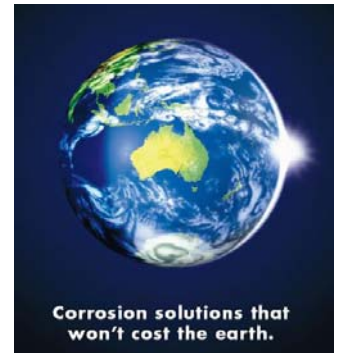


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HDG and Zinc Rich Coatings – A Sustainability Perspective

“Good design and construction can minimise the environmental impact of buildings and consumer products. By using **sustainability** principles **fewer natural resources** and **less energy** are used during manufacture and use. This leads to buildings and products that are **commercially viable** as well as **energy** and **resource efficient**.” - Institute for Sustainable Futures.ⁱ



Cost of Corrosion

The annual **cost of corrosion** in Australia is generally accepted to be between **two and five percent of Australia's GDP**ⁱⁱ (Australia's GDP in 2005-2006 was around \$923 billion)ⁱⁱⁱ. According to the Australian Corrosion Association, that cost was estimated to be \$28 billion in 2006^{iv}. This is largely due to the fact that most of our large cities are located along the Australian coastline^v.

Therefore, from both a fiscally and environmentally responsible point of view, it is fair to say that **corrosion protection in this country is severely inadequate**, and within the scope of ESD (ecologically sustainable development) presents a **huge opportunity for improvement**.

Steel is an **ecologically responsible** choice of building material because it is lighter and stronger than concrete, is faster to build with, and it is easier to recycle at the end of its life^{vi}

Corrosion can be effectively controlled for generations by the **correct specification** and appropriate maintenance scheduling using Dulux Protective Coatings.

Project Design Life – Optimum Performance

From both a **capital investment** and a **sustainable** point of view, the design life of today's structures should be designed to last significantly longer than they have been in the past. There is absolutely no reason Australian buildings cannot have **longevity designed into the structure** to span many generations. Whilst considering recycle potential of building materials is a noble idea, the focus of **sustainable building design** should be on **long-term solutions** offering **sustained ecological benefits**.



What Is The Most Effective Corrosion Protection?

Galvanic Corrosion Protection

When in contact with steel, zinc corrodes preferentially, effectively protecting the steel from corrosion until the zinc has been depleted. This process is known as **galvanic corrosion protection**.

In commercial construction, galvanic corrosion protection in Australia is generally offered by the following methods:

- Hot dip Galvanising (HDG)
- Electroplating
- Inorganic Zinc Silicates (IOZ)
- Organic Zinc-Rich Primers
- Hot Metal Spray

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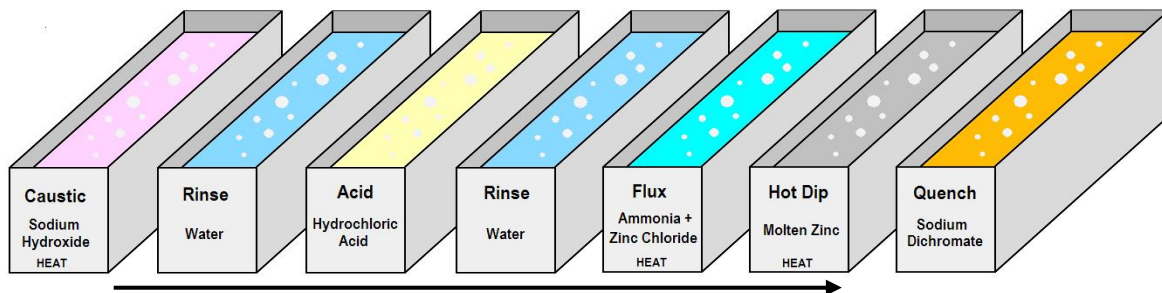
Hot Dip Galvanising (HDG)

What Does The HDG Process Involve?

HDG is a **6 – 7 stage** process, much of which involves many hazardous chemicals.

Surface Preparation of the steelwork prior to HDG involves degreasing the steel in a hot, **caustic** solution, rinsing, pickling in concentrated hydrochloric or sulphuric **acid**, rinsing again and fluxing in a bath of zinc ammonium chloride and ammonia solution.

The galvanising stage uses a bath of **molten zinc metal** dosed with **lead^{ix}** that must be held at **435 - 455°C**, presenting **high** and **prolonged energy inputs**. The final quenching stage involves **chromate quenching** to produce a conversion coating consisting of trivalent and hexavalent chromium compounds in order to prevent wet storage stain.^x



Is Hot Dip Galvanising A Sustainable Process?

Durability

The galvanising industry will frequently quote an extremely long service life for galvanised steelwork “without maintenance in most urban and rural atmospheres”, yet, as mentioned above, most of Australia’s construction occurs along its coastline.

HDG’s ability to protect steel is **proportional** to the **thickness of the zinc layer**, and premature corrosion of HDG steel is often blamed on **insufficient zinc** having been applied to the surface.^{xi}

On a galvanised surface, the zinc layer is **sacrificial**; the zinc metal corrodes to a white chalky substance until conversion is complete. This process is rapid in areas anywhere near the coast. The unprotected steel then begins to red rust, and at this point requires much maintenance work to remove corrosion products and somehow reinstate the galvanising layer. This is not consistent with the concept of sustainability. [The sacrificial process of HDG should be compared with the mechanism by which inorganic zinc silicate (IOZ) corrosion occurs. See relevant section below.]



White rusting of heavy duty galvanised steel and red rusting where thin galvanised steel had been used in a new swimming pool complex. Extensive rectification work delayed the opening of the pool and blew out project costs.

According to NACE International (National Association of Corrosion Engineers) “Most **galvanized** structures **exposed to marine environments** worldwide show evident signs of **deterioration**, particularly in tropical climates. This happens **shortly after erection**, especially with those exposed to erosive environments because of the high wind speeds in those areas.”^{xii}

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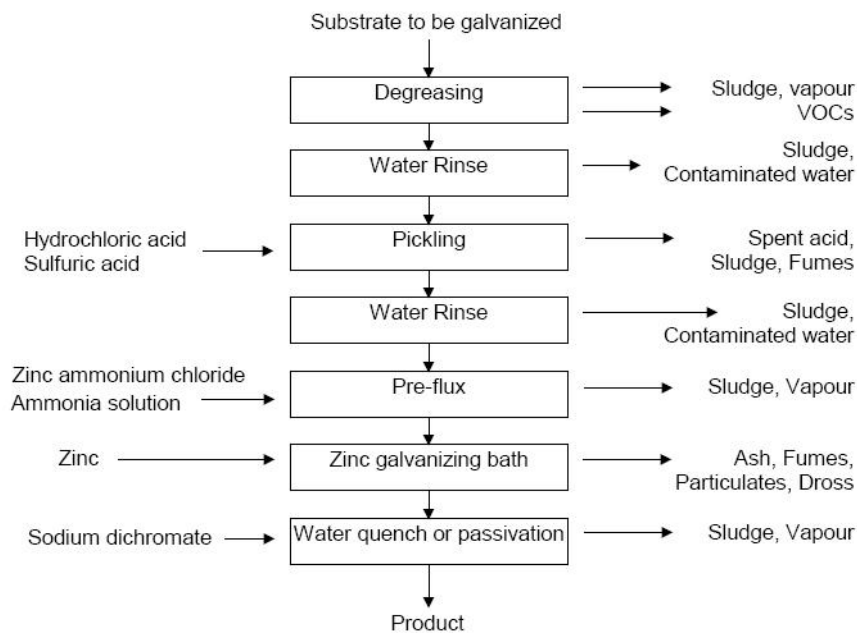
Process Wastage

The Industrial Galvanizers Association lists **five types** of **zinc waste product** from the HDG process:

1. Zinc ash (oxidized) zinc from the zinc bath's surface;
2. Zinc dross (zinc/iron alloy \approx 95% zinc/5% iron) that collects on the bottom of the zinc bath;
3. Zinc fumes (low levels of zinc fumes generated as the steel enters the molten zinc);
4. Spent acid (containing zinc and iron chloride in solution);
5. Waste waters (containing low levels of zinc or iron or both).

Over 50% of the world's production of zinc waste from HDG is recovered and reprocessed for use by the **zinc-rich coatings industry**.^{xiii} The zinc-rich coatings industry's ability to use reclaimed zinc from the galvanizing process assists in reducing the **burden** of disposing of zinc waste material.

According to the Australian Government Department of the Environment and Water Resources, "**Disposal** of the **waste fluid** generated by the overflow rinse tank - consisting of **iron chloride, zinc chloride** and unused **hydrochloric acid** - is **the major environmental challenge** facing the galvanising industry worldwide."^{xiv}



The Basic Galvanizing Process Steps and Likely Emission Points

Source: Emission Estimation Technique Manual for Galvanizing V1.1 by Environment Australia

For example, a galvanizing company in a South Australian case study was quoted as producing **10-12 tonnes of contaminated acid waste per week** until recommendations put forward by the SA EPA were implemented, resulting in a reduction of waste by 4.5% of the weight of zinc used^{xv}.

The EPA (Australia) quantifies in its "Cleaner Production Case Study – Hot Dip Galvanising" 2002 that the percentage of zinc waste in the HDG process is around 30 – 37%; **zinc ash** (20-25% of total zinc) and **zinc dross** (10-12% of total zinc)^{xvi}.

Emissions

Gases, metal vapours and contaminated acid and alkali solutions are **significant sources** of **toxic industrial pollution**.

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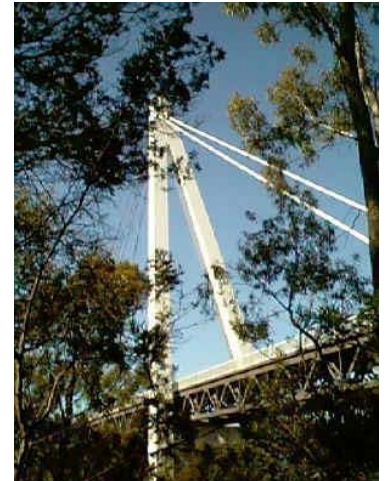
In the Environment Australia handbook entitled "Emission Estimation Technique Manual for Galvanizing", **hydrochloric acid** (HCl) and **sulphuric acid** (H₂SO₄) fumes may be emitted from baths, while **ammonia** and **ammonium chloride** emissions to atmosphere occur from pre-flux, and during the galvanizing bath stage. **Zinc** and **PM10** emissions (particulate matter with an equivalent aerodynamic diameter of 10µ or less) may result from hot dip metal coating activities.^{xvii}

Inorganic Zinc Silicates - Effective Alternatives to HDG

Galvanic corrosion protection can actually be achieved **more effectively** using **inorganic zinc silicates** and at a **lower environmental impact**.

These long-life, high performance coatings contain **metallic zinc particles** encased in an inert, glasslike, **inorganic silicate matrix**. The zinc particles are in intimate contact with the steel and thus provide excellent **galvanic corrosion protection**. Over time, voids in the applied film are filled by zinc corrosion products, which effectively control the zinc's depletion rate. Thus, what effectively starts off as sacrificial corrosion protection becomes more barrier-like with the formation of relatively inert zinc corrosion products. It is for this reason that the IOZ is able to outperform HDG in marine and other severe environments.^{xviii} Better still, **both performance and aesthetics** of IOZ can be greatly enhanced by the application of a wide variety of protective and decorative finishes (Duplex systems) **without the inherent failure mechanisms** associated with HDG. (See below regarding "Duplex Systems".)

According to a paper on NASA's choice of corrosion protection, **inorganic zinc silicate technology** had been selected for its **superior corrosion-resistance** to all other alternatives for the space shuttle.^{xix} Inorganic zinc silicate primers also protect the Statue of Liberty and the Golden Gate Bridge. Here, IOZ protects the NewGen Power Station in Kwinana WA, Tallawarra Power Station in NSW, the Tonkin Highway Bridge WA, Cairns International Airport NT, Batman Bridge Tasmania, Spirit of Tasmania loading ramps, and the Westgate Bridge, Federation Square and The Age Printing Facility in Victoria (to name a few).



Tasmania's Batman Bridge spans the Tamar River. It won the Engineering Excellence Award in 1968. 75 microns of waterborne IOZ protected the structure without topcoat for 20 years. Only the A-frame was topcoated and was maintenance-free for 30 years.

Current Products

Dulux Protective Coatings currently manufactures three inorganic zinc silicates:

- **ZINCANODE[®] 304**
- **ZINCGALV[®] 75**
- **AQUAGALV[®]**

AQUAGALV[®] is a **second-generation water-borne** inorganic zinc silicate, and has a **total VOC content** less than **10 grams per litre**, making it most suitable for "Green Buildings" for both interior and exterior steelwork.

What Does The IOZ Process Involve?

Application of an inorganic zinc silicate primer is a simple, **four-step process**. It involves some energy inputs and results in material wastage, however, we believe that these compare favourably to the HDG process from an ESD point of view. The steel is put through the following stages:

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1. **Spot degrease** (AS1627.1) to remove oily deposits (eg. where drilling or cutting fluids have been used) with a free-rinsing, **biodegradable, alkaline detergent**.
2. **Rinse** with fresh potable water to ensure that all soluble salts are removed (AS 3894.6, A&D)
3. **Abrasive blast clean** (AS1627.4 to achieve a Class 2½ “Near White Metal” blast cleanliness, to replicate visual standard Sa 2½ in AS1627.9, and to generate an angular surface profile of 30 to 60 microns)
4. **Spray application of inorganic zinc silicate primer** according to data sheet (AS4848.1)

Surface preparation of steelwork prior to the application of inorganic zinc silicate requires **no corrosive alkalis** or **acids** or **conversion baths**. **Thermal energy input** is limited to running the **abrasive blast-cleaning unit, spray equipment** and, if used, high-pressure water blasters for the rinsing stage.

Is Using An Inorganic Zinc Silicate A Sustainable Process?

Durability

Inorganic zinc silicate coatings provide very long term corrosion protection, even in **coastal** and **marine** environments, according to the Australian Standard, 2312, “Guide to the Protection of Structural Steel Against Atmospheric Corrosion By The Use Of Protective Coatings”.

Bare (uncoated) IOZ has proven to be equivalent to HDG in rural environments, and **superior to HDG** in **coastal environments**.^{xx} When used properly in a duplex system, IOZ will reliably perform for extended periods of time, whereas the equivalent HDG duplex system may be unreliable and frequently end in delamination.

Process Wastage

The water used in rinsing off detergent contains mainly biodegradable detergent residues and emulsified oily contaminants.

Spent abrasive grit can be reclaimed and reused.

Wastage that occurs from **coating application** is from **overspray** and from **left-over mixed material in containers, spray equipment** and **hoses**. The relative volume of material waste can vary widely, depending on materials estimation accuracy, application technique, applicator care and other factors.

Leftover mixed material is allowed to harden and the resultant non-toxic hard waste is safe to dispose of in non-hazardous industrial hard-rubbish collections.

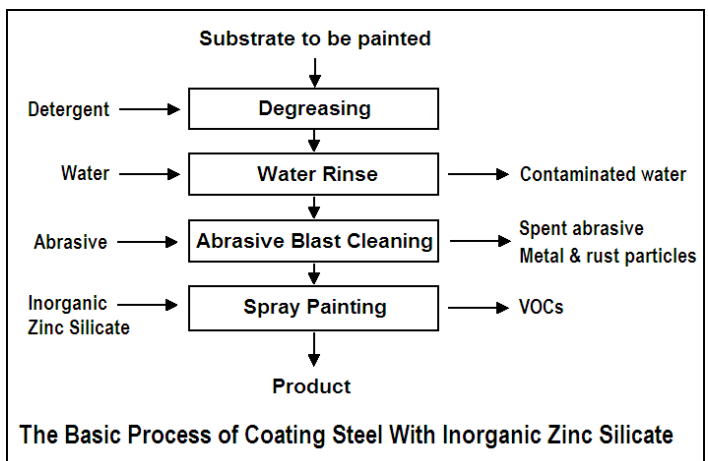
Residual material in spray equipment and hoses

are washed out with **solvents** (or **water** in the case of **AQUAGALV®**) In current industry practice, washout solvent is generally allowed to evaporate into the atmosphere, where it can contribute to the greenhouse effect.

Potentially, **solvents** could be distilled off to leave **no liquid waste** at all, only hard, non-hazardous waste. The recovered solvent could be **reused** for subsequent washing out hoses and spray equipment. Alternatively, industry may instead choose to embrace waterborne IOZ such as **AQUAGALV®**.

Emissions

The primary pollutant from the abrasive blast cleaning process is particulate matter (PM). Different blast media produce different levels of PM; choice of blast medium can reduce PM by 90%. Some blast media can be recovered and reused.



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Particulate matter from materials containing greater than 2% crystalline silica can cause silicosis (a stiffening and scarring of the lungs) and therefore has been banned.

The most commonly used blast media are steel grit and garnet. Neither produces silicosis-related dust. Steel grit is recyclable.

In open-blast operations, garnet is the abrasive medium of choice.

Inhalation of PM can be prevented by the use of dust extraction units and regulation face-masks fitted with dust filters.

ZINCANODE® 304 and **ZINGALV® 75**, being solvent-borne, **release VOC into the atmosphere** during application and drying.

AQUAGALV®, being water-borne and very low VOC, releases **negligible** amounts of VOC into the atmosphere, far below current emission guidelines issued by the Australian Paint Approval Scheme^{xxi} and other industry bodies.

Inorganic zinc silicates do not release any other type of emission into the atmosphere.

Zinc Rich Epoxy Primers

Organic zinc-rich primers contain **metallic zinc particles** encapsulated in epoxy resin. They are used as primers in multi-coat systems, providing outstanding protection that is **equivalent** to that given by **duplex IOZ systems** to steel surfaces in a wide range of environments.

The cost-effectiveness, ease of application, effectiveness as a barrier to salts, water and oxygen and high bond strength to blast cleaned steel of **organic zinc-rich primers** makes them **excellent choices** in corrosion protection, and when considering the overall advantages in comparison to HDG, certainly make them an attractive alternative.

Process, durability, wastage and emissions of organic zinc-rich primers are the same as for solvent-borne IOZS coatings.

Can “Duplex Systems” Extend The Life Of Galvanising?

The American Galvanizers Association states that when paint and HDG steel are used together, the corrosion control is superior to either individual method as the paint gives **additional barrier protection** to the galvanized coating by isolating it from the **corrosive attack of chlorides and sulphides** in the atmosphere.^{xxii} The AGA claims that it is typical for a duplex system to provide corrosion protection 1.5 to 2.5 times longer than the sum of the lifetimes of zinc and paint used individually, which equates to maintenance-free steel for 75 to 100 years “in most instances”.

However, efforts by **specifiers in Australia** to prolong the life of HDG steel in coastal developments by protecting the HDG steel with a protective coating (duplex system) **often ends in the coating delaminating from the zinc**. According to Thomas J. Langill of the American Galvanizers Association, when discussing the application of a paint system to a HDG steel surface, careful surface preparation is required; “...The margin for error is very small when dealing with newly galvanized steel surface preparation. However, there have been many examples of paint adhesion problems on older or more moderately aged galvanized steel surfaces, and the most common cause is improper or incomplete surface cleaning and preparation.”^{xxiii} Furthermore, Langill states in the same article that the usual chromate treatments and water quenching must be avoided if the HDG steel is to be painted, as these can also interfere with coating adhesion.



HDG steelwork near a beach was erected less than six years ago. Some sections were coated with an MIO product, which has inhibited corrosion.

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The zinc layer is **more chemically reactive** than the steel it is protecting^{xxiv}, and rapidly forms **zinc corrosion products** on the surface, which occupy a volume **several times** that of the original zinc. If the coating is not tenaciously adhering to a perfectly sound galvanized layer, or the film build is inadequate, or pinholes are present, corrosion products will form and **push the coating off**. Delamination is a well-documented phenomenon^{xxv} and cannot be considered a failure of either the coating or the HDG steel, but rather, an **incompatibility** between the reactive zinc layer and the coating.

Dulux Protective Coatings' view is that HDG is theoretically **another supplier's coating**, and therefore the **same warranty conditions** would apply with regard to coating HDG steel as for coating another supplier's product. Dulux Protective Coatings has a **range of zinc-rich coatings** that are fully **compatible** with its own intermediate and topcoat systems and that **offer superior corrosion protection** to HDG. One such example is **Dulux AQUAGALV**[®]. The service life of **AQUAGALV**[®] over mild steel can be further extended, and the aesthetics improved, by the application of suitable protective and decorative topcoats. Problems **normally associated with painting over galvanising** do not exist when painting over **AQUAGALV**[®], making it a highly successful "duplex" system.

Why Are Applied Zinc Primers Better?

The process of preparing and painting steel still has wastage, emissions and some thermal energy inputs, however, these must be **balanced** against those by **alternative** processes such as HDG.

1. Less Zinc, Less Solid Zinc Wastage For Disposal

Zinc-rich primers require far **less zinc** metal per unit of area than HDG, yet achieve **equivalent corrosion protection**.^{xxvi} The application of zinc-rich primers **does not produce zinc ash or zinc dross**.

Solid wastage that occurs from zinc-rich coating application is non-hazardous hard waste.

Degree of wastage can vary widely, from **size** of job and accuracy of coating **estimation** to **application techniques** and **work practices** of the applicator.

Given that the galvanising process produces enormous quantities of zinc waste as quantified by the EPA and other agencies, and that over 50% of this waste is reclaimed, reprocessed and used in the manufacture of **IOZ** and **organic zinc-rich coatings**, it is reasonable to conclude that **zinc-rich coatings industry** is **reducing zinc waste!**

1. Lower Thermal Energy Demands

Preparation of steel and applying a **zinc-rich coating** is a relatively quick and simple **four-step process**, whereas HDG is a **6-7 step process**. (Please refer above.)

The **thermal energy input** required to carry out the four-step process of preparing and coating a piece of steel is **significantly lower** than the energy input required in the 6 step process of preparing and hot dip galvanising **the same steel**.

Much of the thermal energy required in the HDG process is in the form of **gas** or **electricity** required to heat and maintain the bath of **molten zinc metal**, and, to a much lesser extent, the caustic and flux baths.

3. Less Liquid Wastage for Disposal

Liquid wastage that occurs from **zinc-rich coating** application arises from wash-out of **left-over mixed material** in **spray equipment** and **hoses**, but the **solvents** can be distilled off to leave **no liquid waste** at all. The recovered solvent can be **reused** for washing out hoses and spray equipment.

Washout water after use of **AQUAGALV**[®] can be left to evaporate, leaving solid material.

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4. Limited Emissions Into The Environment

With regard to **solvent borne primers**, the solvent vapours (VOC) are released into the atmosphere, and largely break down to carbon dioxide and contribute somewhat to the Greenhouse effect. High solids/low VOC **organic zinc-rich primers** are therefore better choices from an ESD point of view. The **environmental problems** of VOC emission have to be balanced against the **environmental problems** associated with production of **zinc vapour, heavy metal vapour, chromates, acids** and other wastes generated by the HDG process.

Waterborne inorganic zinc silicates such as **AQUAGALV**[®] offer by far the **lowest emissions** of **all current zinc options**, whilst offering the **greatest corrosion protection**.

Environmental Footprint

When specifying building materials and protective coatings in **our harsh Australian environment**, a serious **environmental footprint** analysis of options ought to be carried out. Building material and protective coating choices should demonstrate **more efficient use** of our finite raw materials, **lower thermal energy inputs** during application, **lower and less hazardous wastage** production and disposal requirements, **less harmful total emissions, lower maintenance** demands and **longer service life**.

Choosing the right **primer (IOZ or organic zinc-rich)**, a **high-performance intermediate** and a **UV resistant topcoat**, together with a regular and disciplined maintenance regime can offer **superior galvanic corrosion protection** with far **less zinc** and **hazardous waste, lower thermal energy** demands both initially and in maintenance and an **aesthetically pleasing** finish for the life of your project.

Using Dulux Protective Coatings can greatly decrease the **environmental impact and costs associated with rectifying inadequately protected steel** and therefore makes great **environmental** and **economical sense**.

Scope For Further Product Development

The HDG process is over a century old, and whilst there have been improvements in efficiency and waste reduction, HDG still requires hazardous chemicals, high thermal energy inputs, disposal of volumes of waste and produces significant emissions. HDG is technically limited in what it can realistically achieve in terms of a more environmentally sustainable product.

Coatings are much more versatile in that R&D can, and are, working towards formulations with **ever-lower levels of VOC**. We already have **solvent-free and water borne technology** available.

Prior to the emergence of **global warming awareness**, many facets of **industry** had been **reluctant to accept waterborne technology** such as **Dulux Zinc Galv 5** – this reluctance stifled water borne coating development. Now it is an imperative that Protective Coatings Chemists and Engineers work together in supporting the development of **water-borne two-pack formulations** with **ever improving performance qualities**, and that industry adapt to, and indeed, embrace these new technologies.

Green Specifications

When it comes to specifying coating systems for projects designed within Green Star guidelines or to minimise environmental impact, call your Dulux Consultant. Many of our Consultants actively and regularly attend ESD conferences, seminars and training sessions, and can help you to specify the most **environmentally responsible** coating systems for your project. For more information, please contact the Dulux Protective Coatings Technical Consultant in your state.



green building council australia
MEMBER

Dulux is a member of the Green Building Council of Australia.

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