Long term outdoor exposure in different climate zones

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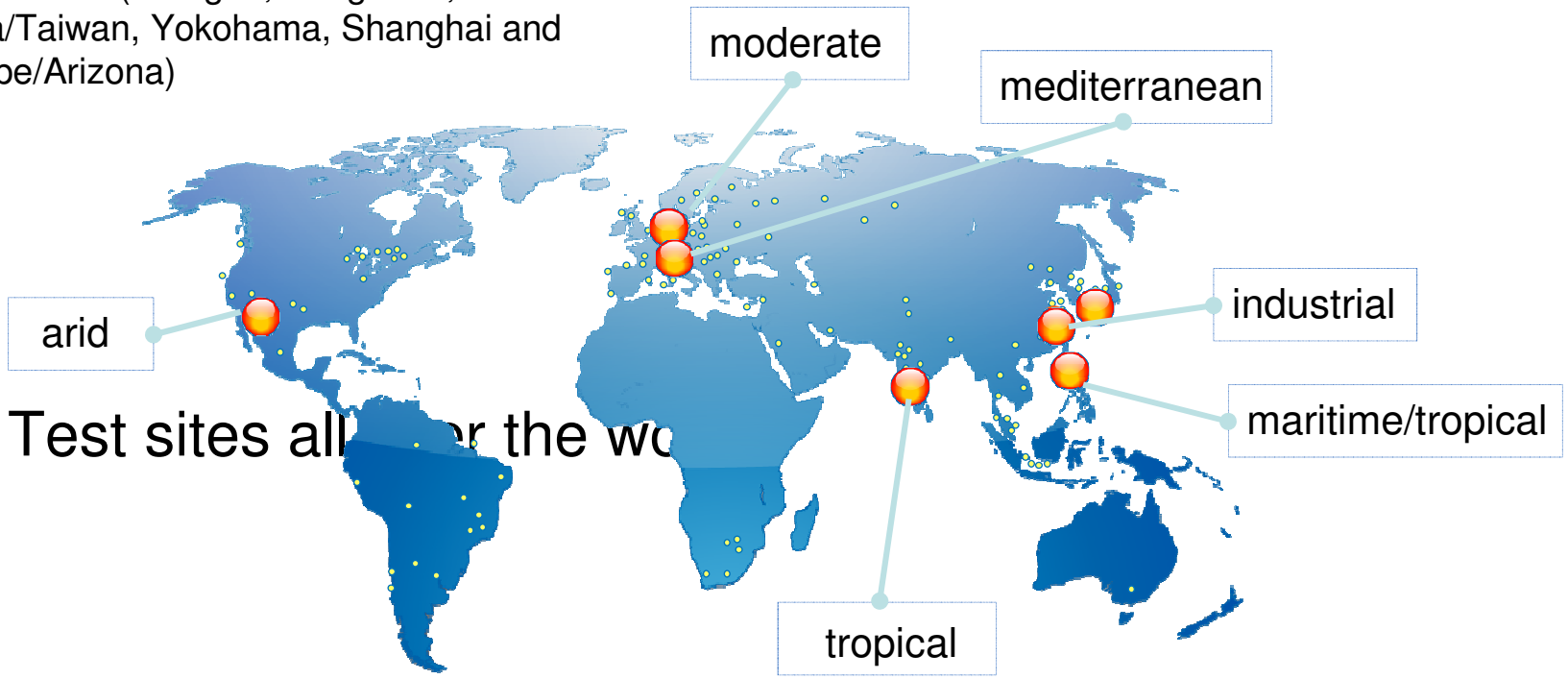
- TÜV Rheinland operates 6 accredited PV laboratories (Cologne, Bangalore, Daya/Taiwan, Yokohama, Shanghai and Tempe/Arizona)



Test sites all over the world

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German joint project ‚PV reliability'
Project description

Study of outdoor weathering effects is part of a German research project focussing on "PV reliability" (2005 – 2009 – 2013)

Supported by the German government

To contribute to the correlation of outdoor weathering and lab testing including the development of new test methods to detect degradation earlier

Institutes involved in outdoor exposure studies

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(Co-ordination outdoor weathering)

Fraunhofer ISE

(Project co-ordinator)

German joint project ‚PV reliability‘
weathering sites

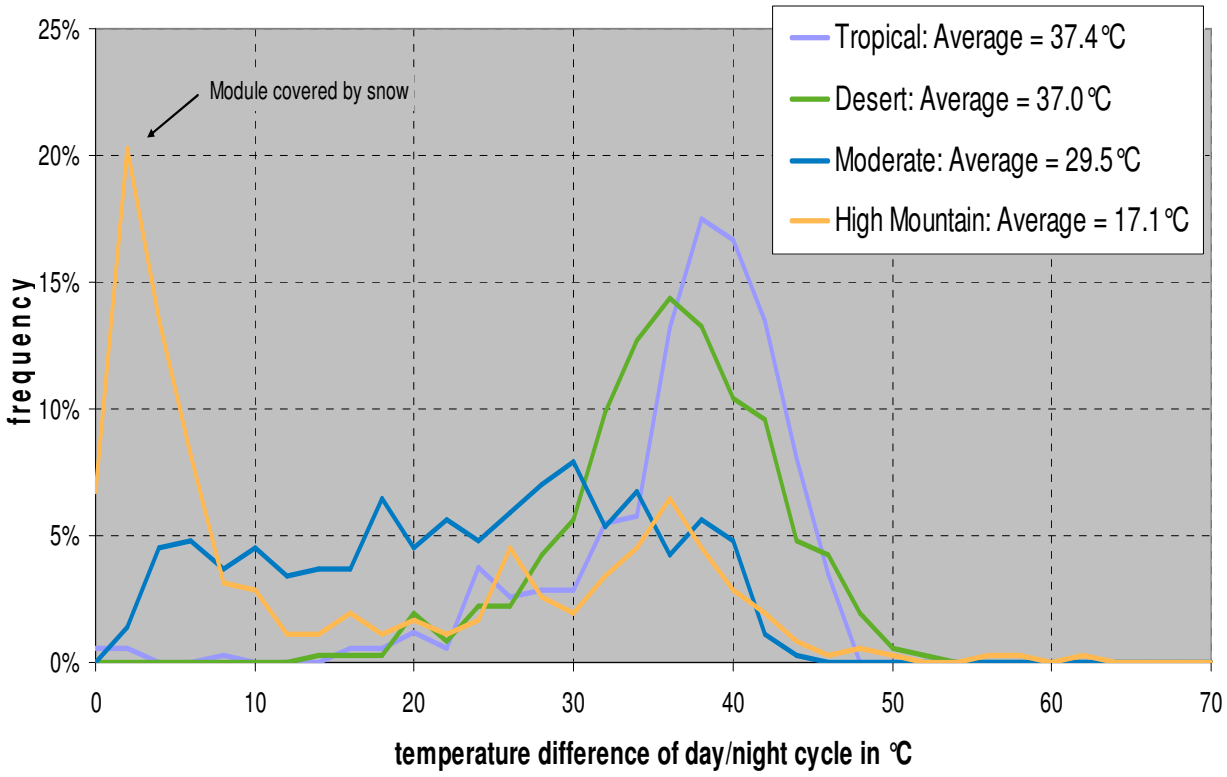
Outdoor exposure
weather

Test location	Daily average kWh/m²	Yearly integral kWh/m²
Moderate	3.0	1092
Mountain*)	2.7*	994*
Desert	6.2	2281
Tropical	4.7	1556

* Sensor partially covered by snow

Test location	Average rel. humidity in %	Aver. Module Temp in °C	Min. Module Temp. in °C	Max. Module Temp. in °C
Moderate	74,5	15.8	-17.9	62.2
Mountain*)	76,8	1.2*	-23.2*	54.8
Desert	63,8	21.7	-9.1	69.6
Tropical	86,6	30.8	15.3	70.1

Outdoor exposure
weather



- largest module temperature gradient found at Zugspitze amounts to 70 °C
- large difference to gradient used for IEC testing (125 °C)

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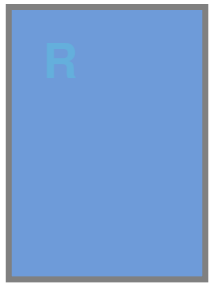
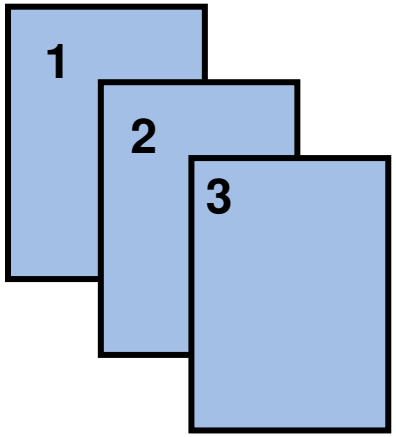
Outdoor exposure
proceeding





Reference module:
Dark storage at
TÜV Rheinland

Installation of 3 test samples of 7 module types at any test location:

- approx. 30 m² installed module area
- Operation via resistive load

Re-shipment and re-measurement:
After 1, 2, 3 years

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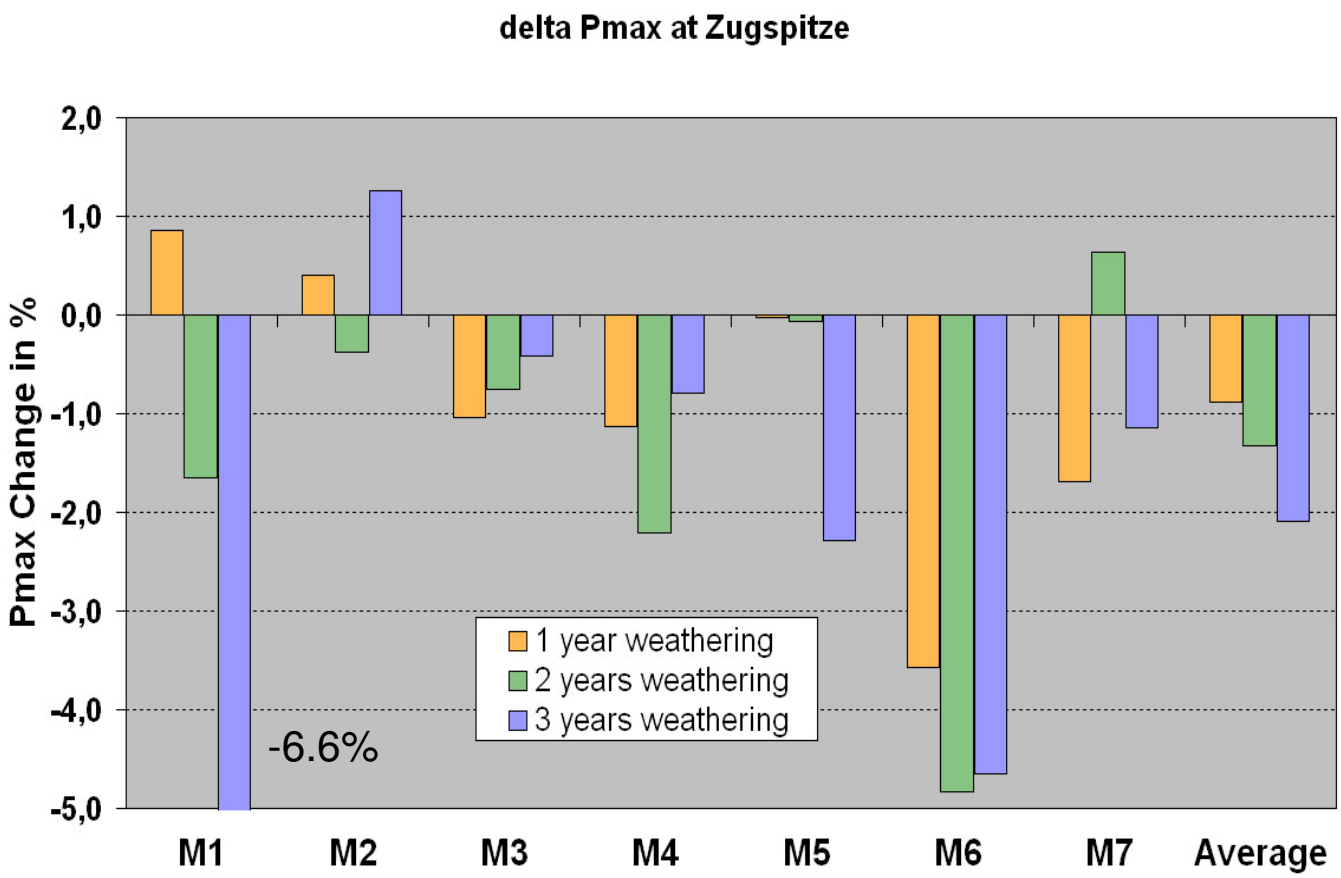
Outdoor exposure
3 years exposure



- largest degradation found for all locations
- up to -6.6% power loss
- major defects caused by cell breakage

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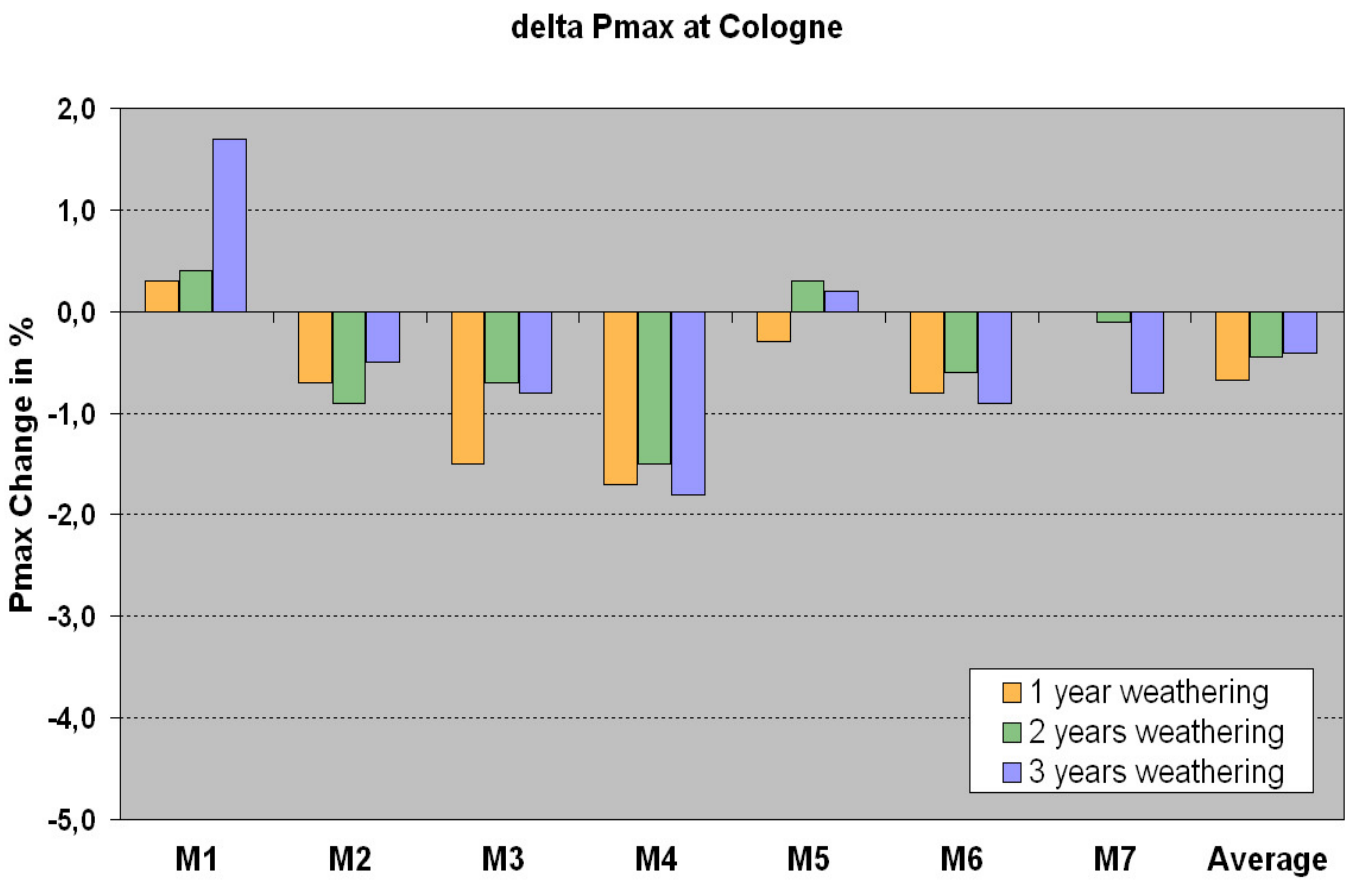
Outdoor exposure
3 years exposure



- degradation mostly in the range of the measurement uncertainty
- M4 suffers from solarization of glass

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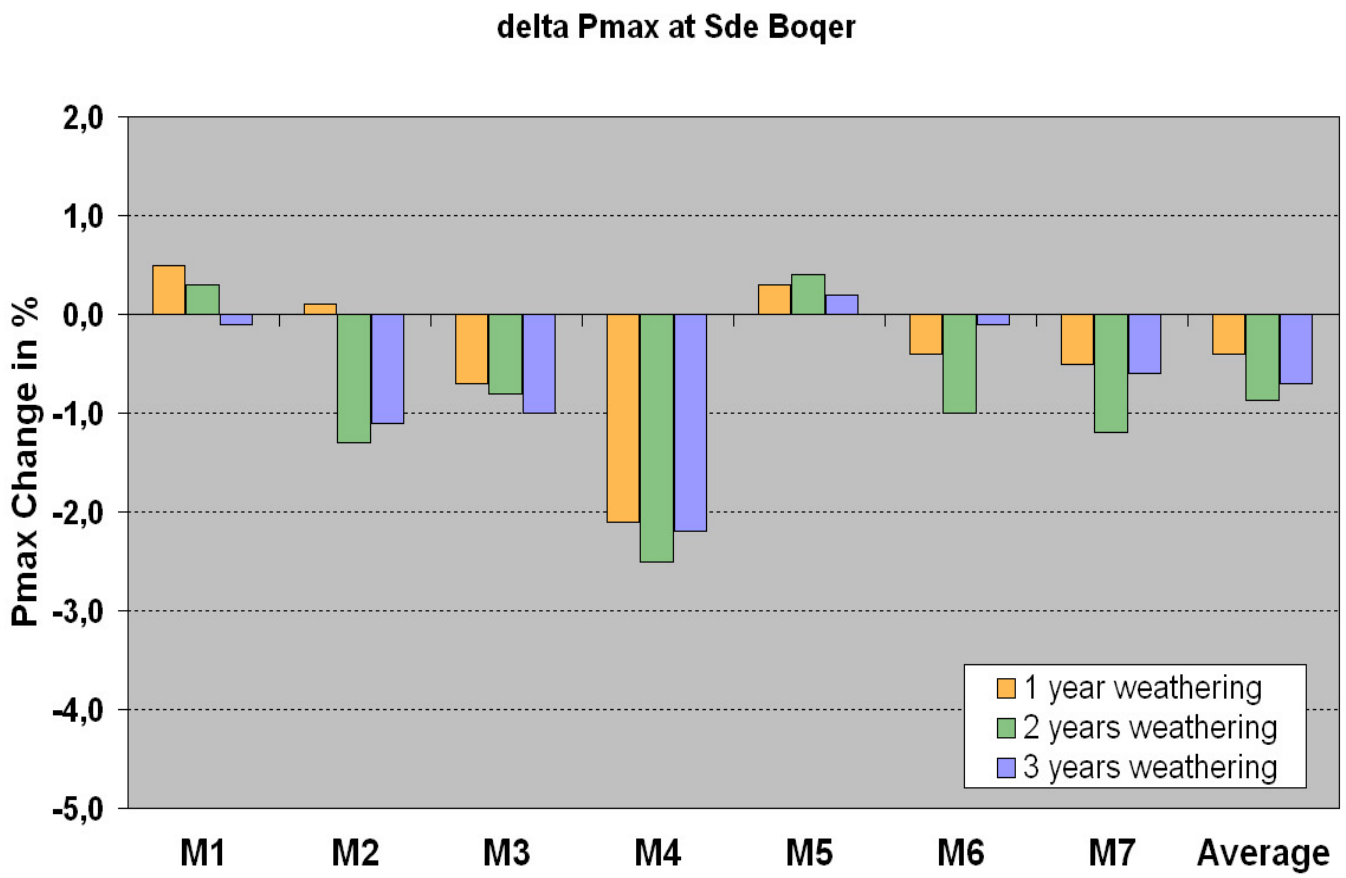
Outdoor exposure
3 years exposure



- degradation for some modules slightly larger than measurement uncertainty
- M4 suffers from solarization of glass
- modules were frequently cleaned

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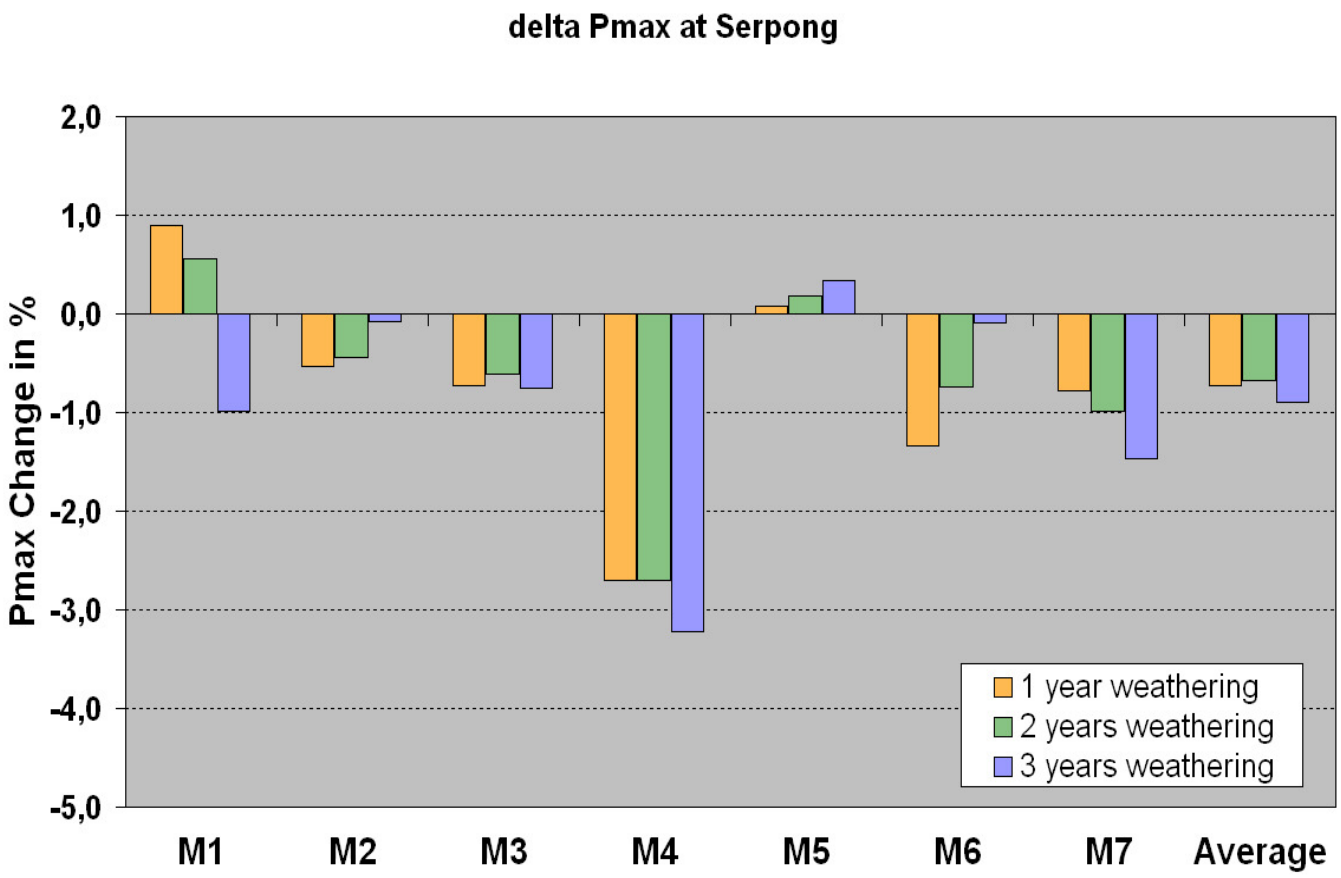
Outdoor exposure
3 years exposure



- Degradation for some modules slightly larger than measurement uncertainty
- M4 suffers from solarization of glass

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Outdoor exposure
visual changes

- power loss up to -3.3% due to soiling at the tropical location (reversible)

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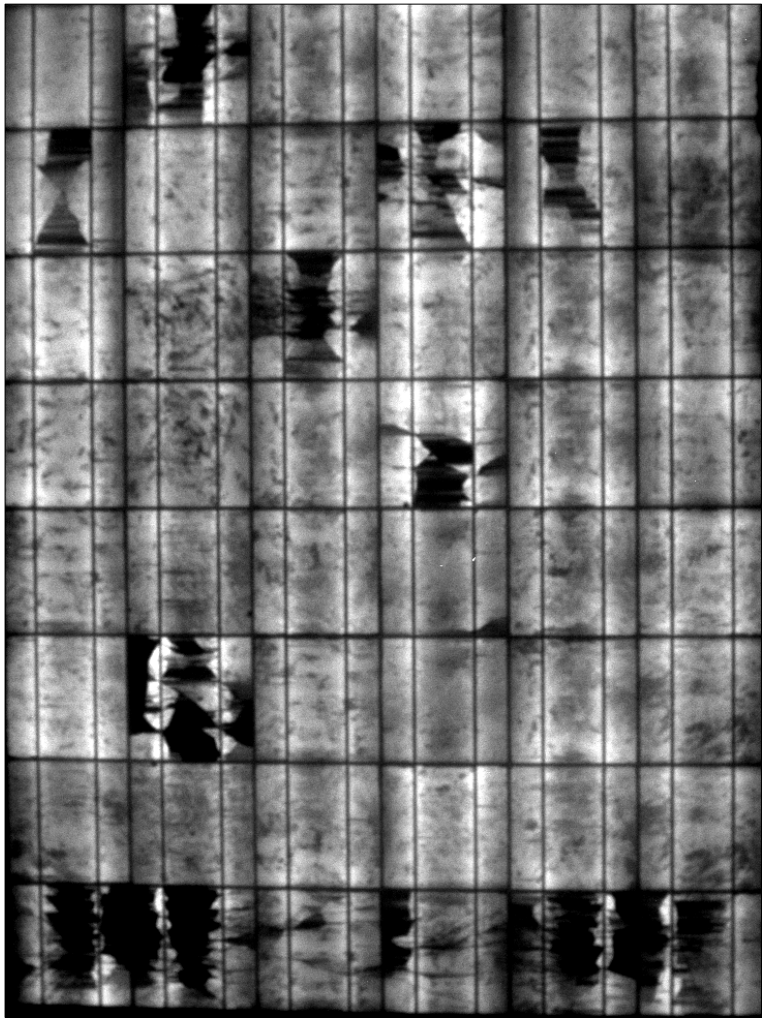
Outdoor exposure
visual changes



- power loss up to -3.3 % due to soiling at the tropical location (reversible)
- power loss up to -6.6 % due to cell breakage at the high mountain location caused by high snow and wind loads (low T => elastic modulus high, stress more easily leads to cell breakage)

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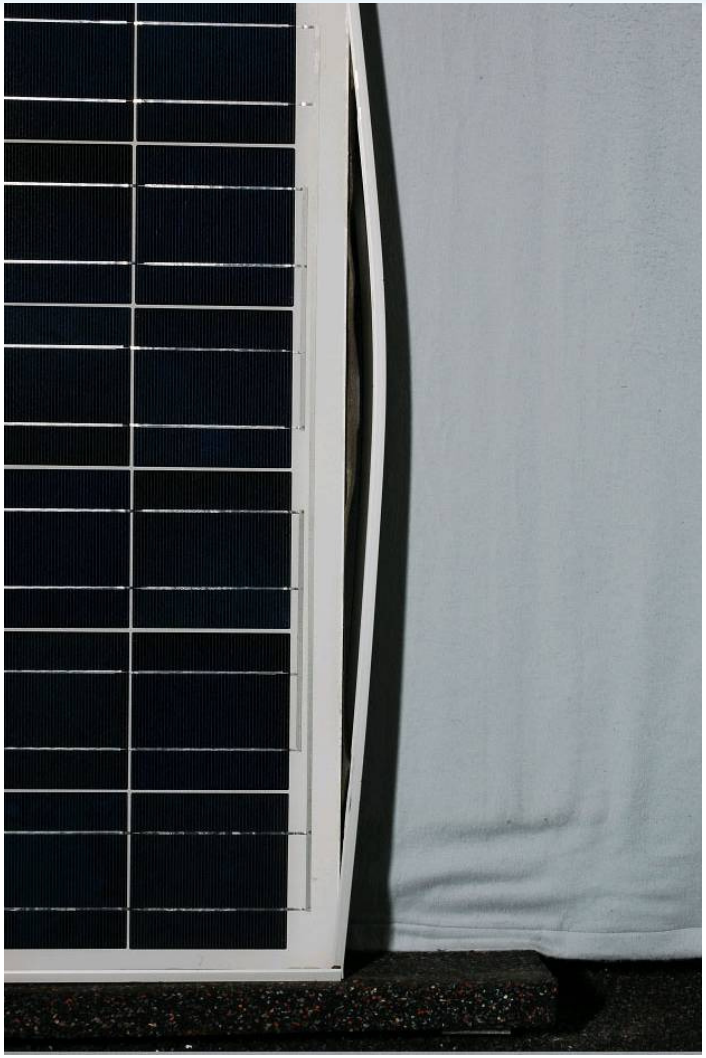
Outdoor exposure
visual changes



- power loss up to -3.3 % due to soiling at the tropical location (reversible)
- power loss up to -6.6 % due to cell breakage at the high mountain location caused by high snow and wind loads
- snow-load also causes other defects such as destruction of the module frame
- No isolation failures for none of the modules exposed!

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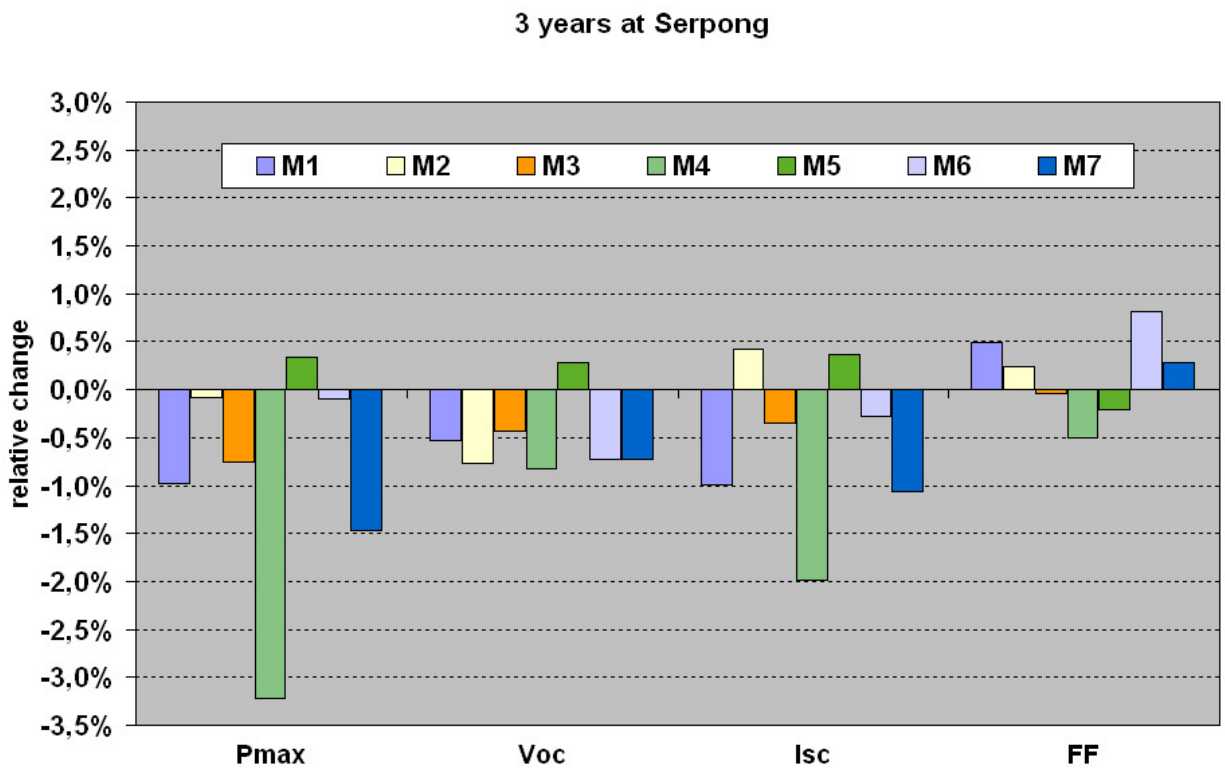
Outdoor exposure
3 years exposure



- different degradation mechanisms impact on different module parameters
- solarization, transmission loss and soiling => I_{sc}
  cell corrosion, contact corrosion and busbar degradation => FF (R_s)

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Outdoor exposure

- average power degradation after 3 years for all locations (despite Zugspitze) is -0.7%
- this value is still in the range of the measurement uncertainty
- secure degradation indication by means of power loss requires more than 3 years of outdoor weathering
- more sophisticated diagnostic tools are needed to detect degradation earlier (before power loss is detectable)

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Conclusions for outdoor weathering

- the big dilemma is: companies must rely on relatively short outdoor exposure durations (due to product cycles), detection of reliable degradation values though takes time
- only the determination of significant outdoor degradation data enables a reliable correlation of lab and outdoor degradation
- power degradation is actually a superposition of several degradation mechanisms which should be evaluated (measured) separately to correlate them to lab values
- outdoor exposure is inevitable to reveal degradation that is not found in lab testing

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Thank you for your interest

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