

Empowering Renewable Energy Sustainably Using Galvanized Steel

Alexa Bishop --Galvanize the Future: A Richard L. Brooks Memorial Essay Contest

Introduction

The global transition to renewable energy demands more than innovative turbines and efficient solar panels, but structural materials capable of lasting as long as the ambition behind them. Wind towers, solar racking systems, and hydroelectric gates must endure decades of exposure to rain, humidity, salt, UV radiation, and mechanical stress, often in remote locations where maintenance is difficult and expensive. Hot-dipped galvanized (HDG) steel meets this challenge comprehensively, offering a corrosion protection system that is simultaneously durable, economical, and environmentally sound. This essay explores how galvanized steel contributes to the sustainability of renewable energy infrastructure across its full lifecycle.

The Galvanizing Process and Key Material Properties

Hot-dip galvanizing is the process of immersing fabricated steel into a bath of molten zinc at approximately 840°F (449°C). The zinc reacts metallurgically with iron in the steel, forming a series of zinc-iron alloy layers topped by a pure outer zinc layer. Critically, this is not a surface coating — it is a metallurgical bond that becomes part of the steel itself.

The resulting protection operates through three mechanisms simultaneously. First, the zinc layer acts as a physical barrier, blocking moisture and oxygen from reaching the steel. Second, zinc corrodes at roughly 1/30th the rate of bare steel under equivalent conditions, meaning the coating degrades extremely slowly. Uniquely, zinc functions as a sacrificial anode: when the coating is scratched and bare steel is exposed, the surrounding zinc preferentially corrodes to protect the exposed area. No paint system provides this cathodic protection.

These properties produce exceptional service life. The American Galvanizers Association (AGA) documents that hot-dip galvanized steel typically remains maintenance-free for 70 to over 100 years in standard atmospheric environments. For renewable energy infrastructure designed to operate 25 to 50 years with minimal human intervention, this durability is essential. Galvanized steel also handles the mechanical demands of renewable energy applications --- wind-induced fatigue loading, thermal cycling, UV exposure, and installation stresses, without compromising its protective layer.

Environmental Benefits and the Circular Economy

Evaluating a construction material for renewable energy requires examining whether the material itself aligns with sustainability goals. Hot-dip galvanized steel does so on multiple fronts.

Steel is the world's most recycled material. In North America, more than 95% of structural steel is manufactured from previously recycled steel. Both steel and zinc can be recycled infinitely without any degradation in their physical or chemical properties, making galvanized steel a genuine fit for circular economy principles, a cradle-to-cradle material rather than a cradle-to-grave one. The AGA notes that lifecycle assessment data credits recycled galvanized steel with significant recovered energy value, and the International Zinc Association has confirmed through lifecycle inventories that both materials retain full quality through successive recycling cycles.

In contrast, organic paint coatings must be periodically stripped and reapplied, generating hazardous waste streams. When painted structures are eventually demolished, contaminated coatings enter the waste stream permanently. Zinc, as a naturally occurring element, already cycles through soil and water ecosystems without introducing disruptive foreign chemicals.

From a lifecycle assessment (LCA) perspective, hot-dip galvanized steel incurs its environmental costs entirely at the production phase, then requires no further environmental input during service. Painted systems, by contrast, require repainting every 10 to 25 years, each cycle generating transportation emissions, volatile organic compounds, and waste disposal impacts. A galvanized structure's environmental footprint is effectively fixed at installation; a painted structure's grows continuously throughout its service life.

Lifecycle Economics

The most persistent misconception about hot-dip galvanizing is that it is expensive. Evaluated on upfront material cost alone, it may appear comparable to paint systems — but this initial-cost comparison is financially incomplete and ultimately misleading.

Corrosion costs the United States approximately 23 billion annually. When steel structures require repainting, the direct cost is usually 2- 5x the original coating cost, and indirect costs, including lost use, inspection, scaffolding, and environmental disposal, are 5- 11x the direct cost. The AGA's Life-Cycle Cost Calculator (LCCC), developed in accordance with ASTM A1068, uses net present and future value analysis to compare the full 75-year costs of galvanizing against

more than 30 alternative coating systems. These analyses consistently show that hot-dip galvanized steel is 2 to 6 times more economical over the life of a project. Because HDG steel requires no maintenance for 70 or more years in most environments, the initial cost is typically the entire lifecycle cost.

For renewable energy, this matters acutely. Solar arrays and wind farms in remote or offshore locations face enormous logistical costs for any mid-service structural maintenance. Repainting turbine towers or solar racking systems requires mobilizing industrial coating crews, potentially partially disassembling operating infrastructure, and absorbing the lost energy production during downtime. Galvanizing eliminates these cycles entirely, keeping renewable energy infrastructure economically productive throughout its intended service life.

Real-World Applications in Renewable Energy

Utility-scale solar farms across the American Southwest rely on galvanized steel torque tubes, driven piles, and mounting brackets, which are all facing decades of UV exposure, temperature extremes, and soil-borne moisture. Ground-mounted racking in agricultural and desert settings benefits from the same zinc coating protecting both above-grade and embedded structural components. The AGA's Project Gallery documents numerous solar carport installations where HDG steel was specified for its combination of structural reliability and zero-maintenance service life in environments with persistent chemical and moisture exposure from vehicle traffic.

Wind energy demands even more from structural materials. Turbine towers stand 80 to over 150 meters tall, subject to continuous fatigue loading from cyclic wind pressure over millions of operational cycles. Keuka Energy's wind tower projects in Iowa specified hot-dip galvanized steel for structural components of low-wind-speed turbine towers, which are designs enabling electricity generation in previously unsuitable regions, recognizing that the humid Midwestern climate, combined with road de-icing salts and freeze-thaw cycling, creates severe corrosion risk for unprotected steel.

In hydroelectric applications, where structures are in or near constant contact with water and may have design lives of 50 to 100 years, maintenance access is not merely inconvenient — it may require partial dewatering of operating facilities. Hydroelectric gates, grating, handrails, and interior structural members at installations such as the Round Butte Dam on Oregon's

Deschutes River are specified in galvanized steel precisely to avoid these costly interventions. Given that hydroelectric facilities typically recoup capital investment within 5 to 8 years, protecting that investment with maintenance-free structural steel is straightforward financial logic.

Conclusion

Renewable energy's promise is only as durable as the materials that support it. Hot-dip galvanized steel addresses every dimension of that durability challenge: its metallurgically bonded zinc coating provides 70 or more years of maintenance-free corrosion protection; its lifecycle cost is 2 to 6 times lower than alternative systems; its steel and zinc are endlessly recyclable, supporting a genuine circular economy; and it eliminates the hazardous waste and carbon emissions associated with periodic repainting. From solar farms in Nevada to wind towers in Iowa to hydroelectric stations in Oregon, galvanized steel is already providing the quiet, maintenance-free structural foundation that renewable energy depends on.

As the world scales up renewable energy construction to meet climate targets, the material choices made by today's specifiers and engineers will define the reliability and sustainability of that infrastructure for the next century. Choosing hot-dip galvanized steel is choosing infrastructure that is ethical, durable, economical, and genuinely circular from the first installation to the last recycling cycle.

References

American Galvanizers Association. (2022). Economic Advantages of Hot-Dip Galvanizing. galvanizeit.org

American Galvanizers Association. (2022). How Long Does HDG Last? galvanizeit.org

American Galvanizers Association. (2022). Life-Cycle Assessment — Transportation Infrastructure. galvanizeit.org

International Zinc Association. (2025). Life Cycle Assessment. zinc.org/life-cycle-assessment

Kloeckner Metals. (2025). Solar Steel Solutions: Strengthening Renewable Energy Projects. kloecknermetals.com

South Atlantic LLC. (2024). How Galvanized Steel Helps with Solar Energy? southatlanticllc.com