

Repowering uncoated solar panels in PV parks

DSM Retrofit Anti-Reflective (AR) coating

PV TechTalk Webinar

joern.brembach@dsm.com

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NUTRITION • HEALTH • SUSTAINABLE LIVING



DSM

BRIGHT SCIENCE. BRIGHTER LIVING.

Content

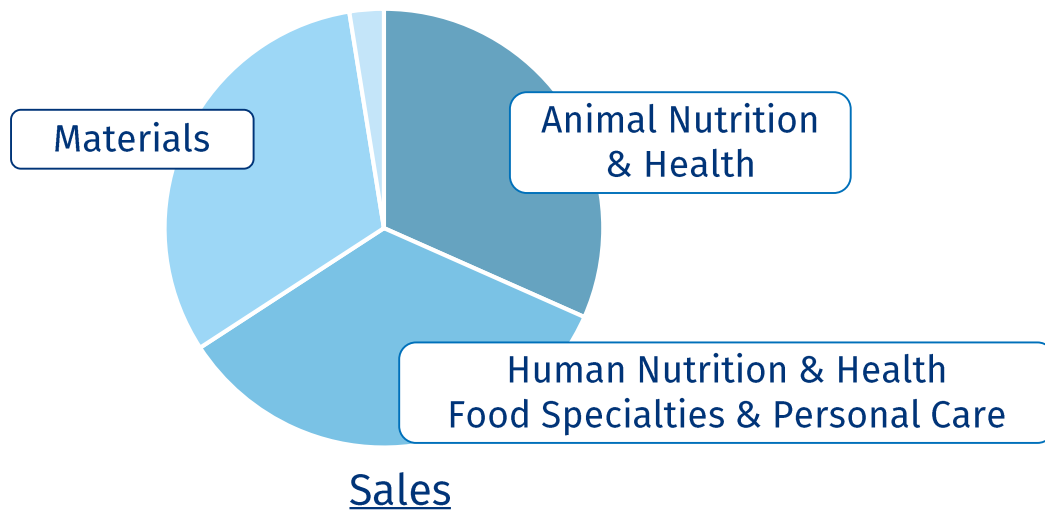
Let's go retro!

- Introduction DSM
- Why applying our Retrofit AR coating
- The science behind our coating
- Retrofit ARC from O&M perspective
- Bankability – investors view
- Way forward



Royal DSM: A company with a purpose

- Global workforce ~22,000 employees
- Sales ~€9.0bn
- EBITDA ~€1,7bn
- 50% purchased electricity from renewable sources
- 63% of our products are "Brighter Living Solutions"
- Global company with 66% of sales outside Europe



DSM solutions are lowering the cost of solar power

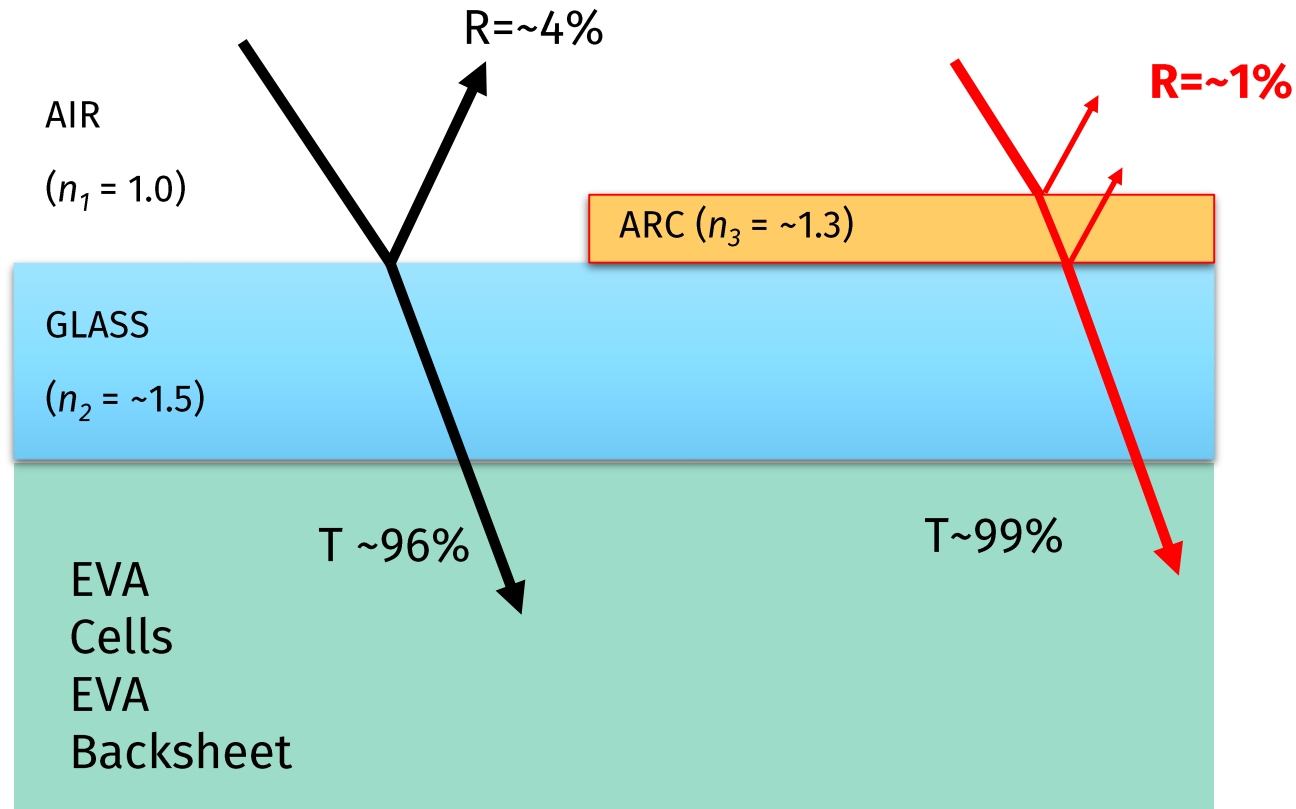


WHY retrofitting older PV parks with AR coating

- MOST older parks don't have an AR coating
- Old PV parks in Europe receive a FiT/PPA based on kWh produced
- PV modules in the field degrade over the years (even in the best case 0.4%/year degradation after the 1st year* is seen in Europe)
- PV parks leave some extra revenues on the table



Basic principles of ARC technology: PV-module, single sided coated

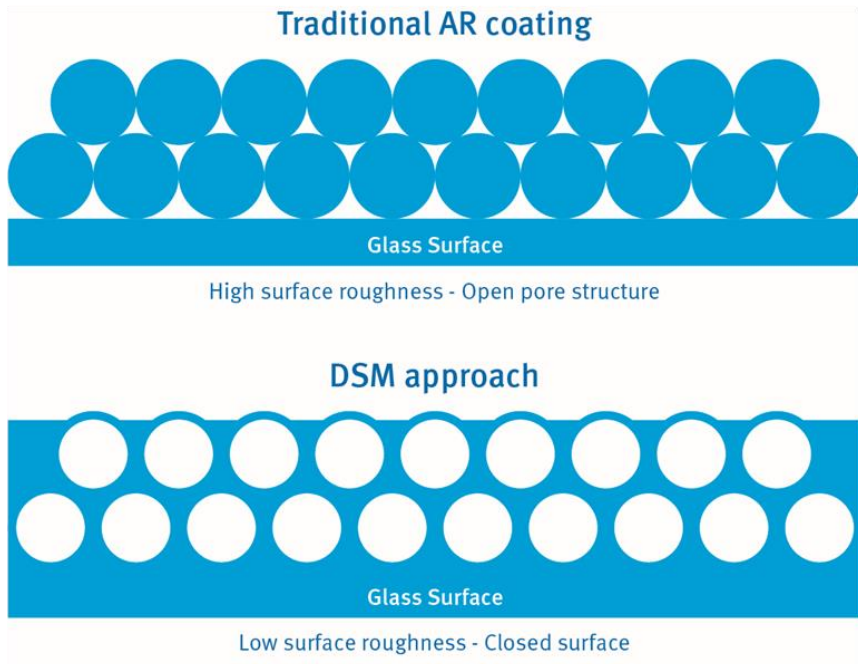


Simplified illustration disregarding e.g. absorption of glass

DSM Retrofit Anti-Reflective coating

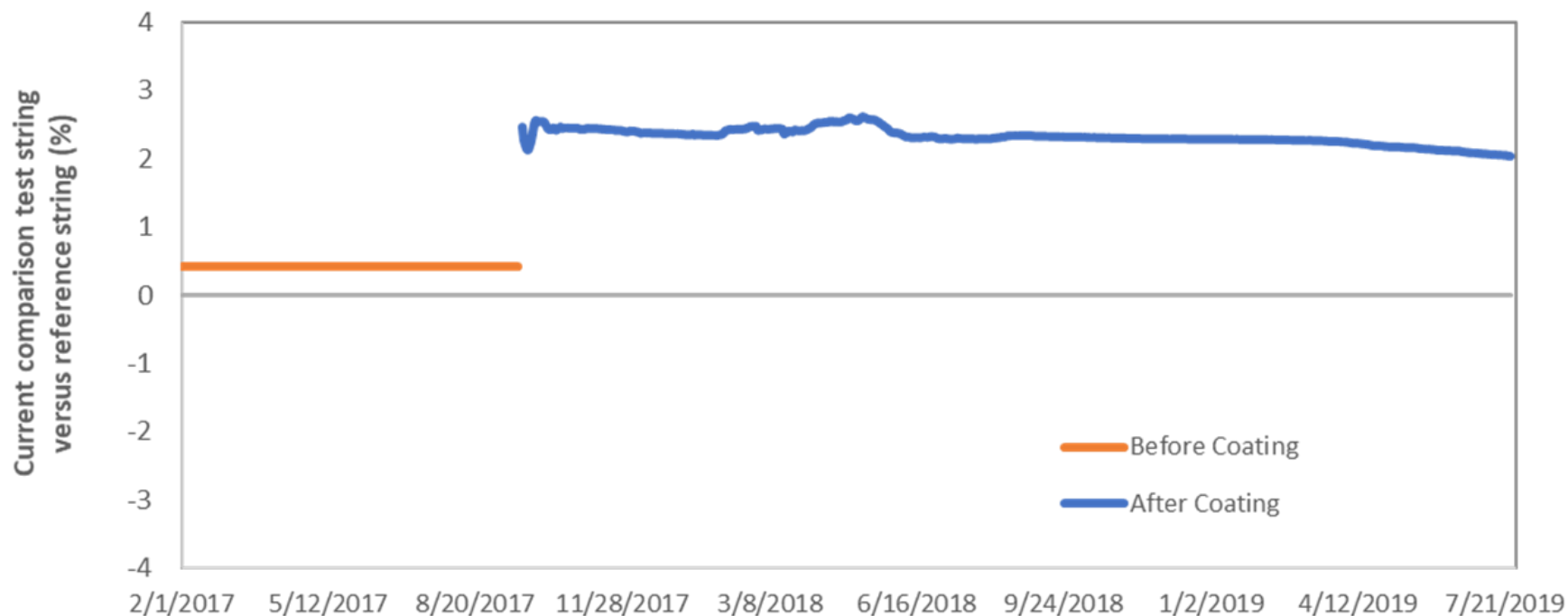
For up to 3% more power

- Based on DSM proven “core-shell” technology, re-formulated for outdoor application
- Patent protected product & application technology
- For older solar parks that are uncoated
- The performance has been extensively lab-tested



DSM Retrofit Anti-Reflective coating – outdoor performance

- DSM is validating the outdoor performance and durability, focusing on existing ground mounted PV parks
- The boost in output is visible immediately after coating application. The coating dries very fast
- The first outdoor tests have been implemented in 2017
- 10 field tests (in total ~1 MWp) have been implemented in 2018 and are continuously being monitored. The typical increase in output is 2-3%



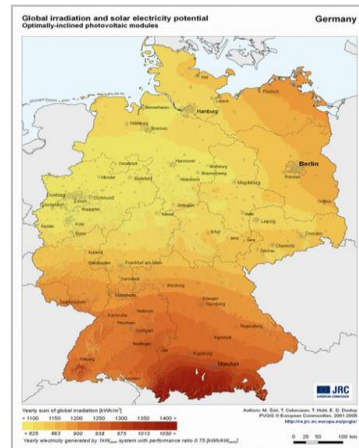
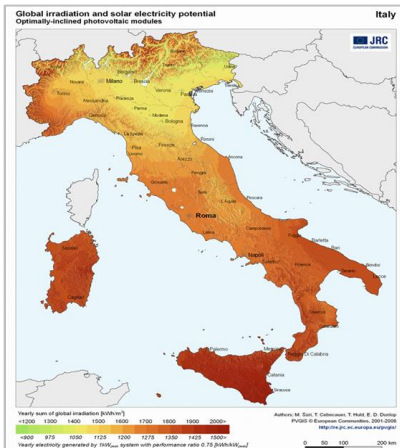
Retrofit Anti-Reflective coating – from O&M perspective

- The coating is applied by a tractor driven spray coating applicator which can coat modules at extremely high speed
- Up to 3% more power output
- Turnkey Service according to field specifications
- Almost zero plant downtime
- Application up to 3 modules portrait or 5 modules landscape orientation
- Further improvements in the pipeline for almost all module table designs

Poll question

Retrofit Anti-Reflective coating – field application

- Environmentally friendly (SHE)
- Machinery regulatory (CE)
- All workmanship according to Risk Assessment/RAMS
- Extensive field data analysis insights



The investor's view: Bankability

- investors leave some extra revenues on the table
- DSM Retrofit AR coating provides up to 3 % more power output
- Average Payback period ≤ 3 years

DSM's Turnkey Service

Best in class bankability

- EU and national product regulatory files
- Module warranty statements
- Documented Reliability and Durability
- Field work insured by leading EU insurance
- Optional project price reimbursement
- Continuous product optimization in terms of application and output gain



✓ Financial strength
✓ Technology leadership
✓ Experience
✓ Global reach

Business case example for a 2.5 MWp park



PV Park & Module

- Italy
- Installed capacity: 2.5MWp
- Grid connection: 2011
- 10638 panels
- 235Wp / Poly 60
- Surface per panel: 1.63m²
- Average energy output: 1330 kWh/kWp



Economics

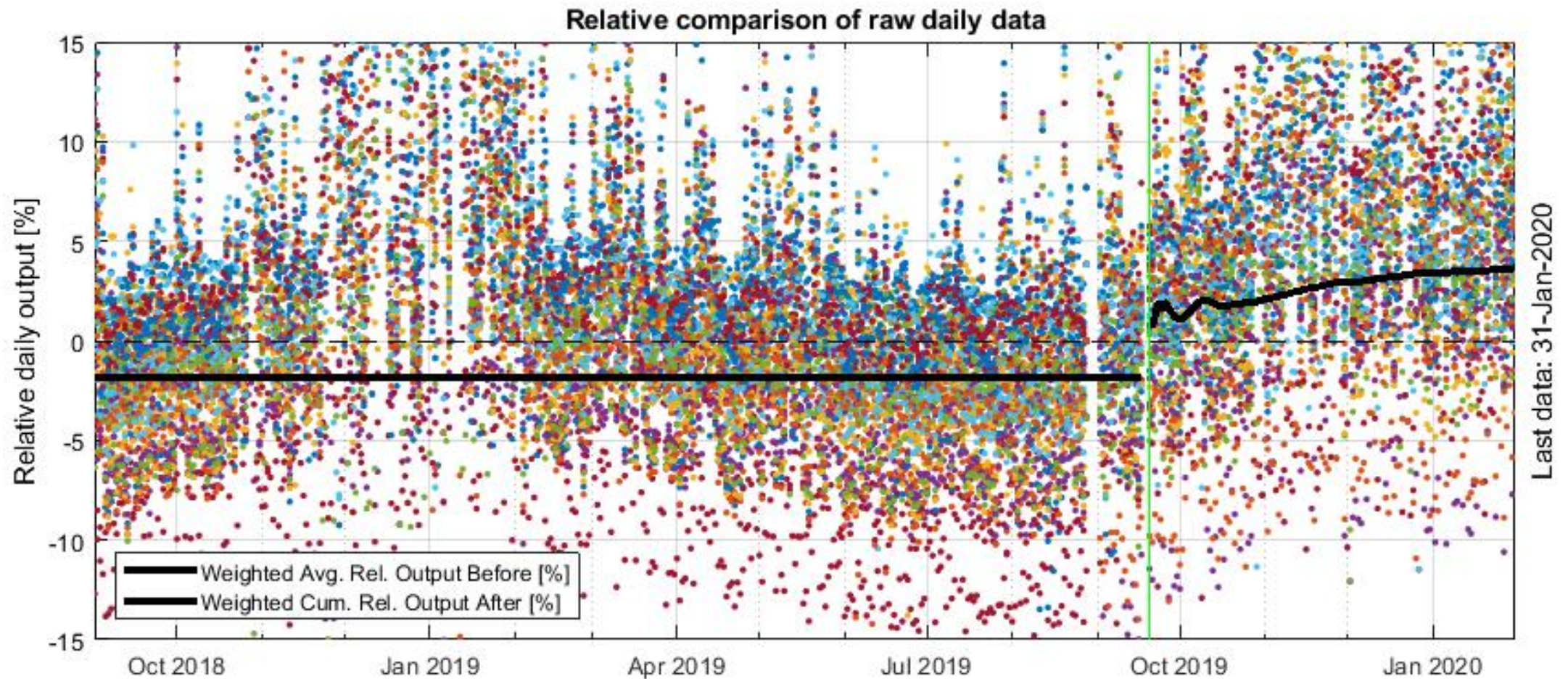
- Energy boost of Retrofit AR coating: 3.0%
- Value calculated for: 6 yrs
- FiT: 0.348 €/ kWh

Value generated by ARC:

~ 190.000€

less than 3 years
pay back time

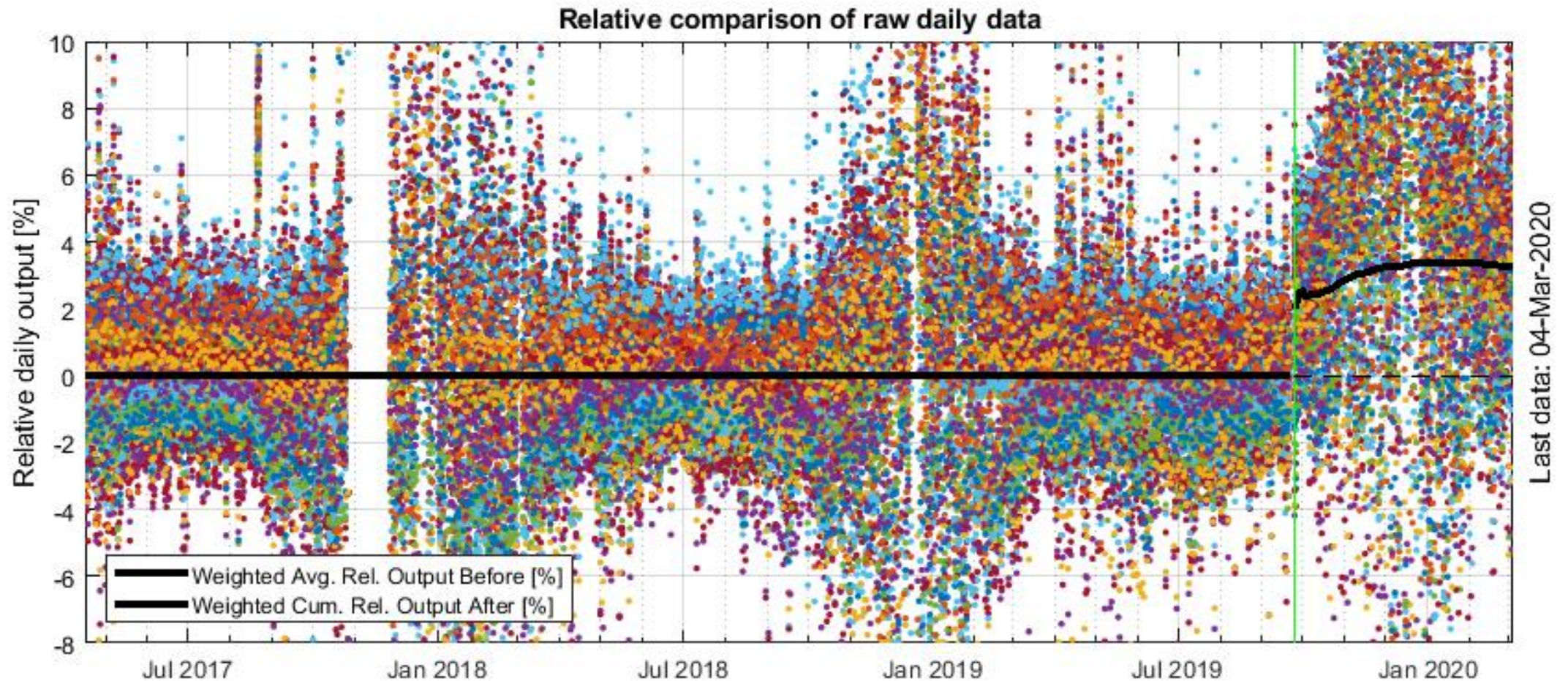
Business case Germany: actual performance



gain expectation: 2.75%

Actual average gain: 4.20%

Business case Italy: actual performance



gain expectation: 2.75%

Actual average gain: 3.10%

Way forward

- Commercial in Europe
- Currently coating applied on multi-MWp PV parks with biggest EU asset owners
- continuous Service and Bankability improvements
- Expansion, both in region and ecosystem partners in 2020



The innovation race is on.
Join us.

BRIGHT SCIENCE. BRIGHTER LIVING.™

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Reliability Measurements on coated PV Modules

JinkoSolar

Andrea Viaro, Head of Technical Service and Product Management

Goal of the Measurements & Analysis Criteria

GOALS:

- Assure that the PV module reliability and performance are not negatively affected by the coating
- Maintain intact the validity of the Product and Power Warranty covering the already installed PV Modules
- Confirm that no hotspots occur within the PV module due to cells' current mismatch caused by possible inhomogeneity of the coating

PASS CRITERIA:

The ΔT between coated and uncoated cells should not exceed 20°C

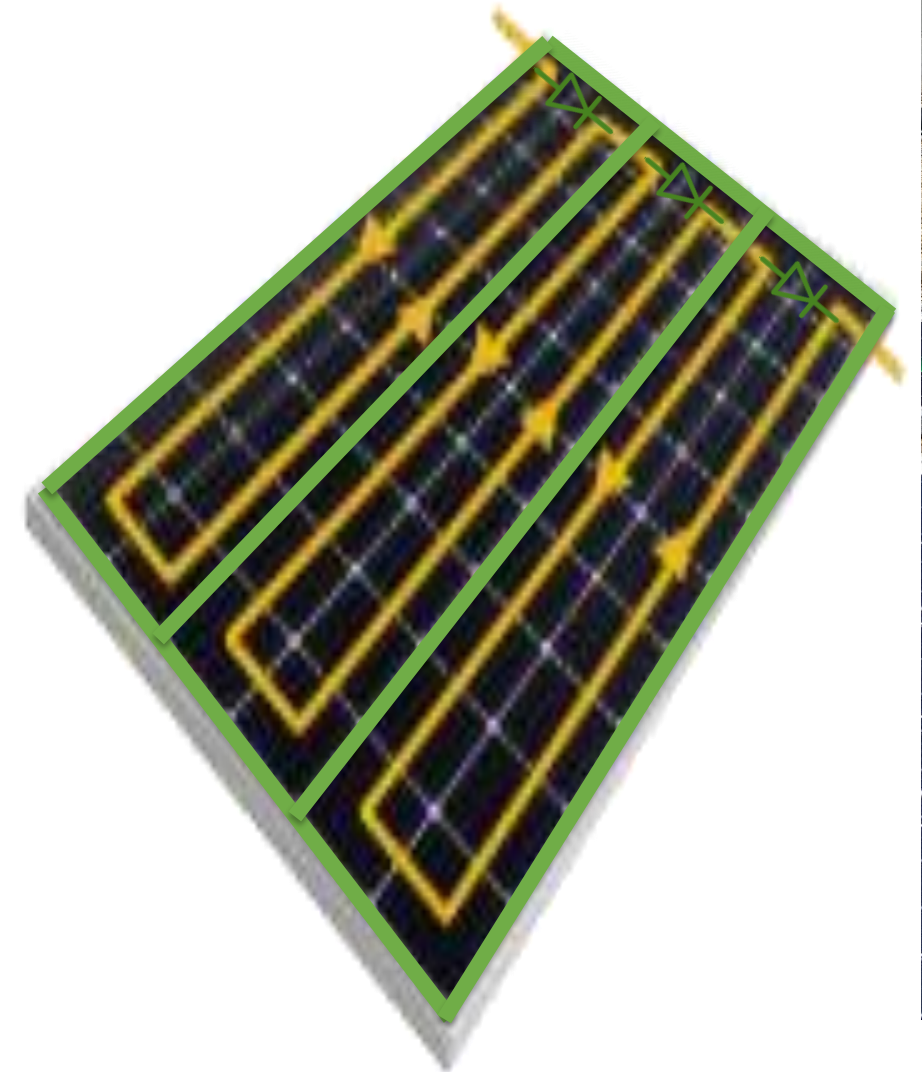
Method for the Measurements

- **Test location:**
 - DSM rooftop test facility
 - Modules are placed in parallel on mounting racks to ensure similar irradiance on all modules at the time of measurements and monitored individually
- **Weather**
 - The irradiance level during measurements was ranging between 950 and 1,150 W/m²
- **Duration**
 - Exposure time of the modules has been 42 days
- **Measurements:**
 - IR camera scanning to measure the relative temperatures distribution on the front of the module, simultaneously with regular picture of the module
 - Current values at the time of the pictures have been also taken, to confirm modules operation conditions (values are extracted from the monitoring software)
 - Performance comparisons from the electrical parameters are excluded (modules are new, not pre-tested indoor nor stabilized, not homogeneously coated so comparisons of electrical parameters would not be accurate nor representing the coating benefit)

Modules Preparation

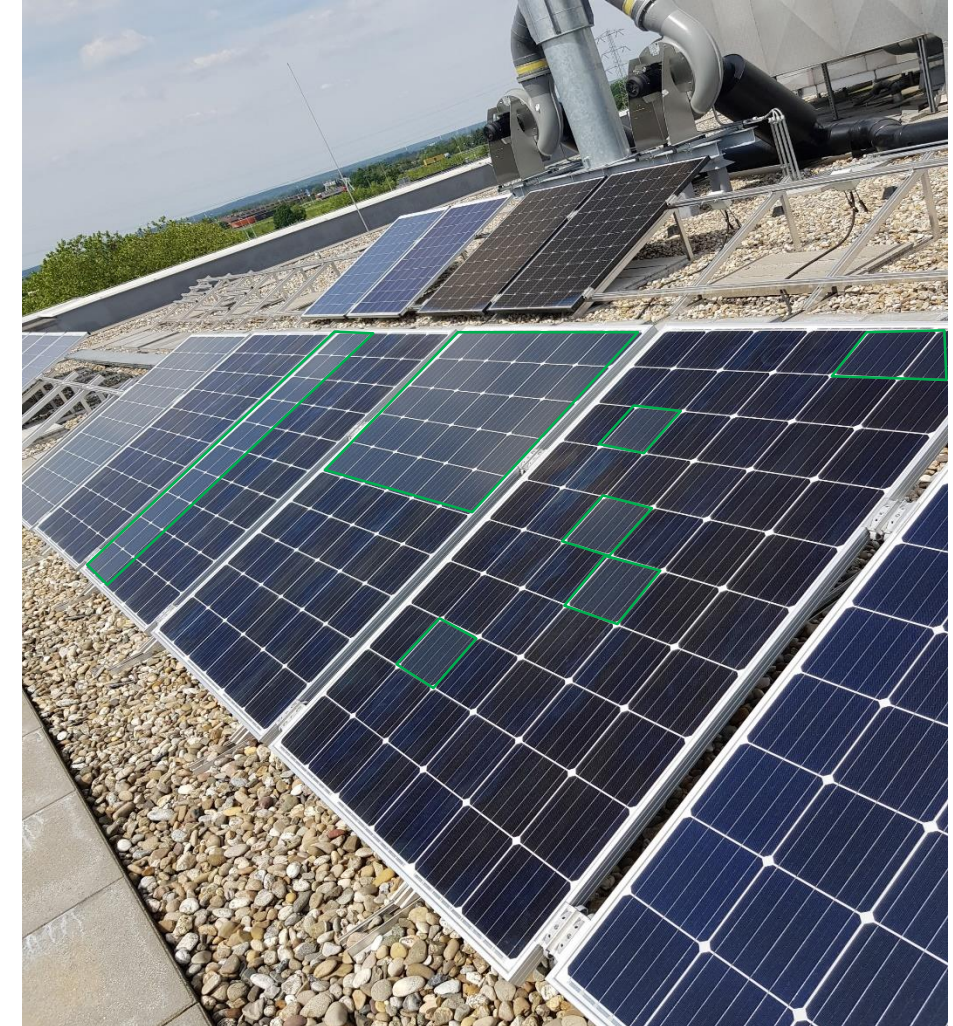
- The modules were coated using the DSM field applicator in the DSM Solar Technology Lab
- The parts of the modules which were intended to remain uncoated were covered with plastic foil and tape prior to the coating application
- 5 modules were prepared:
 - 1 Fully uncoated (reference)
 - 1 Fully coated
 - 1 Module with 1 by-pass diode left uncoated and 2 by-pass diodes coated
 - 1 Module half coated (bottom part)
 - 1 Module with 2 cells left uncoated per by-pass diode, randomly distributed
- Modules rating:

Module type	Pmp at STC	Imp at STC	T coeff Isc	T coeff Pmp	NOCT	Imp at NOCT
Mono c-Si	300W	9.21A	0.06%/°C	-0.4%/°C	45°C	7.35A



Modules Installations

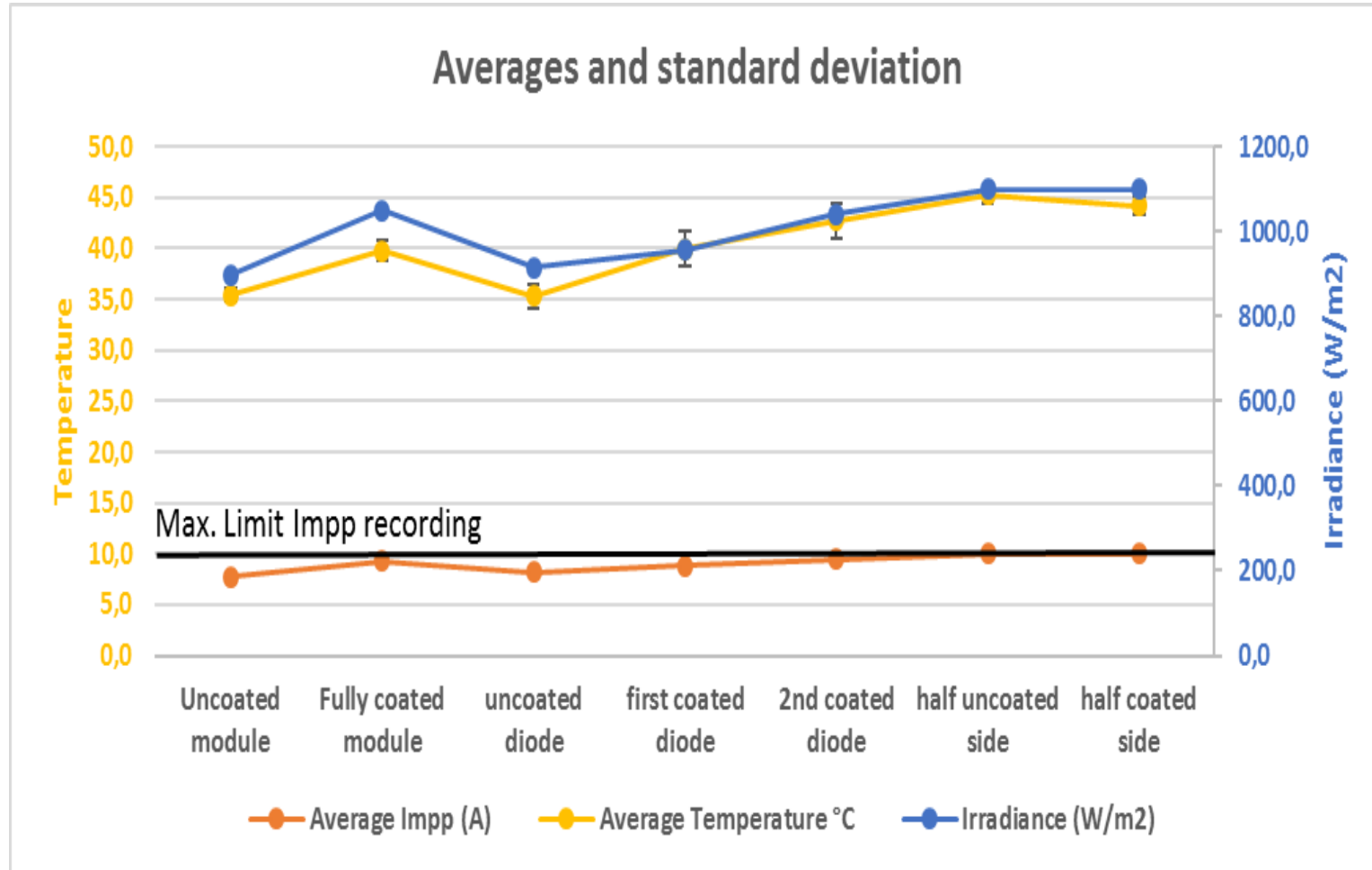
- The modules were installed on the DSM R&D rooftop PV test park on April 17th 2019, in Geleen, Netherlands
- The modules were connected to electronic loads and kept at MPP for 42 days
- The module temperature was measured on May 23rd 2019 around 13:30hrs with IR temperature meter and IR camera
- Weather conditions during measurements:
 - Sunny with a couple of small clouds
 - Wind: ~15km/h
 - Ambient Temperature: 20°C
- The current (in Amperes) at maximum power point (I_{mpp}) and irradiance (W/m^2) were recorded after each series of temperature measurements



*Partially coated modules installed on DSM rooftop test site
(Uncoated parts highlighted in green)*

Summary of the results

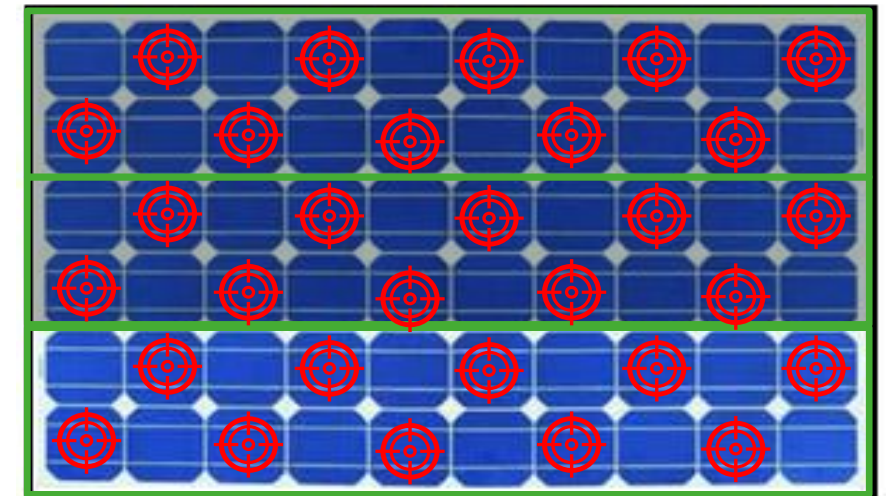
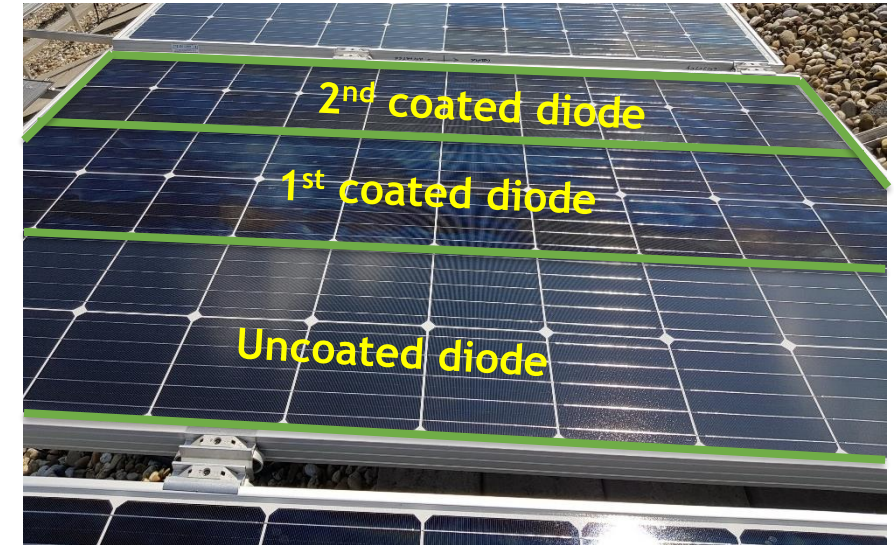
Averages of temperature, irradiance, and Impv values during measurements:



Measurement details diodes coated/uncoated module

- Single cells measurements
- 10 cells measured per by-pass diode
- Temperatures measurements between different diodes follow the variation in irradiance during the measurements:

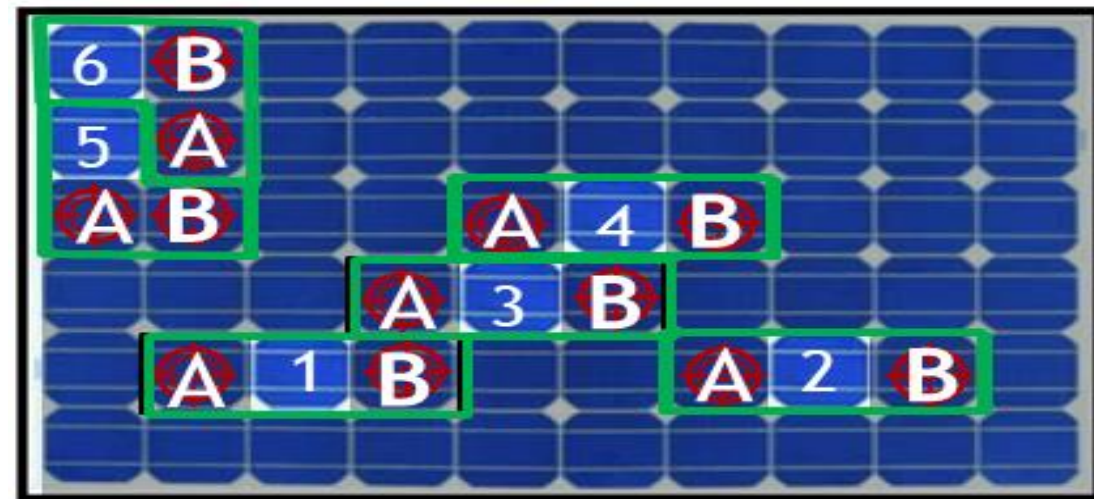
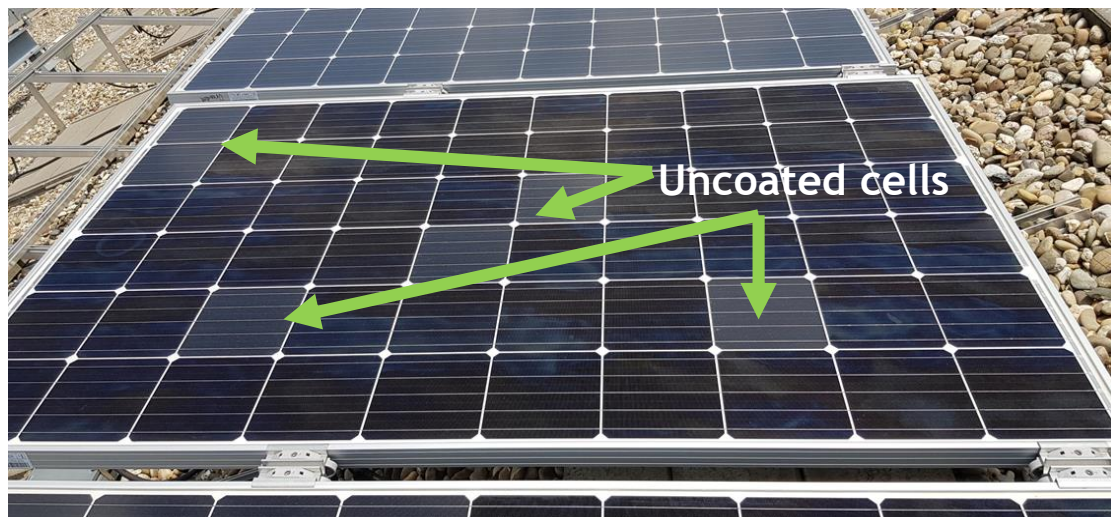
	uncoated diode	1st coated diode	2nd coated diode
Irradiance (W/m2)	915	956	1041
Average Impp (A)	8,2	8,8	9,5
Cell 1	25,2	28,6	30,9
Cell 2	25,6	27,6	31,8
Cell 3	27,2	30,5	32,8
Cell 4	27,1	32,4	33,9
Cell 5	28,5	31,9	34,7
Cell 6	27,5	32	34,2
Cell 7	28,8	32,4	35,8
Cell 8	26,3	31,2	33,7
Cell 9	27,8	32,5	32,2
Cell 10	26,4	31,9	33,7
Average Temperature °C	27,0	31,1	33,4
standard Deviation	1,2	1,7	1,5
Max. temperature delta (°C)	3,6	4,9	4,9



Measurements details Patchwork of uncoated cells

- Single cells measurement
- 6 groups of cells measured including adjacent coated and uncoated cells

	Patchwork cells coated						
	Cells Group 1	Cells Group 2	Cells Group 3	Cells Group 4	Cells Group 5	Cells Group 6	Average cell Temp.
Irradiance (W/m2)	1126						
Average Impp (A)	10 (max)						
coated adjacent cell A	33,9	35,8	35	34,8	35,6	36,1	35,2
Uncoated cell	37	35,2	36	36,7	34,2	35	35,7
coated adjacent cell B	35,7	40,1	35,6	33,2	35,7	34,6	35,8
Delta average uncoated/coated (°C)	+2,2	-2,75	+0,7	+2,7	-1,45	-0,35	+0,175

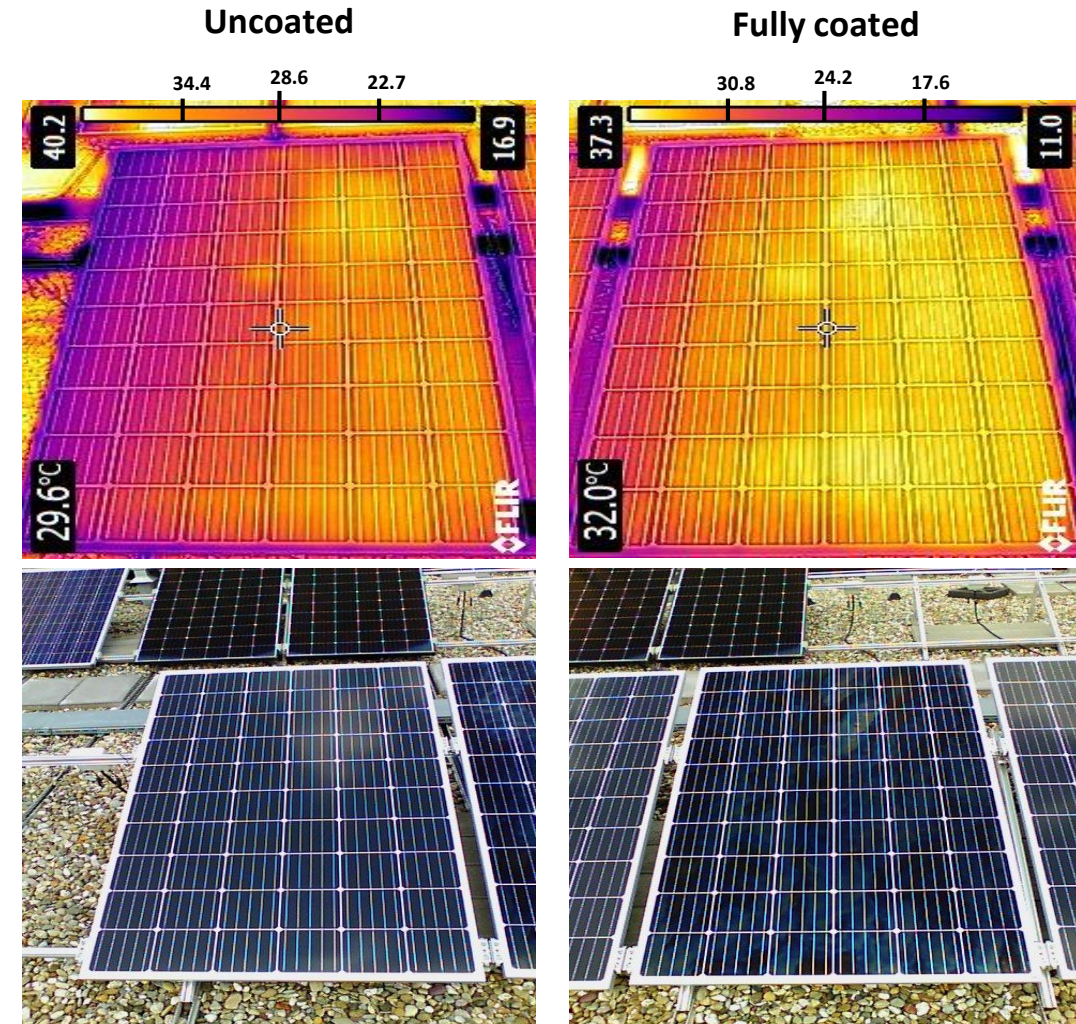


Conclusions: Temperature Measurements

- The temperature differences between coated and uncoated parts of the modules are mainly following the variation in irradiance during the measurements
- The temperature ranges are anyway negligible and below threshold for hot-spots detectability
 - ΔT coated/uncoated ranges between 2.3 and 3.6 °C
 - ΔT within coated parts ranges between 2.5 and 4.9 °C
 - ΔT patchwork cells ranges between -2.7 (uncoated cell warmer than adjacent coated cells) and +2.75°C (adjacent coated cells warmer than uncoated cell)

IR Camera pictures

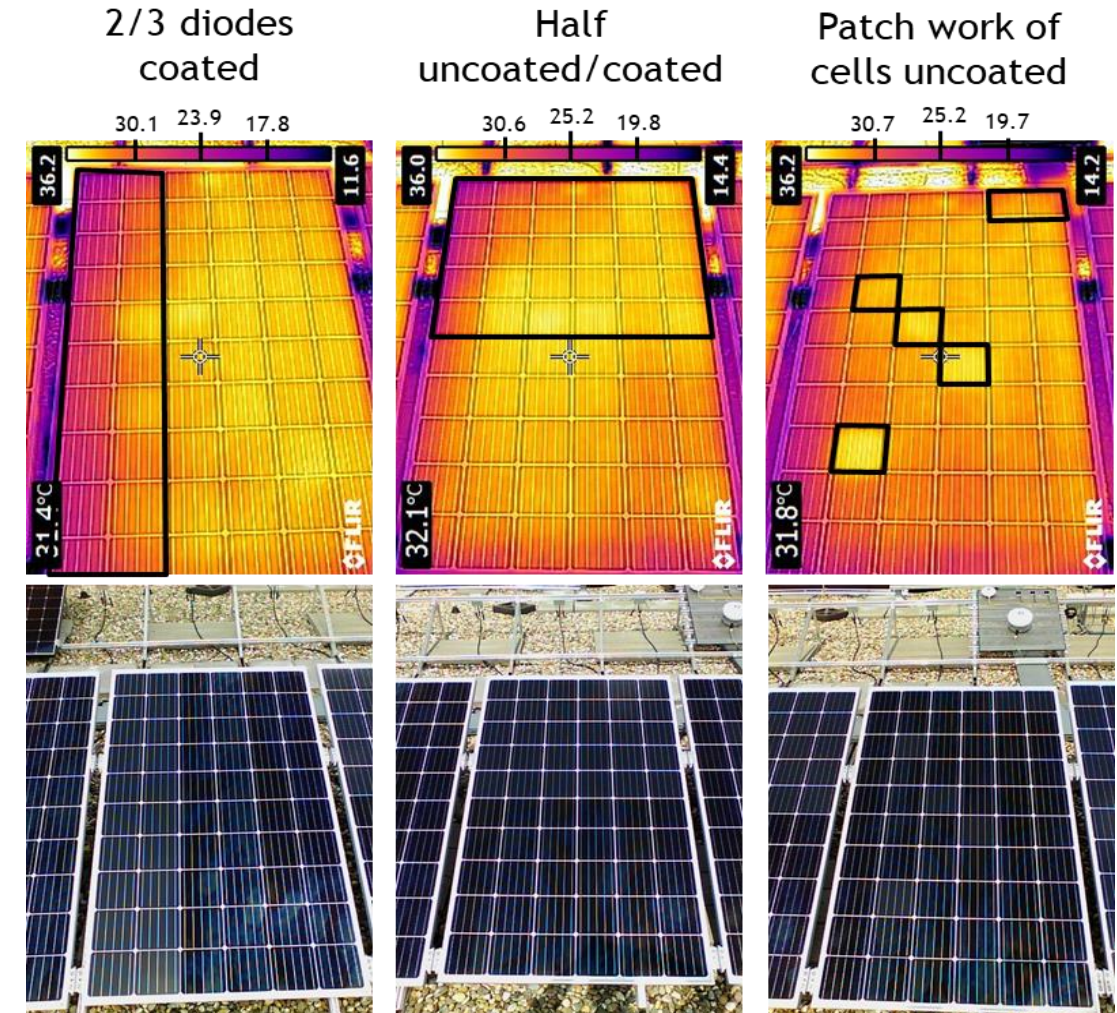
- No obvious hot-spots can be detected on either coated or uncoated module
- The small temperature variations visible on the modules are induced by the reflections of the clouds on the glass of the modules
- The gradient of temperature from left to right for both coated and uncoated modules is induced by the emissivity aberration due to the different angle of view of the IR camera
- With the IR camera is possible to detect a larger temperature gradient within each module than measured with the temperature meter (see example of the uncoated module)



IR Camera pictures

- The partially coated modules also show apparent temperature gradients, similarly to the fully coated and uncoated modules
- The “patchwork” module shows some temperature pattern with some of the uncoated cells a few degrees apparently warmer than the coated adjacent cells
- The small ΔT can be also due to the different emissivity of the coated/uncoated glass
- Despite the measurement uncertainties, all modules are within the same temperature range at the time of the measurements

On IR pictures the partially coated modules show no hot spot. The temperature differences are well below 5°C



Overall conclusions

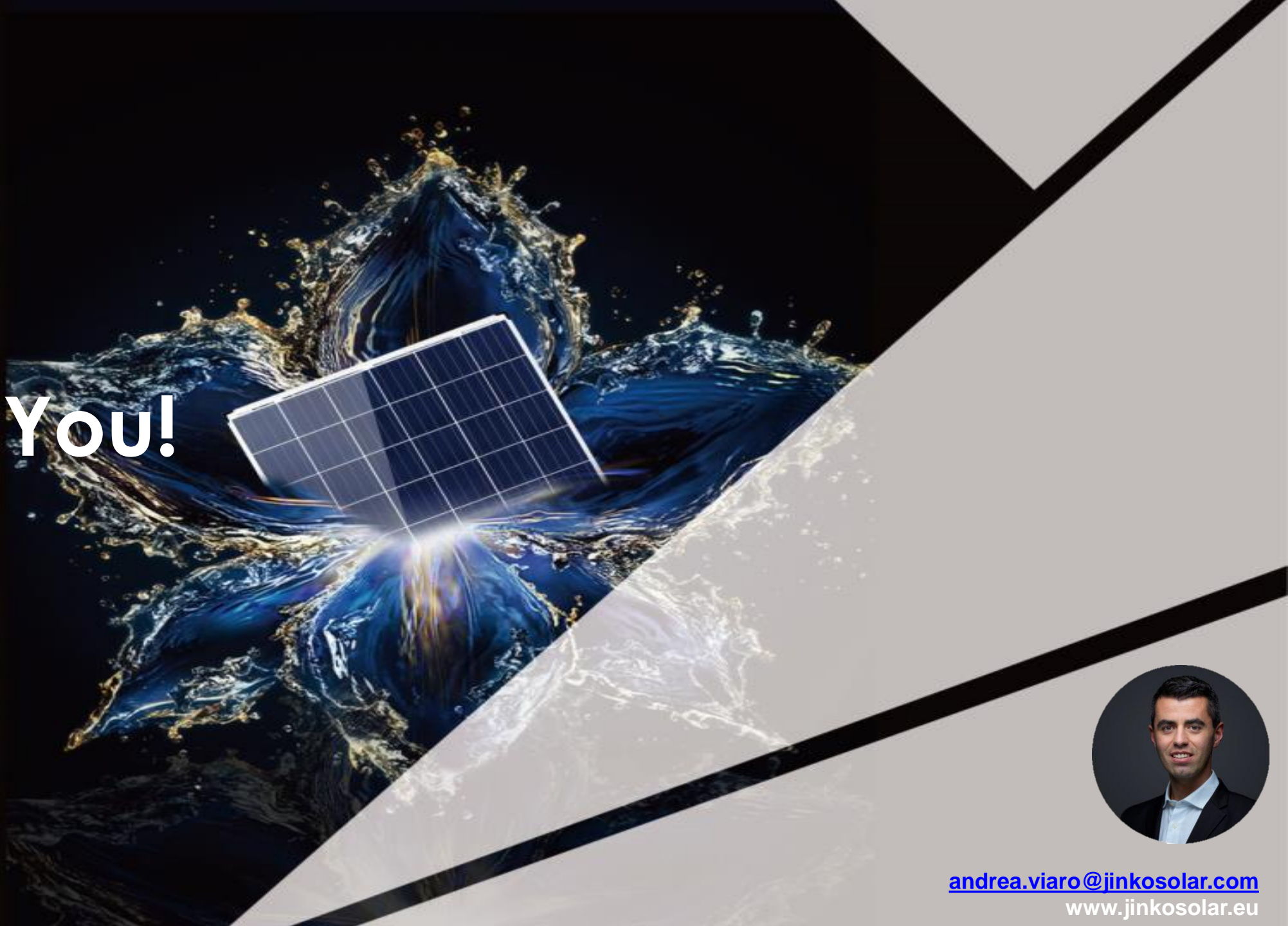
- Both type of measurements – IR temperature meter and IR camera – demonstrate that all modules pass the test criteria and no hotspots have been observed due to possible inhomogeneity of the coating
- In all cases the temperature difference between coated and uncoated parts remain well below the 20°C limit (< 5°C even in the worst case of the patchwork cell scenario)
- The PV module reliability and performance are not negatively affected by the coating
- The validity of the Product and Power Warranty can be confirmed and kept intact also for the retrofitted modules

Note: This test simulates a “worst case” situation in which parts of the modules remain completely uncovered. In practice, such a scenario is highly unlikely to happen and hasn’t been observed in any of the trials which DSM has performed in the last 2 years. In practice, the coating is applied very homogeneously over the entire module surface, so the temperature differences between cells will be even lower than measured in this test.

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Thank You!



andrea.viaro@jinkosolar.com
www.jinkosolar.eu



Retrofit ARC – Asset management prospective

Diego Molina, Innovation Manager



Agenda

About WiseEnergy

Why WiseEnergy is interested in retrofit ARC

WiseEnergy | retrofit ARC experience

Different solutions to mitigate concerns

Conclusions



About WiseEnergy

WiseEnergy is a global solar asset operator with proven ability to increase value of investments by:



Increasing the revenue and yield of assets



Minimising business and operational risk



Maximising profits and reducing opex

We have been in the solar industry for over 11 years and our asset managers have successfully and consistently delivered strong performance to increase the IRR of asset and portfolio investments.

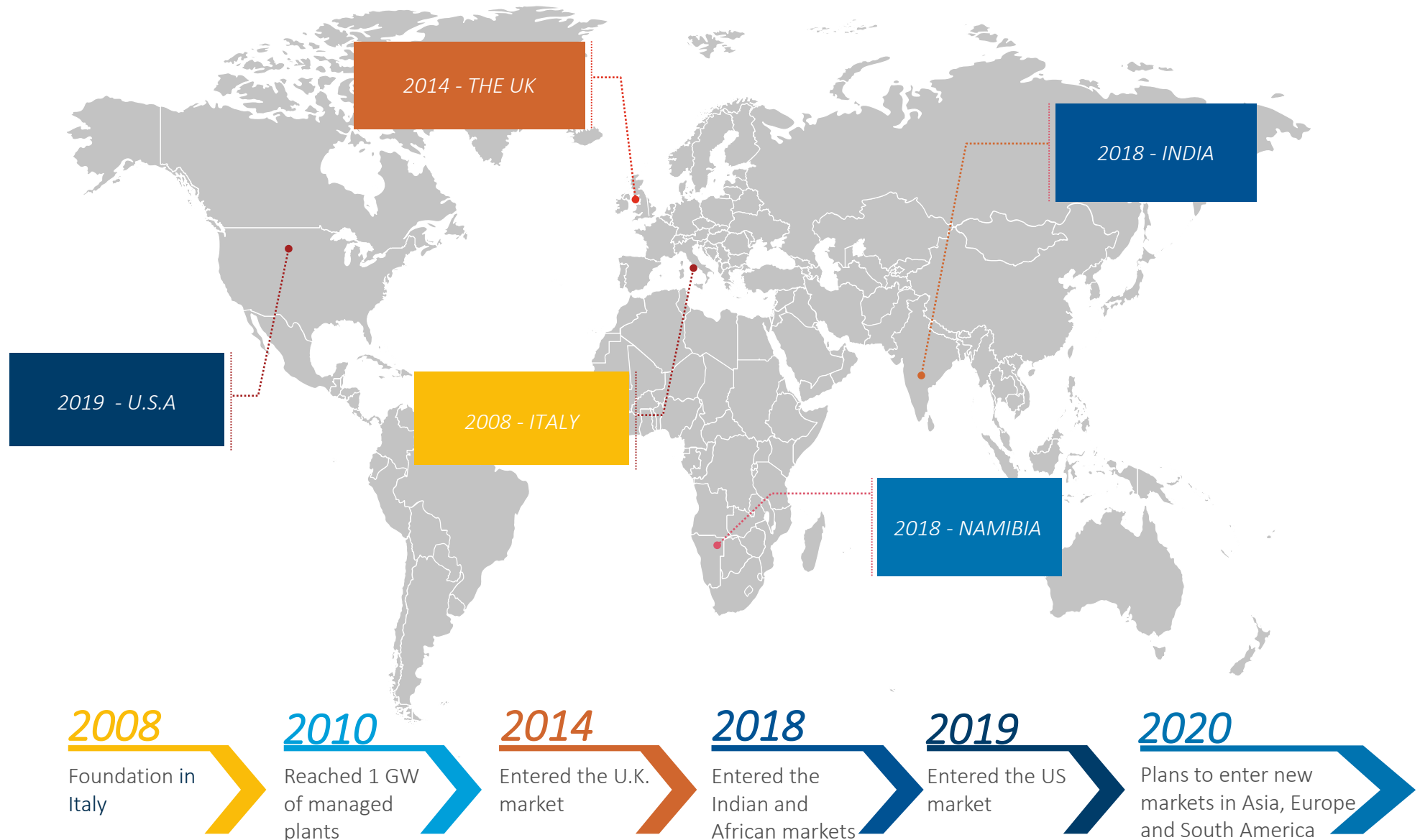
We are uniquely placed to improve and manage every aspect of your operating solar asset.

Our Numbers





About WiseEnergy | our international growth





Why WiseEnergy is interested in retrofit ARC

Following our philosophy, that aims to improve the profitability of our clients' plants and reduce business risks, WiseEnergy created the team unit called "Alpha Team" to bring at our clients' service the best and new technical solution.

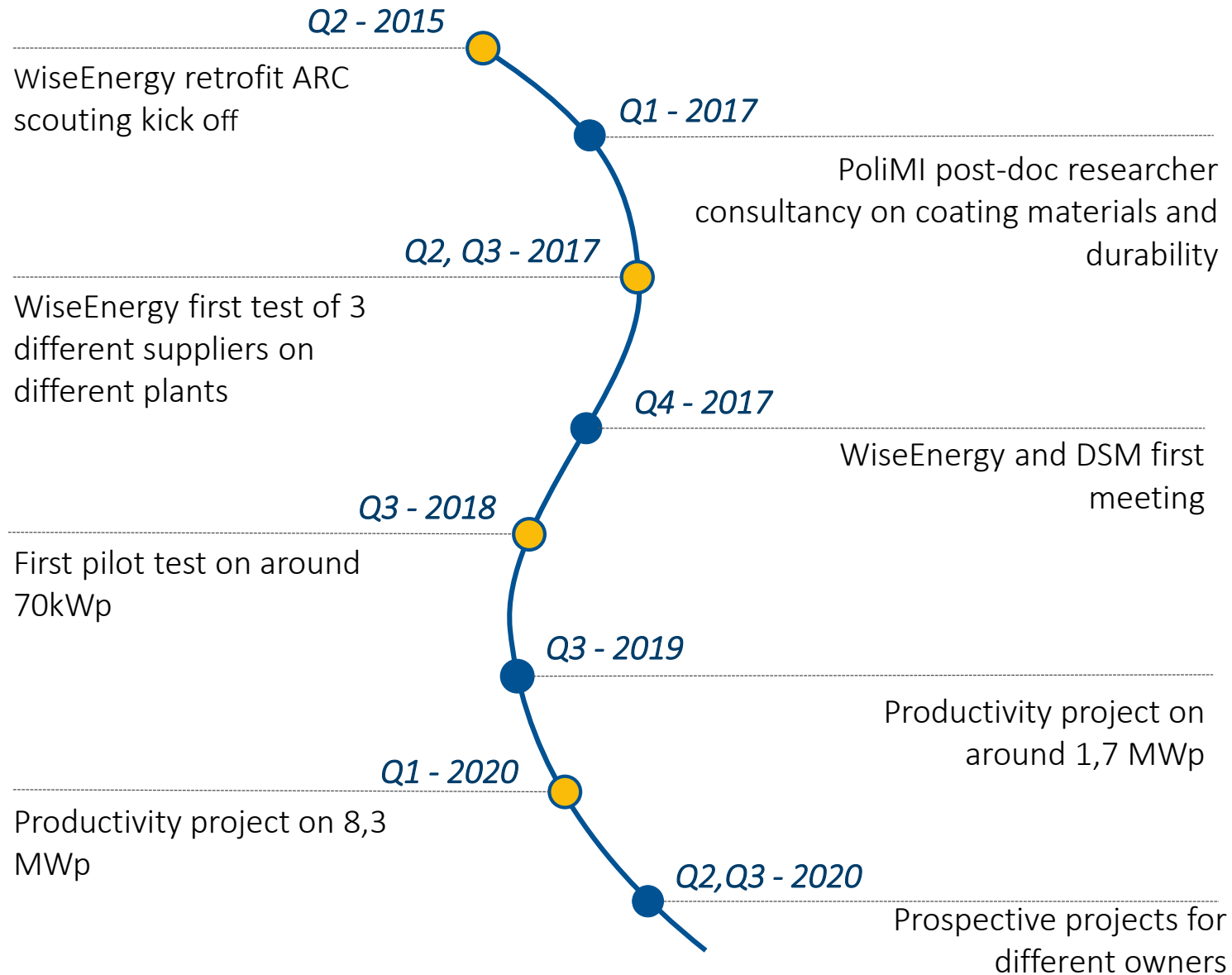
Retrofit ARC is a peculiar optimization that moves a step aside from the traditional. WiseEnergy can do the difference thanks to its knowledge and experience in translating new technologies in customized improvements.

ARC is a great opportunity that most of our clients cannot leave on the table.





WiseEnergy | retrofit ARC experience



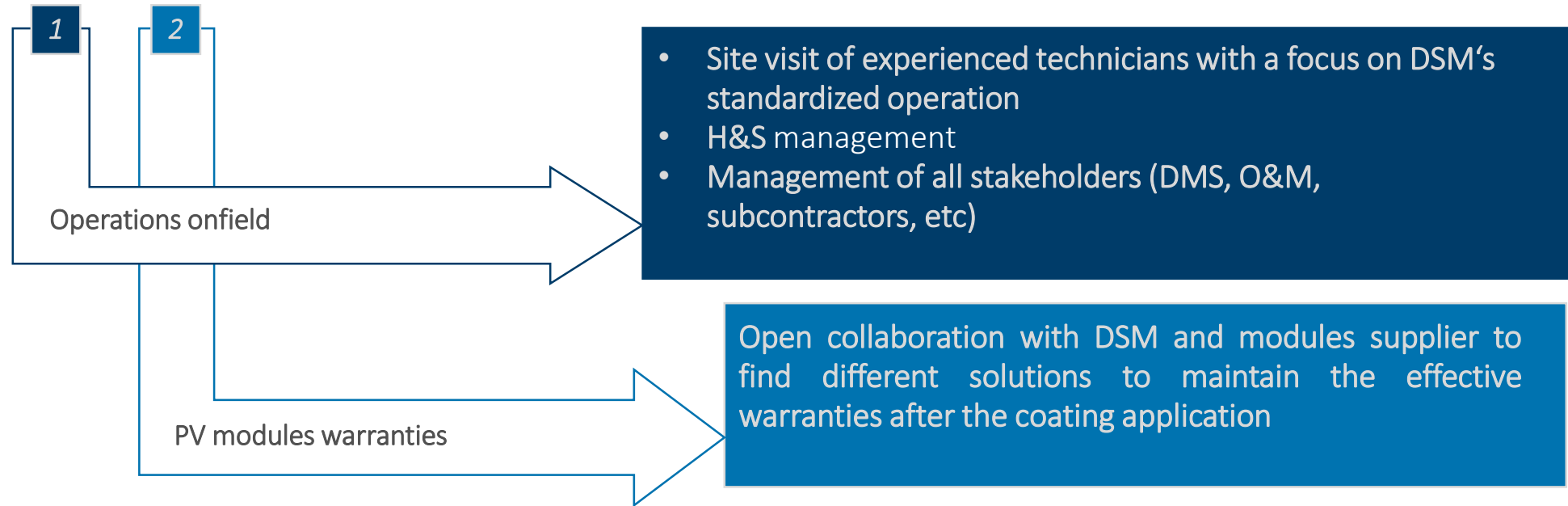


Different solutions to mitigate concerns



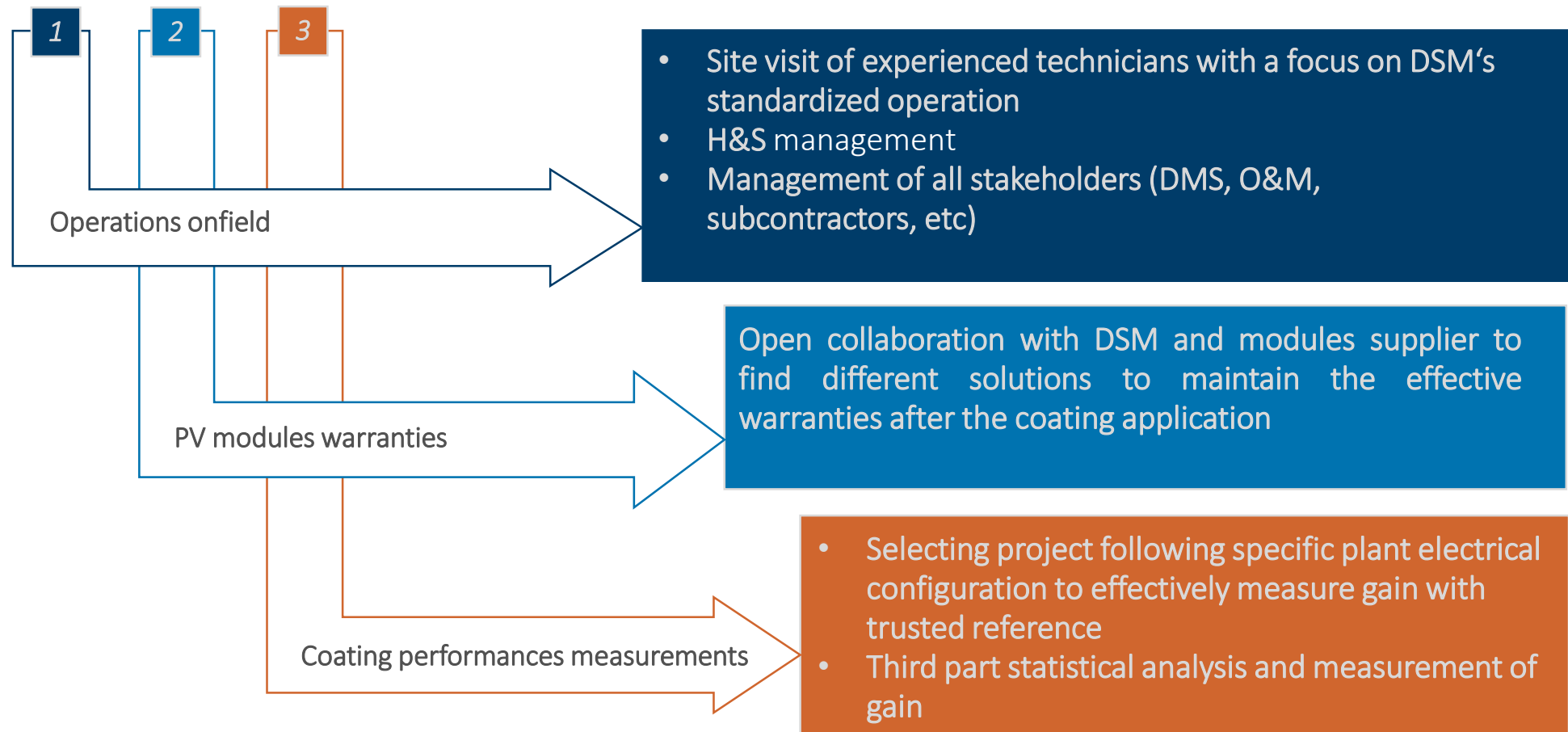


Different solutions to mitigate concerns



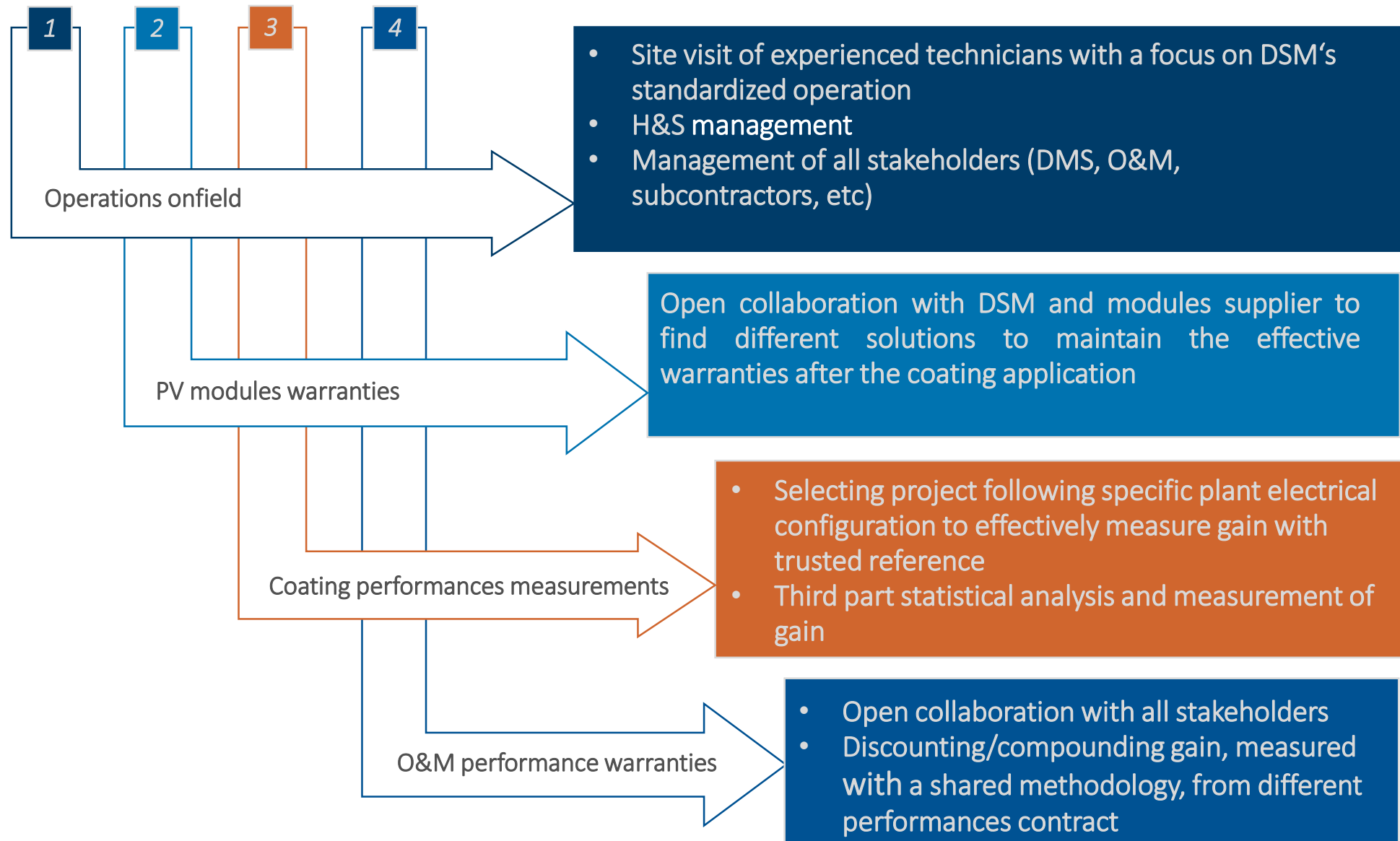


Different solutions to mitigate concerns





Different solutions to mitigate concerns





Conclusions



With our mindset and following our philosophy, we started a trusted collaboration with DSM built on confidence about retrofit ARC technology



Asset Management third party point of view could bring solutions to let our clients catch the opportunity of retrofit ARC



ITALY

Via Orefici, 2 ● 20123 – Milano
T +39 02 3670 6201

USA

Trolley Square, Suite 20 C ● Wilmington, Delaware 198066
T +65 2135 12351

UNITED KINGDOM

20 Savile Row ● London W1S 3PR
T +44 (0)203 929 2200

INDIA

Shangrila Plaza,
Road No. 2 ● Hyderabad – 500034