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Specific considerations for transitional methods for photovoltaics under the horizontal standards

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Practical information to develop standards and criteria on reparability

- Identify the specific components or assemblies
- Identify the tools needed to access and extract them
- The repair operations
- The number and type of steps to access and extract them
- The risk associated with the repair (e.g. hazardous substances)

Practical information to develop standards and criteria on recyclability

- Recovery of CRM, identify PV module and inverter hot spot components and materials as a priority for future recovery (e.g. silver = hot spot, silicon metal = CRM)
- Dismantling, there is ongoing research into how to dismantle a PV module in order to recover materials e.g. KU Leuven

  - Different delamination routes followed by chemical treatment. To what extent can module design have an influence on this issue?

Relevant requirements of other standards on selective treatment/separation of components

Repair/Dissassembly

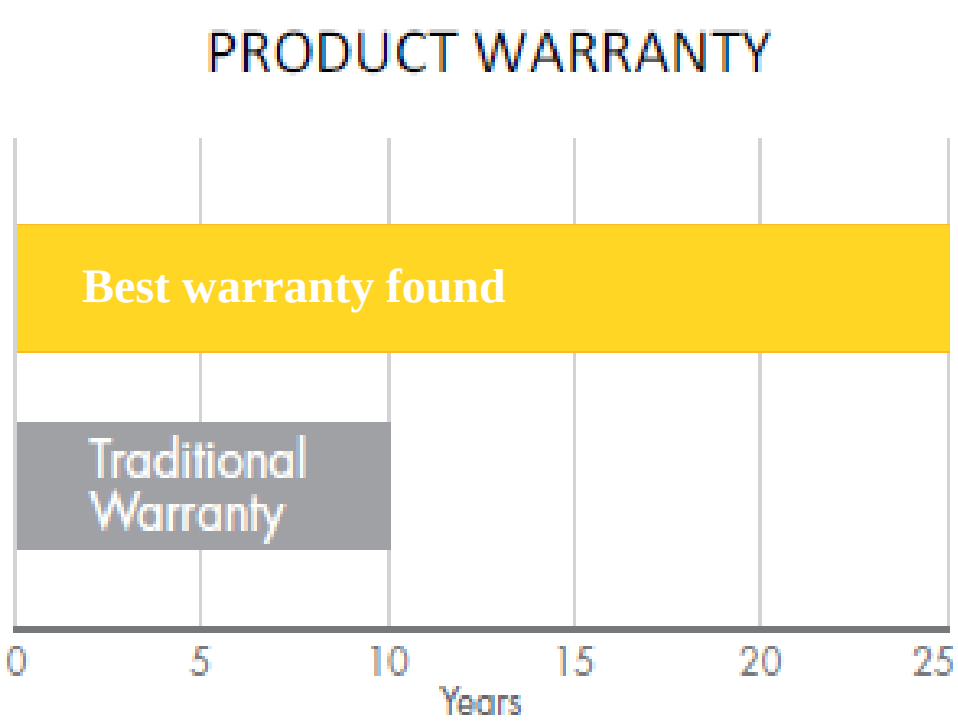
- Declaration of the following substances content:
  − Metals and metal oxides (conductor)
  − Semiconductor materials, Metals and metal compounds, Organometallics, Non-metals that are used as photoactive substances (photoactive substances). NSF 457
- Short circuit to be avoided for PV-modules for preparation for reuse and for recovery. UBA

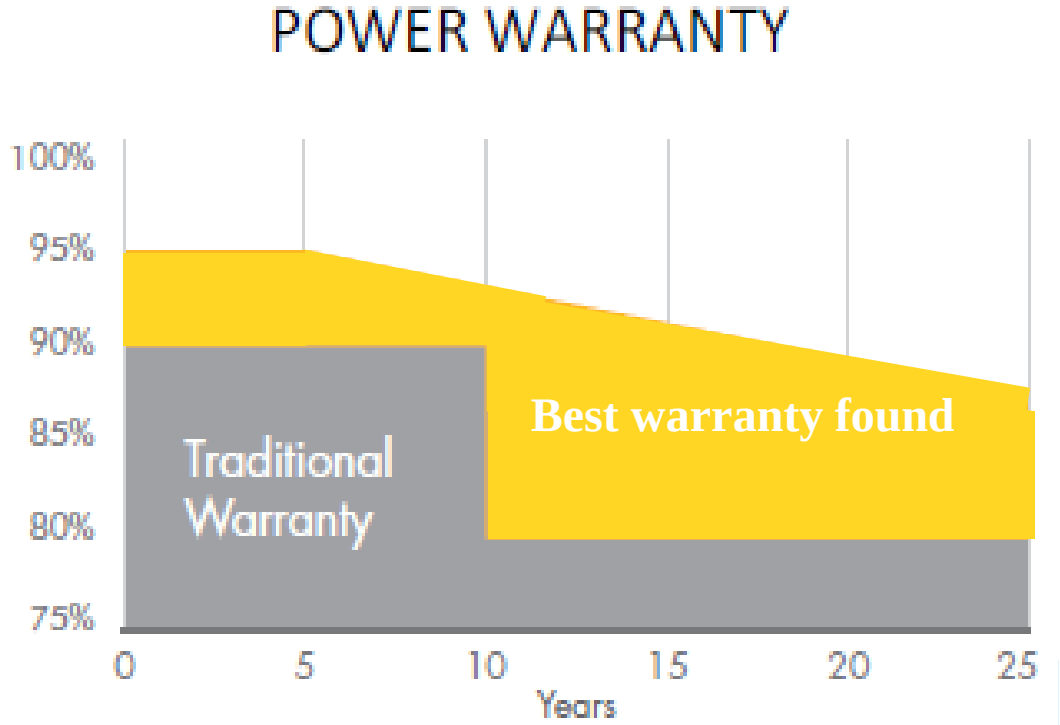
Dismantling/End of life

- Manufacturers shall provide a nationwide product take-back service for recycling for products. NSF 457
- PCBs > 10 cm2 WEEE Directive
  - UBA specific recommendations:
    - ✓ minimum reclamation efficiency of 90 % for Cu, Au, Ag, Pd
    - ✓ with reclamation of Sn, Pb, Sb in the process chain
    - ✓ fulfil BAT conclusion of the EU Industrial Emission Directive for PCDD/F-emissions (≤ 0,1 ng I-TEQ/Nm3)
- 2030 (2025): Application of reclamation processes for In and Ga (Ag) from PV-modules; 2020: Review of this requirement. UBA
- Threshold values for Si- and non-Si-based modules. E.g. 10 mg Pb/kg non Si modules. UBA and EN 50625-3-5.
- Maximum concentration of hazardous substances for glass and other fractions for recovery. E.g. Si based modules: Pb 100 mg/kg

Initial findings from the Preparatory study for PV modules

- Product and performance warranties are linked to product performance in terms of, respectively, infant failures and long term degradation in the power output.





Initial findings from the Preparatory study for PV modules

Failures can be categorised into **components:**

- modules,
- inverters,
- structure,
- connection and distribution boxes,
- cabling, grounding, protection system,
- weather station,
- monitoring,
- transformer station,
- infrastructure,
- storage system,
- and miscellaneous

Or related to **phases** in the value chain of a PV project:

- product testing,
- photovoltaic (PV) plant development,
- installation/transportation,
- operation and maintenance,
- and decommissioning

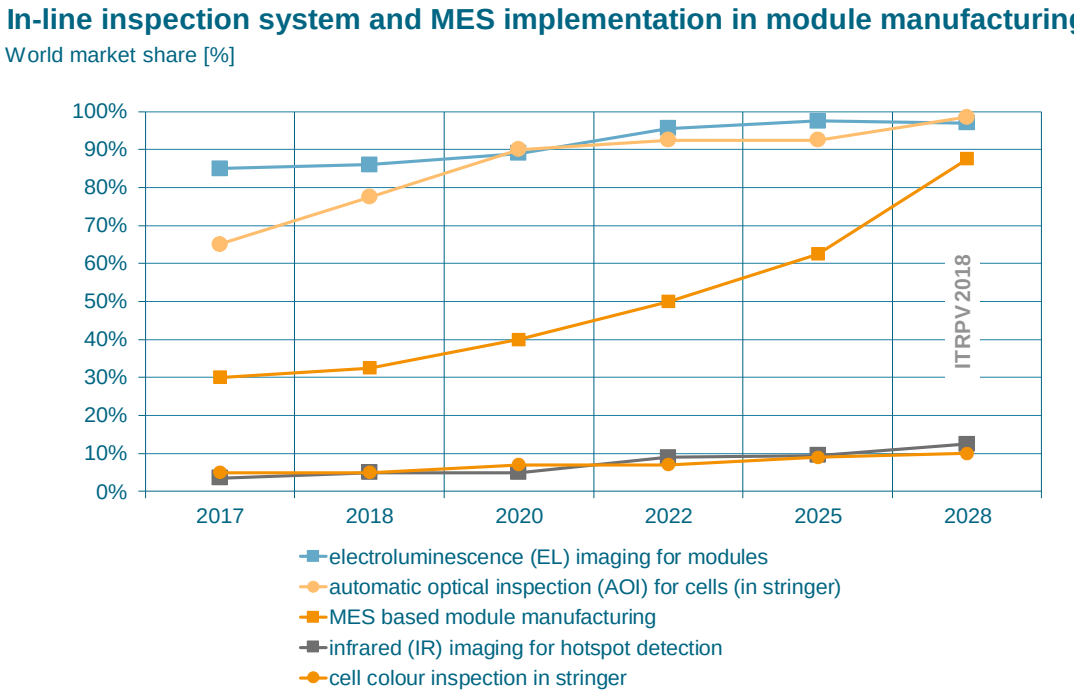
Initial findings from the Preparatory study for PV modules

During the operation/maintenance phase, failures and degradation in performance can be found in the PV array such as:

- snail trail
- hot spot
- diode failure
- EVA discoloration
- glass breakage
- delamination with breaks in the ribbons and solder bonds
- light induced degradation
- low irradiance losses
- potential induced degradation
- shading effect
- soiling effect
- sun tracking system misalignments
- wiring losses
- mismatching effect in solar array
- and other failures such as ground faults, line-to-line faults, and arc faults;

Initial findings from the Preparatory study for PV modules

A focus on **module burn-in** period would reduce infant stage defects, which are in turn strongly influenced by factory quality procedures. This is reflected in the 'product warranty'.



In a study of 3 million modules, from 20 manufacturers, it was found that 0.44% of the modules were returned after an average deployment of 5 years, with the vast majority of returns associated with failures that can usually be identified visually.

Hasselbrink M. et al. Site Data Validation of the PVLife model using 3 Million Module-Years of Live. In Proceedings of the 39th IEEE PVSC Tampa, FL, 16–21 2013; pp. 7–12.

54,500 PV systems installed between 2005 and 2015 by NREL and they found a median failure rate of just 5 out of 10,000 modules annually (0.05% failure rate)

Jordan, D.C. et al. Photovoltaic Failure and Degradation Modes. Prog. Photovolt. ***2017****, 25, 318–326.*

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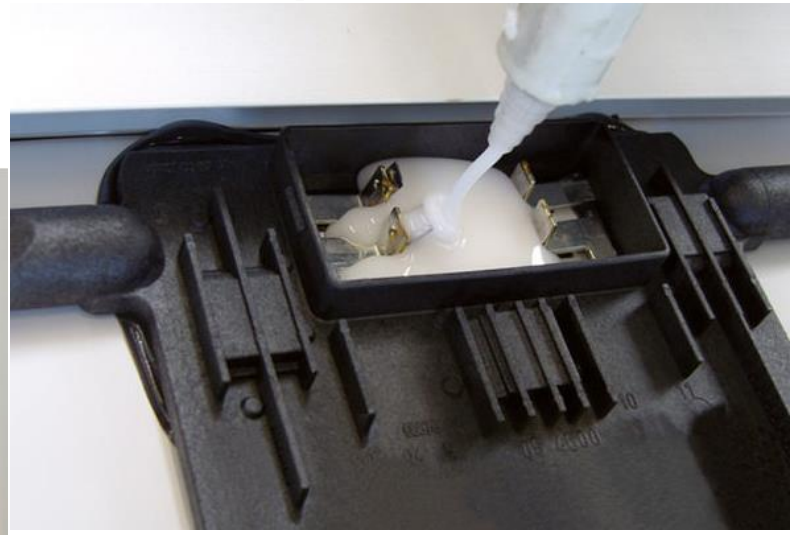
Initial findings from the Preparatory study for PV modules

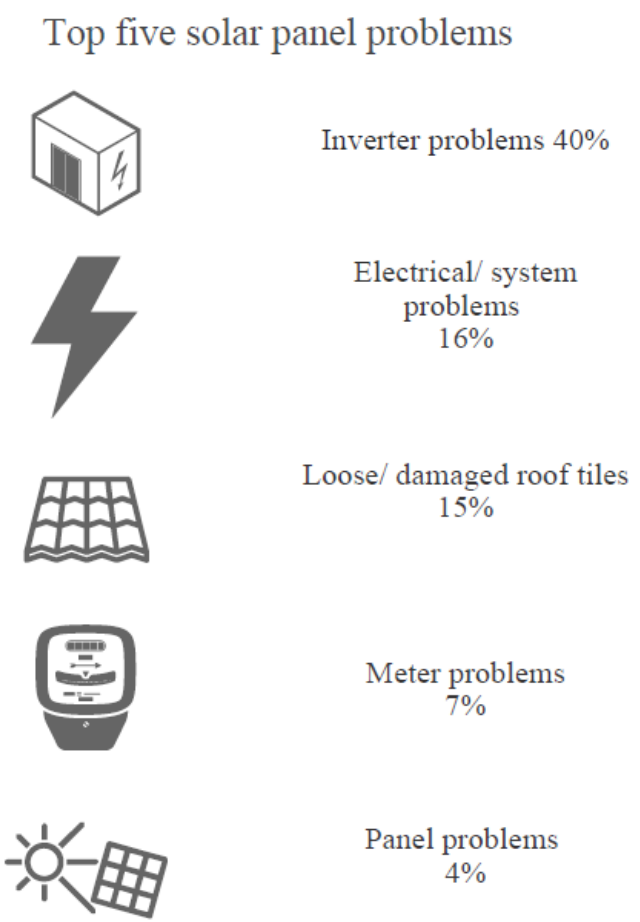
Taking the **junction box** as an example - Bypass diode may in more recent modules and because of changing manufacturing practices, be more difficult to access (sealed box) and replace (ability to unplug the diode)



Initial findings from the Preparatory study for PV inverters

Data indicate that the **inverter** is the element of the photovoltaic plant that has the highest number of service calls and the greatest operation and maintenance cost burden. They are critical to the power output of PV system.

Hacke et al. Renewable and Sustainable Energy Reviews 82 ***2018****, 1097–1112*



Initial findings from the Preparatory study for PV inverters

"One in ten (9%) owners told us they've had to replace their inverter since they've had their solar panel system installed. Most commonly, they replaced the inverter four years after they bought their solar PV system – almost a quarter (23%) told us this. Some 16% said they'd replaced their inverter more than five years after purchase. But the same percentage said they'd had to replace it less than a year after buying their system."

Table 1
Reported component failures observed in MLPE devices.

Component	References
Capacitors	[9,10]
Boards, mounting mechanical failure	[9–11]
Component connections (ICs, resistors, diodes), including fatigue, corrosion	[9,10,13]
Enclosure failure (moisture ingress)	[11]
Cabling (UV weathering, mechanical)	[11,13]
Transformer/power conversion	[11,13]
Power devices	[11]
Connectors (AC or DC)	[12]
Control devices (ICs, memory, etc.)	[11]
Die attach (thermal runaway failure)	[13]
Varistor (for AC-side overvoltage protection)	[12]
Potting	[9,10,14]

Online survey in June 2017 of 1,265 Which? members with solar panels.

Hacke et al. Renewable and Sustainable Energy Reviews 82 ***2018****, 1097–1112*

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Initial findings from the Preparatory study for PV inverters

Evidence suggests that inverters are regularly repaired rather than replaced. Intention is to identify the most common repairs to be carried out and their disassembly routes. This can then form the basis for 'design for repair' criteria.

"The reviewed data from PV power plant operators show that **inverters are the most costly O&M** area of PV systems, responsible for between 43% and 70% of the service tickets. These are in addition to planned maintenance activities."

Hacke et al. Renewable and Sustainable Energy Reviews 82 ***2018****, 1097–1112*

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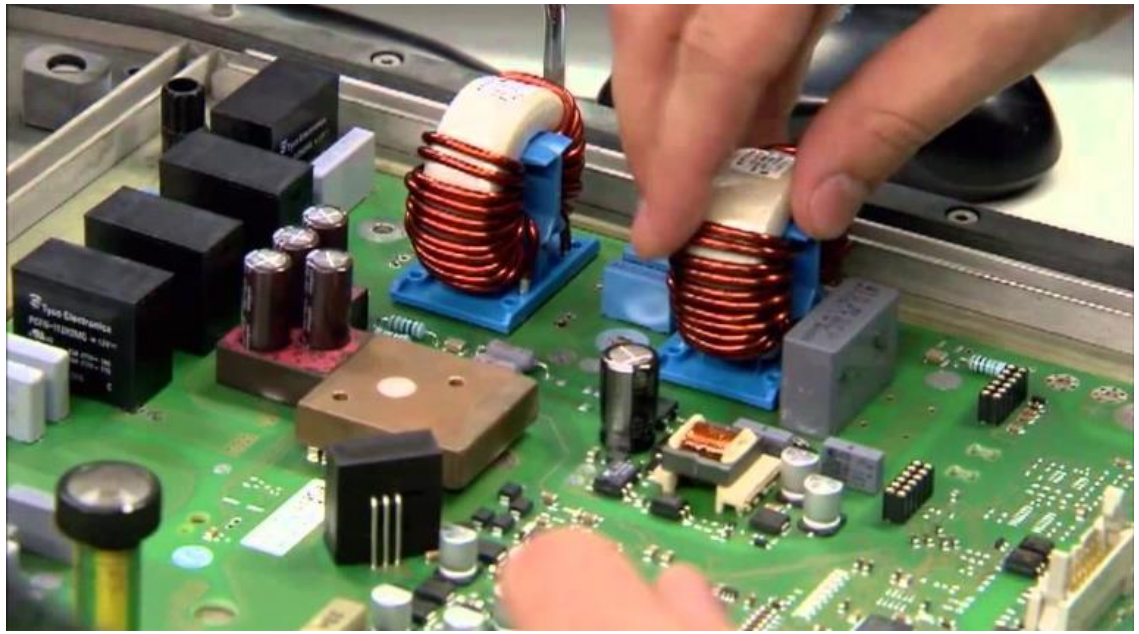
Initial findings from the Preparatory study for PV inverters

Environmental hotspot analysis

PCBs are a hotspot form the environmental perspective



SMA inverters out-of-warranty repairs

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Thanks for your attention

Any questions?

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