Sustainable Solutions

for corrosion protection

Hot-Dip Galvanized Steel

The green choice for protecting your alternative energy investment

MEET HDG

Hot-dip galvanizing (HDG) has provided steel corrosion protection for over 150 years and at least half a century for structures used in the generation, transmission, and distribution of energy from traditional sources. As awareness and demand for renewable energy has grown, private utilities will continue to receive pressure to provide a larger percentage of their electricity from renewable sources such as wind or solar, and to reduce their carbon dioxide emissions (carbon footprint) at existing plants.

As the construction of alternative energy facilities (windmills, solar panel fields, biodiesel plants) and infrastructure accelerates, it is imperative the owners of these new sources of energy production recognize the inevitability of corrosion and make intelligent economic and environmental decisions to protect these newly developed assets. Due to its use of naturally occurring zinc metal, 100% recyclability, speed of application, delivery to the job site, aesthetic durability, and no maintenance requirement for decades, hot-dip galvanized steel delivers unparalleled performance over other corrosion protection methods.

RECOGNIZE

the inevitability of corrosion, and make intelligent economic and environmental decisions to protect your alternative energy investment

Environmental Cost of Ownership

In order to 'walk the talk,' designers and owners of alternative energy structures select construction materials and techniques with the smallest ecological footprint and highest level of sustainability. Because steel is 100% recyclable without loss of physical properties, readily available, and durable, it is often the material of choice. However, because exposed steel corrodes over time - eventually leading to loss of structural integrity and unsafe operating conditions - and is also unsightly, it must be protected. Hot-dip galvanizing is the longest lasting and one of the most common coatings for steel corrosion protection.

The metallurgic reaction of iron in steel with molten zinc in the galvanizing kettle succinctly defines the hot-dip galvanizing process. The zinc metal and steel diffuse to develop the galvanized coating. The galvanizing process uses energy, water, and cleaning solutions, and emits small amounts of zinc into the air; and like the finished product, is environmentally friendly and improving constantly. Energy efficiency is growing in galvanizing plants, where water is generally contained in a closed loop (i.e., it is used and reused), and cleaning solutions are either filtered and reused within the process or sent to facilities where iron chlorides are converted for use in the treatment of municipal waste. Emissions are often captured in air containment systems and sent to further processes where they become other useful products, (e.g. fertilizer.)

A review of available life-cycle studies[1] indicates the typical metrics for hot-dip galvanizing one kilogram (2.2 lbs.) of steel are 3.4 – 5.3 MJ of gross energy consumed and a global warming potential of 0.1 – 0.33 kg CO_2 equivalent. Using this knowledge of the environmental burdens of corrosion protection with galvanizing, it is possible to compare the consequences of the different choices of corrosion protection.

In a 2004 case study conducted in Finland[2], the environmental footprint of a hot-dip galvanized balcony was compared to a two-coat zinc-epoxy/polyurethane painted balcony. The results are displayed in *Table 1* below, revealing hot-dip galvanizing is clearly more sensitive to the environment.

[1] Life Cycle Engineering, Torino, Italy
[2] VTT Technical Research Centre of Finland, 2004

Table 1: Environmental impact of HDG vs. zinc-epoxy/polyurethane paint

Environmental Impact (60 yrs.)	Hot-Dip Galvanizing	Paint
Life-cycle Energy	16% of total (23,700 MJ)	63% of total (53,500 MJ)
Resource Consumption*	37	100
Greenhouse Effect*	16	38
Acidification*	22	26
Eutrophication*	8	18

* Normalized to highest contributory factor

Economic Cost of Ownership

As revealed in the previous analysis, it is important to factor durability and frequency of maintenance when considering the service life cost of alternative energy facilities. Obviously, the more maintenance needed, the greater the energy, labor, and resources consumed.

This also means a higher total cost to own and operate the facility. Using the web-based tool, the Life-Cycle Cost (LCC) Calculator located at **www.galvanizingcost.com**, the total economic cost to hot-dip galvanize a windmill tower, the support frames for a solar panel farm, or the exposed structural steel of a biodiesel plant can be compared to the cost of protecting the same piece with a number of different paint systems.

Consider a windmill farm, with a total of 500 tons of steel, located in a rural area where pollution and corrosive elements are low. The towers are expected to provide energy for 60 years.

If the towers are hot-dip galvanized or painted (zinc epoxy primer/polyurethane topcoat), and considering the time value of money (interest earned and inflation loss), the cost comparison is shown in *Table 2*, see below.

The paint will need touchup in year 24, maintenance painting in year 32, and a full repaint in year 44. The hot-dip galvanized towers require zero maintenance over the 60 years. Considering indirect costs associated with shutting down production are often two- to four-times the direct cost, the total cost to own a painted windmill farm could be $282,000 to $760,000 higher than a galvanized version.

Case studies have demonstrated the high environmental and economic costs associated with the repeated maintenance painting of steel structures. These burdens can be significantly reduced by an initial investment in long-term protection... hot-dip galvanizing.

Table 2: Windmill Farm case study results

Corrosion Protection System	Initial Cost	Total Direct Cost of Ownership (60 years)
Hot-Dip Galvanizing	$4.00/ft^2	**$200,000**
Zinc Epoxy/Polyurethane	$2.10/ft^2	**$241,217***

* Includes maintenance costs of touchup in year 24, maintenance repaint year 32, and full repaint in year 44. Hot-dip galvanizing requires no maintenance in 60 years.

Corrosion Protection

Zinc, used to coat steel in the galvanizing process, provides both barrier and cathodic protection. It is a superior barrier because the metallic coating is impervious to moisture and harder than the steel it is protecting, thus preventing corrosion from starting and providing resistance to damage from handling and erection.

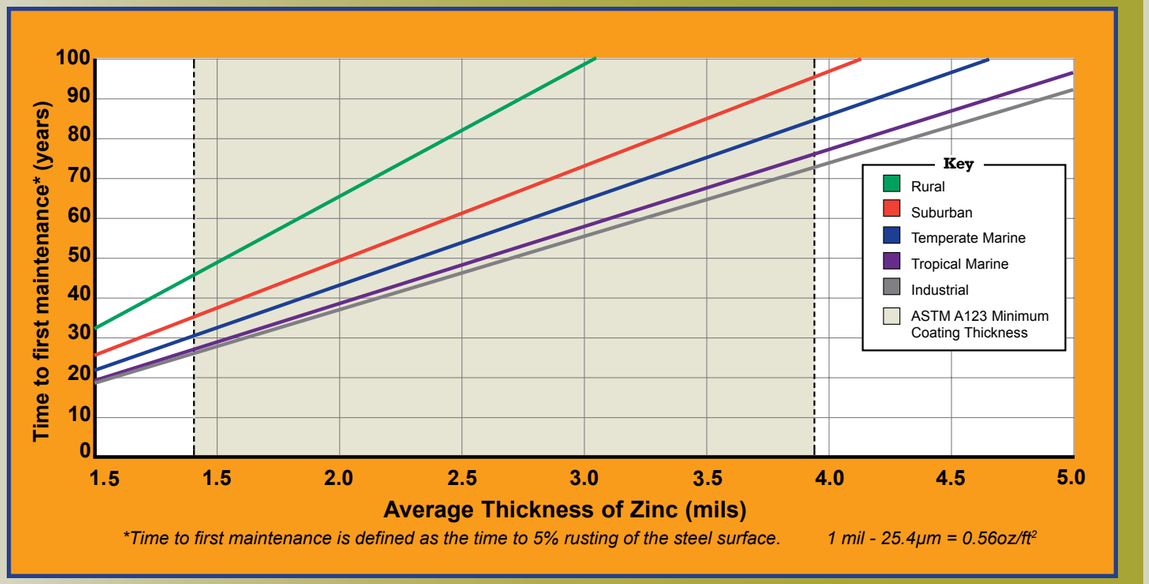
Cathodic protection, which further distinguishes galvanizing from paint, simply means the zinc will preferentially corrode prior to any corrosion of the underlying steel. Even if there is a scratch exposing the steel, the surrounding zinc will protect the exposed area and no corrosion will occur. Unlike paint, where underfilm corrosion caused by paint porosity or age cracking results in blisters and flaking along the entire surface, hot-dip galvanized coatings isolate corrosion to the area of exposed steel.

An overlooked feature of hot-dip galvanizing is it coats corners, edges, difficult to reach pockets, and the inside of tubular sections uniformly. It is at these locations where corrosion typically begins on unprotected steel. For large towers supporting turbine blades, this is a critical benefit.

The time to first maintenance for a hot-dip galvanized coating is directly proportional to the thickness of the coating, and ASTM specifications dictate the minimum for type and thickness of steel. Studies of corrosion rates collected worldwide indicate galvanized coatings provide excellent long-term corrosion protection. These corrosion rates were used to develop the time to first maintenance chart for hot-dip galvanized coatings in five general environmental classifications (see *Figure 1*). Note, the minimum coating thickness for 1/4" thick and greater steel is 3.9 mils (100 µm,) and thus the time to first maintenance in the harshest environment (industrial) is at least 72 years.

When steel is hot-dip galvanized, zinc - a 100% recyclable natural element - can provide superior barrier and cathodic corrosion protection.

Figure 1: Time to First Maintenance for Hot-Dip Galvanized Coatings



*Time to first maintenance is defined as the time to 5% rusting of the steel surface. 1 mil - 25.4µm = 0.56oz/ft²

"...the maintenance-free service life in the HARSHEST environment is at least 72 YEARS"

BIOFUEL

The Lake Erie Biofuel Plant is one of the top ten alternative energy production facilities in the nation.

The exposed galvanized steel used in this plant will be protected from harsh snow and rain exposure.

Lake Erie Biofuels Plant

Erie, Pennsylvania

The Lake Erie Biofuels (LEB) Plant is the first plant of its kind developed on the banks of the Great Lakes, an area marked as an emerging force in the biodiesel industry. Designed to produce 45 million gallons of biodiesel annually, this new multi-feedstock plant is one of the top ten alternative energy production facilities in the nation.

Members of the Erie Management Project office had prior experience with galvanized steel products, and were well aware of the superior corrosion protection, reduced maintenance costs, and extended service life associated with utilization of hot-dip galvanized steel. Completed in 2007, the Lake Erie plant is consistently exposed to harsh rain, snow, wind, and sun. With much of the handrail and walkways at the plant exposed to these weather conditions, LEB chose hot-dip galvanizing to protect these steel elements from corrosion, as well as to minimize maintenance costs.

As a commercial plant under continual operation, minimal maintenance is a requirement to reduce costs and keep a productive workflow. The barrier and cathodic protection of hot-dip galvanized steel ensures, unlike paint or other methods of corrosion protection, maintenance will be unnecessary for 50 years or more.

Citing durability as a key issue in the plant's development, LEB specified 250 tons of steel beams, tees, plates, stringers, channels, angles, trapeze supports, handrails, stairways, platforms, and fuel line supports be hot-dip galvanized for corrosion protection. Doing so assured the protected elements of the facility will last for decades to come.

With more than 50 new biodiesel plants under construction in this burgeoning section of the biofuel industry, plant owners have not only an economical option for corrosion protection, but also an ecological option that will further the green intentions of their industry. By reducing the carbon footprint caused by decades of repeated paint maintenance, as well as utilizing the natural protective properties of zinc, the hot-dip galvanized steel in this Lake Erie plant makes it a model for area biofuel plants seeking a green alternative for corrosion protection.

Located in an area where the biofuel industry is booming, the Lake Erie Biofuel Plant is designed to produce 45 million gallons of biodiesel each year.

BIOFUEL

Utilizing more than 550 tons of exposed galvanized structural steel, the Louis Dreyfus Plant produces more than 88 million gallons of ethanol biodiesel a year. In addition to contributing a source of alternative energy, this facility will work to bolster the country's agriculture industry with a new venue for crop production.

Louis Dreyfus Integrated Soybean-Based Biodiesel Plant

Claypool, Indiana

The Louis Dreyfus' new biodiesel facility is the largest integrated biodiesel plant in the world. As their motto states, the soybean-based biodiesel plant is dedicated to "burning the bean—" producing 88 million gallons of biodiesel, as well as one million tons of soybean meal to be used to help feed Indiana farmers' livestock.

The development of biodiesel as an alternative fuel source provides an eco-friendly solution to the nation's fuel production woes, as well as bolsters the country's agriculture industry with a new venue for crop production. Citing the alternative energy focus of the Claypool plant as a vital aspect of his company's future, Robert Louis-Dreyfus chose to employ a hot-dip galvanized coating on elements of the facility to provide long-term corrosion protection that requires little or no maintenance.

The plant has more than 550 tons of exposed hot-dip galvanized structural steel, including beams, columns, ladders, platforms, stairs, and handrails. The fabricator noted the ease of specifying as a benefit of galvanizing over paint; however, he may not have known galvanizing would also be a better choice for the environment.

The routine maintenance required by painting for corrosion protection creates an unnecessary carbon footprint over the life of the structure – one that can be significantly reduced by the use of galvanized steel. Because of the superior corrosion protection of the natural zinc coating, the facility will require little or no maintenance for more than 50 years.

The durability of hot-dip galvanized steel also provides abrasion resistance that will extend the time to first maintenance of the plant and keep the facility "burning the bean" long into the future. With the inherent protective properties of natural zinc protecting the exposed steel, the plant will minimize its carbon footprint while helping produce alternative energy.

Cambridge Ethanol Project

Cambridge, Nebraska

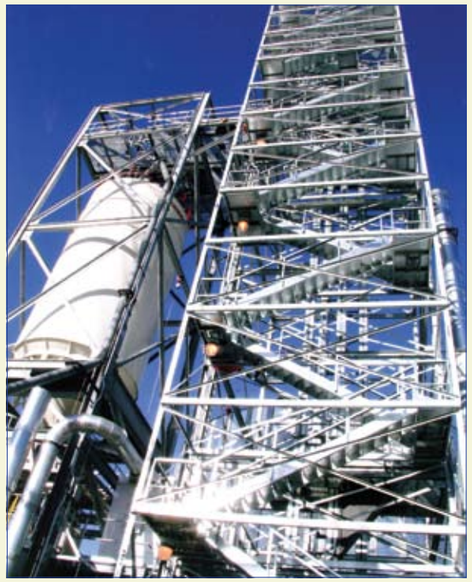
The Cambridge Ethanol Project evokes great pride in the surrounding rural community, as the prominent structure looms high and large on the horizon. The plant, which specializes in creating ethanol alternative fuel, operates in two phases: one which produces 88 million gallons of ethanol per year, and the other which produces 150,000 tons of by-products.

With the extreme hot and cold temperatures the plant is exposed to, hot-dip galvanizing was chosen for its durable, long-lasting corrosion protection. Also, the strong barrier and cathodic protection of the zinc coating will keep the plant aesthetically pleasing for decades. The fabricator for the project is a long-time believer in the quality of hot-dip galvanizing.

While the plant works to produce a clean-burning, sustainable fuel source, the all-natural zinc coating will be working to protect the structure from unsightly corrosion. The durability of the galvanized steel will allow the owners to focus their resources on creating alternative energy, rather than spend money, time, and effort maintaining corrosion protection. Because the galvanizing process means a quick turnaround time – there are no seasonal delays, as the process is performed indoors - the project was completed right on schedule. With the durable galvanized steel protecting the structure from corrosion, it will be 50 or more years before maintenance even needs to be considered.

> "The galvanized steel will allow owners to focus their resources on creating alternative energy, rather than spend money, time, and effort maintaining corrosion protection"

Walkways, ladders, platforms, handrails, structural steel, and pipe racks comprise the 466 tons of galvanized steel used to protect this structure from corrosion. The use of 100% recyclable zinc aligns perfectly with the earth-friendly purpose of the plant, while the durability of the coating means no harsh chemicals or energy will be expended to maintain protection. Hot-dip galvanized steel will keep this alternative energy source corrosion-free and environmentally friendly for generations to come.



Many Ethanol plants originally painted for corrosion protection are now being retro-fitted with hot-dip galvanized steel after just a few years. As new ethanol plant production has slowed, this area continues to grow.

WIND

Gaspe Wind Energy Project

Gaspe, Quebec

With wind energy becoming increasingly popular, worldwide market growth for the alternative energy source is close to 25 percent per year. Taking advantage of this economically and environmentally friendly growth in market presence, the owner of these wind turbines wished to create a durable structure that would minimally impact the surrounding environment.

In order to meet the requirements of this project, the client built a plant in Matane to assemble the 847 windmill towers for the first phase of development – a move that represented a major investment in the rural community by helping alleviate the unemployment problem in the Gaspe region. Manufacturing and processing time needed to be quick and efficient. Hot-dip galvanizing, a process that can be completed independent of weather conditions, was the clear choice.

The galvanized coating blended pleasantly into the rural environment surrounding the structure. Zinc, an element found in nature, is 100% recyclable and is naturally suited to corrosion protection. Its cathodic properties will protect a structure from corrosive conditions at a molecular level, as well as provide strong barrier protection from wind, rain, snow, and sunlight. With a hot-dip galvanized coating protecting the structure from unsightly and destructive rust, these turbines will continue to produce environmentally-friendly renewable energy for generations.

Because of the natural, earth-friendly nature of zinc, galvanizing this structure had minimal impact on the environment.

Hot-dip galvanizing a hollow structure coats the interior as well as the exterior with zinc, protecting this windmill from the inside out.

Indiana Wind Farm

Indiana

Because many of the best winds blow in difficult-to-access locations, installation and frequent maintenance of wind turbine towers is highly impractical. The owner of these wind energy towers in Indiana recognized the impracticality, waste, and harm to the environment caused by corrosion protection systems that require continual maintenance.

By specifying the towers to be hot-dip galvanized for corrosion protection, the owner ensured the structures would remain maintenance free for more than 50 years – meaning no unnecessary gas, energy, chemicals, or manpower would impact the environment for as long as the zinc coating is protecting the structure.

Separating the wind tower into several pieces made it considerably more economical to transport.

The towers are designed in separate pieces, hot-dip galvanized for corrosion protection, then quickly erected on site. By separating the tower into multiple pieces, the owner was able to avoid costly special transportation permits and vehicles, and ship the pieces on standard flatbed trucks. Once the sections arrived at the site, a forklift or all-terrain crane moved the pieces into place to be bolted together.

The cost of assembling the tower on site was significantly less expensive than the cost of specialized transportation, and the galvanized coating means this process is only required once for many decades – sparing the surrounding environment from any unnecessary detrimental impact.

The durable coating will stand up to wind abrasion and other elements, keeping the structure from corroding and allowing the wind energy turbines to produce clean alternative energy without interruption.

HYDROELECTRIC

Norris Dam Steel Substation

Knoxville, Tennessee

In keeping with the environmentally-friendly purpose of this hydroelectric substation, the Norris Dam Steel Substation was hot-dip galvanized with natural, sustainable zinc for corrosion protection.

This galvanized steel substation, powered by the 72-year-old Norris Dam, handles more than 100,800 kilowatts of hydroelectricity. The Norris Dam and Power Plant, named in honor of Nebraska Senator George Norris, was the first substation built in the Tennessee Valley Authority system. Measuring 1,860 feet long and 265 feet high, the dam supports Norris Lake, the largest reservoir on a tributary of the Tennessee River.

The dam is equipped with two 50 megawatt electrical generators. Electricity created by the dam is transferred through the substation; a bolted lattice structure supported by exposed hot-dip galvanized steel. All structural members and bolts were galvanized before assembly.

Situated next to a reservoir popular with local anglers, this alternative energy source reflects the surrounding natural environment, as well as the earth-friendly purpose of the facility. Galvanizing takes advantage of zinc's natural ability to protect steel from unsightly rust stains using cathodic and barrier protection created during the galvanizing process.

A natural element, zinc is not harmful to the surrounding environment, and is 100% recyclable. As hot-dip galvanizing protects steel from corrosion for 50 or more years, no extra energy will have to be wasted on repeated maintenance, nor will any chemicals be released into the air. So long as the water flows from the reservoir, this substation will be able to support eco-friendly alternative energy well into the future.

Xcel Energy
Big Falls Hydro Plant

Ladysmith, Wisconsin

Xcel Energy, which owns 19 hydroelectric plants in Wisconsin, operates the Big Falls Hydro Plant. Utilizing the flow of the 155-mile Flambeau River, Big Falls generates 7.4 megawatts of power. The 100% natural zinc coating will provide earth-friendly corrosion protection for decades.

SOLAR

"Galvanized steel does not waste energy, chemicals, or manpower to protect steel from corrosion."
--South San Joaquin Irrigation Distribution Solar Farm

Located in the sun-drenched deserts of Nevada, the Solargenix Energy project harvests solar energy.

Nevada Solar One - Solargenix Energy

Boulder City, Nevada

The Nevada Solar One - Solargenix Energy project is the third largest solar energy center in the world, and the largest-capacity facility built in 15 years. The massive project covers 400 acres with reflective mirrors, which are computer-controlled to rotate according to the angle of the sun in the sky.

The desert location of the project means hot-dip galvanized steel will be exposed to intense UV rays. Solargenix's past experience with hot-dip galvanized steel convinced them maintenance-free galvanized steel was the most cost effective option for the facility. The 180,000 mirror panels are capable of producing 64 megawatts of power.

This renewable energy source has the potential to compete directly with conventional fossil fuel powered technologies, and is fast becoming a well-known alternative energy source. Protected from corrosion by 100% recyclable, natural zinc, the solar energy farm is practicing environmentally conscious decision-making in its own facility.

This project is a first in the U.S. of this size and magnitude, but larger projects are planned in Nevada and California. After the success of employing hot-dip galvanized steel in this project, it is expected the additional plants will use galvanized steel as well. The durability and longevity provided by galvanized steel will ensure hot-dip galvanized steel will be a player in the expanding alternative energy market well into the future.

This solar energy farm is the largest capacity facility of its kind built in the past 15 years, spanning more than 400 acres with computer-controlled reflective mirrors.

Sixty-four megawatts of power will be generated by the 180,000 mirror panels in the farm.

Johnson & Johnson Solar Roof Panel

New Brunswick, New Jersey

When planning their solar panel project, Johnson & Johnson desired a coating that would withstand the harsh New Brunswick winters and require little future maintenance. With longevity and low maintenance as primary requirements, hot-dip galvanized steel was the logical choice.

The system was installed on the roof of a multi-level parking garage and utilizes galvanized structural framing, tube steel supports, and brackets. These pieces, protected by 100% recyclable galvanized steel, will withstand the harsh elements of the climate, as well as the rigors of vehicle emissions. The natural zinc coating blends nicely with the concrete substructure and surrounding environment, and will protect the structure from unappealing rust stains.

With the alternative power market expanding steadily, this project has helped to designate hot-dip galvanizing as a natural choice to complement environmentally conscious projects.

South San Joaquin Irrigation Distribution Solar Farm

Oakdale, California

The South San Joaquin Solar Farm, one of the largest solar projects in the United States, is a 1.9 megawatt single-axis solar tracking system constructed to provide electricity to the De Groot Water Treatment Plant. In this forward-thinking, environmentally friendly project, 11,040 solar modules produce 3.7 million kilowatt hours of electricity annually - enough to power 550 homes and offset nearly 4 million pounds of carbon dioxide emissions per year.

Also decreasing the solar farm's carbon footprint, the galvanized steel utilized in the structure for corrosion protection will require little or no maintenance for 50 years or more. Unlike other corrosion protection systems that require regular maintenance, galvanized steel does not waste energy, chemicals, or manpower to protect steel from corrosion. Instead, the properties found naturally in zinc work to protect steel cathodically, while barrier protection created during the galvanizing process adds an extra level of protection.

Nearly 9,000 pieces were galvanized on this project. This solar farm will transform San Joaquin into one of the "greenest" spots in California and will nearly wipe out the entire $500,000 annual electricity bill the Irrigation Department pays to run their plant. As the need to go green continues, the need for hot-dip galvanizing on solar projects will undoubtedly continue to increase as well.

Galvanized steel, in addition to saving the expense of corrosion maintenance and repair, is also recyclable - making it an environmentally friendly choice that easily integrates with the intentions of the Solar Farm.

One of the largest solar projects in America, the South San Joaquin Irrigation Distribution Solar Farm in California produces 3.7 million kilowatt hours of electricity per year for the De Groot Water Treatment Plant.

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