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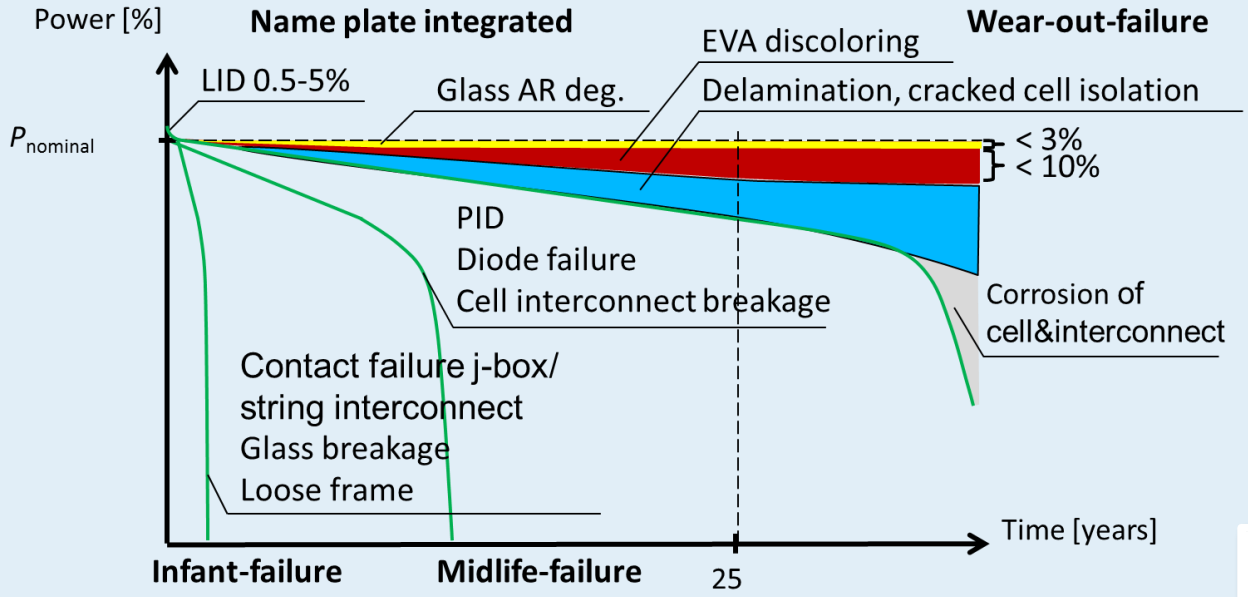
Statistics of Photovoltaic Module Failure

M. Köntges[1], A. Morlier[1], U. Jahn[2], K. A. Berger[3]
[1]Institut für Solarenergieforschung Hamelin
[2]TÜV Rheinland Energy GmbH
[3]Austrian Institute of Technology GmbH



Activity 3.4 in IEA TASK13

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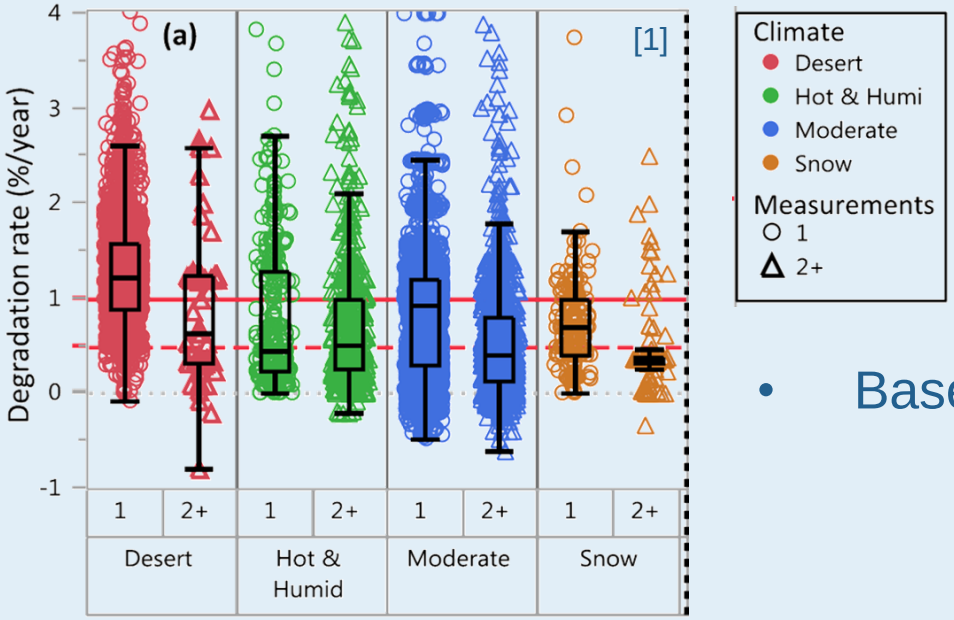
Degradation Rates of PV Modules/Systems[1]

- x-Si mean degradation in the 0.8–0.9%/a range
- HIT and microcrystalline silicon ~ 1%/a
- Thin-film > 1.4%/a, strong variations depending on technology



- Based on 11029 data points
- Degradation rate: no clear climatic zone dependence[2]

[1]D. C. Jordan et al., Prog. Photovolt. Res. Appl., 2016, DOI:10.1002/pip.2744.

[2]D. C. Jordan et al., Prog. Photovolt. Res. Appl., 2017, DOI: 10.1002/pip.2866.

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Structure of the Survey[1]

New form | Copy form | Delete form | Survey version | 08 February 2016

PV system basics | Goal of this survey | How to start ? | Other questions

System ID:	Example ID	PV module type			Multicrystalline Si
Source of data	Expert	Inverter type			String inverter wit
Country	Germany	Mounting system type			Rail system at lon
Climate zone	Moderate (C-climate)	Grounding of substructure & module frames/conductor			Grounded/non
Special stress		Other system component			
Kind of system	Roof top commercial	Nominal system power	[kWp]		100
Orientation	0 (south)	Date of system start	[MM/YYYY]		Juni 13
Inclination	30	Date of failure documented here	[MM/YYYY]		Juni 15
Comment if a field is orange					

Integral data

	Following failure specifications are based on investigated percentage of					
Total system power loss [%]	Inverter [%]	Cable and interconnector [%]	PV module [%]	Mounting [%]	Other [%]	Comment
2			50			

5 x

Failure specification for 25 **% of the system**

Failed system part	Failure 1 specification	Power loss 1 [%]	Failure 2 specification	Power loss 2 [%]	Safety failure 1	Safety failure 2
Inverter	No failure	No detectable loss	No failure	No detectable loss	No failure	No failure
Cable and interconnector	No failure	No detectable loss	No failure	No detectable loss	No failure	No failure
PV module	Cell cracks	]3%-10%]	No failure	No detectable loss	No failure	No failure
Mounting	No failure	No detectable loss	No failure	No detectable loss	No failure	No failure
Other system component	No failure	No detectable loss	No failure	No detectable loss	No failure	No failure
Comment if a field is orange						

[1]http://iea-pvps.org/index.php?id=344

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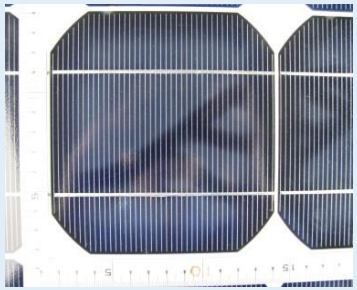
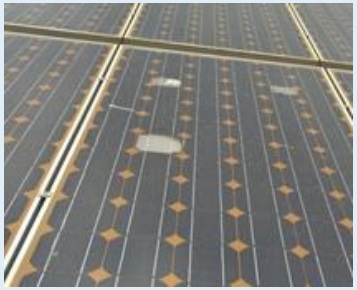
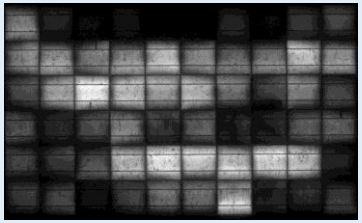
Selected PV Module Failure Examples



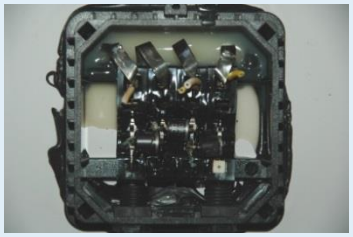
Cell cracks



Discolouration of laminate



PIDs



Defect bypass diode

Delamination

Disconnected cell or string interconnect ribbon

- But also information on soiling, snow load, storm …

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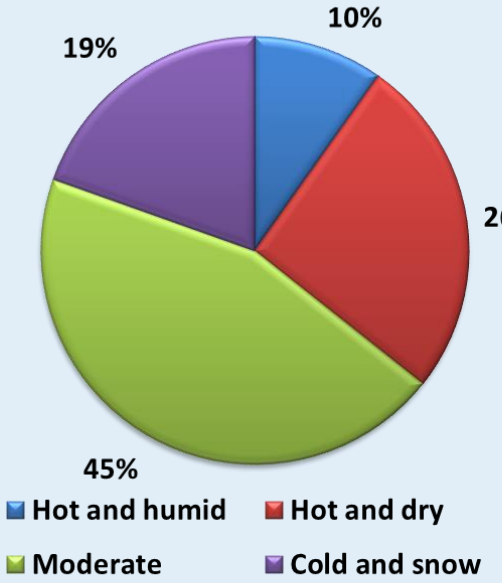
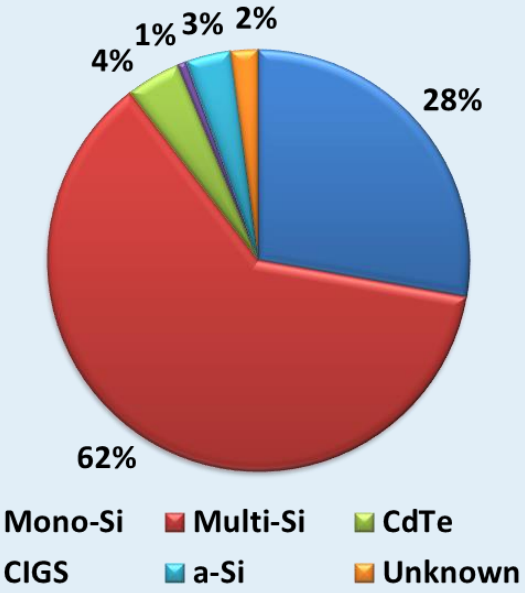
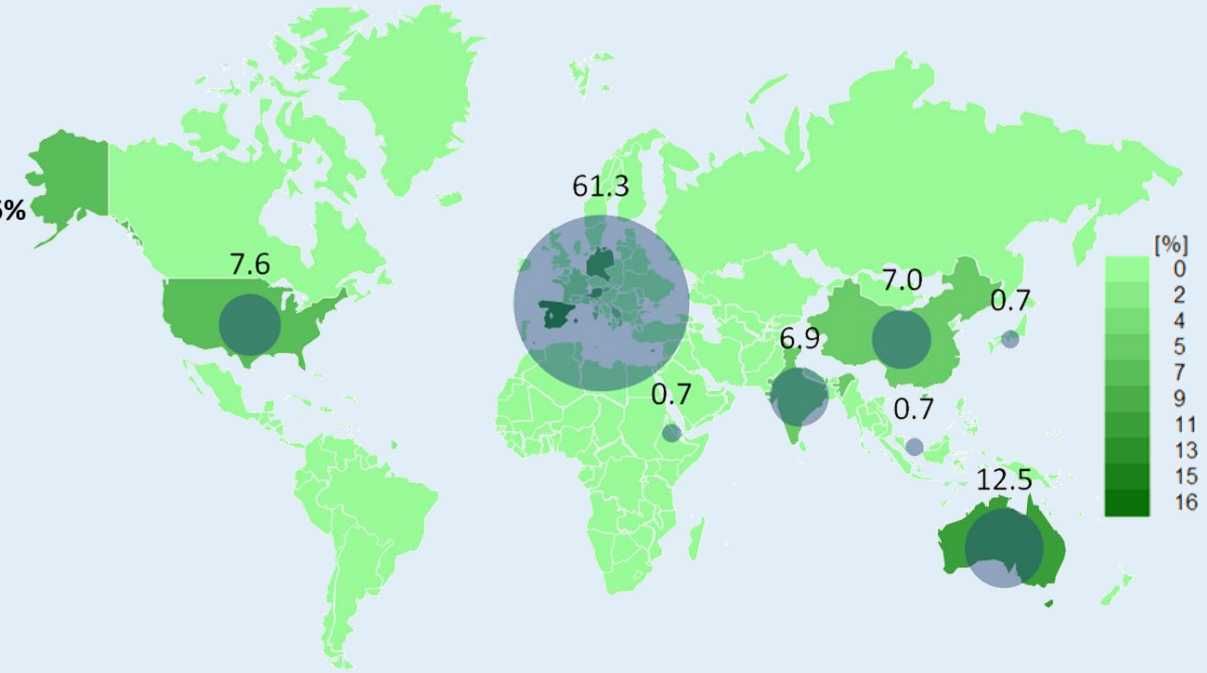
Database Composition







- Main survey data from Europe
- Moderate climate dominates data
- Technology distribution equal to market distribution
- 144 failure-survey-data sets from 18 countries

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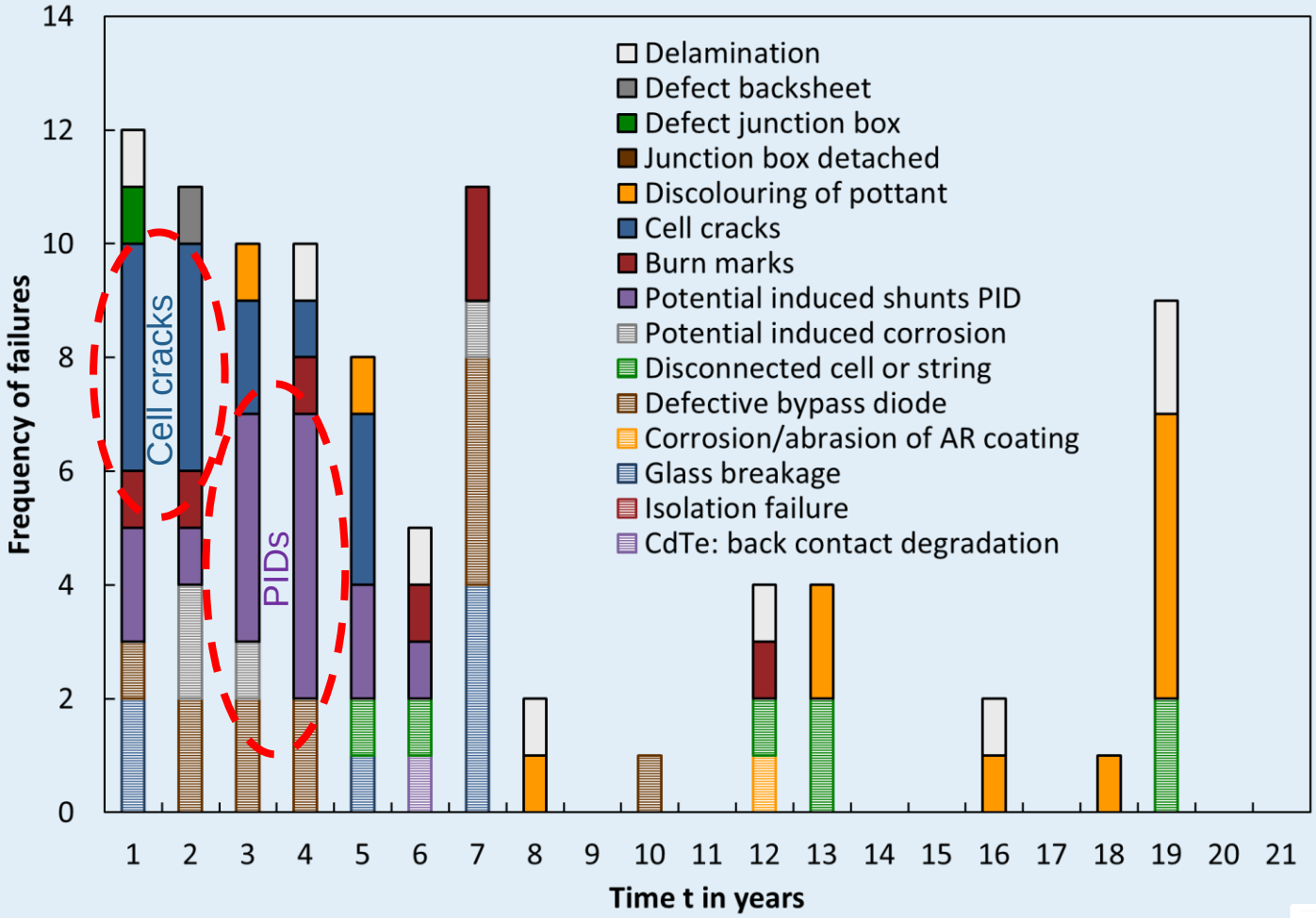
Analysis of Failure Occurrence



- Count only failures leading to power loss
- Cell cracks in 1-2 year, PIDs in 3-4 year

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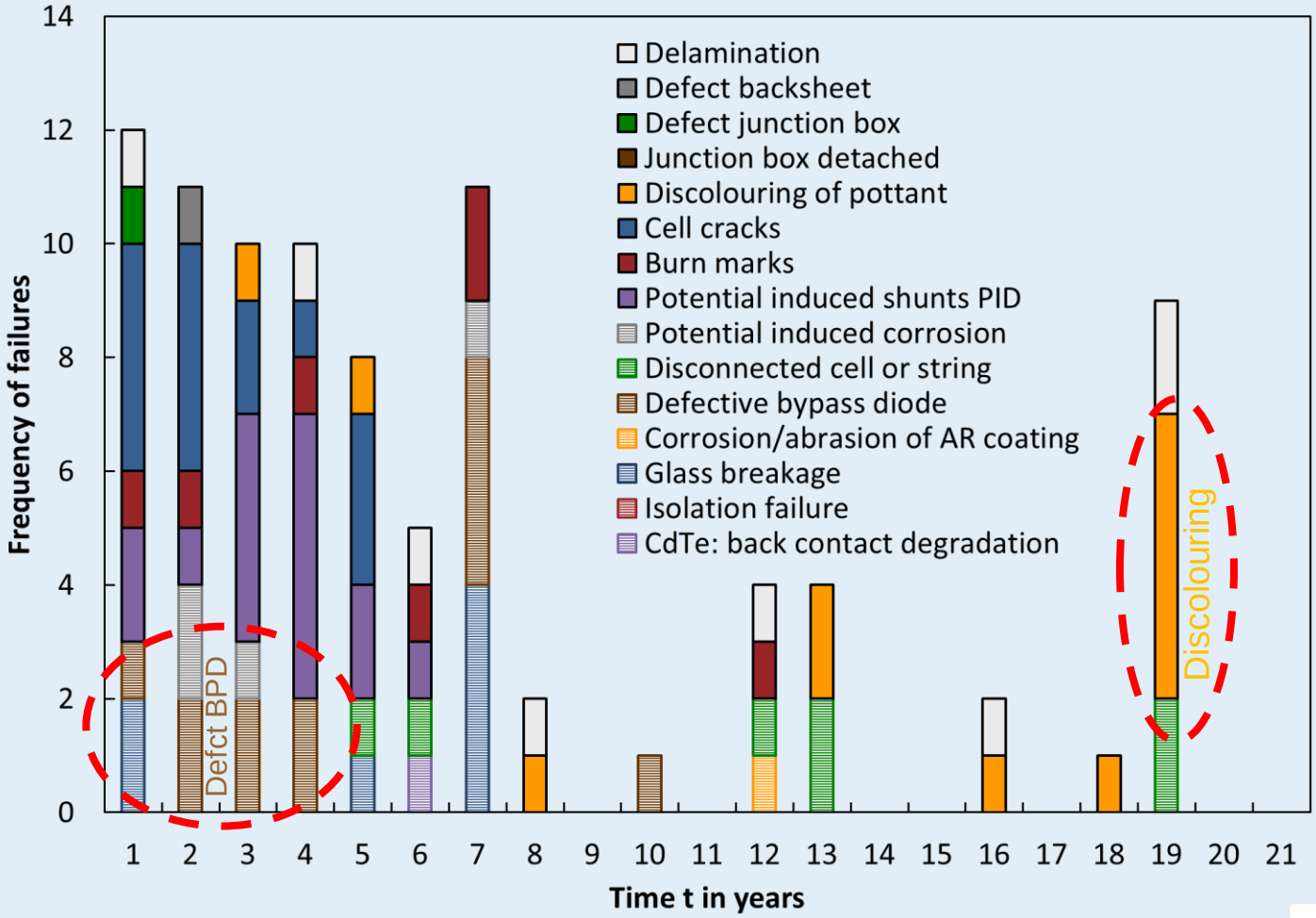
Analysis of Failure Occurrence



- Defect bypass diodes, in the first years but also later
- Discolouring all years, but accumulate after 18 years

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Degradation Rates – Impact on Affected PV Modules

- Degradation rate of PV modules affected by failure *x* of system *i*:

$$d_{i,x} = \frac{\Delta P_{i,x}}{\tau_{b,i} - \tau_{a,i}}$$

Power of whole system:

P_i in kW_p

From failure *x* affected system part:

$z_{i,x}$ of system i ➔ $d_{i,x}$

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Degradation Rates – Impact on Investigated Part of PV System

- Degradation rate of the investigated system part:

$$\delta_{i,x} = d_{i,x} \frac{z_{i,x}}{y_i}$$

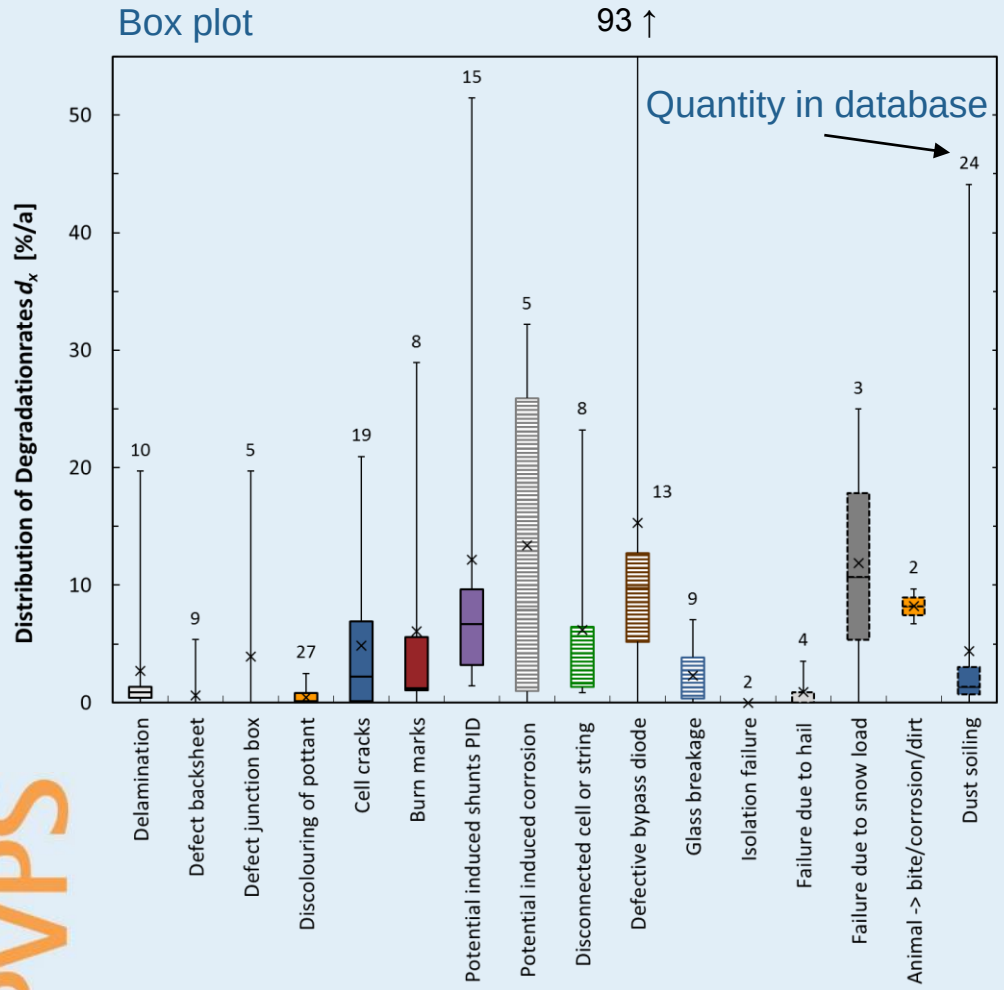
- Degradation not necessarily linear
- But method allows comparing power loss for different system ages

Power of whole system:
P_i in kW_p

From failure *x* affected system part:
$z_{i,x}$ of system i ➔ $d_{i,x}$

For failure x investigated part:
y_i of system i ➔ $\delta_{i,x}$

Degradation Rates (DR) for Affected PV System Part



- All failure modes have high DR variations
- Potential induced shunts (PIDS) (mean 12%/a), PID-corrosion (13%/a) and defect bypass diode (15%/a) are most critical
- Cell cracks lead in some cases to power loss (5%/a), but not as critical as PID
- Discolouring of pottant occurs often, but with low DR (0.4%/a)

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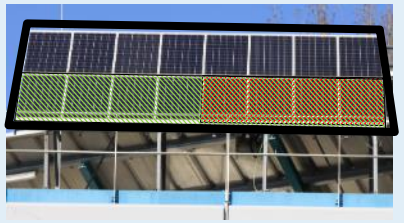
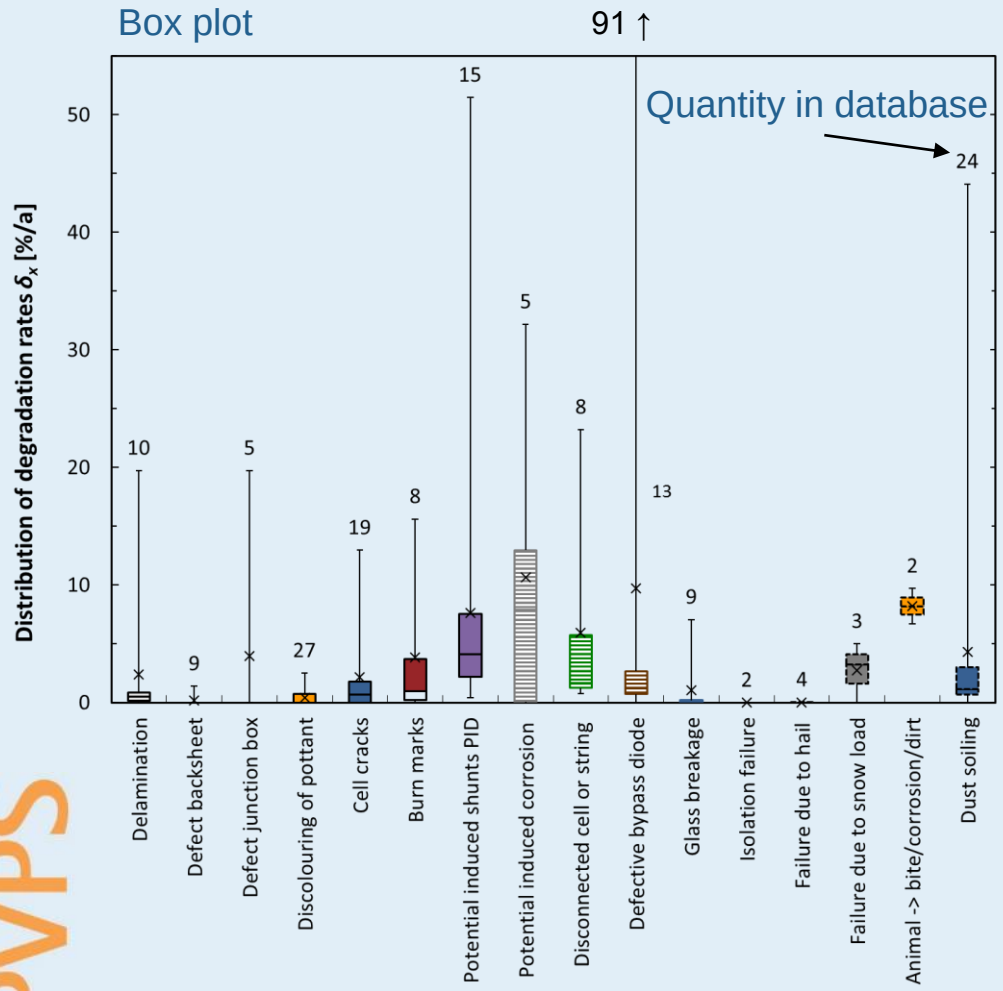
Degradation Rates for Investigated PV System Part





- Most DR are reduced on system level, because not all modules are affected!
- DR of PIDS (8%/a), PID-corrosion (12%/a) and defect bypass diode (10%/a) are reduced on system level
- DR of cell cracks is substantially reduced (2%/a),
- Discolouring DR does not change, mostly all modules in a system are equally affected (0.4%/a)

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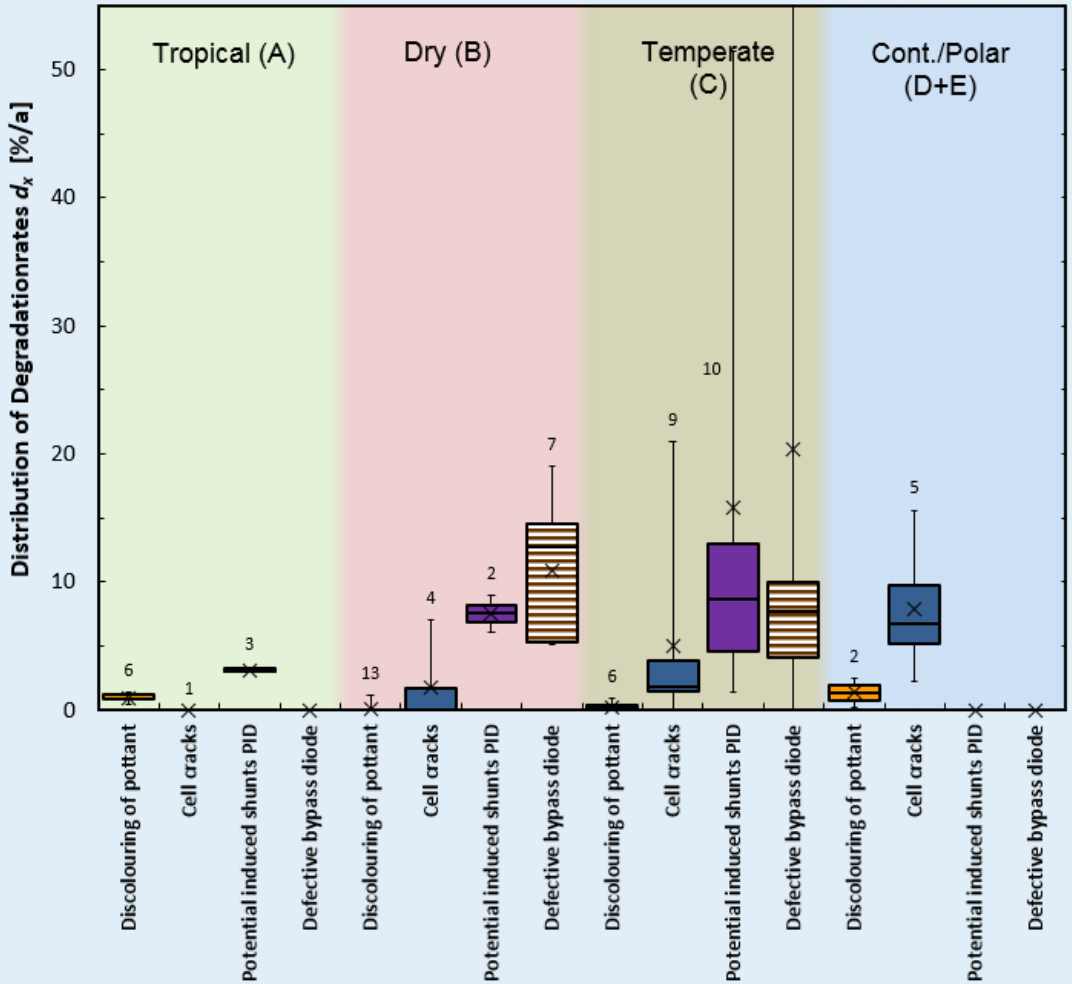
Degradation Rates of Failure Affected Part of PV System



- Cell crack degradation rate highest (8%/a) in continental climate
- Mean PID 16%/a for temperate climate but high variations in rates
- Discolouring highest in tropical climate but mean <1%/a

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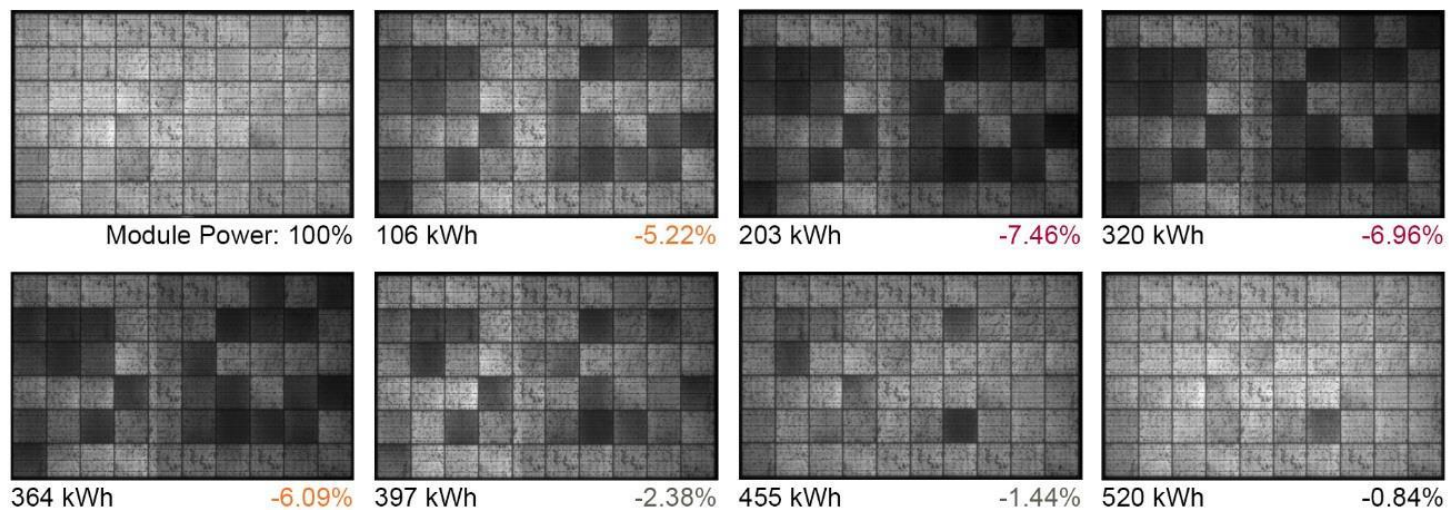
LID for PERC modules not in statistic



- P-type multi crystalline PERC cells susceptible for Light and enhanced Temperature Induced Degradation (LeTID) 1.5%-15% degradation in 1-5 years (V_{mpp}), propritär solutions[1]
- P-type mono crystalline PERC cells susceptible for B-O degradation 1% - 10% degradation multiple days (V_{mpp}), industrial solutions available

[1] F. Kersten et al., 31st EUPVSEC, Hamburg, Germany (2015), p. 1830

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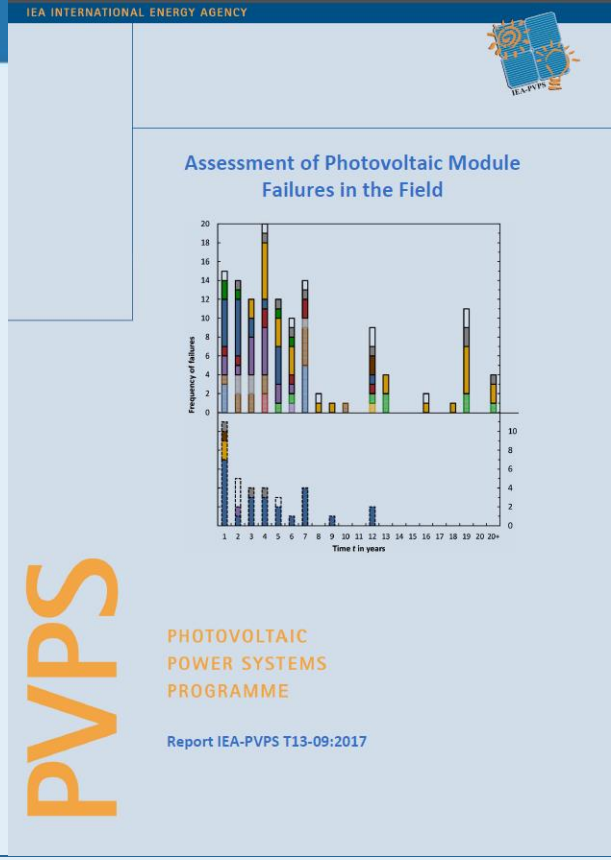
Conclusions

- Cell cracks dominate the early failures during year 1 and 2.
- Degradation rate caused by cell cracks is highest (8%/a) in continental and snow climates.
- PIDs dominates year 3 and 4 in the failure statistic (16%/a) in moderate climate.
- Great variation of degradation rates for bypass diode failure, may cause dramatic power loss.
- In all climates mean degradation rate of discolouring is below 1%/a.
- Be aware of LID degradation

Outlook

- Assessment of PV Module Failures in the Field
  http://www.iea-pvps.org/index.php?id=435
- Support us to collect anonymous data
  http://iea-pvps.org/index.php?id=344
- Send to: **m.koentges@isfh.de**
- TASK13 extension start in September 2018



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