

EXTENDING SOLAR PILE SERVICE LIFE WITH PROTECTIVE COATINGS

How Protective Coatings Help Mitigate Corrosion and Uplift in Utility-Scale Solar Foundations

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Utility-scale solar projects rely on steel pile foundations to maintain alignment and structural integrity for decades. However, corrosion, frost heave, adfreeze forces and challenging soil conditions can compromise long-term performance if not properly addressed.

Protective coatings designed for buried service help mitigate these risks by providing a durable corrosion barrier while reducing soil adhesion and uplift potential. By addressing both corrosion and soil interaction, these coatings play a critical role in improving solar asset reliability and reducing total cost of ownership.

In this guide, we cover how protective coatings help protect solar pile foundations from corrosion and uplift while supporting longer-lasting, more reliable utility-scale solar projects.

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PROTECTING THE FOUNDATIONS BEHIND UTILITY-SCALE SOLAR GROWTH

Solar photovoltaic generation is projected to become the dominant source of new electrical capacity over the coming decades. The International Energy Agency’s Renewables 2025 report forecasts renewable power capacity to approximately double by 2030, with solar accounting for roughly 80% of that growth. [1] Beyond 2030, continued deployment of utility-scale solar positions photovoltaic generation as a cornerstone of grid decarbonization, electrification and resilience.

The long-term success of this expansion depends on much more than innovations in panel efficiency or inverter technology. It also relies on the durability of the equipment used. That includes the foundational structures (steel piles) that support solar installations for 30 to 40 years or longer. The better those piles can resist corrosion above and below ground, and the better they’re able to remain in place where installed without shifting during soil upheavals, the better the long-term performance of solar panel installations **(Figure 1)**.



Figure 1. *The steel piles that support solar installations for decades must resist corrosion and remain in place where installed over the long haul to help owners realize long-term performance and reduce their total cost of ownership.*

Coatings applied to steel piles can play a large role in ensuring both that corrosion protection and installation stability. These materials not only stave off corrosion for long periods of time above and below ground but also provide a low surface energy below ground, allowing moisture and soil to glide past the coating, which mitigates the ability for freeze-thaw cycles and expansive soils to lift or shift piles embedded in the earth. With corrosion and pile uplift minimized, panel maintenance is also minimized, helping solar owners reduce their total cost of ownership and contributing to keeping solar a cost-effective energy source that's on par with energy produced from fossil fuels.

SOLAR PILE FOUNDATION CHALLENGES THAT IMPACT LONG-TERM PERFORMANCE

As solar development pushes into colder climates, lower-cost land and geotechnically challenging environments, the performance of steel pile foundations has become an increasingly critical design consideration.

Ground-mounted solar facilities rely on millions of driven steel piles to support racking systems and maintain alignment over decades of service. Once installed, these piles are largely inaccessible for inspection or repair, which makes early design decisions around corrosion control and uplift mitigation especially consequential.

Typical solar pile foundations experience a combination of environmental stressors **(Figure 2)**.

- **Corrosive soils** with low resistivity, elevated moisture, acidic pH and high chloride or sulfate concentrations can corrode unprotected piles
- **Freeze-thaw cycles** in frost-susceptible soils generate adfreeze forces that can push piles upwards through the earth
- **Expansive clay soils,** which swell and contract with moisture fluctuations, can also uplift and shift piles
- **Atmospheric and UV exposure** above grade can eat away at piles and weaken their structural support
- **Mechanical damage** during transport, handling and pile driving can expose steel below grade, removing the very protection that was meant to keep corrosion at bay

Each of these factors can reduce service life, increase maintenance risk or increase construction costs if not addressed holistically.

INACTIVATING THE "ACTIVE ZONE" WHERE CORROSION AND UPLIFT BEGIN

The most critical region for both corrosion and uplift performance is the upper subsurface of the earth. This is often referred to as the "active zone." It covers the portion of the pile that experiences seasonal temperature and moisture variation and remains exposed to oxygen at the surface, dissolved salts above and below ground, and frost movement from below **(Figure 3)**.



Figure 2. *As utility-scale solar installations become more prevalent, asset owners will need to contend with more corrosive soils, expansive clay soils and earth subject to repeated freeze-thaw cycles.*



Figure 3. *The area where solar piles experience the most aggressive conditions, including seasonal temperature and moisture variations, is known as the "active zone" and includes the portion of piles that remain exposed to oxygen at the surface, dissolved salts above and below ground, and frost movement from below.*

From a corrosion perspective, the active zone typically presents the most aggressive conditions for steel, with soil properties varying dramatically over short distances across a project site. From a geotechnical perspective, this same region is where frost adfreeze and expansive soil uplift forces originate.

Without mitigation, these combined effects can require piles to be embedded deeper in the ground, be constructed with heavier steel and/or feature increased corrosion allowances to account for steel loss from corrosion. Each of these factors can increase material, freight and installation costs.

Historically, corrosion protection and uplift resistance have been treated as separate design challenges. Galvanized piles are commonly specified to manage corrosion risk, but they typically require deep embedment and/or oversized steel to resist uplift. In addition, field experience and laboratory testing have shown that these strategies can be both limited and cost-intensive in challenging soils.

The reasons:

- Galvanized coatings may perform poorly against corrosion in acidic or high-chloride soils, leading to accelerated zinc consumption and eventual exposure of the underlying steel.
- As corrosion progresses, surface roughness increases, which can raise the friction of the coated steel and increase the associated uplift forces from adfreeze and expansive soils as they encounter the rougher surface.
- Longer piles increase exposure to corrosive layers in the earth, compounding long-term durability risk rather than mitigating it.

Addressing corrosion and soil-steel interaction simultaneously at the source has proven to be a more effective and economical approach.

SPECIFYING BURIED SERVICE COATINGS FOR SOLAR PILE PROTECTION

Coatings designed for buried service in direct contact with soil can provide both the corrosion resistance and uplift mitigation needed to improve outcomes for solar installations. These coatings should be applied to the entire pile for comprehensive corrosion protection, but they especially help both causes in the active zone of the pile.

This approach to protecting buried steel is well established across critical utility infrastructure, including power transmission and distribution structures. In these applications, a barrier coating is applied at the ground-line transition where galvanized steel enters the most aggressive corrosion zone. This practice reflects decades of field experience showing that buried conditions effectively create an immersion environment, where moisture, dissolved salts and variable soil chemistry can accelerate the degradation of galvanized steel over long service lives. Solar pile foundations are exposed to these same conditions. By specifying buried-service coatings, designers can apply a proven protection strategy used on critical assets to extend service life, manage corrosion risk and improve performance where soil interaction is most severe.

A properly specified and applied coating system for piles can:

- Create a continuous barrier that isolates steel from aggressive soils
- Reduce corrosion rates to support 30- to 40-plus-year service life expectations
- Minimize soil-to-steel adhesion, which reduces the friction forces between frost adfreeze and the coating film for less lifting potential
- Enable shorter pile lengths while maintaining structural performance

This approach allows designers to reduce steel tonnage without sacrificing durability or safety.

A notable coating option that fulfills these goals is Poly-Cote™ 110 from Sherwin-Williams Protective & Marine. This fast-setting, 100% volume solids polyurethane coating is engineered for buried steel service. When applied to carbon steel or galvanized substrates in the active zone, it provides a durable corrosion barrier while significantly reducing soil interaction forces.

Key performance characteristics of Poly-Cote 110 include:

- **Corrosion Protection Across Soil Conditions:** The coating's ultra-low permeability makes it suitable for a wide range of soil environments, including low-resistivity, low-pH soils with high chloride or sulfate content. This enables designers to eliminate the corrosion allowance of the steel pile, meaning the pile doesn't require extra steel thickness to account for metal loss due to corrosion over time. Therefore, panel owners can reduce the steel thickness of pilings from their previously standard practices without

compromising service life. Steel cost savings follow. The coating also provides excellent atmospheric corrosion protection.

- **Uplift Mitigation via Reduced Soil Adhesion:** Independent laboratory testing and field-experienced engineering reviews have demonstrated that coated steel surfaces can achieve 40% to 50% reductions in frost adfreeze bond stress compared to bare steel. In frozen soil load tests, coated piles have also shown approximately 40% lower coating film friction, supporting 20% to 30% reductions in the required embedment length of piles where site conditions allow. That means owners can also realize savings by using shorter piles.
- **Mechanical Durability During Installation:** High impact resistance helps the coating maintain integrity during transportation, handling and pile driving. This durability reduces the likelihood of coating damage occurring and compromising long-term performance.
- **Efficiency in Application:** Single-coat application and rapid cure support high shop throughput and consistent quality, which helps manage installed costs for solar panel owners.

HOW APPLICATION CONSISTENCY MAXIMIZES SOLAR PILE COATING PERFORMANCE

Application quality plays a critical role in coating performance, particularly where uplift mitigation depends on maintaining a smooth, uniform surface. The smoother the coating film and the more consistently it's applied, the better the result, as smoother finishes boost the surface tension of the coating to reduce soil adhesion.

Any quality control measures that help to minimize variability in the applied coating film thickness will help as well to prevent runs, thin applications and stippling from creating friction. The more repeatable the process, the better to realize real-world installation outcomes and strengthen confidence among geotechnical engineers and asset owners.

TESTING AND FIELD PERFORMANCE OF COATED SOLAR PILES

Various testing conducted by independent laboratories and geotechnical consultants **(Figure 4)** has consistently highlighted the limitations that bare and galvanized piles experience in challenging soils, including:

SALT FOG CORROSION LAB TESTING RESULTS



Hot Rolled Steel: 250 hours | *Galvanized: 250 hours (white rusting)* | *Coated: 1,000 hours*

Figure 4. *Independent salt-fog corrosion laboratory testing highlights the corrosion-resistance benefits of coated steel compared to uncoated and galvanized alternatives. Hot rolled steel showed corrosion after 250 hours, galvanized steel showed white rusting after 250 hours, and coated steel maintained protection through 1,000 hours of exposure.*

- Salt fog exposure testing has shown coated steel maintaining integrity beyond 1,000 hours. Bare and galvanized specimens exhibit corrosion or white rust at significantly shorter durations.
- Long-term field exposure studies have identified corrosion penetration and increased surface roughness on uncoated and galvanized piles within a few years in aggressive soils. These conditions can elevate pile uplift loading over time **(Figure 5)**.



Galvanized piles after six years. Documented average corrosion rate of 4 to 15 mils per year.

(In background) Poly-Cote™ 110 coated pile four years in highly corrosive soil. (In foreground) Carbon steel pin that was near pile.

Figure 5. *Field observations reinforce the role of buried-service coatings in supporting both corrosion protection and uplift mitigation in challenging soils. Galvanized piles showed measurable corrosion after six years, while a Poly-Cote 110 coated pile showed continued coating integrity after four years in highly corrosive soil.*

- Coated piles demonstrate more consistent performance, with surface characteristics that remain stable throughout the service life. Therefore, piles can maintain both corrosion resistance and reduced friction on the coating film.

These findings are particularly relevant as solar projects increasingly target sites with high corrosivity, freeze-thaw exposure or expansive clay soils.

REDUCING COSTS AND ECONOMIZING AT UTILITY SCALE WITH SHORTER PILES

Pile length is one of the most significant cost drivers in solar foundation systems. Each additional foot of embedment increases the steel tonnage, freight weight, driving effort and installation time for a project. And those factors may be multiplied across thousands or tens of thousands of piles.

With piles coated with an ultra-smooth Poly-Cote™ 110 finish significantly mitigating uplift, installers can reduce pile lengths by 20% to 30%, depending on the soil conditions. The cumulative savings can be substantial with lower steel material costs, reduced shipping and handling expenses, and faster installation and improved construction productivity.

Poly-Cote 110 coated piles can also provide a significant advantage over alternative approaches that rely on pre-drilled holes or sleeves to mitigate soil interaction. Where site conditions allow for driven pile installation, contractors can avoid the added mobilization, equipment, and labor costs associated with drilling operations, while also accelerating installation schedules. Driven piles can be installed in a single, continuous operation, reducing both project duration and the risk of construction delays.

Just as importantly, reducing the amount of steel required also lowers the amount of embodied carbon associated with a project, as each metric ton of steel production carries an estimated 1.9 metric tons of carbon dioxide (CO_2) emissions. In this way, optimizing the steel pile foundations for solar installations contributes directly to the sustainability objectives that drive that solar deployment in the first place.

IMPROVING LONG-TERM SOLAR ASSET RELIABILITY WITH PROTECTIVE COATINGS

Maintaining the alignment and structural stability of solar piles over decades of service is essential for preserving energy output, minimizing maintenance interventions, and protecting racking and electrical components from stress induced by seasonal movement.

By controlling corrosion and uplift where they originate in the active zone, buried-service coatings like Poly-Cote 110 support:

- Predictable long-term performance
- Reduced risk of seasonal displacement of piles
- Improved confidence in 30- to 40-year service life expectations

As land availability decreases and projects increasingly move into more demanding soil and climate environments, these benefits become not just advantageous, but necessary.

The continued growth of solar photovoltaic generation depends on more than surface-level innovation. It requires foundational systems capable of performing reliably for decades under increasingly complex environmental conditions.

By integrating corrosion protection and uplift mitigation into a single, targeted solution, engineered coating systems applied in the active zone enable shorter piles, lower costs, reduced carbon impact and more durable solar assets. As utility-scale solar expands into colder climates, corrosive soils and expansive geological conditions, these approaches will play a critical role in supporting long-term project performance and economic viability.

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FIGURES AND CAPTIONS

All images courtesy of The Sherwin–Williams Company.

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[1] Renewables 2025: Analysis and Forecasts to 2030. The International Energy Agency (IEA). (2025). www.iea.org/reports/renewables-2025

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