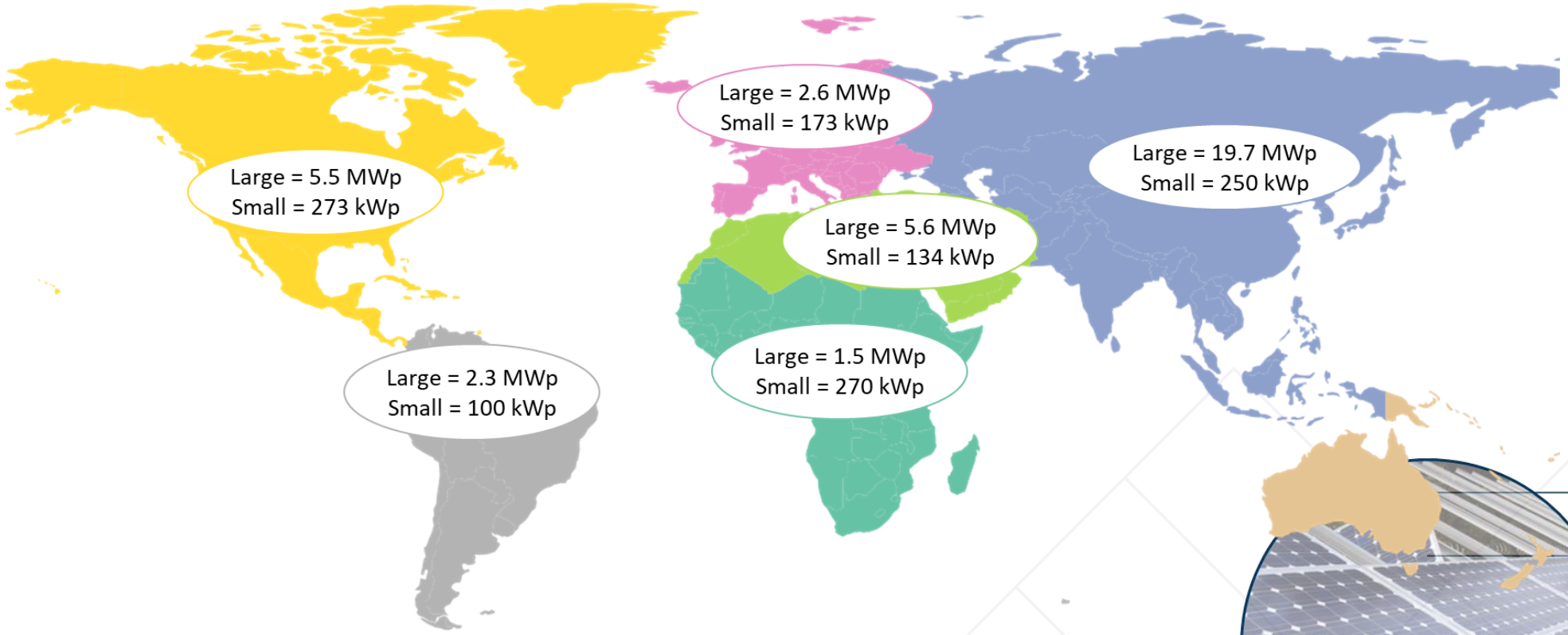
INNOSEA An LOG Company — Monitoring data from Floating PV plants

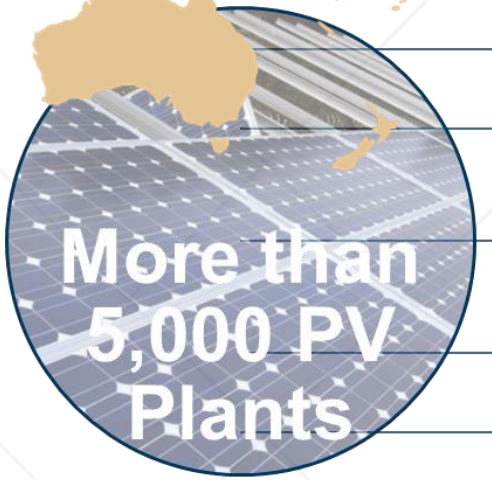
- More than 7 GW of connected assets
- Metadata
- Monitoring data
- O&M data

TRUSTP SOLAR PV, PERFORM

CONTEXT SENSITIVE BENCHMARKING

World map with average plant DC capacity per world region





>100k Inverters
>10 years Operational Data
> 65 Inverter Manufacturers
> 200 Module Manufacturers
>40 Countries

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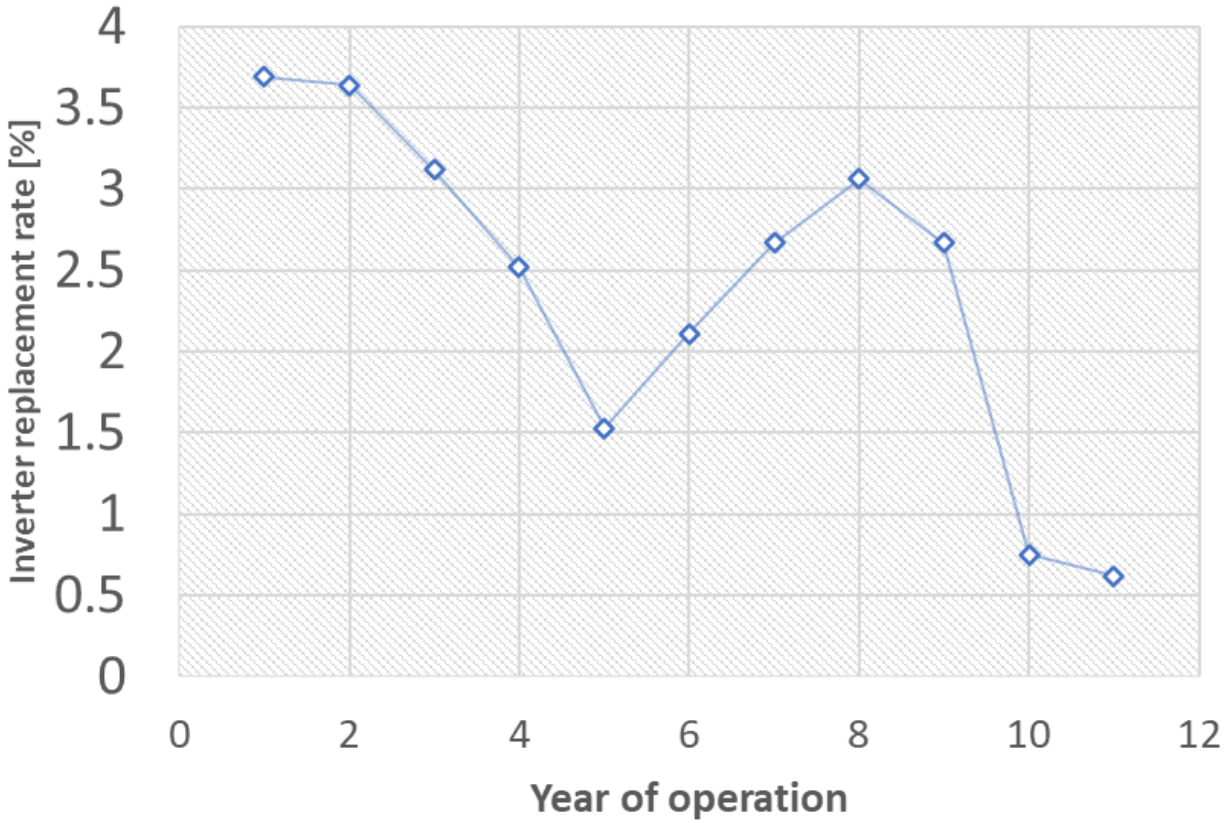
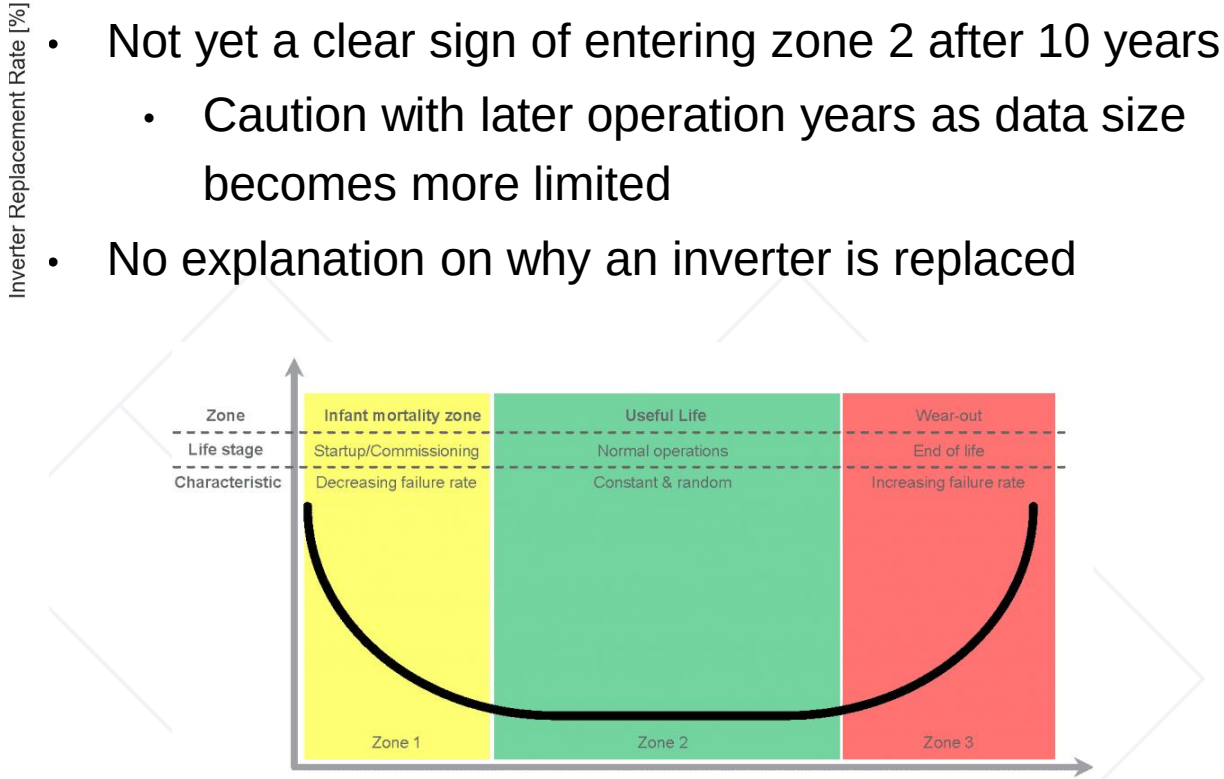
CONTEXT SENSITIVE BENCHMARKING:
Inverter replacement rate



- Bathtub curve based on actual measured big data
  - One of the first of its kind for inverters
- Not yet a clear sign of entering zone 2 after 10 years
  - Caution with later operation years as data size becomes more limited
- No explanation on why an inverter is replaced



LAYER 2 | SYSTEM

RESULT | 4

More accurate energy yield prediction for PV systems with novel technologies and system layout.

Read more »

RESULT | 5

Progressive Repowering.

Read more »

RESULT | 6

Augmented Reality for improved skills of O&M operators and disruptive concepts for PV systems engineering.

Read more »

RESULT | 7

Wireless Sensor Networks using Narrowband Internet of Things (IoT) and 5G technology for on-site sensors such as energy meters for combined AI – physics based diagnostic

Read more »

RESULT | 8

Automated fault diagnostic based on combined image analysis (PL/IR/EL/UV) and electrical signatures

Read more »

RESULT | 9

Large database for failure rates calculation, mitigation measures and failure rate reduction functional to a fully integrated CPN methodology including grid and novel PV plant design

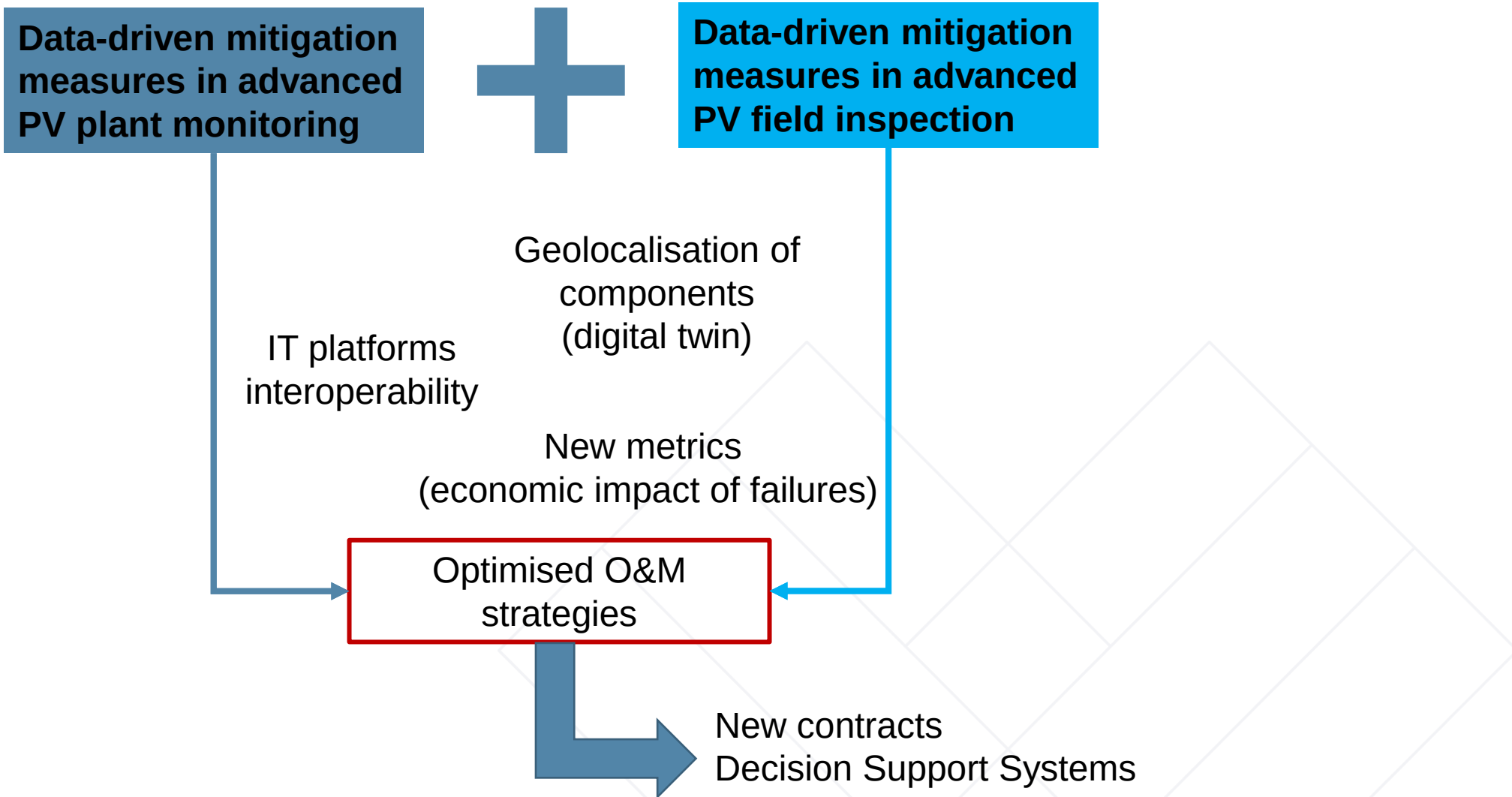
Read more »

RESULT | 10

Decision support platform from fab to field

Read more »

DATA DRIVEN QUALITY MANAGEMENT



RISK MATRIX: TAXONOMY (OR ONTOLOGY)

Failure appearance in PV plant

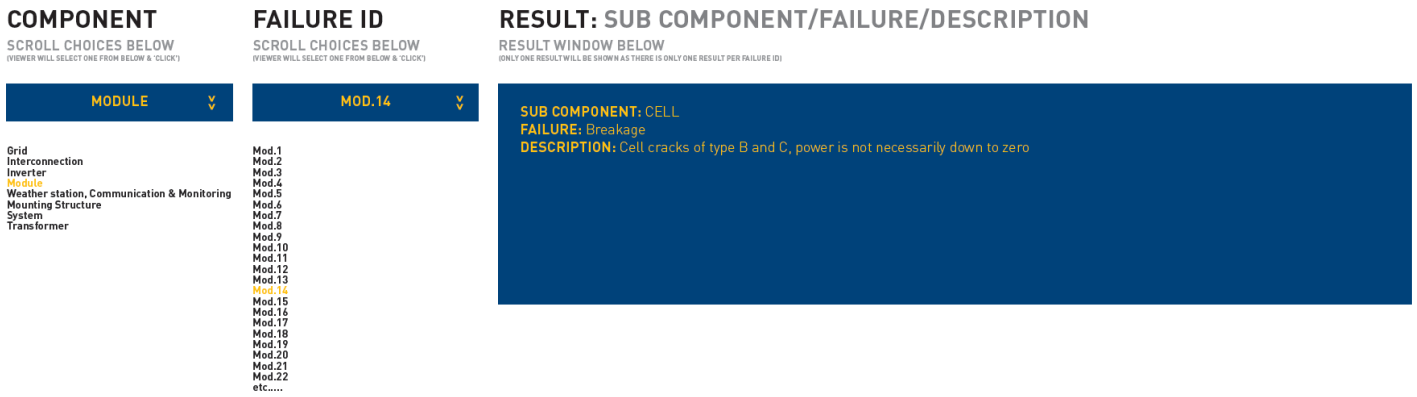
Creation of ticket in SCADA system

Classification of failure according to TRUST PV's Risk Matrix

Resolution of failure

Statistical analysis of failure (CPN)

Risk Matrix Update



Ticket Alignment

>30,000 tickets of >100 PV plants aligned

INNOSEA An LDC Company · Statkraft · enel Green Power · BayWa r.e.

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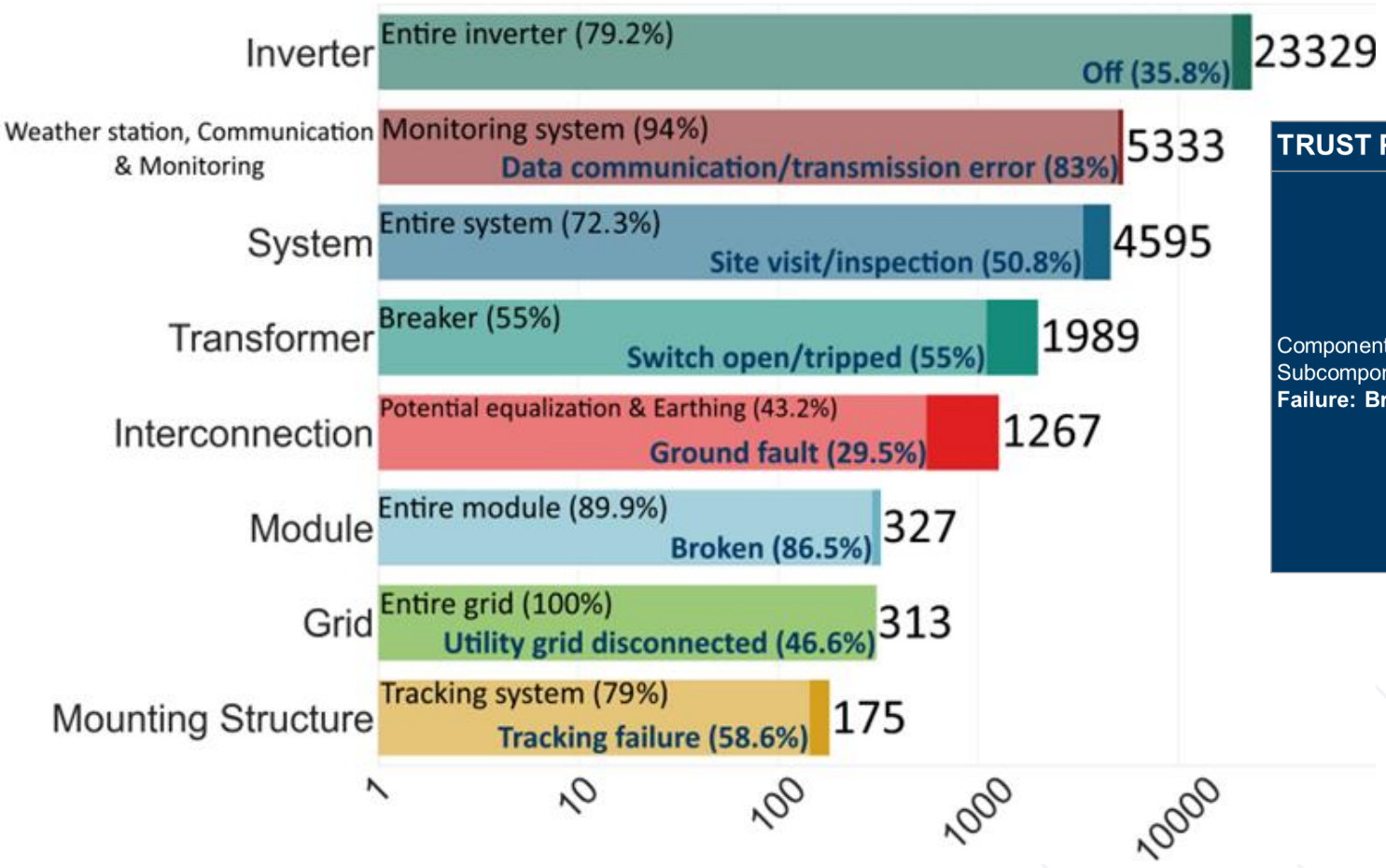
Available at www.trust-pv.eu

RISK MATRIX



TRUST PV's RISK MATRIX	O&M TICKETS
Component: Module Subcomponent: Entire Module **Failure: Broken module**	Damaged PV Module Found broken panel Faulty panel Isolated broken panels 2 broken panels found at string X PV panel outage String isolated due to broken panel Damaged panel Damaged module Broken module Faulty module Module broken Smashed module

What is the level of detail at component level? Need of common dictionary

Is this a true representation of reality or is it biased by the ease of detection?

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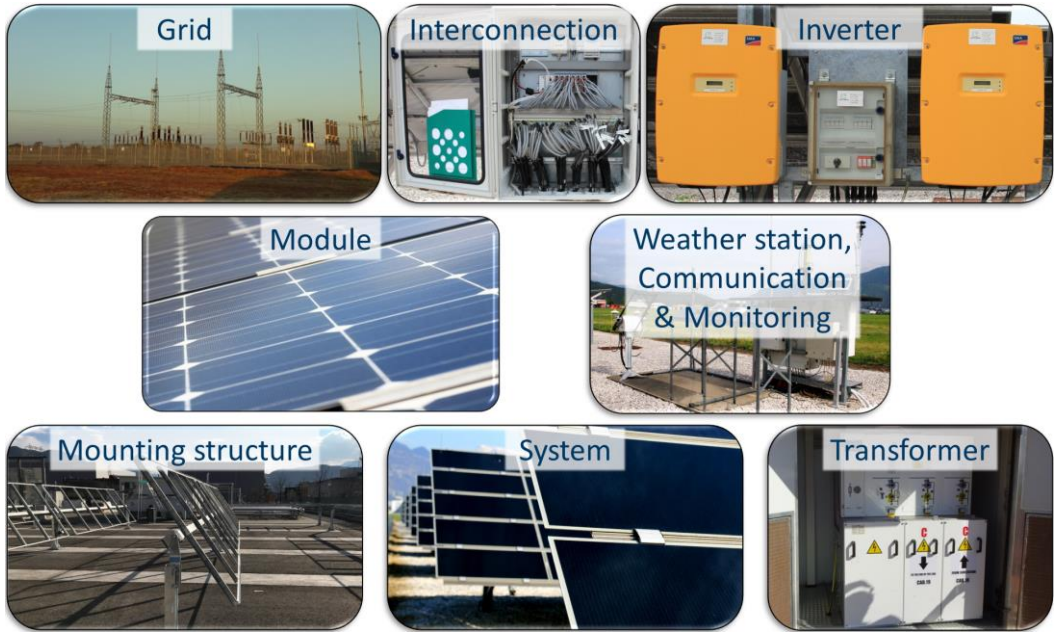
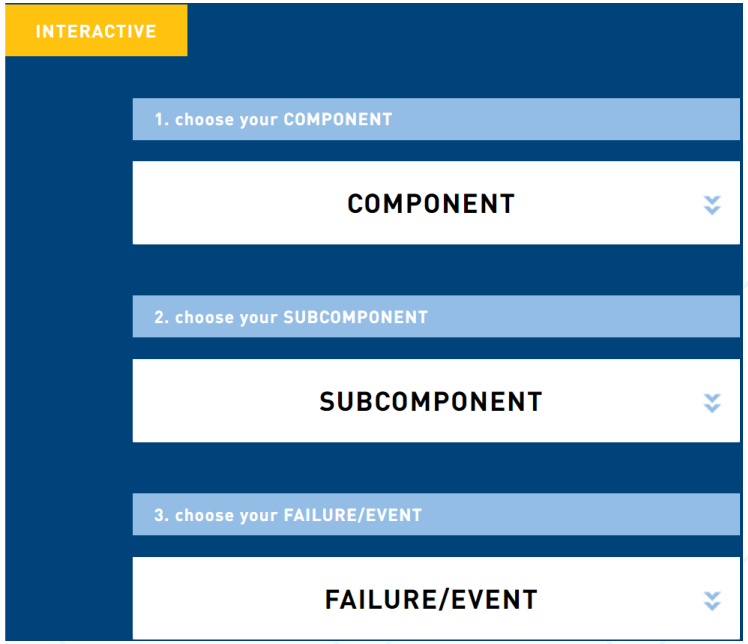
Towards the development of an optimized Decision Support System: a comprehensive Statistical and Economical Assessment of over 35,000 O&M tickets



https://trust-pv.eu/reports/risk-matrix/



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Statkraft

BayWa r.e.

TÜVRheinland®

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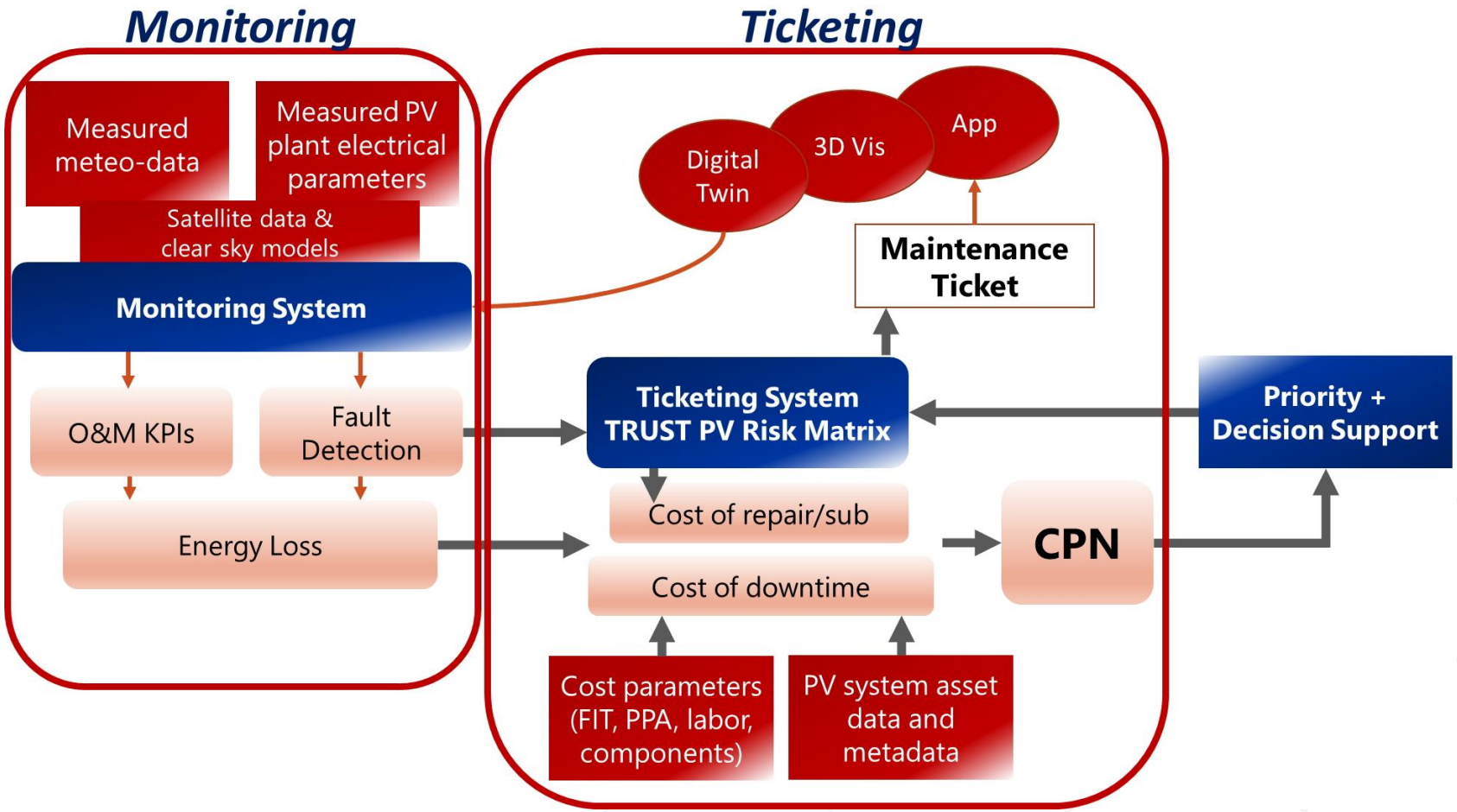

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Statkraft

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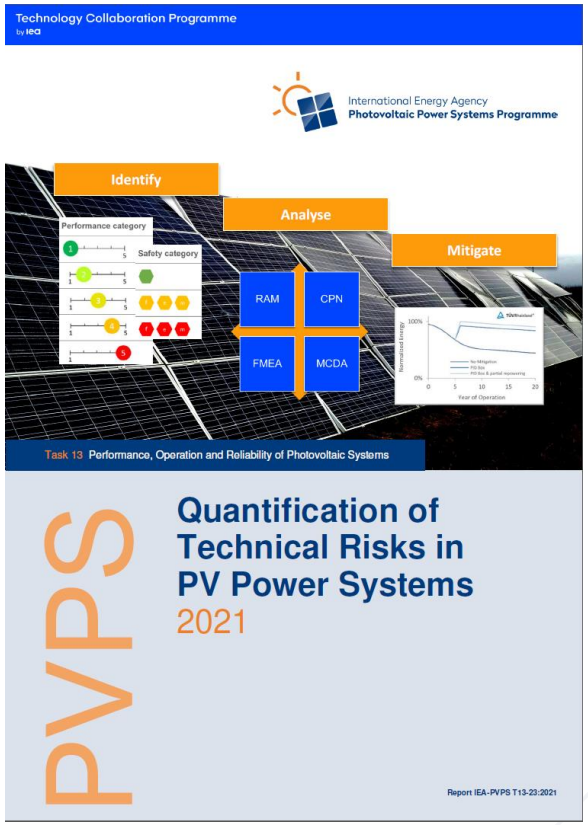
IDENTIFY, ANALYSE, MITIGATE: – QUANTIFICATION OF TECHNICAL RISKS IN PV POWER SYSTEMS

Herz, M., Friesen, G., Jahn, U., Köntges, M. Lindig, S., Moser, D.



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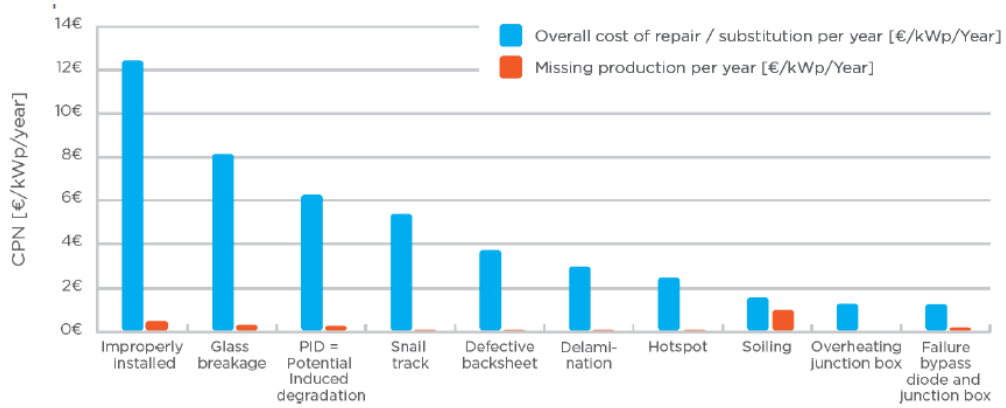
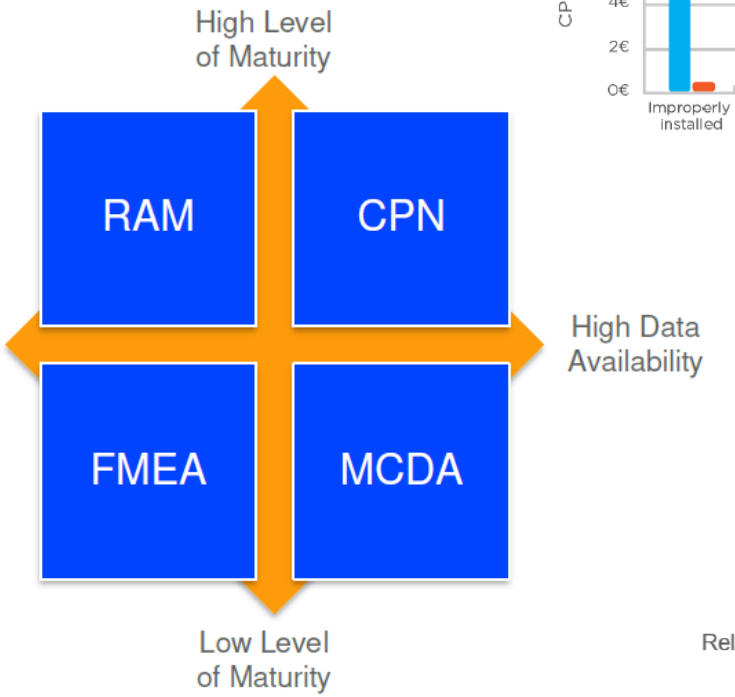
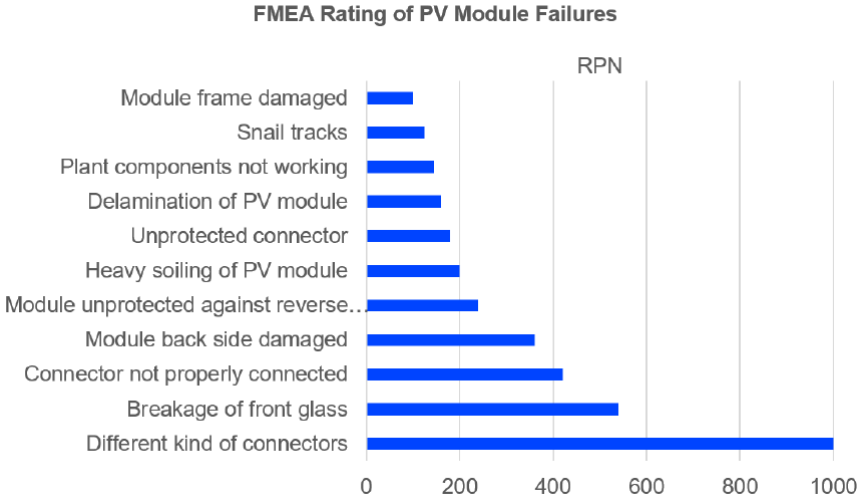
Component	Reliability (after 20 years)	Availability	Energy Losses [MWh]
PV string	88.7%	99.85%	805
Combiner Box	14.4%	99.69%	1656
Inverter	0.1%	99.42%	2842
Transformer	55.6%	99.50%	2601

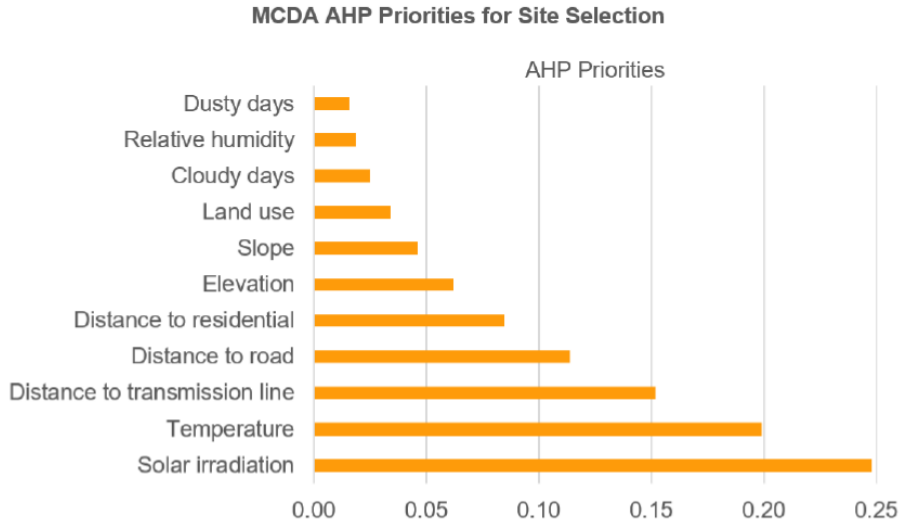
Quantitative





Qualitative





LAYER 3 | POINT OF CONNECTION

RESULT | 11

Fully flexible and interoperable PV plants solutions

Read more »

RESULT | 12

Use of forecasting for advanced diagnostic and grid dispatch

Read more »

RESULT | 13

Enhanced Digital Twin concept

Read more »

VALUE CHAIN APPROACH: management, sharing and federation of PV asset information throughout the lifecycle

Virtual construction of a facility prior to its actual physical construction

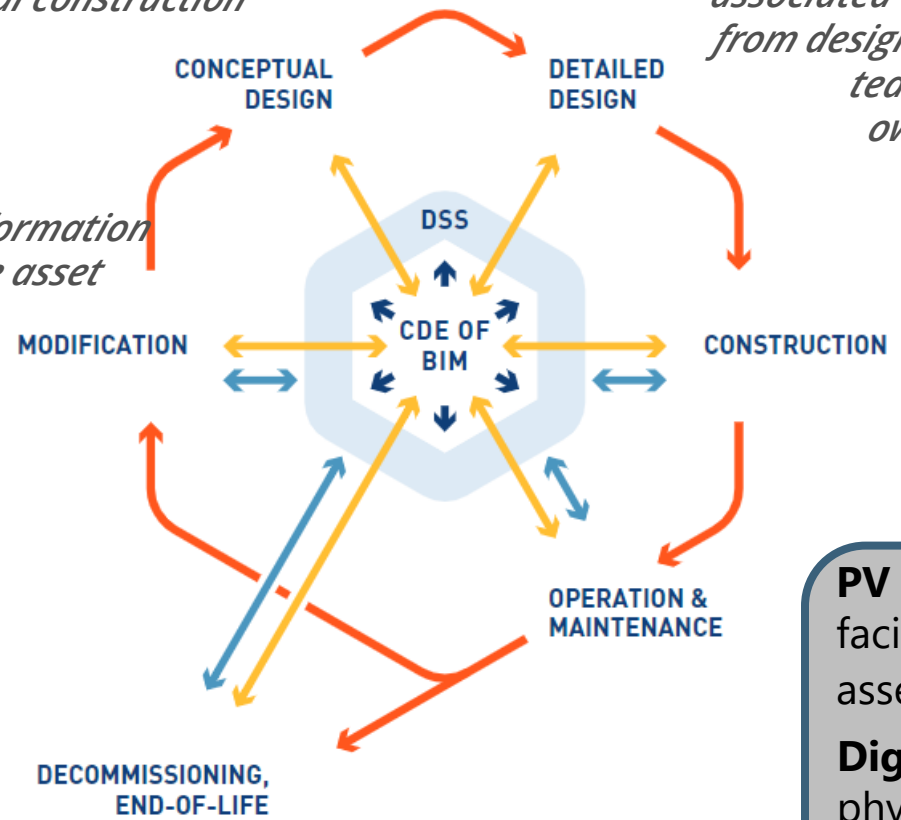
Bridge the information loss associated with handling a project from design team, to construction team and to asset owner/operator

Lifecycle processes request from and provide information to a shared repository or Common Data Environment (**CDE**)

Dynamic information about the asset

Advanced digital services request information and perform federation

Advanced digital services interact with lifecycle processes to aid decision making e.g. through a Decision Support System (**DSS**)



Report available

PV BIM = Digital repository to facilitate the storage, modification and exchange of all PV asset information throughout the entire PV lifecycle

Digital Twin = parametrized 3D model, containing all physical information needed to simulate the behavior and performance of the real PV plant it represents

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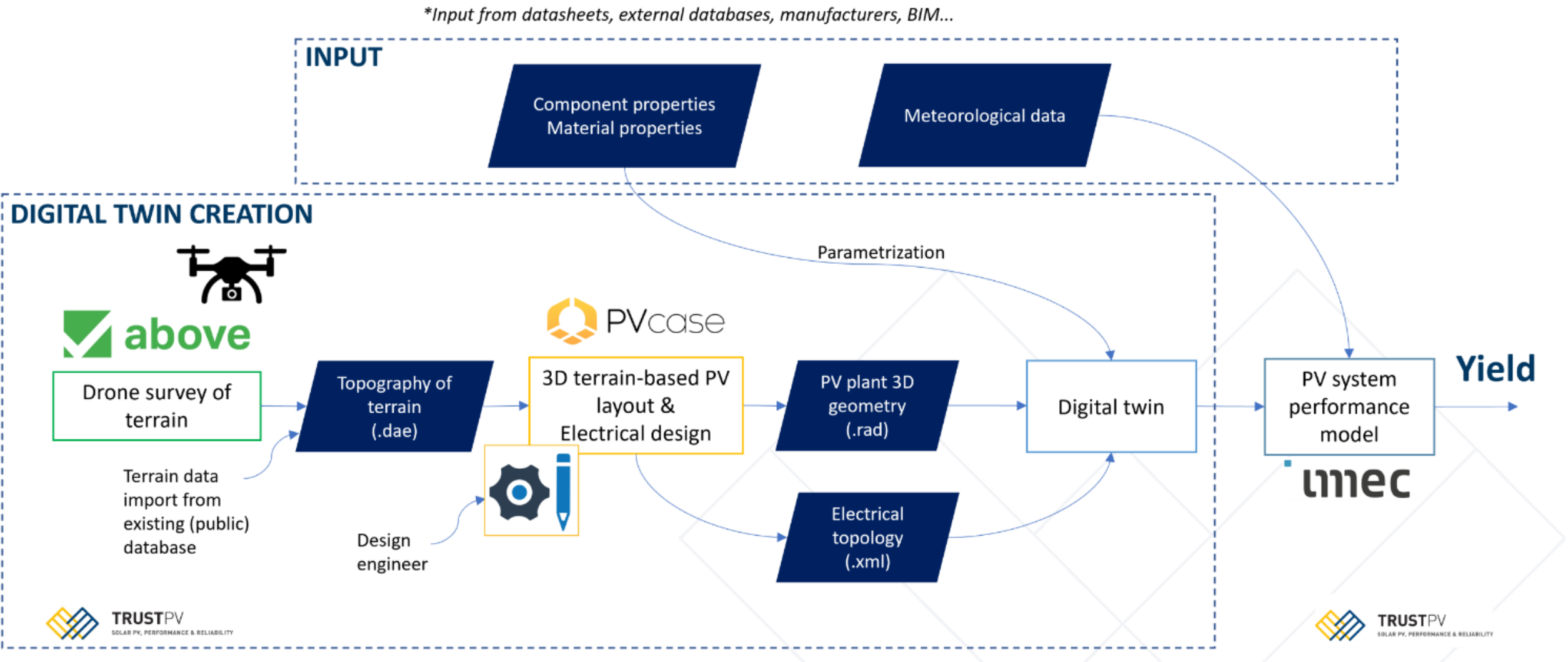
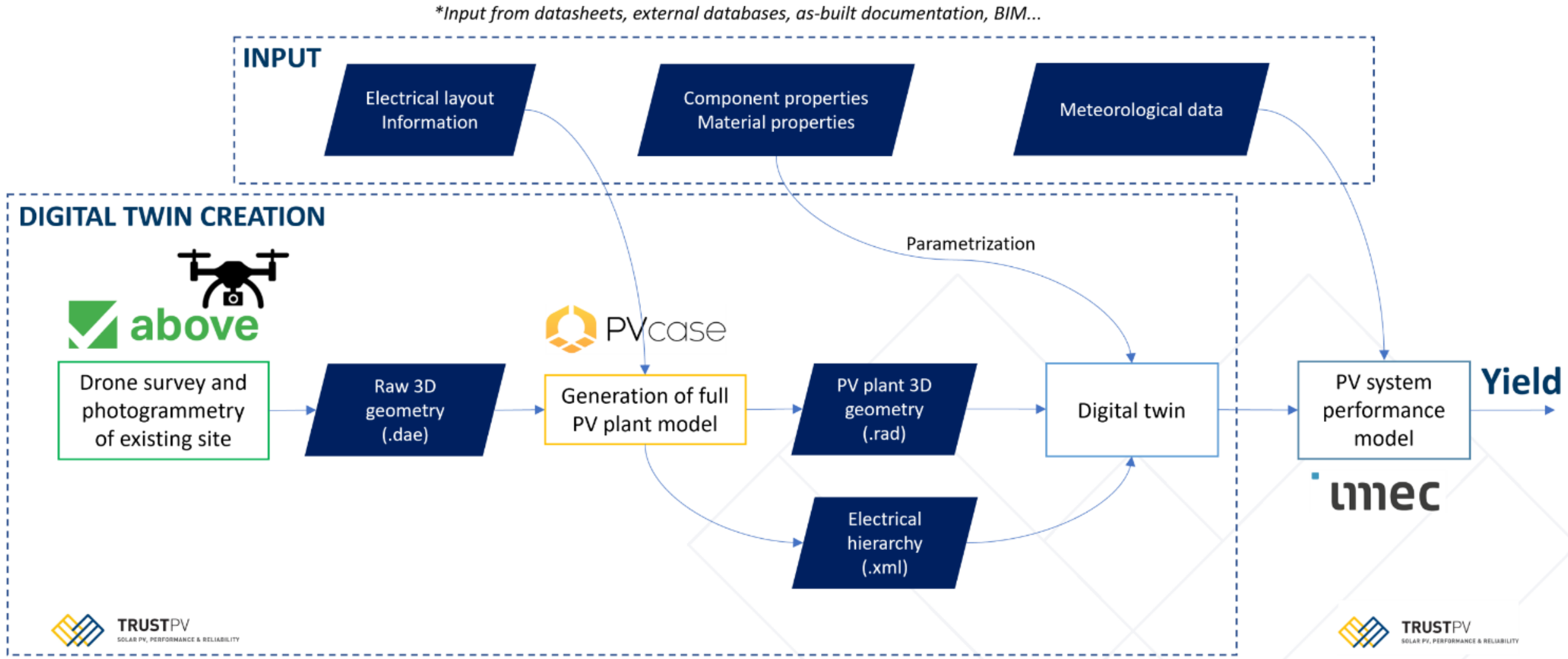
DIGITAL TWIN CREATION WORKFLOW: NEW PV PLANT



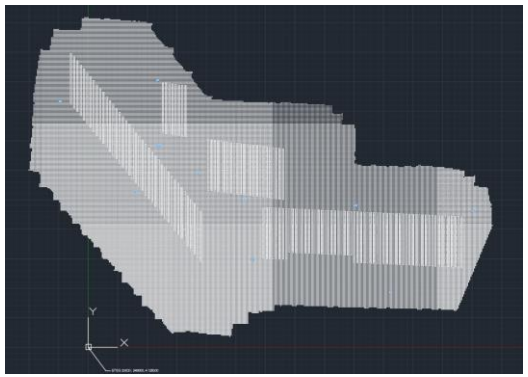
DIGITAL TWIN CREATION WORKFLOW: EXISTING PV PLANT



AUTOMATED DIGITAL TWIN CREATION

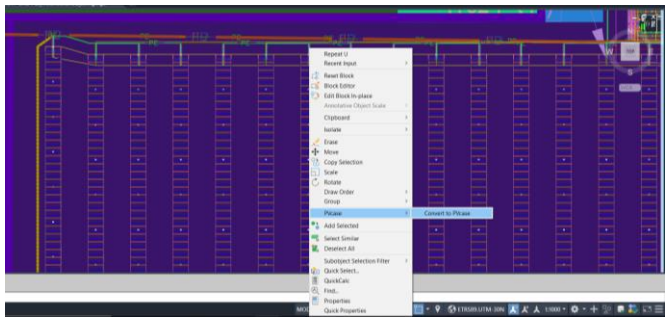
Drone survey → AutoCAD 3D

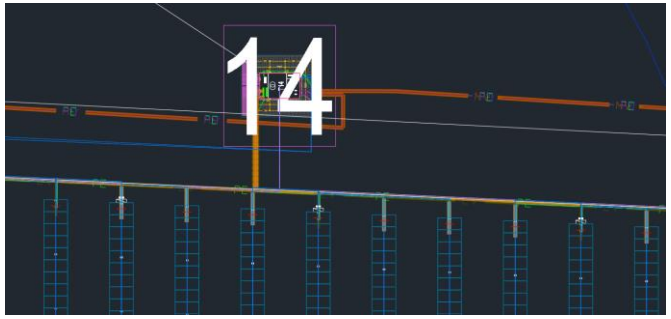
above



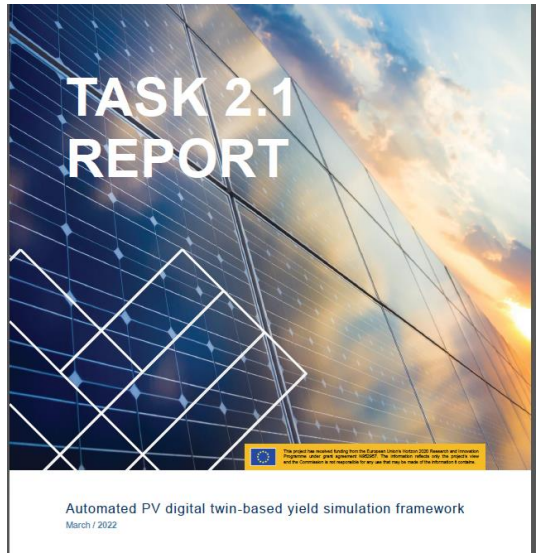
PV design software: electrical devices + connections

PVcase



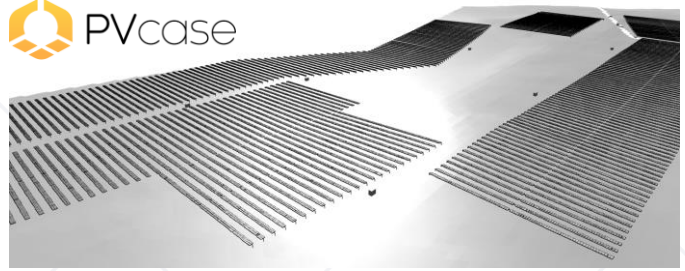


Functional Digital twin vs as-built

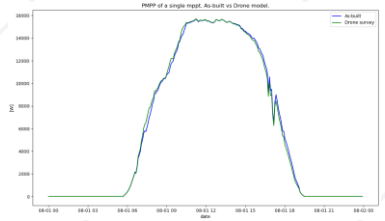


Functional digital twin

PVcase

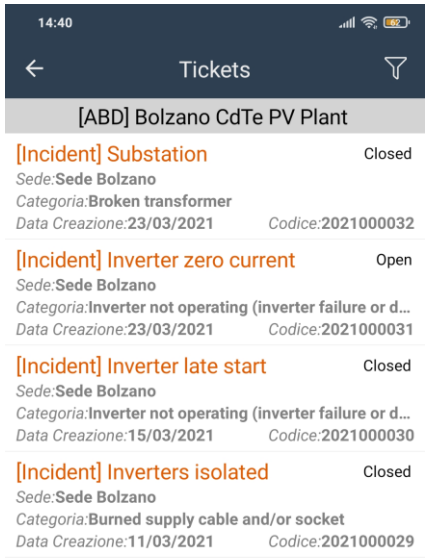


imec



TRUSTPV
SOLAR PV, PERFORMANCE & RELIABILITY

DIGITAL TOOLS INTEGRATION



Component geolocalised
History / logging at component level
Integration in digital platforms
Common nomenclature: statistics
Suggestions on actions
H&S / skills management

CONCLUSIONS

TRUST-PV is developing:

- Approaches to ensure and measure quality of components, systems and projects
- New metrics to quantify the impact of decisions taken over the lifetime of a PV project
- Methodologies to break silos between stakeholders by evaluating the impact of decision taken during a phase on the next phases and developing O&M friendly components
- Interoperable digital solution to carry information along the value chain (eliminate work repetition)
- Standardisation of data format and collected data (metadata / PV plant passport, product data, monitoring data, ticketing, common dictionaries, etc)

Solar bankability must be based on hard facts / data and is an approach that heavily relies on data / quantification of quality

THANK YOU!

PROJECT PARTNERS

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www.trust-pv.eu

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Thank you!

"We ensure quality and sustainability in a PV driven energy transition"

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