DIGITIZATION POTENTIAL FOR PV SYSTEMS

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Prologue | About Me

Main Research

- Simulation and modelling of the performance
  of photovoltaic devices and systems
  - Life cycle prognosis and evaluation
  - Quality assurance of systems and components
  - Applied metrology
- Quality Management throughout the value chain

Academic Resumé

- **since 2018**
  Director Fraunhofer Center for Silicon Photovoltaics CSP and
  Professor of Photovoltaic Energy Systems at Anhalt University of Applied Sciences, Köthen

- **2010-2018**
  Professor of Applied Photovoltaics at Loughborough University

- **2001-2018**
  Head of Applied Photovoltaics Research Group at Loughborough University, UK

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Prologue | Short Profile of Fraunhofer CSP

- **founded in 2007** as a joint institution of the Fraunhofer Institute for Microstructures of Materials and Systems IMWS and the Fraunhofer Institute for Solar Energy Systems ISE.

- **Locations** in **Halle (Saale)** and **Schkopau**

- **Key Topics**
  - Quality assurance throughout the value chain
  - Root cause analysis of semiconductor- and material-based failures
  - Materials composition and -reliability
  - Life-time and warranty prediction
  - Technology and process analysis
  - System design, monitoring and diagnostic

OUTLINE

- Why would we want system digitisation and what are the road blocks?

- Repositories to understand PV system performance
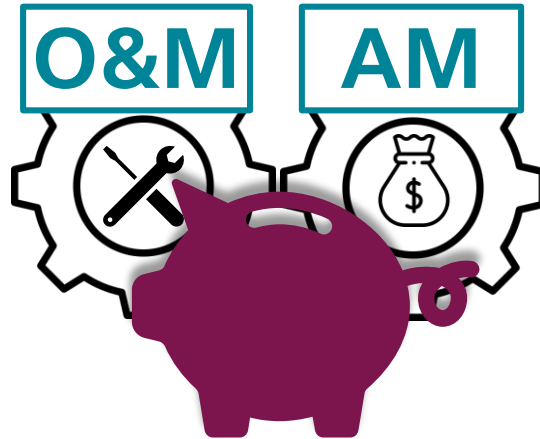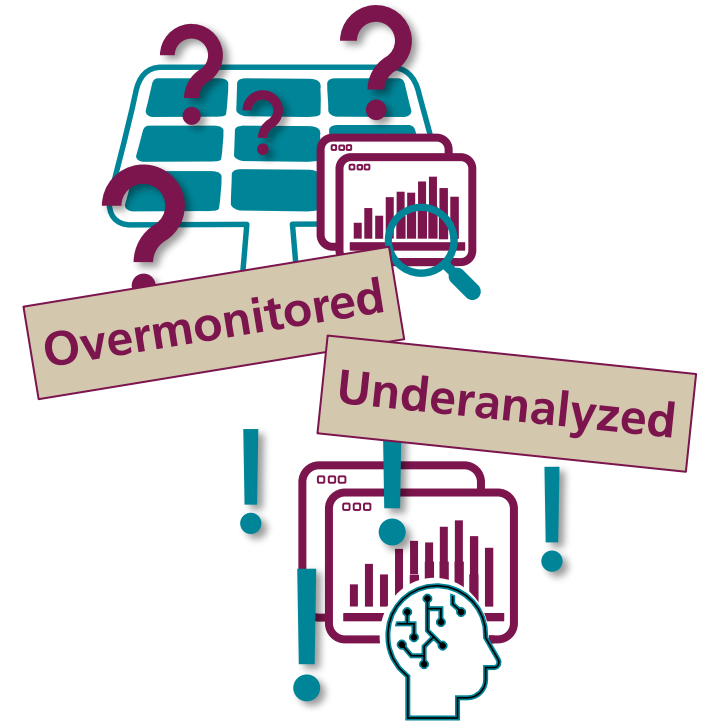
- Beyond monitoring

- Summary

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Introduction

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Why Digitization in PV?

REDUCE LIFE CYCLE QUALITY COSTS

O&M   AM

POTENTIAL FOR COST REDUCTION

Overmonitored

Underanalyzed

AI DATA ANALYSIS

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Digitisation of PV in research and industry

- Relevant keywords are getting more and more prominent in scientific literature.
  Is digitizing taking over?

- Uptake in industry has been slower than anticipated.

- **Stakeholders are separate**

  - Researchers do not keep in mind industry requirements

  - **Developers** are keen to develop tools but **don't have sufficient data** and cannot develop tools

  - **Data owners** spends time and money for obtaining data and **want to be rewarded** for this.
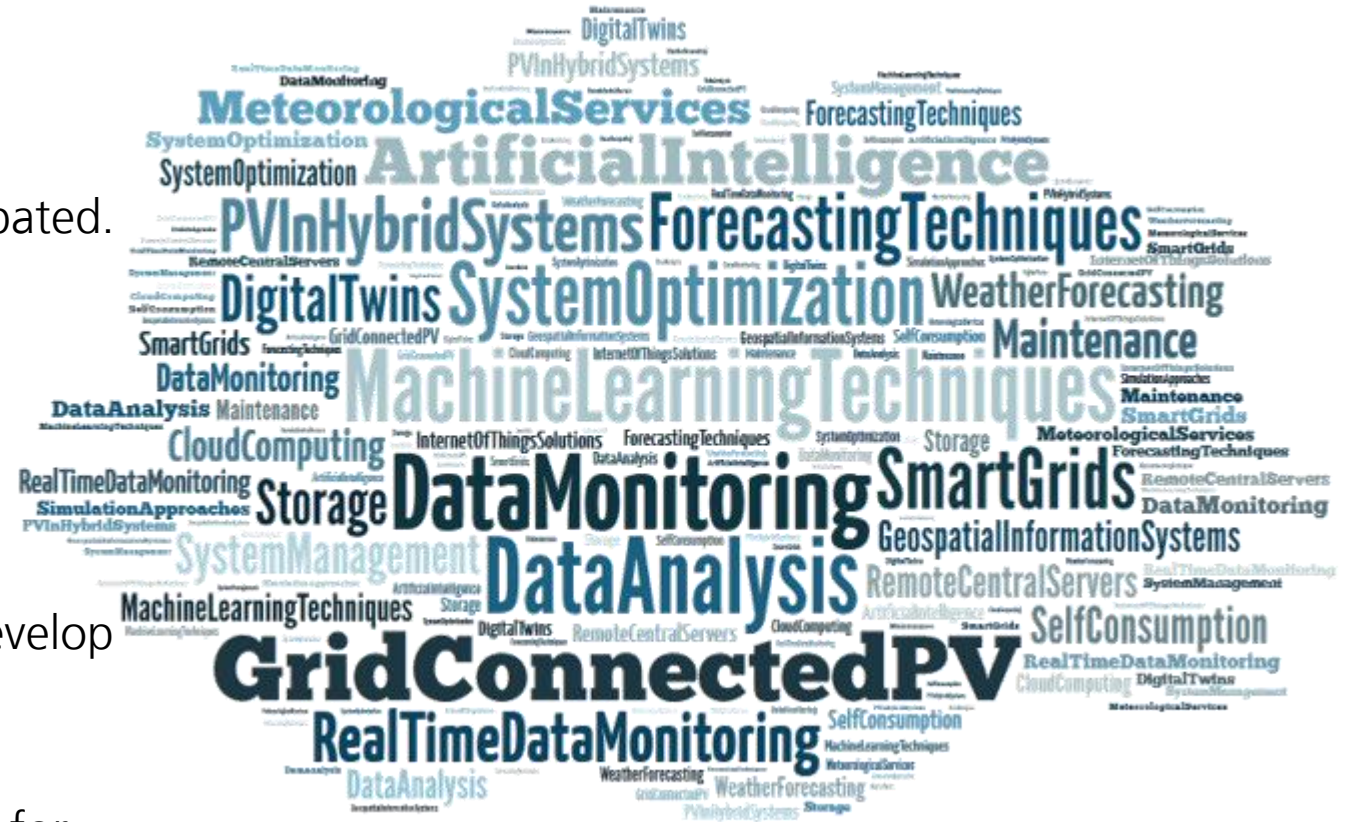
→ **Need to bridge the gap to enable digitization**

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Some Examples of Existing Repositories

- **PV module data**

  - PV modelling collaborative has some trial data

- **PV systems performance**

  - UK (early 2000s) – field trials (domestic field trial, large scale BiPV field trial) - Data available as CD

  - Sheffield MicrogenDB (2011-2021); Online availability

  - IEA PVPS T13 performance database (around 2000) Data available as CD

  - **PV-CAMPER database (2019 -)**

  - Various company or governmental repositories data remains confidential

→ **Repositories today may not meet requirements**

Thanks to Nicola Pearsal for this material

Repositories to Understand System Performance

What Is Required for Use of AI Digital QM & AI?

Single Training Effort

IdentifyMetrology Idiosynchracies

Requirements

- Transferable
- Reliable
- Low Costs
- Unbiased

Unphysical Values

Sensor Issues (e.g. Imperfect Temperature Sensor)

False Positives

False Negatives

Computing Costs

Training Costs

O&M Cost Uplift

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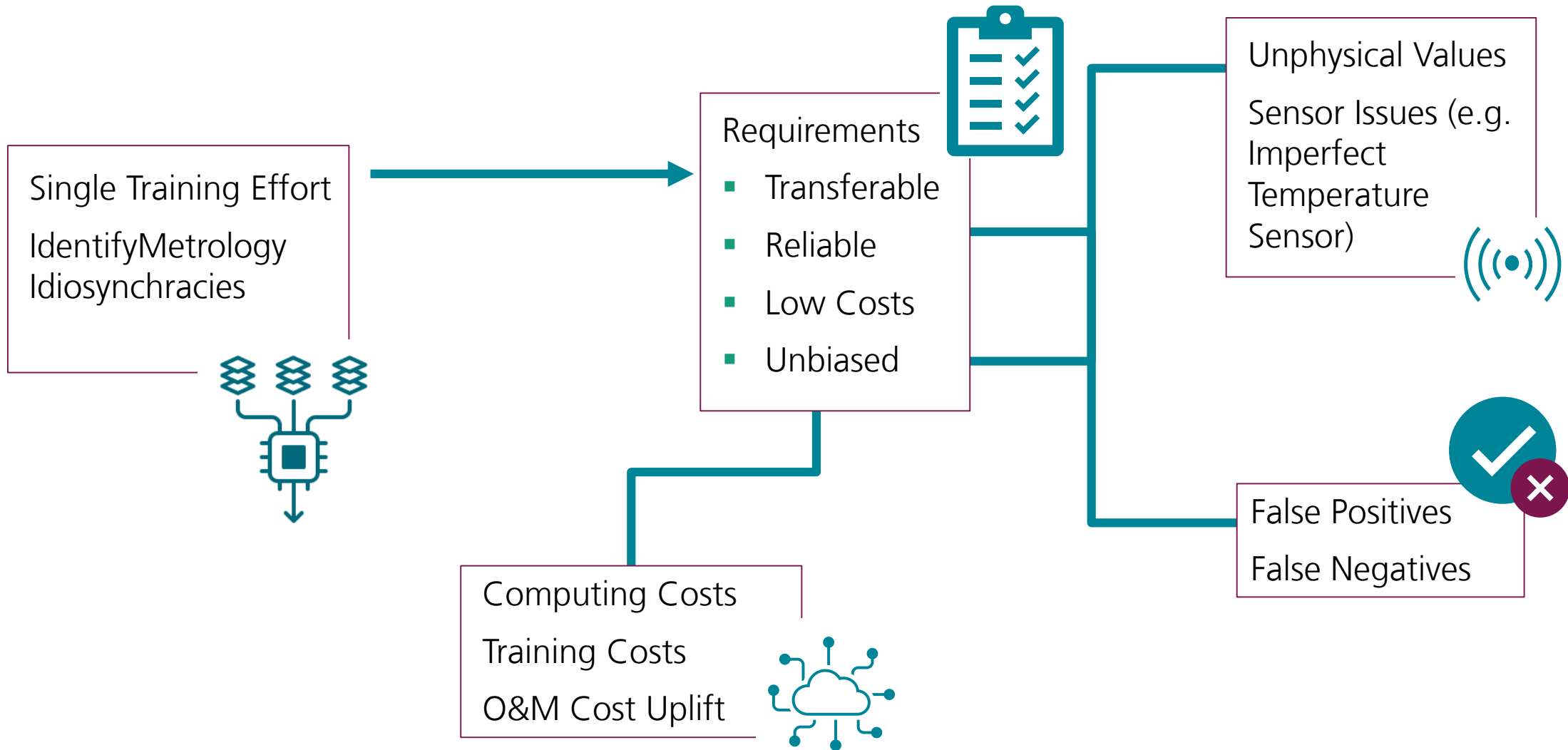
Why Do We Need New Repositories?

- NOT because they do not contain certain technologies

- NOT because they may have outdated system architectures

- NOT because …..

Without appropriate repositories we will not be able to capitalize on the benefits of digitalization in PV, not realise potential cost savings and hamper research into performance of PV

Lessons Learnt from the Past (Existing Repositories)

RELIABLE?

C O M P A R A B L E ?

T R A N S F E R A B L E ?

- Past repositories do not necessarily enable AI development

- The main reason is that they were set up as an afterthought (imho)
  - Not having a purpose in mind often means that data is insufficient (missing key information)
  - **Data quality** or uncertainty is **insufficient** (→ **transferability** between assets is **limited**)
  - There are faults in the data, which affect the results (crap-in-crap-out principle)

- Depending on the purpose **data quantity** is **not sufficient to train AI** (e.g. understanding a fault mechanism needs comparable systems in various settings – often that is not included)

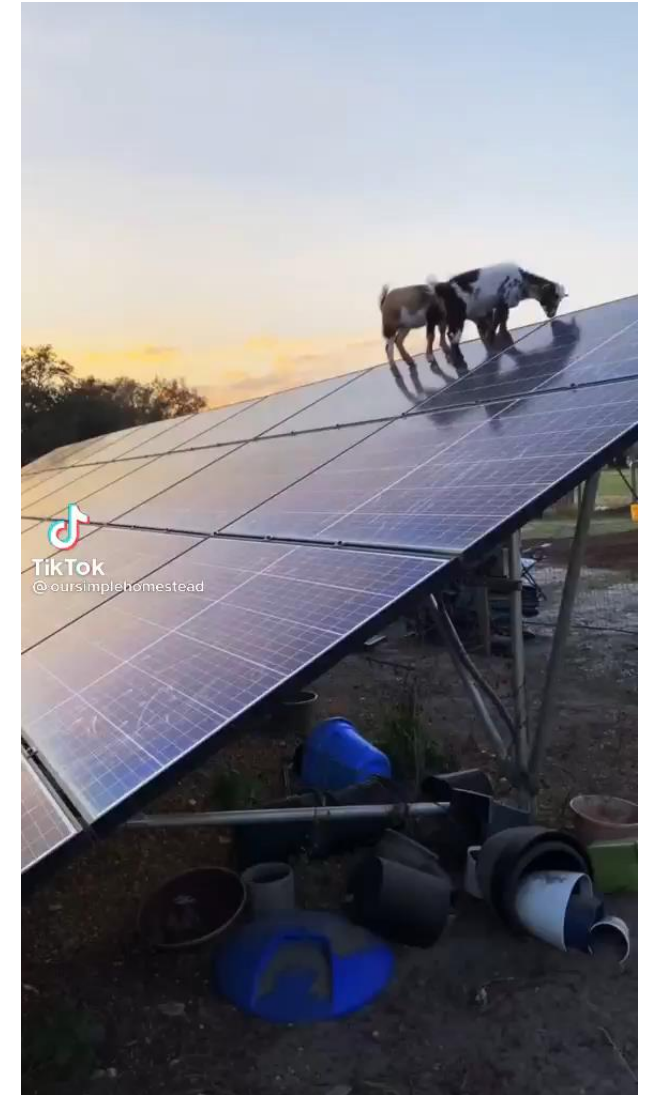→ **Repositories need to be planned for their purpose!**

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Data Quality – Need for Quality Marks
Understanding Outdoor Measurements Is Complicated

Video extracted from LinkedIn

- Life is full of surprises and un-foreseen issues.

- There may be some data entry issues which needs correcting.
  (Why are so many systems located in Afghanistan?)

- Data is noisy – smoothing vs. filtering vs. raw data vs. integration

- Individual data points may move into unexpected territory
  → when correcting need to ensure that no bias is introduced

- There is a location specific mismatch between sensors and system
  response (spectrum, time, AoI, …)

- Some ‚trivial' measurements are not as easy as they look (module
 temperature – especially bifacial)

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Avoiding False Positives – Need to Qualify Data in a Repository

- Any **performance analysis** needs to
  - Deliver **actionable** information
  - Deliver **meaningful** analysis
  - Be **bias free**

- Incomplete sets may bias analysis (winter/ summer performance)

- There is a **danger of overspecific analysis** (sensor specifics, built issues, data issues)
  - → not transferable from training system to others
  - → each system needs to be trained individually when analysing
  - → just adding work load

- **Repositories are the key to enable making AI happen!**
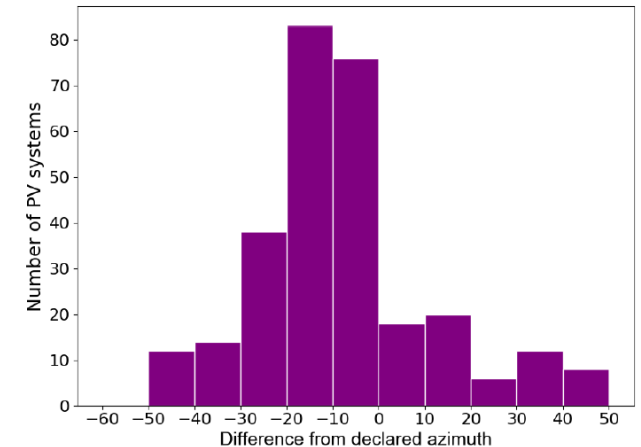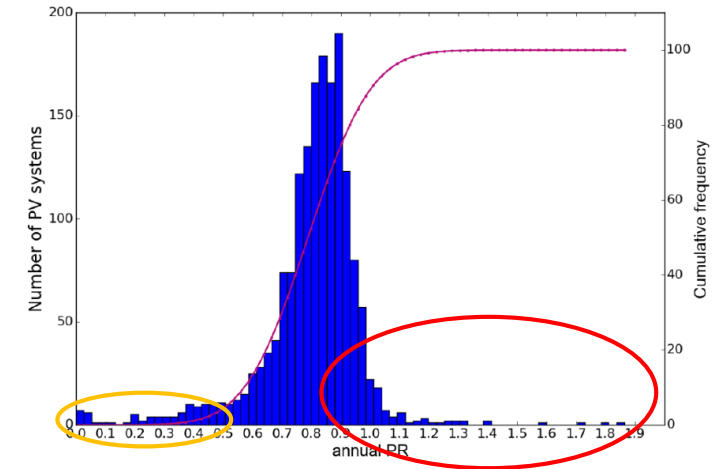
Koubli, E., et al. (2016). Investigating Two Thousand PV Rooftop Systems in the UK: Performance Analysis and Fault Diagnosis. 12th Photovoltaic Science, Application and Technology Conference (PVSAT-12), Liverpool, UK-ISES.

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My Personal Requirements for a Repository for Performance Assessment

- **Data** needs to be **widely assessible** and **easily portable** to the database environment of the users choice (Everybody likes to work with their favorite tools)

  → **Reduced development costs**

- **Dataset needs** to be qualified in terms of **robustness, completeness** (incomplete data can change result from e.g. problematic to unproblematic system)

- **Data-points** need to have an **individual uncertainty attached** (when training AIs, it is critical to attach ‚weights' to individual points)

  Reduction of false positives

  Increased site-to-site **transferability**

- I would like to **go beyond performance data**; I would like to go **towards quality management** as I think there is more ‚value' in this. Including digital twins of the systems and key components

  → **Higher impact on LCOE**

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Beyond System Monitoring

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Beyond Monitoring Algorithms

- Worth remembering – in the real work finding the maximum number of faults is not helpful

- Most operators are already swamped with reported issues and ignore them

- A high percentage of O&M costs is attributed to issues in metrology.

→ **There needs to be a methodology/repository to qualify the robustness/ transferability/ bias-freeness of digital system diagnostic**

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Specific Need for Repositories

- At the moment **AIs** identify failures but **how reliable** is that**?**
  - What is the **percentage of failures** was **identified correctly?**
  - How many **false positives**?
  - **How accurate** was the **performance assessment?**
  - … and further KPIs which should be set by industry and academia

- It would be exceedingly useful to have a **repository** that can be used **to qualify algorithms**
  - To have **independent training datasets** to the actual assessment datasets
  - **Detailed mark-up of specific failure modes** to know what was really in the dataset

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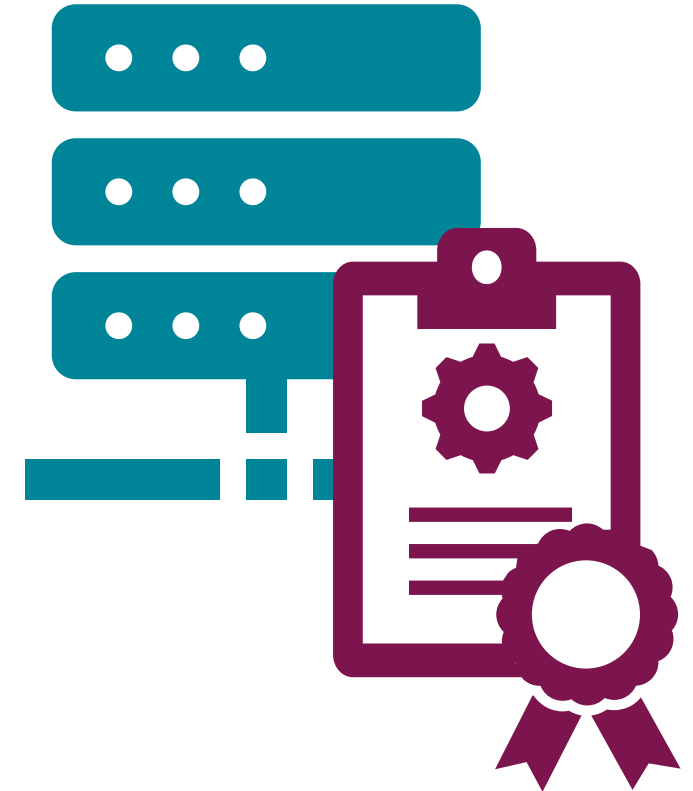
Value of Digitization – How to Maximize It

- **Performance assessment** is only a relatively **small part of** the annual **O&M costs**

- Big contributions are
  - Asset management
  - Corrective maintenance
  - Periodical maintenance

- Especially corrective maintenance increases in time

- **Major gain** would be to reduce corrective maintenance requirements – i.e. minimize failures before they occur.

Average O&M Costs 2019 (€/MWp/a)

- Monitoring
- Periodical maintenance
- Panel cleaning
- Vegetation control
- Corrective maintenance
- Asset management

740, 2460, 1460, 720, 2320, 3400
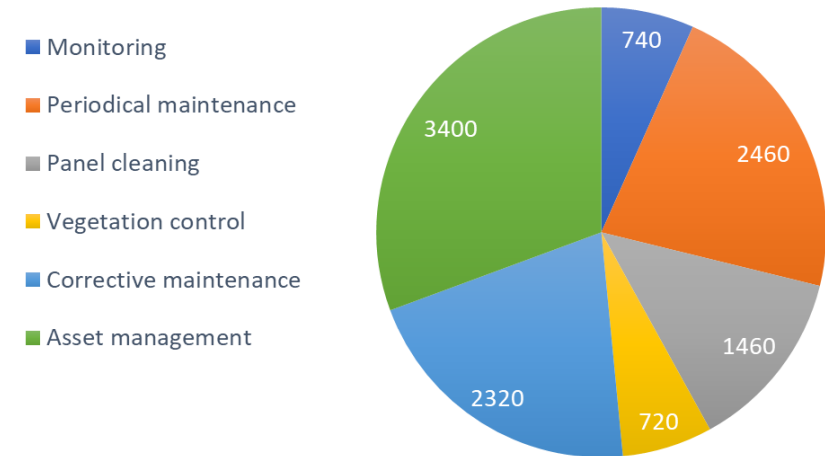
PV O&M Cost Model Example: 10 MW ground-mount

PV O&M Cost Model NREL68023

- Operations administration (planned)
- Inverter replacement reserve (corrective)
- Module replacement reserve (corrective)
- Component parts replacement (Planned)
- System inspection and monitoring (Planned)
- Module cleaning and vegetation management (Planned)

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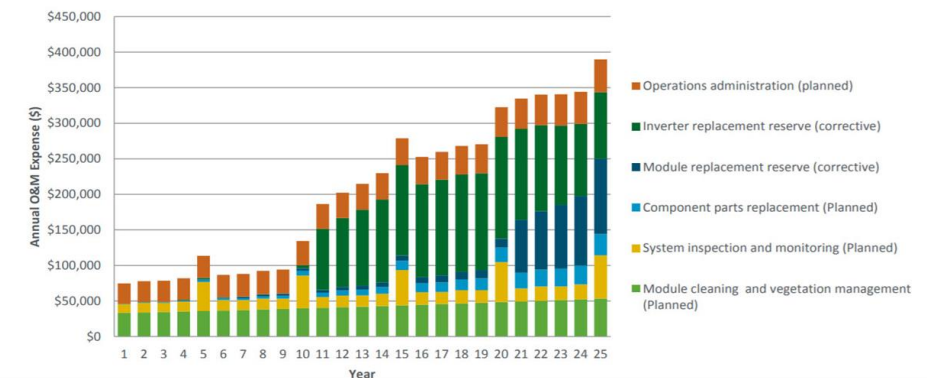
Moving towards Holistic Quality Management – Digitisation Requirements

- Quality management is moving towards a **holistic approach**

- **Performance** is
  - **Planned** in the engineering phase
  - **Managed** in the procurement & construction phases
  - **Verified** in the commissioning phase
  - **Ensured** in the O&M phase
  - → **Digitisation needs to span the entire life cycle!**

- → Performance monitoring (and thus repositories for AI training) need to cover the entire process

- → Only if performance assessment is seen as a circle can maximise cost savings
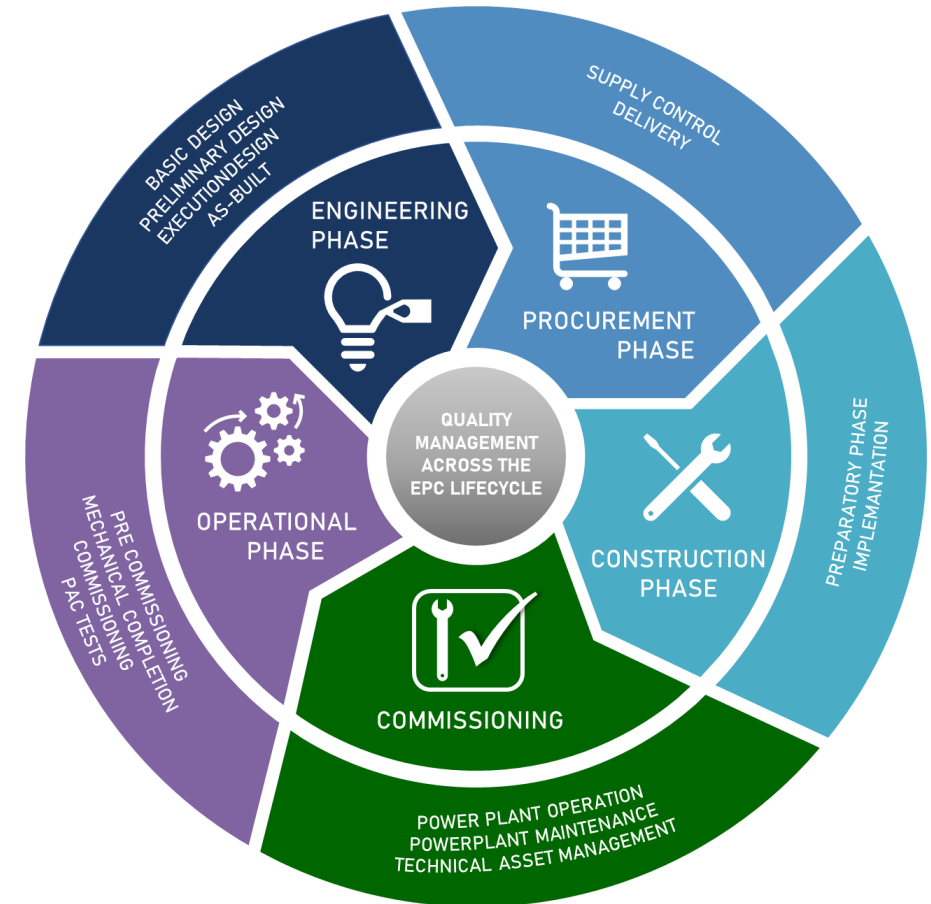
SPE – EPC Guidelines, 2020

Data Availability Problems

- While commercial benefits may be apparent, it is **still difficult to get performance data** because

  - **Performance data** is **seen as commercially sensitive**
    It links to the investment success and people do not want to disclose it.

  - **Monitoring costs money** – why should anybody give
    the data away (to potentially help competitors)?

- **High quality data** is **not in** the **interest of O&M or EPC**

  - Sensors cost money; cost pressures means agreeing on the lowest common denominator

  - Data quality is linked to the contractual conditions of the O&M provider (response time, accuracy, …) ; anything over the bare minimum gets cut

→ **Relying on voluntary data is difficult**

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Specific Questions for Digitization & AI Training

Planning	Procurement	Building	Commissioning	Operation

Planning
- Performance forecasting
- Context simulation (near shading)
- Setting **reliability** specifications

Procurement
- Specification verification
- Batch-tracing
- Documentation
- Online and offline metrology

Building
- Digital twin of the actual built system
- What went where?
- Documentation

Commissioning
- System Power Verification
- 100% string testing

Operation
- Fault Identification
- Integration online/offline metrology
- AR support in Maintenance
- AM support
- Feeding back into planning….

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Summary

Summary

- The potential of digitization is largely underutilized – there is a need to bring industry and researchers together.

- There is an **urgent need for repositories**
  BUT they need to be **planned for** the **intended purpose**

- **Repositories** do not only need to collate data, they also **need to qualify data**

- In the **short term** the biggest need would be a **repository for qualifying AIs for O&M support**

- In the **mid-term** digitization should **support the entire life-cycle of PV-Plants**, resulting in significant cost reductions.

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