

Galvanized Steel - Empowering Renewable Energy Sustainability

Introduction

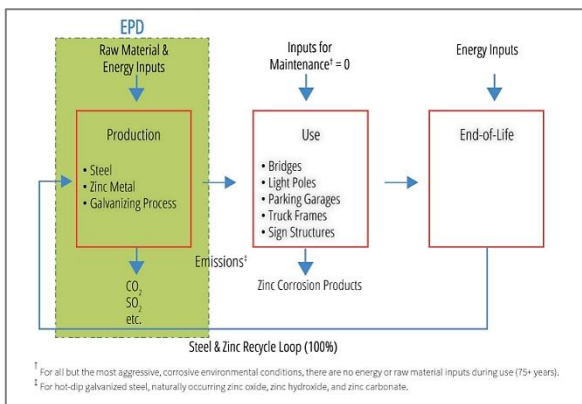
Galvanized steel, celebrated for its sustainability, features energy-efficient manufacturing and minimal environmental impact throughout its lifespan. The hot-dip galvanizing process, which involves zinc and steel—both natural, abundant, and essential elements—provides a corrosion-resistant finish that greatly extends the material's lifespan. Notably, zinc plays a crucial role in environmental health. The infinite recyclability of both materials without losing integrity (physical and chemical properties) bolsters a circular economy, as evidenced by high recycling and reclamation rates (see Table 1). Life-cycle assessments confirm galvanized steel's low environmental footprint, with all material and energy inputs and emission outputs confined to the production phase. This steel demands no maintenance over the practical service life of most structures, which can exceed 75 years, underscoring its preference in sustainable construction and manufacturing ¹.

Table 1. Recycling and reclamation rates for Zinc and Steel ².

	Zinc	Steel
Reclamation Rate	80%	100%
Recycling Rate	30% [*]	70%

** The recycling rate of zinc is lower mainly because its durability and longevity allow it to remain in use for decades, limiting available zinc for recycling.*

The potential of galvanized steel for recycling and reuse is paramount for the circular economy, notably



within the renewable energy sector. This material's suitability for reuse, reprocessing, or recycling mitigates landfill disposal. Its robustness permits repurposing beyond initial design life, promoting environmental and cost efficiencies. The 100% recyclability of hot-dip galvanized steel (as shown in Fig. 1.) underscores its minimal environmental impact and highlights why galvanized steel is an excellent choice of construction materials that align with the sustainability goals of renewable energy infrastructure ³.

Fig. 1. Life-cycle assessment of hot-dip galvanized steel

¹ "HDG Environmental Advantages," American Galvanizers Association, accessed March 23, 2024, <https://galvanizeit.org/hot-dip-galvanizing/is-galvanizing-sustainable/hdg-environmental-advantages>.

² "Home | ZINC. International Zinc Association," accessed March 23, 2024, <https://www.zinc.org/>.

³ "Hot-Dip Galvanizing: Reuse, Reclaim, Recycle," American Galvanizers Association, accessed March 23, 2024, <https://galvanizeit.org/sustainable-development-hot-dip-galvanizing-online-seminar/steel-plus-zinc/hdg-reuse-reclaim-recycle>.

The burgeoning role of renewable energy facilities, which have seen their energy generation share climb from 10% in 2010 to an expected 37% of all new capacity additions within the next 25 years, underscores the critical importance of sustainable construction materials. The rapid expansion in renewable energy projects, spurred by tax incentives and a societal shift towards environmental consciousness, introduces new challenges, particularly in corrosion protection. Hot-dip galvanized (HDG) steel, with its impeccable recyclability and corrosion resistance, emerges as an ideal solution. Its maintenance-free durability eliminates the need for additional raw materials, energy consumption, or waste generation over the life of the structure, presenting a sustainable solution to the corrosion challenges facing North American power projects. Therefore, HDG steel exemplifies the connection between long-lasting construction materials and the goals of green energy generation, providing a robust foundation for the growth of renewable energy sources ⁴.

Applications of galvanized steel in renewable energy projects

Galvanized steel, renowned for its strength and sustainability, is increasingly central to the progression of renewable energy technologies. It stands as a material of choice across a spectrum of applications within the renewable energy domain, notably in the construction of solar panel mounting systems, wind turbine bases, and the framework of hydroelectric facilities. Each of these applications capitalizes on the intrinsic qualities of galvanized steel: its formidable durability, superior corrosion resistance, and the expectancy of long-term performance with minimal maintenance. These attributes are critical in bolstering both the operational efficiency and environmental sustainability of renewable energy projects.

Solar Energy Infrastructures

Galvanized steel's role in solar energy infrastructure is pivotal for enhancing sustainability and reliability. It is employed in the construction of mounting systems and frames for solar panels due to its exceptional corrosion resistance and strength. This quality is especially crucial in harsh environmental conditions,



Fig. 2. Nevada Solar Farm

providing a robust, maintenance-free solution. The zinc coating in hot-dip galvanized steel, resilient to UV degradation, safeguards solar racking systems from extreme weather and temperatures—ranging from -40 F to 392 F—like those experienced at large solar farms in regions such as Boulder City, NV (see Fig. 2). With solar installations often situated in remote areas, the minimal maintenance requirement of galvanized steel is a significant advantage, ensuring uninterrupted energy production and protecting the investment in renewable energy sources ⁵. The integration of galvanized steel into solar projects aligns with the growing demand for sustainable and durable structures in the expanding field of renewable energy across North America.

⁴ "Renewable Energy," American Galvanizers Association, accessed March 26, 2024, <https://galvanizeit.org/hdg-in-use/electrical-utility-and-communication/renewable-energy>.

⁵ "Solar," American Galvanizers Association, accessed March 31, 2024, <https://galvanizeit.org/hdg-in-use/electrical-utility-and-communication/renewable-energy/solar>.

Wind Energy Infrastructures

The United States, a global leader in wind energy, recognizes the pivotal role of galvanized steel in developing resilient wind farm infrastructure. Galvanized steel is integral to building turbine towers and foundations, providing the robustness required to withstand wind-induced dynamic loads and harsh environmental conditions. Its application in the U.S., particularly across the wind-rich Great Plains, as shown in Fig. 3, aligns with the Department of Energy's findings on wind energy's vast potential.

The hot-dip galvanizing process equips these massive structures with a protective zinc coating, ensuring longevity and structural integrity against elements like wind, rain, and abrasive debris—crucial for both rural and offshore wind farms. This protection is especially important considering the high costs associated with turbine structures, both in production and maintenance.



Galvanized steel's extended maintenance-free lifespan reduces the need for specialized personnel at isolated wind sites, directly cutting operational costs and supporting wind energy's clean and sustainable promise. Furthermore, the coating's strong bond withstands the environmental rigors without polluting, preserving both wildlife habitats and rural aesthetics. Its non-reflective, matte gray finish is designed to blend seamlessly into natural landscapes, minimizing visual impact and ensuring wind structures are not disruptive to local communities or wildlife ⁶.

Fig. 3. Barton Wind Farm

Hydroelectric Infrastructure



Fig. 4. The Round Butte Dam on the Deschutes River in central Oregon

Galvanized steel is a cornerstone in hydroelectric infrastructure, essential for long-lasting support structures, gates, and penstocks. Its superior corrosion resistance is vital in installations in water prone areas, where the risk of rust is substantial. This material ensures hydroelectric facilities' (see Fig. 4) longevity, significantly contributing to their ability to generate clean energy for 50-100 years—often exceeding the operational lifespan of fuel-fired plants.

As 88% of the world's renewable energy comes from large-scale hydroelectric plants, which supply about 7% of the US and over 20% of the global energy needs, the importance of durable and maintenance-free materials cannot be overstated. The internal and external corrosion protection

provided by hot-dip galvanizing, where zinc coating covers every surface, is paramount. This process

⁶ "Wind," American Galvanizers Association, accessed March 31, 2024, <https://galvanizeit.org/hdg-in-use/electrical-utility-and-communication/renewable-energy/wind>.

shields the critical internal and external surfaces of pipes and penstocks from corrosion, ensuring uninterrupted water flow and energy production.

The hydroelectric sector benefits greatly from galvanized steel's low maintenance, especially given the inaccessibility of many components. With facilities often recouping their initial costs within 5-8 years of operation, it's prudent to employ materials like galvanized steel that prevent costly downtimes and maintenance, enhancing the return on investment. Hence, hot-dip galvanized steel is not just a material of choice but a strategic decision in constructing hydro-electric facilities and equipment ⁷.

Biomass and Geothermal Applications

Beyond solar, wind, and hydroelectric power, galvanizing is also employed in the biomass and geothermal industries. In biomass facilities, critical components like boilers, chimneys, and storage units are commonly made of steel and benefit from galvanizing for best protection against the corrosive effects of high heat and biomass substances. Similarly, geothermal plants, mining into the Earth's subterranean heat, demand materials that can resist corrosion for their piping, heat exchangers, and infrastructure. Galvanization serves as a dependable protection, preserving the operational effectiveness and extending the service life of geothermal systems ⁸.

Case Studies

A Case Study of the Metropolitan Tea- 702 kW Solar PV Installation-Toronto, ON ⁹

The Metropolitan Tea Company Solar PV Installation in Toronto, Ontario, demonstrates the effective use of galvanized steel in renewable energy infrastructure, offering a strong, cost-effective alternative to traditional extruded aluminum for supporting solar panels over 30-40' spans since its initiation in 2012.

Opting for post-fabrication hot-dip galvanizing ensured the installation's resilience to Toronto's diverse climate, preserving both its aesthetic and structural integrity. This choice also emphasized galvanized steel's durability and cost-effectiveness, particularly for steel cable trays and strut channels, while offering robust corrosion protection against rough handling and environmental stress, positioning it as a viable, less expensive alternative to materials like aluminum or stainless steel.



Fig. 5. Metropolitan Tea- 702 kW Solar PV Installation-Toronto, ON

This case study highlights how galvanized steel, through its durability and corrosion protection, offers an economically and

⁷ "Hydro-Electricity," American Galvanizers Association, accessed March 31, 2024, <https://galvanizeit.org/hdg-in-use/electrical-utility-and-communication/renewable-energy/hydro-electricity>.

⁸ "Galvanizing for the Renewable Energy Sector: Applications and Advantages," accessed March 31, 2024, <https://gaa.com.au/2023/07/05/galvanizing-for-the-renewable-energy-sector-applications-and-advantages/>.

⁹ "Solar."

environmentally sustainable option for renewable energy projects, underscoring its role in enhancing system resilience and sustainability.

A Case Study of the Keuka Energy Wind Towers- Ainsworth & Fairfield, IA ¹⁰

Keuka Energy's Wind Towers in Ainsworth and Fairfield, Iowa, illustrate the crucial role of galvanized steel in wind energy advancement. Transitioning to wind energy research in 2006, Keuka Energy developed patented designs for towers that efficiently produce energy at lower wind speeds, enabling wind power in areas once considered unsuitable due to limited wind resources.



Fig. 5. Keuka Energy Wind Towers- Ainsworth & Fairfield, IA

These towers uniquely generate electricity in low-wind conditions without a gearbox, reducing power consumption and expanding wind energy's viability to unconventional locations. The sustainability and longevity of Keuka Wind Towers are bolstered by hot-dip galvanizing, which improves their elemental resistance and operational lifespan, underscoring the feasibility of building sustainable energy projects with environmental considerations.

The Keuka Energy case study underscores the importance of innovative design and material selection in expanding the feasibility and applicability of wind energy. It highlights how hot-dip galvanized steel, known for its durability and corrosion resistance, is instrumental in the development of wind towers that are both sustainable and capable of operating under less-than-ideal wind conditions. The successful implementation of galvanized steel in this context showcases its effectiveness in protecting the infrastructure.

The Keuka Energy case study underscores the importance of innovative design and

A Case Study of the Clackamas Hydro Project- Estacada, OR ¹¹

The Clackamas Hydro Project in Estacada, Oregon, embarked in 2014, embodies a pioneering approach to hydroelectric development, emphasizing the coexistence of renewable energy generation with environmental conservation. This project, unfolding in two phases, aims to ensure a 97% survival rate for wild fish navigating through its waters, an indication to its commitment to minimizing human impact on natural life cycles.

¹⁰ "Wind."

¹¹ "Hydro-Electricity."

Phase one of the Clackamas Hydro Project enhanced accessibility and fish safety through new routes, flow



Fig. 5. Clackamas Hydro Project- Estacada, OR

control, and filtration systems, blending infrastructure with environmental care to balance renewable energy advancement and ecosystem preservation. Emblematic of sustainable engineering, the project emphasizes wildlife conservation within hydroelectric generation, pioneering a model for future industry developments. Its innovative, eco-conscious hydroelectric design exemplifies a progressive approach to renewable energy that coexists harmoniously with nature.

Conclusion

In conclusion, the extensive exploration of galvanized steel's application in renewable energy projects underscores its significant role in advancing sustainable energy infrastructure. Through its superior corrosion resistance, exceptional durability, and maintenance-free longevity, galvanized steel emerges as a pivotal material that not only meets the rigorous demands of renewable energy projects but also aligns with global sustainability goals. The case studies highlighted, ranging from solar farms in Ontario to wind towers in Iowa and the hydroelectric project in Oregon, showcase the material's versatility and its critical contribution to enhancing the resilience and sustainability of renewable energy systems. Moreover, galvanized steel's inherent recyclability and minimal environmental impact throughout its lifecycle reinforce the material's alignment with the principles of a circular economy, making it a strategic choice for future projects aimed at reducing carbon footprints and promoting environmental stewardship. As the world continues to pivot towards greener energy solutions, the role of materials like galvanized steel, which bridge the gap between industrial demands and ecological sensitivity, will undoubtedly grow, highlighting the importance of sustainable material selection in the renewable energy sector's ongoing evolution.