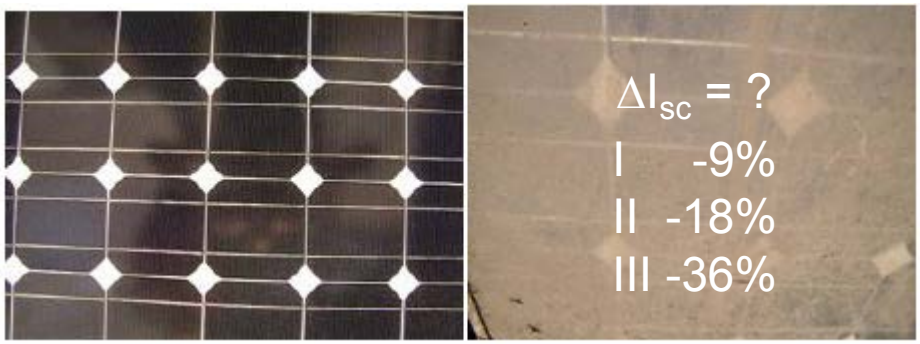
DAP-PL-4314.00

Impact & Consequences of Soiling and Cleaning of PV Modules



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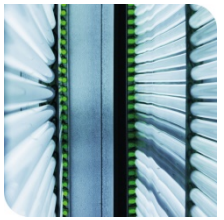
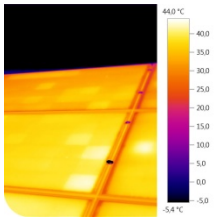
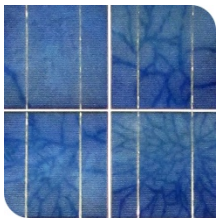
PI Photovoltaik-Institut Berlin AG, Wrangelstraße 100, 10997 Berlin

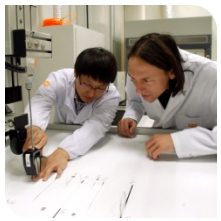
PI Photovoltaik-Institut Berlin AG

Photovoltaik Class A PID Institut Berlin No. 12012123









Business Units | Services

Customer

Quality

PV-Module Quality & Lab Services
(ISO 17025 accredited labs)

- Head of BU: Dipl.-Ing.(FH) Michael Schoppa
- Services: Supplier Qualification, In-depth Factory Inspections, Module Tests, Certification

Power plants

PV-Systems

- Head of BU: P. Eng. Steven Xuereb
- Services: Yield Optimization, Due Diligence, Plant Certification, Plant Analysis

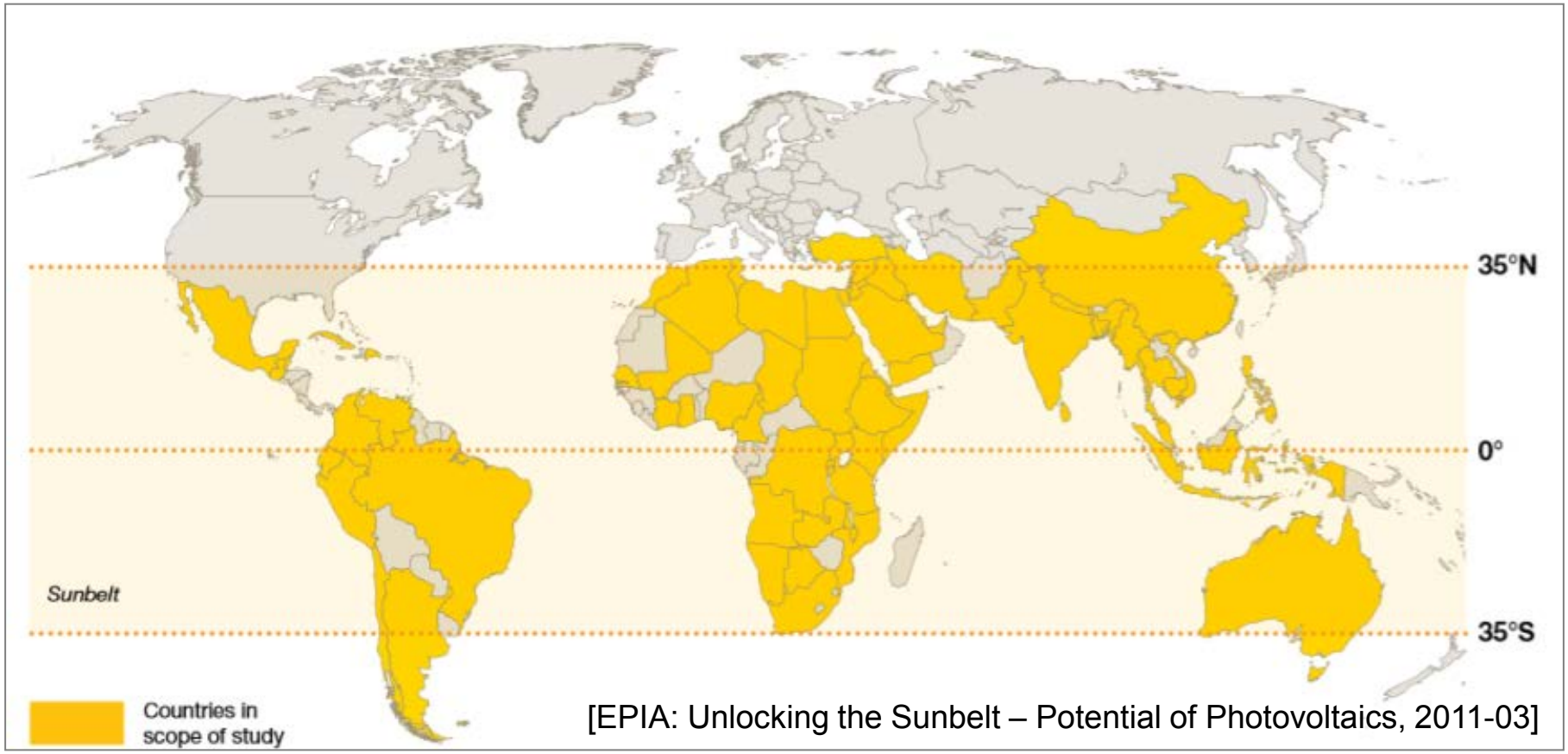
Technology

PV-Module Technology and R&D Services

- Head of BU: Dr. Juliane Berghold
- Services: Failure Analysis, Component Analysis, Expert Opinion, Funded Projects

Report

1) Motivation
Why turn soiling, cleaning and Abrasion into interest?

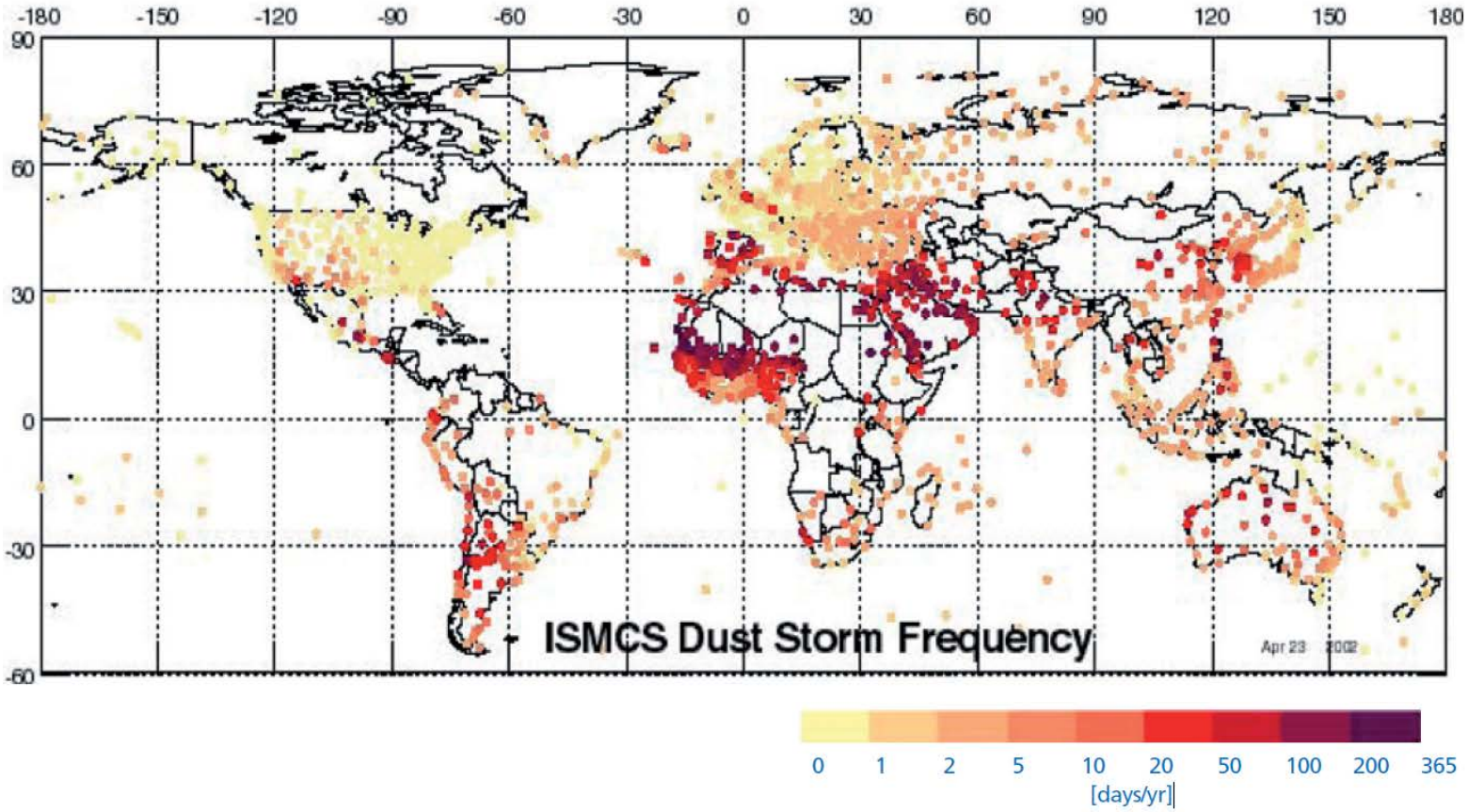


[EPIA: Unlocking the Sunbelt – Potential of Photovoltaics, 2011-03]

- 5 billion inhabitants in 66 Sunbelt countries representing 75% of the world's population

→ **deserts**, **pollution**, and **flat tilt angles** lead to **strong soiling impact** on PV modules

1) Motivation
Dust Storm frequency



[Tegen et al., "Relative Importance of climate and land use in determining present and duture global soil dust emission", Geophysical Research Letters 31, 2004]

- **Soiling and Abrasion impact is location dependent**

→ Mani contributed a usefull categorization of climatic zones and recommended cleaning schedules

[M. Mani et al. "Impact of dust on solar photovoltaic (PV) performance: Research status,challenges and recommendations", Renewable and Sustainable Energy Reviews 14 (2010) 3124–3131]

Overview

1) Motivation

2) Introduction

3) Soiling Test:

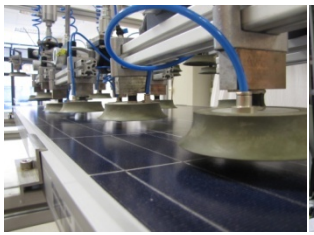
How one can **simulate soiling** and **determine self-cleaning properties.**

4) **Cleaning Impact** on modules

5) Abrasion Test:

How **coatings are effected by abrasion**.

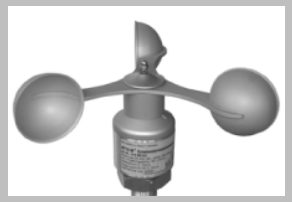
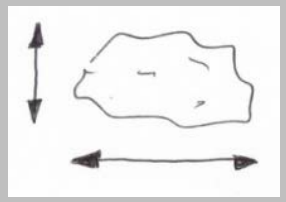
6) Summary



2) Introduction

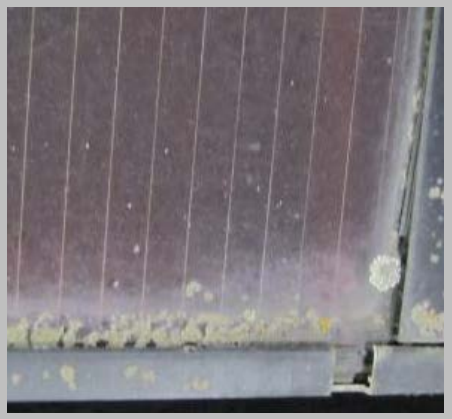
Environmental conditions of spec. location:

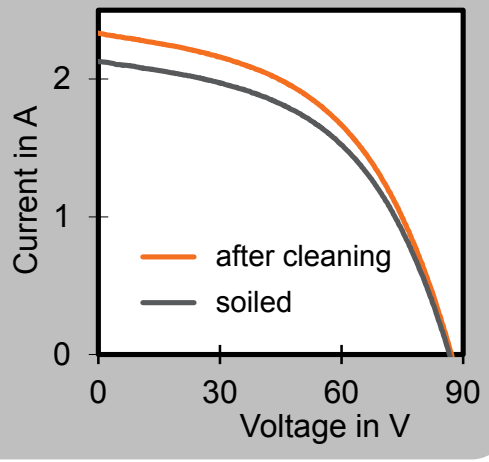
- wind speed / direction
- kind of dust
- moisture
- natural cleaning
- availability of water as cleaning resource

Power reduction:

- less significant e.g. in Germany
- 15 to 30% for moderate dust cond.
- losses up to 100% possible, if cementation





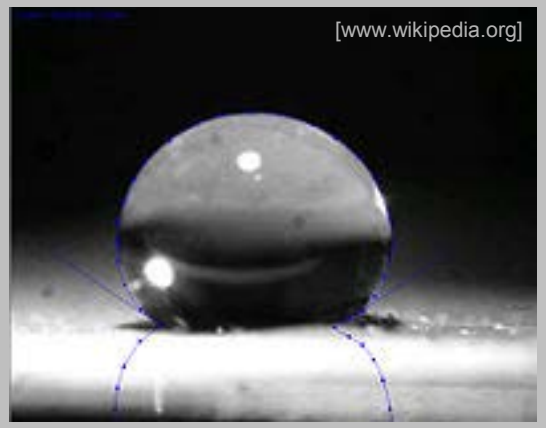
2) Introduction

Mitigation / corrective measures:

- water, air or mechanical cleaning
- manual or autom.

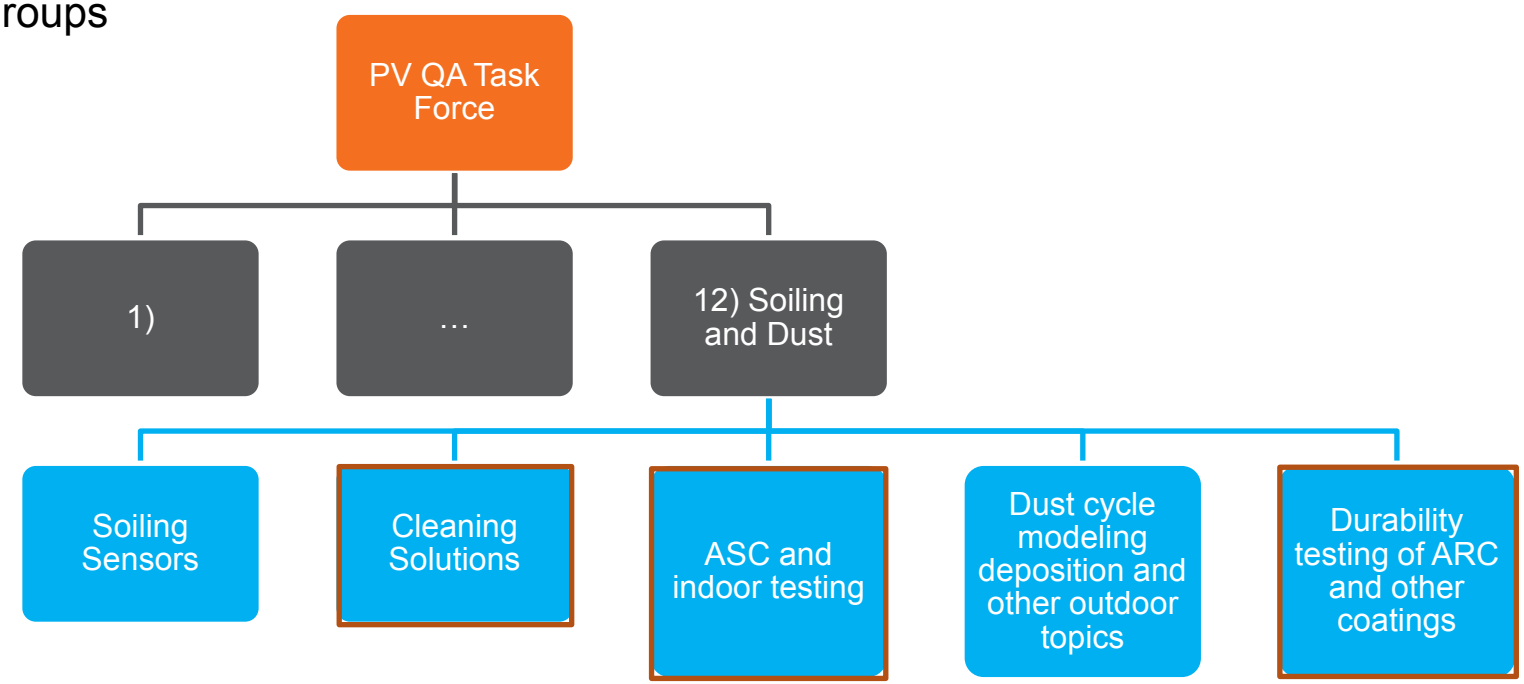
Mitigation / preventive appr.:

- ‘passive’ methods:
anti soiling coatings (ASC)
- ‘active’ methods:
repelling by charge



2) Introduction
Overview to PV QA Task Force 12) Soiling and Dust

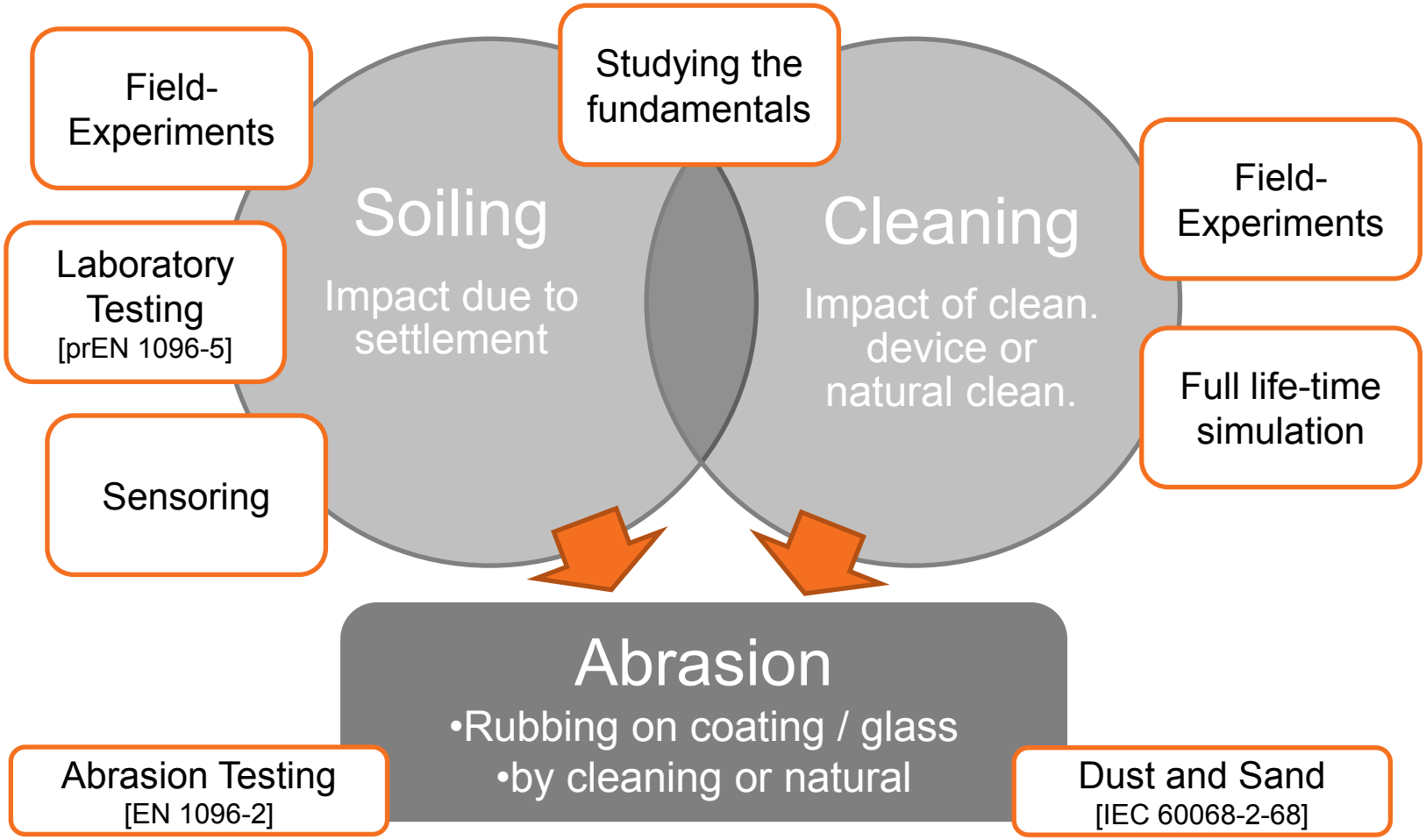
- PV QA Task Force was initiated at the International PV Module QA Forum 2011 in San Francisco
- Task group 12) Soiling and Dust
  - Leader of group Mike Van Isegheim (EDF) and Sarah Kurtz (NREL)
  - 5 subgroups



→ Look to the wiki-page:http://pvqataskforceqarating.pbworks.com

2) Introduction: Soiling, Cleaning and Abrasion [Sarver et al.]

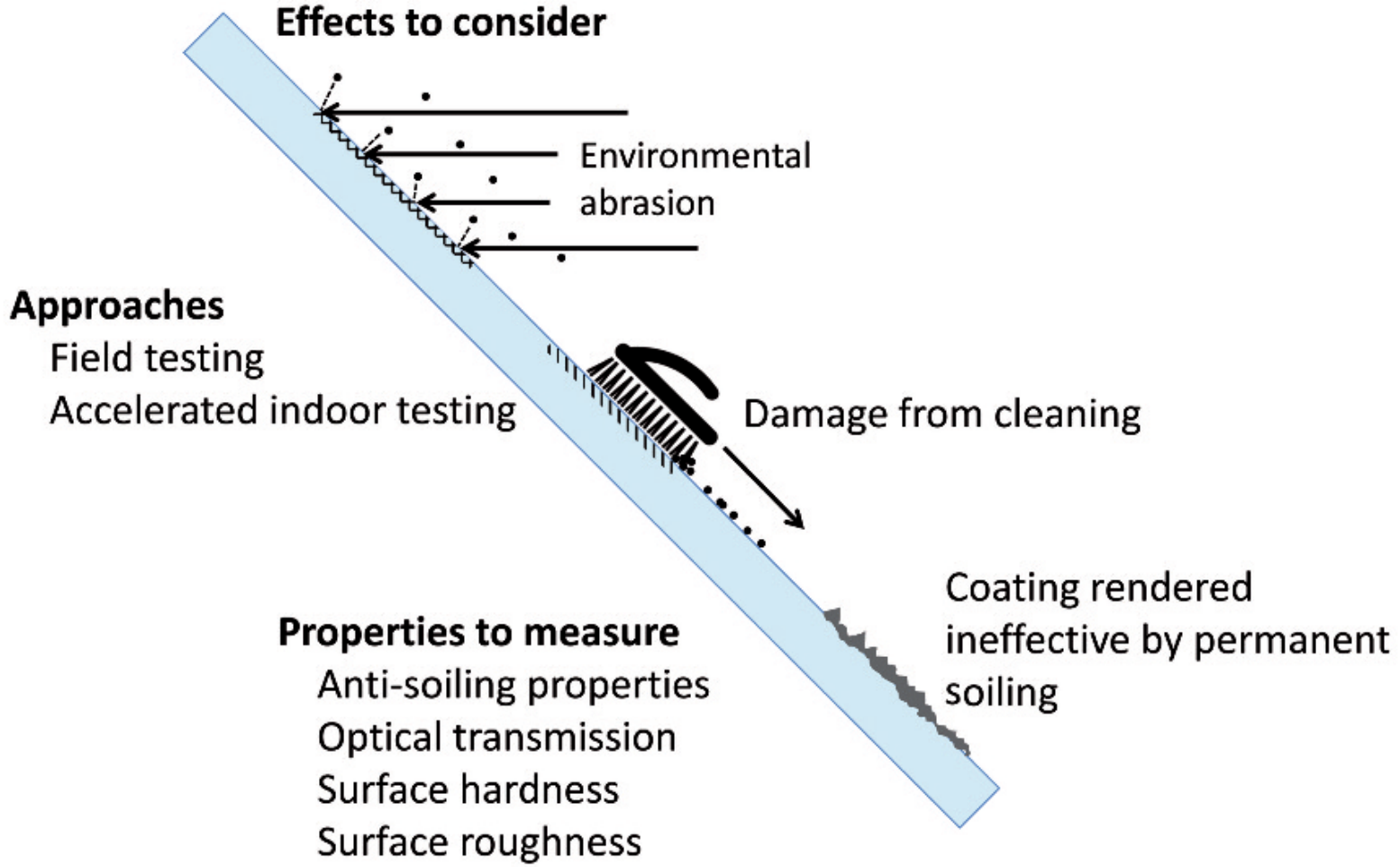
- Up till now no PV standard exists for soiling, Cleaning and abrasion



[T. Sarver et al. "A Comprehensive review of the impact of dust on the use of solar energy: History, investigations, results, literature, and mitigation approaches", Renewable and Sustainable Energy Reviews 22 (2013) 698-733]

→ Aim: Simulation of realistic soiling, cleaning and abrasion conditions

2) Introduction: Soiling, Cleaning and Abrasion

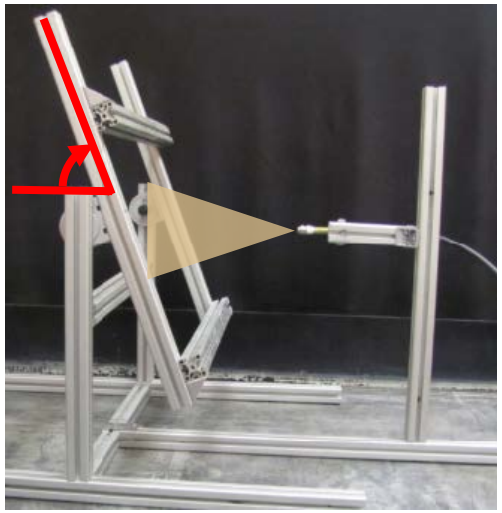


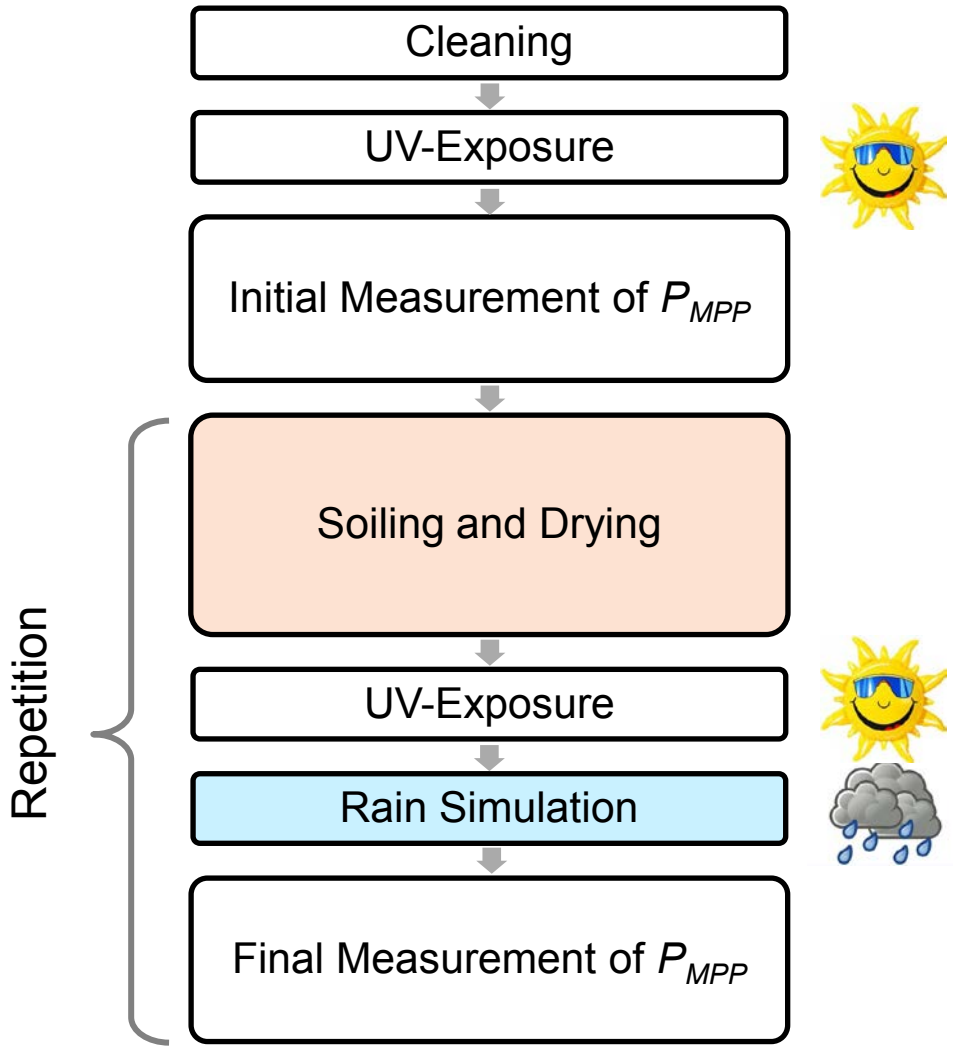
[M.Van Isegheim] et al., „The PVQAT Soiling Collaborative“, EU PVSEC 2014 Amsterdam, 5CV.2.25]

3) Soiling
3.1) Test Bench and Procedure

- We built up a soiling test acc. prEN 1096-5:2011
- Variable spray angle
- „Dirt solution“ acc. Standard

→ For evalutaion of the self-cleaning performances of coated glass surfaces





3) Soiling
3.2) Test Results of Self-Cleaning on Glasses

Evaluation of Procedure on Different Glasses:

- one-cell mini module with soiled glasses as filter infront of it measured in the flasher
- Error on repeatability of measurement 0.3%

Investigated Parameters:

surface structure of glass and tilt angle

Solar glass	ΔP_{MPP} in %	
	30°	10°
Float glass (flat)	-1.0	-1.9
Slightly structured glass	-1.3	-1.9
Prismatic glass	-1.5	-3.7

Results:

→ Prismatic glass soil most (especially under flat angles)

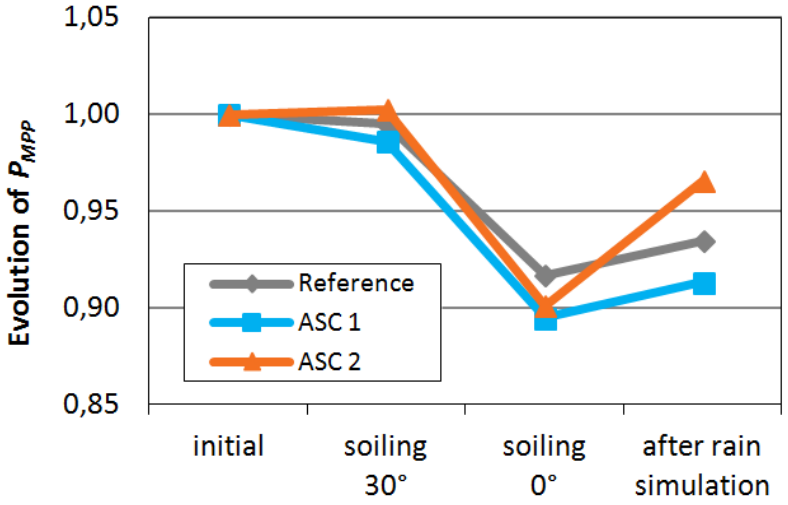
→ Structure of surface influence self cleaning property

→ Flat angles (10°) soil much more than standard angles (30°), two times in our case

3) Soiling
3.3) Results – Anti-Soiling-Coatings (ASC)

Comparison of Two Different Coatings on Standard mc-Modules vs. Reference

- ASC 1: Titanium dioxide
- ASC 2: Zinc/Silver dioxide

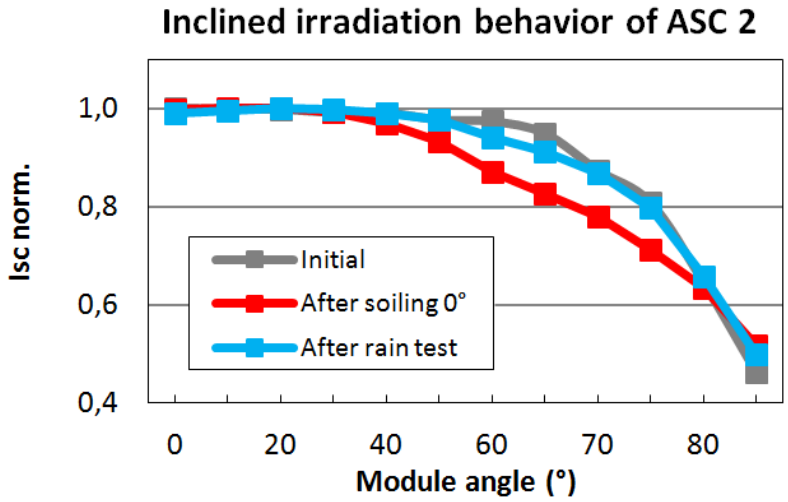


Results:

→ ASC 2: better self cleaning effect than ASC 1

→ resulting in higher yields

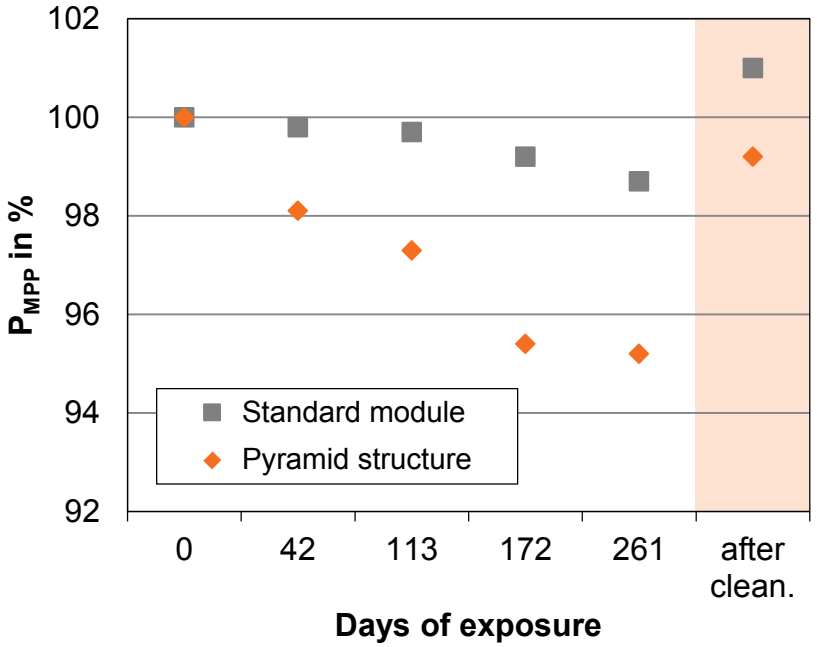
Specific Energy Yield			
	Reference	ASC 1	ASC 2
kWh/kWp	31.5	32.0	32.3
Dev. to Ref.		1.8	2.8



3) Soiling
3.4) Outdoor test results

Long-Time Test on Modules

- over 260 days from May ‘11 to April ’12
- Outdoor test facility PI-Berlin
- Module with pyramid structure vs. standard flat glass
- Pmpp determined under STC at laboratory flasher



Results:

→ Both modules soil, but the module with pyramide structure 4 times more

4) Cleaning
4.1) Kind of cleaning

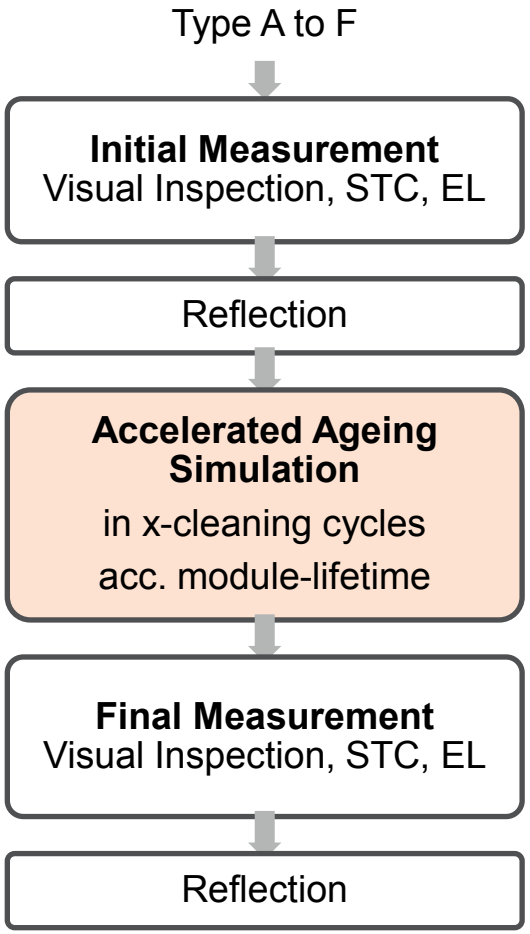
- Manual vs. Automated cleaning
- Many different solutions are available on the market

4) Cleaning
4.2) Evaluation of dust cleaning solutions

Evaluation of Dust Cleaning Solution:

- Testing of the impact of a **cleaning device** on the performance of PV modules
- **Full life-time simulation** according 'years of operation in field' and 'cleaning frequency'

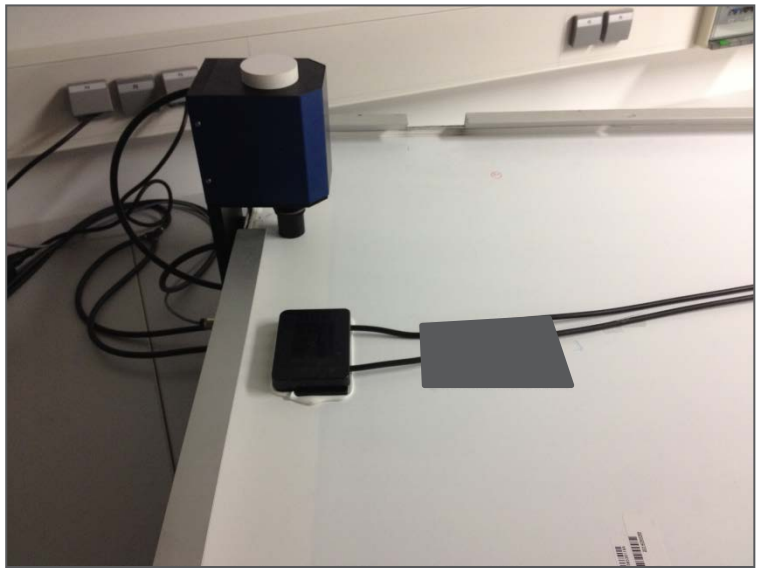
Investigation on Modules of well-known producers: Anonymous A to F



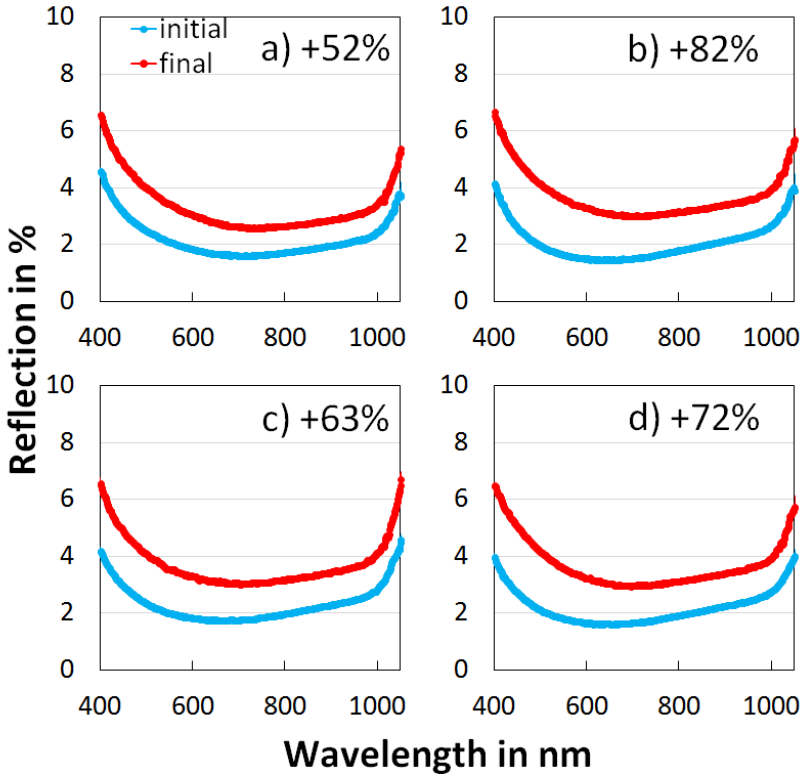
4) Cleaning
4.3) Reflection measurement

Device properties and measurement:

- 10mm measurement spot
- Range 400 – 900nm, uncertainty < 0.2
- Mean value out of 10 measurements per point, four points per module



→ Reflection results of module Type A



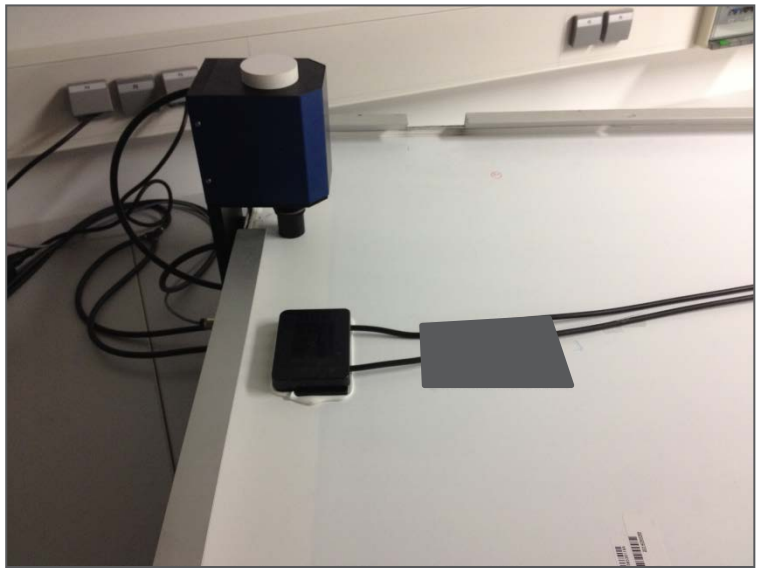
→ Homogeneous results

→ mean change of reflectance = 67% due to abbraded ARC

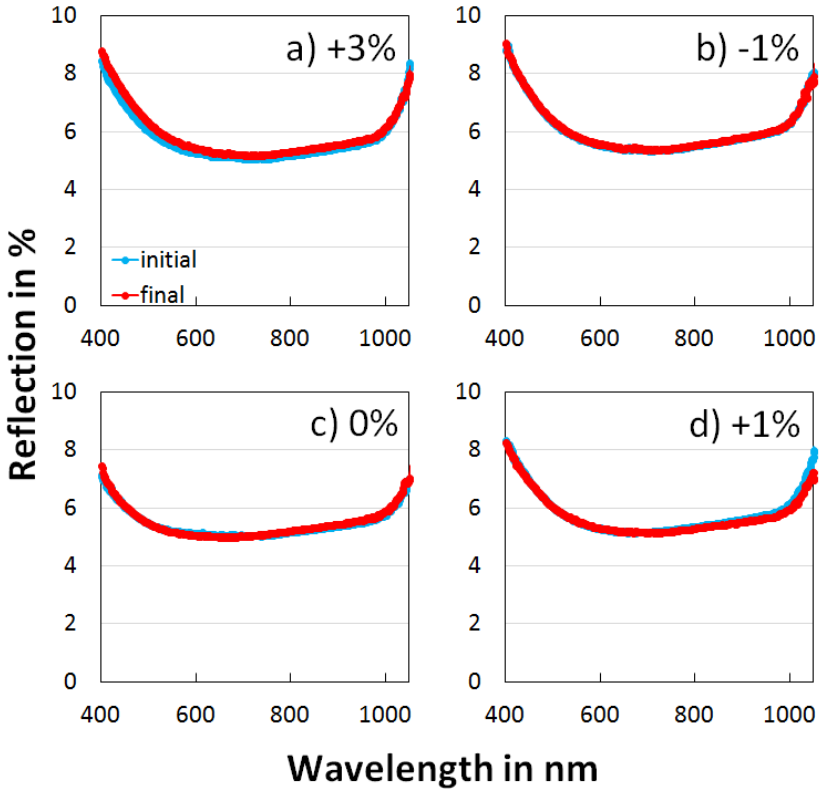
4) Cleaning
4.3) Reflection measurement

Device properties and measurement:

- 10mm measurement spot
- Range 400 – 900nm, uncertainty < 0.2
- Mean value out of 10 measurements per point, four points per module



→ Reflection results of module Type E



→ Homogeneous results, no ARC on glass

→ mean change of reflectance = 1%

4) Cleaning
4.4) Evaluation of dust cleaning solutions - Results

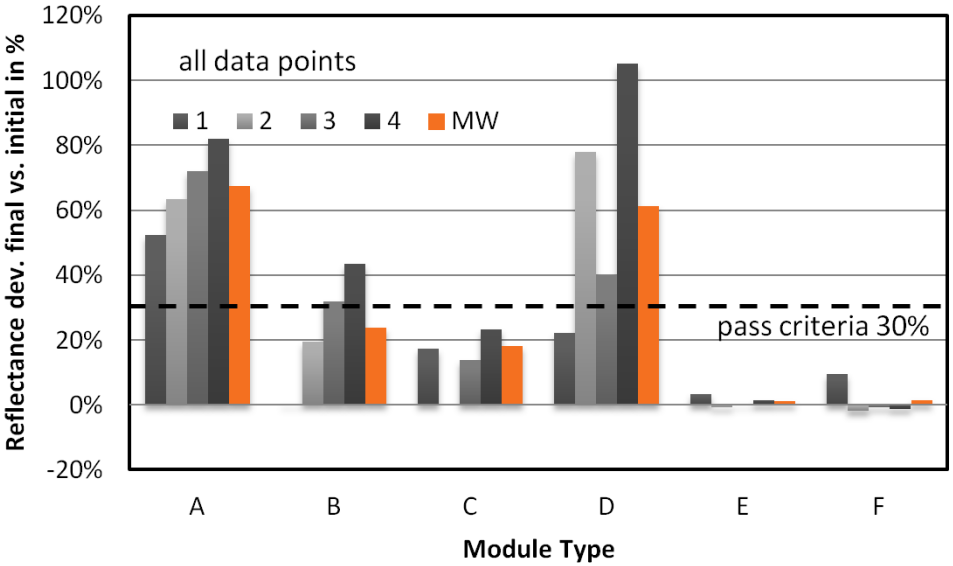
Results:

- No change in Power and Electroluminescence → means no mechanical impact on cells

→ Type A to D show change in the reflectance

→ Reflectance change is correlating with visible stripes on the front glass

→ Type E and F is completly stable



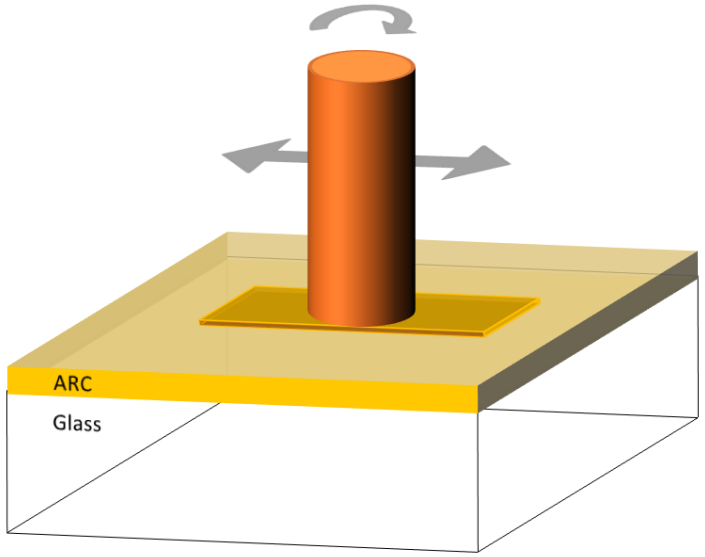
Conclusion:

→ No significant impact of the cleaning operation on the (STC-)performance but on some types a significant impact on the reflectance (influencing yield)

5) Abrasion
5.1) System and Methodology

Utilisation of an Abrasion Tester
acc. EN 1096-2

– Details can be found elsewhere [weber et al.]



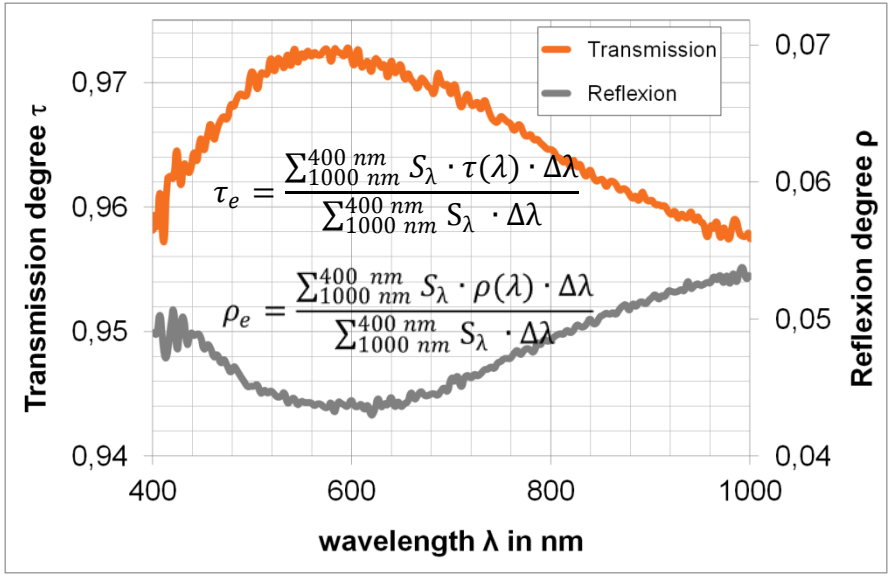
Spectral Transmission and Reflection Scans and Analysis

– acc. ISO 9050 incl. a distribution of AM1.5

Questions:

– Evaluation of test parameters

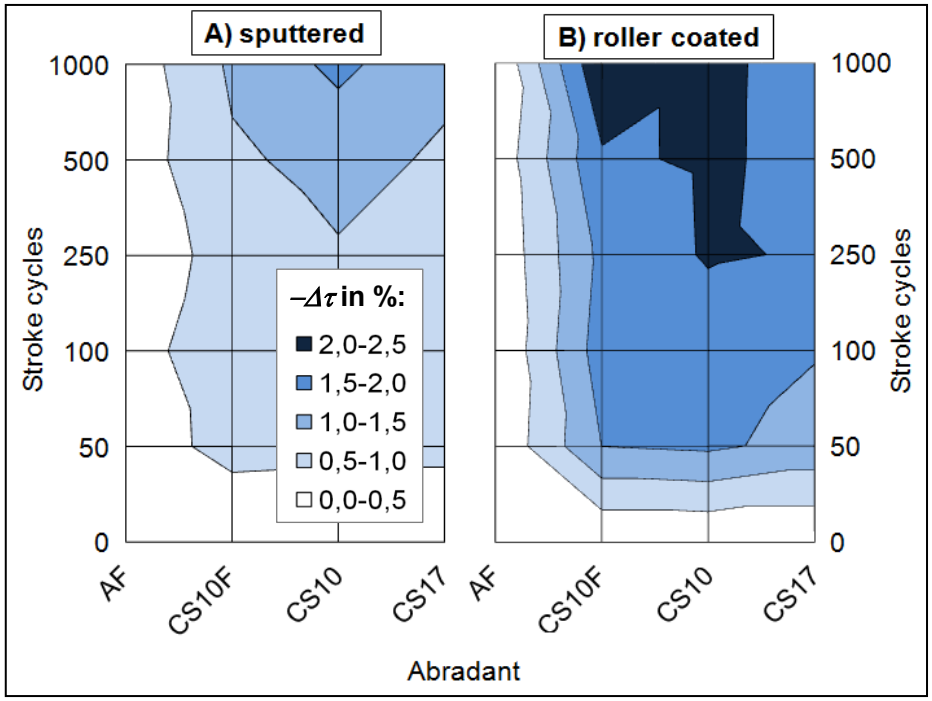
– Evaluation of different ARC's



5) Abrasion
5.2) Results comparing two ARC

Investigation on two different ARC‘s:

– change of transmission degree $\Delta\tau$ was determined



Results:

→ elastic soft (CS10) abradant show fastest results for investigated ARC‘s

→ **At Maximum abrasion for**

Sputtered: $\Delta\tau$ = -1.6 %

Roller-Coated: $\Delta\tau$ = -2.5 %

AF	CS10F	CS10	CS17
Abrasion felt	elastic extrem soft	elastic Soft	Elastic hard

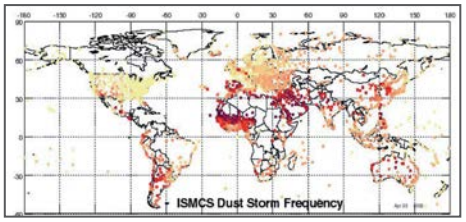
Conclusion:

→ The sputtered ARC (A) has a better abrasion resistance than the roller coated (B)

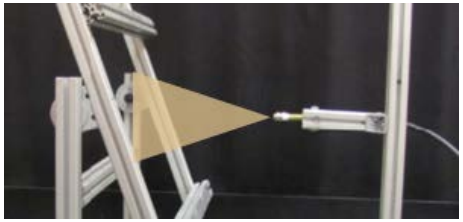
6. Summary and Conclusion

Future Fab: funded by
Bundesministerium für Bildung und Forschung
Bundesministerium für Wirtschaft und Energie

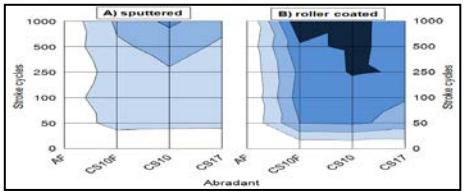
- **Soiling** strongly ***depends*** on the environmental condition of a ***specific location***
- Moreover **Soiling** ***depends*** on ***surface*** morphology and ***tilt*** angle



Soiling



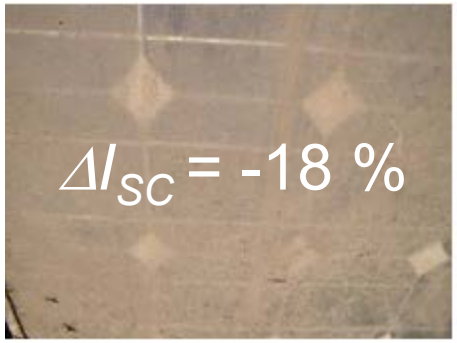
- The impact of a **cleaning device** can be determined by ***life-time simulation***
  - ***reflectance change*** indicate ***abrasion of coating***
  - coorelation to abrasion Tester will help to understand



- To ***investigate*** self-cleaning properties of surfaces a ***test method*** and ***test equipment*** was presented
- The **abrasion** on coatings by simulating soil or cleaning devices can be investigated with an ***abrasion test***

Abrasion

Cleaning



Thank You !

Recommended literature

[1] EPIA: Unlocking the Sunbelt – Potential of Photovoltaics, 2011-03

[2] Tegen et al.,“Relative Importance of climate and land use in determining present and duture global soil dust emission“, Geophysical Research Letters 31, 2004

[3] M. Mani et al. “Impact of dust on solar photovoltaic (PV) performance: Research status,challenges and recommendations”, Renewable and Sustainable Energy Reviews 14 (2010) 3124–3131

[4] T. Sarver et al. “A Comprehensive review of the impact of dust on the use of solar energy: History, investigations, results, literature, and mitigation approaches”, Renewable and Sustainable Energy Reviews 22 (2013) 698-733

[5] Weber et al., “From the impact of harsh climates and environmental conditions on PV-Modules - Development of a Soiling and Abrasion Test”, EU PVSEC 2014 Amsterdam, 5DO.11.5

This presentation contains no confidential information