Highly Durable Anti-Reflective Anti-Soiling Coating for PV Module Glass

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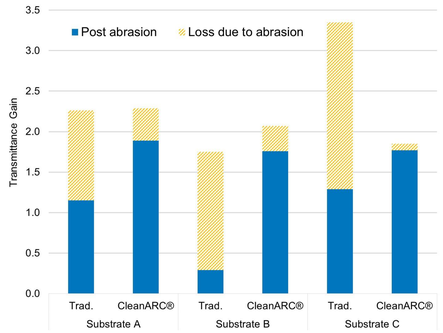
Abstract

- Greater than 4% of light is lost due to reflection at the interface of air and glass
- Soiling losses in arid regions have been reported as high at 30% per month
- Desert environments provide the most challenging conditions for coating durability
- Enki CleanARC® coating, a new highly durable anti-reflection and anti-soiling coating was compared to traditional coatings for durability and field tested at several US locations demonstrating significant anti-soiling performance
- The results were used to model project level value creation, and showed up to a 3x increase in value compared to traditional coatings

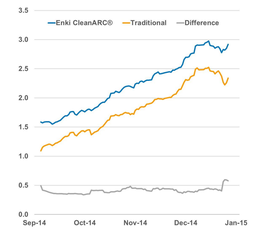
Reflection Before and After Abrasion

Initial coating performance is expressed as the percentage increase of transmittance (%ΔT/T) of solar weighted photons. Below are the initial optical gains of the Enki CleanARC® coating vs. a traditional coating on different glass substrates, and the loss due to standard abrasion testing.



While the traditional film show a higher initial performance, the degradation is far worse and they **failed** the test criteria, with greater than 0.5% loss. The Enki CleanARC® coating passed the specification and had higher energy gains than the traditional coating after abrasion.

Field Performance Test Array



10kW Yingli Test Array at Sandia National Laboratories, Albuquerque, New Mexico, USA.

Comparative energy generation between Enki CleanARC® coating and a competing traditional coating.

30 day moving average shows about 0.5% positive difference between Enki CleanARC® and the competing coating.

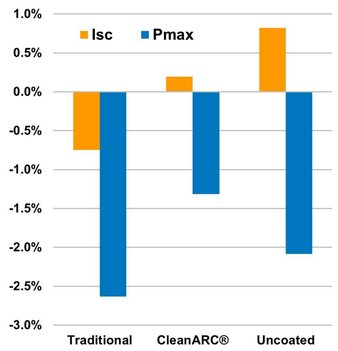
Damp Heat Performance Test

Traditional Coating

Enki CleanARC® Coating

Control (uncoated)

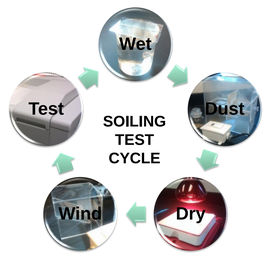
Test modules after 1000 hours damp heat (DH) testing at Underwriters Laboratories (UL). The modules with the CleanARC® coating were **visibly defect free** after cleaning with water, as opposed to the traditionally coated and control module

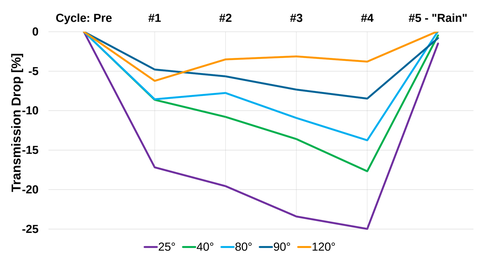


The change of I_{sc} and P_{max} of the modules after the DH test was measured at UL using a flash tester.

- CleanARC® coated and uncoated modules have no reduction in I_{sc}.
- Power loss is highest for the traditional coatings, and lowest for the CleanARC® coating
- Module with the CleanARC® coating displayed on average a lower loss than the control glass, exhibiting the added protective capability of this film against glass degradation by severe moisture exposure.

Laboratory Soiling Test





- A selection of glass coatings with different surface energies were subjected to a series of soiling test cycles
- Each test cycle included wetting the surface, applying dust with blowing air, drying, removal of loose dust with blowing air, and then testing for optical transmission loss.
- There is a very clear correlation between soil accumulation and surface energy as measured by water contact angle. Hydrophobic coatings with low surface energy and high contact angle performed best.
- Enki CleanARC® is represented by the coating with a 90° water contact angle.

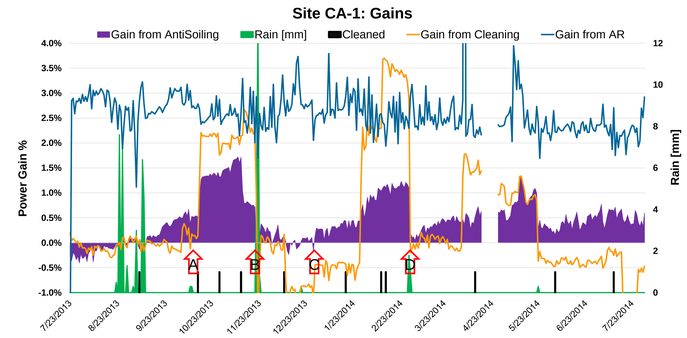
Anti-Soiling Field Test

Testing of CleanARC® coating's anti-soiling performance was performed at 10 sites across the USA in collaboration with a major system operator. Data has been collected for over 1 year.

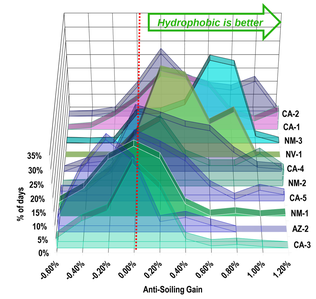
	Dirty	Cleaned	
Coated	E_{HD}	E_{HC}	
Uncoated	E_D	E_C	

Isolating both the Anti-Reflection and Anti-Soiling components of the power required four calibrated cells from Atersa, with half of the cells periodically cleaned.

$E_C - E_D$ = Cleaning Gain
$E_{HC} - E_C$ = Anti-Reflection Gain
$(E_{HD} - E_D) - (E_{HC} - E_C)$ = Anti-Soiling Gain



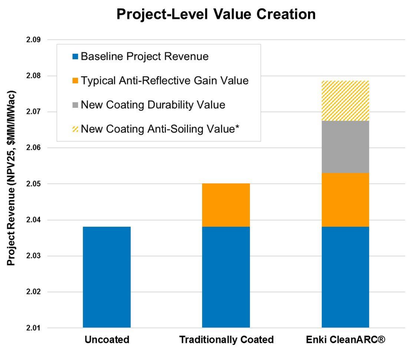
Anti-Reflection power gains were typically between 2-4%. Cleaning (soiling) gains ranged between 1-2% for certain periods. Anti-Soiling could be seen between rain cleaning and rain events (e.g. A-B and C-D in graph).



For 7 of 10 sites, the Anti-Soiling gains were clearly positive with an overall average daily gain of 0.35%.

Three of the sites demonstrated negative gains, indicating that for these climates and soiling types, perhaps a hydrophobic coating is not preferred.

Conclusions and Result



The CleanARC® coating can increase a project's energy yield and ROI through its anti-soiling properties and long-term durability. Our analysis shows it can deliver up to 3x more value than traditional coatings, resulting in over 1% additional energy production over the modules' lifetime.

* Project-level anti-soiling and cleaning value varies based on site specific conditions. The example assumes the solar project is located in central California with a baseline production of 1,738 MWh/MWdc; PPA rate of $70/MWh; 6% discount rate;0.5% baseline annual power degradation; 4% baseline soiling loss fraction, and one module wash per year.