Galvanized Steel
Empowering Renewable Energy Sustainability

Zachery S. Campbell, EIT
The Citadel – Military College of South Carolina

INTRODUCTION

The cornerstone of renewable energy is the ability to build and maintain the structure throughout the expected life of the facility. To ensure that the structure, or facility, remains at peak performance it must be designed and constructed with materials that are readily available and resist degradation from the elements. One of the most used and recycled construction materials on the planet is structural steel. It is recyclable over multiple uses, has high tensile and compressive strength to weight ratios, and provides easy installation and maintenance to the structure. However, steel that is left exposed to the elements has a tendency to oxidize which drastically reduces its serviceability and threatens the safety and performance of the structure. Hot-dip galvanizing of steel provides a corrosion resistant barrier that is cost-efficient, fully recyclable, and requires little to no maintenance over the life of the structure. This is a very important factor when considering that the intent of renewable energy is to reduce the amount of waste and pollutants that are emitted as a biproduct of energy production. This includes the production and fabrication of the materials utilized in its construction. Hot-dip galvanized steel is the most important structural component in ensuring that renewable energy platforms remain green by reducing waste, yielding exemplary corrosion resistance, and providing performance-based solutions to the ever-evolving industry of renewable energy.

RECYCLING STATISTICS

In 2022, the United States recycled 56.6 million tons of steel and produced 80.5 million tons of new steel, according to the Bureau of International Recycling [1]. Of the world's steel production nearly 40% is produced using recycled scrap steel [1]. **Table 1** shows the statical reduction in waste and required materials for recycled steel when compared to crude steel production.

Table 1: Consumption of Raw Materials and Energy Reduction from the Use of Steel Scrap [1].

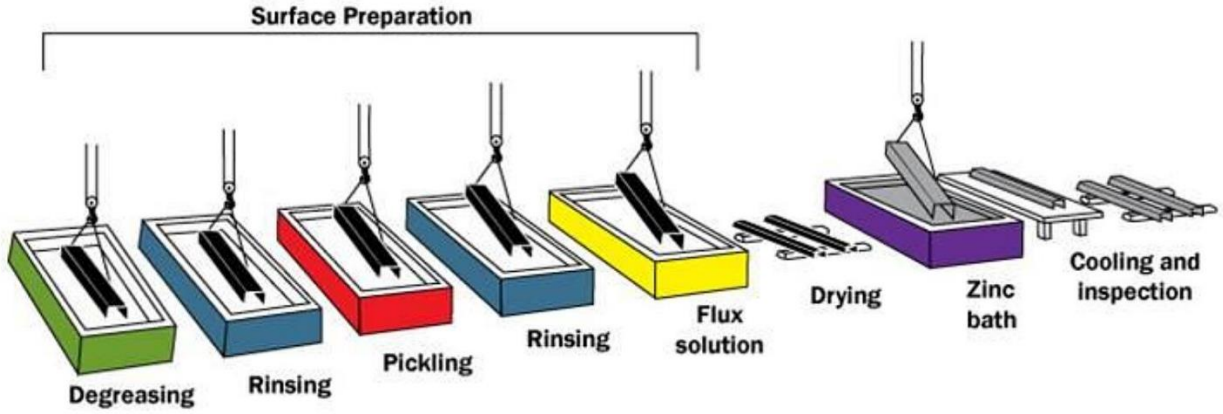
Raw Material	Percent Reduction	Reduction per Metric Ton of Steel
Energy	74%	642 kWh
Virgin Materials	90%	1100 kg iron ore 630 kg coal 55 kg limestone
Water	40%	
Air Pollutants	86%	
Mining Waste	97%	

Approximately 80% of the world's zinc is recycled, of which 30% accounts for the global zinc production [2]. Materials recycling is one of the greatest contributions to reducing the global dependance on mining and non-renewable forms of production. Zinc is considered 100% recyclable without loss in material properties, most importantly its ability to resist corrosion [3]. The global recovery of zinc amounts to approximately 2.9 million metric tons, 1.5 million from residual production and 1.4 million from scrap materials [2]. The recycling process considerably reduces the carbon footprint of materials production and the requirement for new materials to meet the growing needs of the world's infrastructure development.

GALVANIZED STEEL

The galvanizing of steel is the process of coating the steel component with a layer of zinc. As with all things, it's not as simple as merely submerging the steel in molten zinc and hoping that it adheres to the surface. The surface must be meticulously cleaned and prepared in order for the zinc to adhere and create a strong and durable bond with the steel component. These characteristics of galvanization are directly responsible for the corrosion resistance and longevity that this process provides. The steel goes through a series of surface preparation stages to remove any dirty, grease, oil, paint, and oxidization or mill scale from the steel before the flux and zinc can be administered. The stages of hot-dip galvanization are degreasing, pickling, fluxing, and galvanizing. **Figure 1** shows the stages of this process.

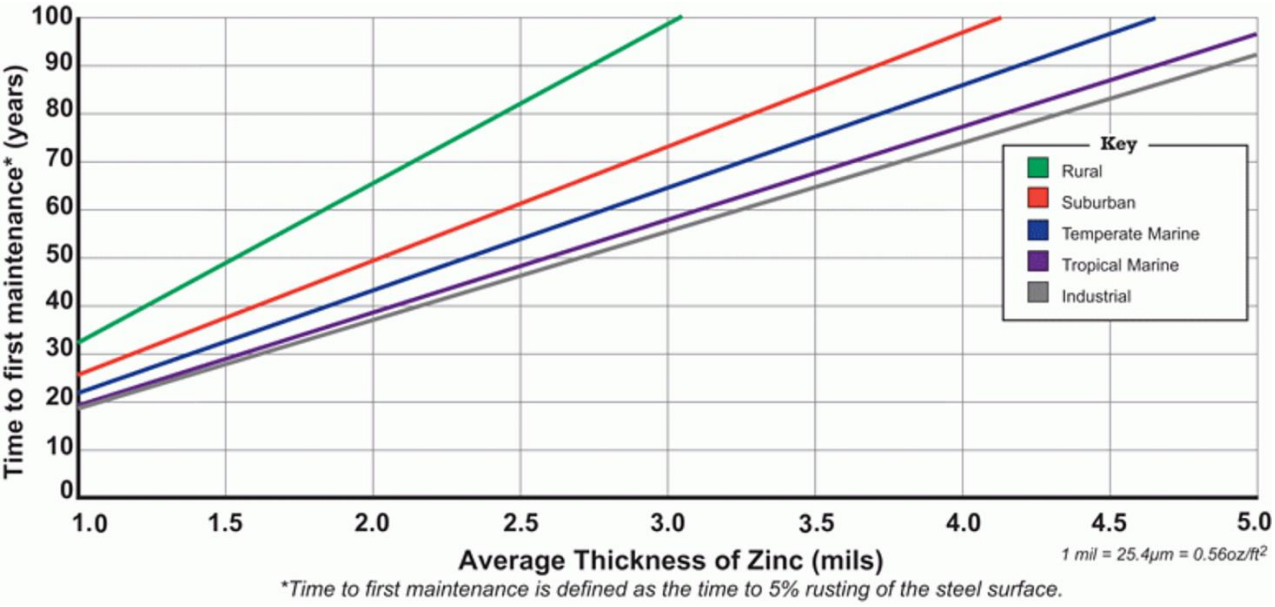
Figure 1: Surface Preparation and hot-Dip Galvanizing Process. [3]



With steel being the premier choice of construction materials, it is paramount that it is treated to protect against corrosion and oxidation. Of the total zinc production globally, more than 60% is used specifically to protect steel from the elements [4]. The function of this coating is to increase the lifespan of steel components by creating a sacrificial layer that is resistant to corrosion and creates a barrier between the steel and environmental factors. The individual degradation rate of

the zinc coating is correlated to the location of the steel application and the average thickness of the coating that is applied. Hot-dip galvanized steel can last between 20 and 100 years before requiring maintenance. **Figure 2** shows the expected time to first maintenance versus the average thickness of the zinc coating. Rural applications of galvanized steel have the longest expected time to first maintenance based on thickness while industrial applications assume the quickest time to first maintenance.

Figure 2: Time to First Maintenance vs. Average Thickness of Zinc with Respect to the Location of Application [5]



The minimum coating specifications are dictated by ASTM 123 to conform to the requirements of steel shape and thickness. Further specifications covering the coating requirements of hardware and castings can be found in ASTM A153. Galvanized steel has been researched for applications in reinforced concrete and assessed based on the bonding strength between the steel and its zinc coating, as well as the coating and the concrete matrix. Hot-dip galvanized steel is 2 to 4 times more resistant to chloride ions that would otherwise corrode the reinforcing carbon

steel [6]. There is strong evidence showing that galvanized steel is not only comparable to other protective coating but may be superior at its full 28 day curing period [6]. The specifications for galvanized reinforcing steel can be found in ASTM A767 and ASTM A1094. Further specifications may be found in American Galvanizers Association Suggested Specifications for Hot-Dip Galvanizing [7].

RENEWABLE ENERGY

The global dependance on energy is not going anywhere anytime soon. As such, the demand will continue to increase and so must the advances in renewable energy and the capacity to which it can reduce the use of fossil fuels or other non-renewable resources. In 2018, the United States used approximately 29.7 terawatt hours (1 TWh = $1x10^9$ kWh) of energy [8]. To put this into perspective, the average American household uses 10.5 thousand kWh per year, nearly 0.000035% of the total use [8]. The global investment into renewable energy sources amounted to 289 billion USD in 2018 [9]. Of the 289 billion invested globally, the United States invested 48.5 billion USD in renewable energy infrastructure during the same period, 24.6 billion of which was put into wind power alone [9]. Furthermore, the increase in the United States contribution to renewable energy resulted in the creation of 855 thousand new jobs across the energy sector [9]. The result of these contributions yielded a 267.2-gigawatt (GW) capacity, that could be utilized at a given time from renewable energy sources [9]. **Table 2** shows a comprehensive breakdown of the energy contributions by source. Biofuels production was not included in the final number due to their function being both used in energy production and use in combustion engine applications. For clarification, solar PV refers to solar photovoltaic (PV) panels and CSP is concentrating solar thermal power.

Table 2: United States Renewable Energy Production- 2018 (GW, unless specified otherwise) [9]

Energy Type	Total
Biofuels	38.4 Billion Liters
Geothermal	2.54
Hydropower	80
Solar PV	62.4
CSP	1.74
Solar Water Heating	24
Wind	96.5
Total [e]	267.2

[e] Excluding Production of Biofuels

RENEWABLE ENERGY APPLICATIONS

As discussed previously, galvanized steel is at the forefront of effective, economic, and ethical construction of renewable energy facilities. It has applications in solar energy, hydroelectric facilities, wind energy, and a number of emerging technologies such as marine hydrokinetic electricity. The United States has invested large contributions into the advancement of its renewable energy resources. The top three sources of renewable energy in the United States are hydroelectric, solar, and wind. Galvanized steel is most often utilized as a structural component, accessory access supports, and in nearly all exposed steel construction of these facilities.

HYDROELECTRIC

Hydroelectric dams utilize the flow of water to turn turbines and generate electricity. They accomplish this by channeling the water through a series of pipes into the turbine which rotates due to the hydraulic force of the water. In the construction of hydroelectric facilities, galvanized steel is utilized to protect the channeling pipes from corrosion. The pipes would otherwise be susceptible to oxidation from the constant moisture contact. Since these are such a critical part of the hydroelectric facilities operation, it is necessary to ensure that the steel is protected. The use

of galvanized steel in this application allows the pipe to be coated inside and out to ensure it withstands the elements. Hydroelectric plants account for nearly 7% of the United States' power needs and over 20% of the global requirement [10]. One such facility that has benefitted from the use of galvanized steel is the Keeyask Hydroelectric Generation Station located in Keeyask, MB Canada. The station boasts 16 miles of dam structure, containing 400 thousand square miles of drainage basin, and producing 695 megawatts (1 MW = 1000 kW) [11]. An overview of the completed project can be seen in **APPENDIX A**, Photo 1.

SOLAR ENERGY

Solar energy utilizes the energy of the sun to create electricity. This is accomplished through a variety of methods, mostly commonly this is done through solar photovoltaic (PV) panels and concentrating solar thermal power (CSP). Solar PV is without a doubt the most common and widely recognized forms of solar energy harvesting. The use of solar panels to collect sun and transfer the heat energy into electrical energy is shown in the form of large solar farms. One such farm is the Mugga Lane Solar Park seen in Canberra, Australia. The farm produces 24.5 thousand MWh of energy from more than 53 thousand solar modules for over 3000 homes [12]. The solar panels are constantly exposed to a number of environmental factors from the extreme Australian climate. The panels are constructed using a fixed two-post system to support two solar modules per structure [13]. The panel supports utilize hot-dip galvanized posts, which were pre-cut and dipped to allow for expedient and efficient assembly [13]. See **APPENDIX A**, Photo 2, for an overview of the completed facility.

WIND ENERGY

Wind energy relies on the force of wind acting against a set of blades to rotate the internal turbine of the system. As mentioned before, the United States invested more than 24.6 billion USD into the construction of wind powered energy solutions. Wind farms are incredibly diverse and can be utilized both on land and offshore. As with solar energy, wind energy solutions are under constant attack from the elements and with an average height between 100 and 300-feet it is even more important to ensure that they remain functional without having to worry about the structural steel being corroded. In Shenandoah, Pennsylvania one such wind turbine was constructed using nearly 30 tons of galvanized steel, the majority of which went into the housing at the top of the structural mast [13]. The Locust Ridge Wind Farm produces 128 MW of electricity for over 64 thousand homes [14]. This particular farm is home to 64 wind turbines stretched across the Locust Mountain ridge line [14]. **APPENDIX A**, Photo 3, shows the overview of the Locust Mountain ridge strewn with wind turbines.

CONCLUSSION

Galvanized steel is an invaluable resource in the ever-growing industry of renewable energy. Its ability to bond with steel creates an extremely reliable, long-lasting, and efficient layer of protection against the unwavering elements. As renewable energy continues to grow so will the need for galvanized steel, further providing energy for the world and jobs across all spectrums of the industry. There are few industries that can boast such a wide and impactful influence as the galvanizing industry.

REFERENCES:

[1] Bureau of International Recycling, "Bir," www.bir.org, https://www.bir.org/component/flexicontent/download/996/175/36 (accessed Mar. 2024).

[2] Bureau of International Recycling, "Non-Ferrous Materials," BIR, https://archive.bir.org/industry/non-ferrous-metals/ (accessed Mar. 2024).

[3] American Galvanizers Association, "Hot-Dip Galvanized Renewable Energy," *American Galvanizers Association*. 2016

[4] S. Grund, E. Genderen, and M. Leeuwen, "Advances in the circular economy," *Resources, Conservation and Recycling*, vol. 141, pp. 499–500, Feb. 2019. doi:10.1016/j.resconrec.2018.05.013

[5] Daniel Barlow, "Estimating the life of hot-dip galvanized coatings," American Galvanizers Association, https://galvanizeit.org/knowledgebase/article/estimating-the-life-of-hot-dip-galvanized-coatings (accessed Mar. 2024).

[6] P. Pokorný, P. Tej, and M. Kouřil, "Evaluation of the impact of corrosion of hot-dip galvanized reinforcement on bond strength with concrete – a review," *Construction and Building Materials*, vol. 132, pp. 271–289, Feb. 2017. doi:10.1016/j.conbuildmat.2016.11.096

[7] American Galvanizers Association, "Specifications for Hot-Dip Galvanizing", 2022 [Revised Dec. 2022]

[8] A. Mcfarland, "In 2018, the United States consumed more energy than ever before - U.S. energy information administration (EIA)," In 2018, the United States consumed more energy than ever before - U.S. Energy Information Administration (EIA), https://www.eia.gov/todayinenergy/detail.php?id=39092 (accessed Mar. 2024).

[9] REN21, Renewables 2019 Global Status Report, (Paris: REN21 Secretariat), 2019, ISBN 978-3-9818911-7-1

[10] "Hydro-Electricity," American Galvanizers Association, https://galvanizeit.org/hdg-in-use/electrical-utility-and-communication/renewable-energey/hydro-electricity (accessed Mar. 2024).

[11] "Keeyask Hydroelectric Generating Station," American Galvanizers Association, https://galvanizeit.org/project-gallery/keeyask-hydroelectric-generating-station?sector=electrical-utility-communication (accessed Mar. 2024).

[12] "13MW utility-scale solar PV project," Mugga Lane Solar Park, https://mlsolarpark.com.au/ (accessed Mar. 2024).

[13] F. E. Goodwin, “Hot Dip Galvanizing in Renewable Energy Applications,” Research Gate, https://www.researchgate.net/publication/344825965_Hot_Dip_Galvanizing_in_Renewable_Energy_Applications (accessed Mar. 2024).

[14] Centralia PA, “Centralia Pa Windmills: Locust ridge wind farm,” Centralia PA, https://www.centraliapa.org/centralia-windmills-locus-ridge-wind-farm/#:~:text=Completed%20in%202009%20and%20built%20by%20Iberdrola%20Renewables%2C,is%20easily%20visible%20from%20Centralia%20when%20looking%20east. (accessed Mar. 2024).

APPENDIX A- PHOTOS

Photo 1: Keeyask Hydroelectric Generating Station

Photo Courtesy of American Galvanizers Association

Photo 2: Mugga Lane Solar Park Canberra, Au

Photo Courtesy of Mark Jekabsons

Photo 3: Locust Wind Farms Centralia, Pennsylvania

Photo Courtesy of Centraliapa.org