GALVANIZING AND SUSTAINABLE CONSTRUCTION

A SPECIFIERS' GUIDE

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TOM WOOLLEY

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He has worked at the Architectural Association, Strathclyde University and Hull School of Architecture. He was editor of the Green Building Handbook and author of Natural Building. He has contributed to many other books and international conferences and is Chairman of the UK Hemp Lime Construction Products Association.

He is a member of the Ministerial Advisory Group for Architecture (Northern Ireland) and a Board member of the Architects Registration Board (UK).

EUROPEAN INITIATIVE FOR GALVANIZING IN SUSTAINABLE CONSTRUCTION

The European general galvanizing industry began its response to the challenge of sustainable construction in 2004 - with the engagement of Professor Fabio Iraldo (Bocconni University, Milan) to research and document the demands of green public procurement and other drivers of the green building agenda on the galvanizing industry. The results of that study resulted in a number of initiatives, many in conjunction with the zinc metal industry, to generate relevant environmental data and explore the use of galvanizing in achieving more sustainable buildings and structures.

This guide draws together the best available information on the contributions of galvanizing to sustainable construction.

That information was compiled by a working group of industry experts from the national associations that comprise the European General Galvanizers Association, under the guidance of Professor Tom Woolley.

We are especially grateful to the following individuals for their contribution to the guide:

Dr Gian Luca Baldo and Stefano Rossi,
Life Cycle Engineering (Turin)

–

Raymond Sempels,
International Zinc Association Europe (Brussels)

–

Michael Sansom,
Steel Construction Institute (UK)

–

Rachel Bevan,
Rachel Bevan Architects (Belfast)

–

Linda Forbes.

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FOREWORD

I am known as a radical advocate of green and natural building because I believe that we should try to ensure that buildings are based on reduced resource consumption, much greater energy efficiency and reduced indoor and external pollution. However, I am not naive enough to think that it is possible to create buildings that do not raise environmental questions. My work on hemp and lime makes it possible to use a renewable crop-based material that actually locks CO_2 up in the building fabric but it still requires the manufacture of lime with quarry extraction and the use of energy to fire kilns. Insulation from sheep's wool or hemp requires the use of chemical flame-retardants, timber has to be cut down from a forest, then processed and transported. Even the greenest of materials has some environmental drawbacks.
Thus, our task is to select materials and products carefully, and ensure that we do everything possible to minimize negative environmental outcomes. Those working in the industry have a moral obligation to take on board these issues and do what they can to improve their performance.

The galvanizing industry can undoubtedly make many improvements, but I welcome their willingness to address the issues and take a hard look at themselves to see whether they can contribute to the sustainability imperative.

Galvanizing has been around since the late 1800s and the industry is fortunate in that there are some inherently sustainable features of galvanizing steel that will be investigated.

Hopefully, this guide will also remind us of the wide range of uses of galvanized steel and how it has contributed to many vital aspects of our daily lives as well as attractive and exciting architecture. Being well informed is an essential aspect of making environmental policy decisions.

Unless the challenge of our global footprint is tackled in a radical way in the very near future, many of these discussions will be academic as it will be too late to put things right. But we have to hope that industry and ordinary people will rise to the challenge.

Tom Woolley
March 2008

THIS GUIDE AIMS TO HELP ARCHITECTS, ENGINEERS AND THEIR CLIENTS CONSIDER HOW TO USE GALVANIZED STEEL IN THE CONTEXT OF SUSTAINABLE CONSTRUCTION.

This is not a marketing or advertising publication, but the result of a study involving a number of independent experts from different parts of Europe and draws on academic and scientific studies on the environmental impact of galvanized products and their alternatives. We have tried to be as frank and open as possible about the issues so that readers can make up their own minds about the information presented here. Our view is that all manufacturers and suppliers of building materials need to provide accurate environmental data.

Ideally this should follow a standard format that allows for fair comparisons to be made between different options. Currently, the construction industry does not follow an agreed system of Environmental Product Declarations based on the same methodologies and, as a result, there is a great deal of confusion about the environmental impacts of different products.

This document discusses the most recent policy initiatives and how these impact on material and product specification.

At a European level there are moves towards greater harmonization and these are also discussed. It is common for manufacturers and suppliers to claim that their products are “sustainable” even though there is no commonly accepted definition of sustainability. The Brundtland definition, however, is frequently quoted:

The Brundtland Report of the World Commission on Environment and Development defines sustainable development as follows: “Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their needs.” (WCED 1987)

This statement is frequently used to support almost any proposition from burying nuclear waste to extracting oil from under the North Pole, and has, therefore, become devalued. However, if interpreted correctly, it provides a very good benchmark from which to judge most human activities. In terms of building construction it implies that we should be extremely careful about using resources which are scarce and cannot be renewed and whatever we do should be able to last a long time or be recycled and used again.
In addition, the use of fossil fuel energy should be minimized and pollution be severely restricted.

There should be no toxic impact on human health and no disruption to ordinary everyday activities of people.

For some, the use of steel and zinc might appear to be difficult to justify if the Brundtland principle is applied rigorously.

However, humanity will not prosper if it simply avoids activity and does nothing. There are massive problems of starvation and poverty throughout the world and infrastructure needs to be improved to prevent such natural disasters as flooding and earthquakes. Sustainable development means dealing with these issues without damaging the planet and selfishly using resources which will not be available to our children or their children.

So challenging are these problems that radical measures are required to deal with them. In rich developed countries, we are complacent and expect to have what we want when we want it. This means that resources are not used sustainably and the West consumes substantially more than its fair share of the world's resources.

Measuring Impacts

One way to measure impacts is using a method called ecological footprinting. This measures how much land and resources are required to sustain a particular activity (http://www.wwf.org) According to WWF's Living Planet Index 2004, a third of the Earth's natural wealth has disappeared since 1972. This includes our wildlife, forests, rivers and seas. Action to stop destruction and to reverse the damage that has been done by mankind is urgently required and cannot be responded to simply by adopting a "business-as-usual" attitude.

Thus, we are required to review every form of human and industrial activity and examine its life cycle impacts and its ecological footprint. This does not mean that we need to go back to living in caves and scraping a living off the land, but it does mean giving up many of the needless and wasteful activities that are part of modern culture.

Activities such as constructing buildings will need to use materials that have a low impact, perhaps using renewable materials that can offset the carbon emissions from the production of other materials. Glass is a good example of a material that is essential to low impact buildings because it allows absorption of solar energy using passive solar design and brings in natural daylight, reducing the amount of energy used on artificial lighting. On the other hand, even though glass is made from a material which is readily available, a great deal of energy is required to manufacture it.

It is virtually impossible to build or renovate buildings without having some impact on the environment. There is much talk about "zero-carbon" buildings, but such buildings still require resources and energy for production. In most cases these resources are non-renewable and thus cannot be replaced. Society must make an informed decision about how such non-renewable resources should be used and increasingly we must become more resource-efficient and responsible about protecting the planet from pollution and waste. As fossil fuel energy becomes scarce and more expensive, we have to find alternatives and use the limited energy to create materials and products that are genuinely sustainable in that they will last a long time serving our needs well into the future.

Use of Steel

Steel is a vital and necessary part of modern construction for both buildings and transport systems. While in some applications, other materials such as concrete and timber can replace the use of steel, it is often the preferred option for a range of reasons. In particular, steel can be recycled and used over and over again and, therefore, the need to use up new materials is reduced. Steel, unfortunately, can corrode in exposed situations and must therefore be protected from the elements either by painting or alloying (eg. stainless steel) or through galvanizing. As long as modern society carries on using steel for buildings and infrastructure, then it must be protected to ensure its durability.

Galvanized steel is so common in our environment that we barely notice it but it is useful to give more information about the nature of galvanizing, how galvanized steel is used and the work that has been done to understand and mitigate its impact on the environment. Just as we inevitably use glass in sustainable buildings, so we will use steel, but its use must be justified in terms of what has been done to reduce any negative impacts on the environment. This involves careful examination of every aspect of steel from the extraction of iron ore, transportation, smelting, processing and recycling.

This guide is concerned with one part of the use of steel, its protection from corrosion through the use of galvanizing. Galvanizing requires the use of another metal, zinc, which also must be mined, processed and transported and we have to explore whether this is the best option from an environmental perspective for protecting steel in exposed situations.

A BRIDGE TOO FAR

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Maosi Bridge over River Po
(for details see page 38)

SECTION
ONE
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TITLE
GALVANIZED STEEL: AN INTRODUCTION
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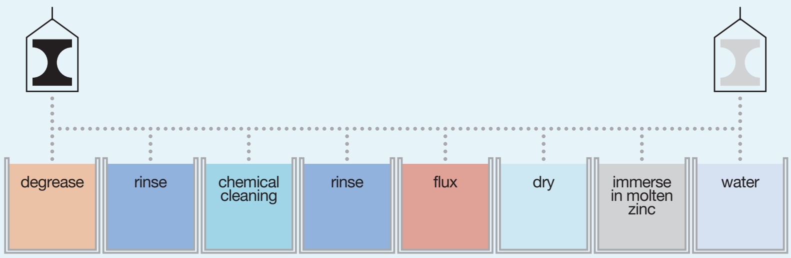
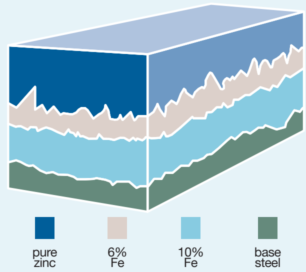


Typical galvanizing process



Schematic section through a typical hot dip galvanized coating.

Galvanized steel is all around us and plays a vital role in our everyday lives. It is used in construction, transport, agriculture, power transmission and everywhere that good corrosion protection and long life are essential. It, for instance, helps light our roads (lighting columns) and provide power for our homes, hospitals and offices (high voltage pylons). There are many other important industries that make use of galvanizing.

A large proportion of galvanized steel in Europe is used in construction. However, it is a very versatile process and articles ranging in size from nuts and bolts to large structural sections can be protected.

Galvanizing is a corrosion protection process for steel, in which the steel is coated with zinc to prevent it from rusting. The process involves dipping cleaned iron or steel components into molten zinc (which is usually around 450°C). A series of zinc-iron alloy layers are formed by a metallurgical reaction between the iron and zinc creating a strong bond between steel and the coating. A typical time of immersion is about four or five minutes, but it can be longer for heavy articles that have high thermal inertia or where the zinc is required to penetrate internal voids. Upon withdrawal from the galvanizing bath, a layer of molten zinc will be deposited on top of the alloy layer. Often this cools to exhibit the bright shiny appearance associated with galvanized products. In reality, there is no demarcation between steel and zinc but a gradual transition through the series of alloy layers which provide the metallurgical bond. Conditions in the galvanizing plant such as temperature, humidity and air quality, do not affect the quality of the galvanized coating.

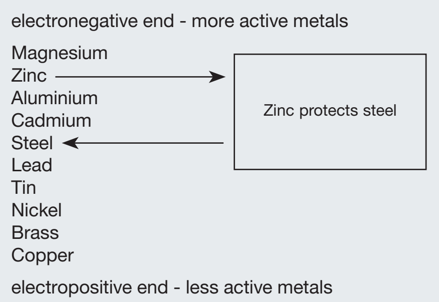
Zinc protects steel
One of zinc's most important characteristics is its ability to protect steel against corrosion. The life and durability of steel are greatly improved when coated with zinc. No other material can provide such efficient and cost-effective protection for steel.

When left unprotected, steel will corrode in almost any exposed environment. Zinc coatings stop corrosion of steel in two ways - a physical barrier and electrochemical protection.

Barrier Protection
Zinc coatings provide a continuous, impervious metallic barrier that does not allow moisture and oxygen to reach the steel. The metallic zinc surface reacts with the atmosphere to form a compact, adherent patina that is insoluble in rainwater. Typical coating thicknesses can range from 45µm to over 200µm.

Research over many years has shown that the life of this barrier protection is proportional to the zinc coating thickness[1]. In other words, doubling the coating thickness will double the life of the coating.

Electrochemical Protection
Zinc also has the ability to galvanically protect steel. When bare steel is exposed to moisture, such as at a cut edge or damaged area, a galvanic cell is formed. The zinc around the point of damage corrodes in preference to the steel and forms corrosion products that precipitate on the steel surface and protect it. There is no sideways corrosion at points of damage.



Zinc's position in the galvanic series

GALVANIZING IS A UNIQUE WAY TO PROTECT STEEL WITH ZINC

Zinc is used extensively in construction for the protection of steel. It is also used as rolled sheets of metallic zinc in roofing and cladding.

The zinc coating described in this guide is:

- **general (batch) galvanizing**
  is the immersion of steel fabrications into a bath of molten zinc to form a thick, metallurgically bonded zinc coating. These coatings are the longest lasting and are most suitable for exterior environments, aggressive conditions and high durability

There are many other ways to apply zinc coatings to steel. It is important to understand the difference between these types – because they have different durability and suitability for specific applications. In construction, the most common metallic zinc coatings are:

- **continuously galvanized steel**
  has a thin zinc coating applied at the steel works to sheet or strips of thin steel. It is then used for products where the steel is bent or shaped after the coating is applied (e.g. cladding, car bodies, washing machines)

- **thermally sprayed zinc coatings**
  are applied when zinc wire or powder is fed into a flame gun to spray molten droplets of zinc onto a steel surface

- **electroplated zinc coatings**
  are thin coatings applied by electrolysis. They have no metallurgical bond between zinc and steel. Normally only suitable for indoor or short-life applications

- **sherardized steel components**
  have a thin coating of iron-zinc alloys that are produced by tumbling small parts in a drum of zinc powder at ~ 380°C




SECTION
TWO
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TITLE
USING GALVANIZED STEEL IN SUSTAINABLE CONSTRUCTION
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Typical values for galvanizing of one kilogramme of steel to EN ISO 1461	
Gross Energy	3.4 – 5.3 MJ
Global Warming Potential	0.1 – 0.33 kg CO_2 equivalent
Based on a review of existing LCA studies. Values exclude steel burdens and recycling credits.	

Attention to durability of steel structures and components has important environmental, economic and social consequences. Some of these are less obvious than others.

The overall economic cost of corrosion has been studied in several countries[2,3]. It is commonly estimated at up to 4% of gross domestic product.

The long-term durability provided by galvanizing is achieved at relatively low environmental burden in terms of energy and other globally relevant impacts, especially when compared to the energy value of the steel it is protecting.

A review of available life cycle studies by Life Cycle Engineering (Torino, Italy) has indicated the typical metrics shown in the above table. The range represents variations in type of steel component, geographical factors and study methodology.

These burdens have been measured on a full life cycle basis, from raw materials extraction to transportation to the customer.

Using this knowledge of the environmental burdens of corrosion protection with galvanizing, it has been possible to compare the consequences of the different choices of corrosion protection systems.

Several studies have demonstrated the high economic and environmental costs associated with the repeated maintenance painting of steel structures[4]. These burdens can be significantly reduced by an initial investment in long-term protection.

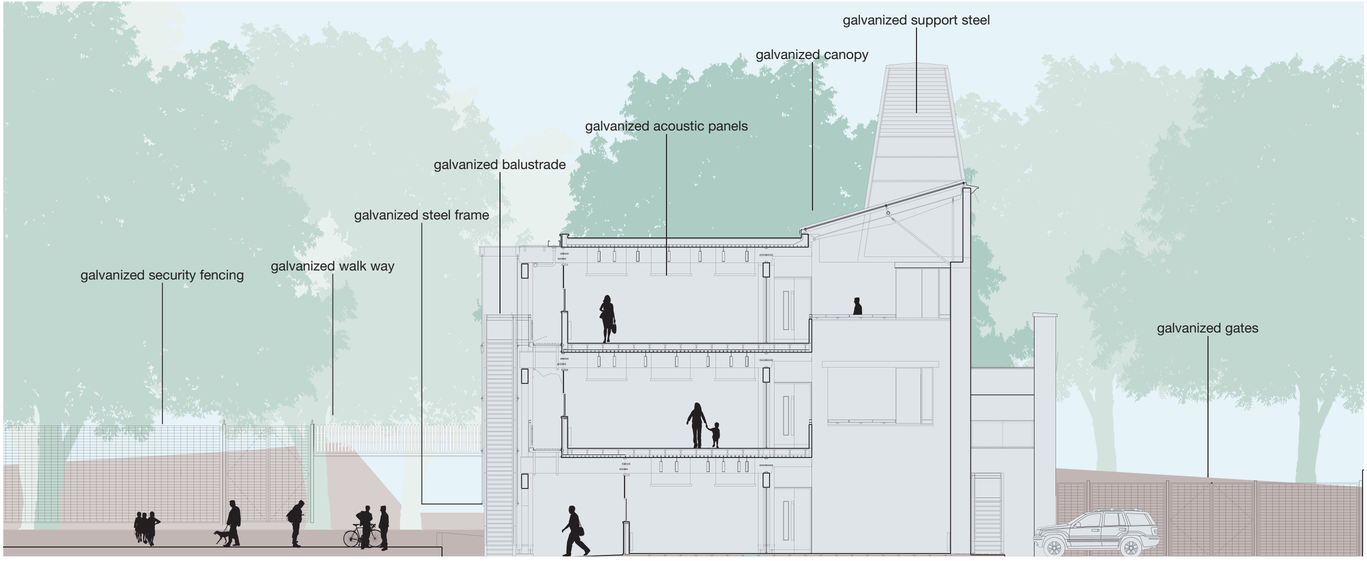
Lack of attention to optimal corrosion protection can leave a damaging economic legacy of repeated maintenance costs. In social housing projects, future maintenance costs will be borne by the local authorities. In public infrastructure projects, use of galvanized steel leads to lower maintenance budgets, releasing public funds for other purposes.

This section shows how galvanized steel can be used to enhance the sustainability of construction products and buildings. More detailed examples and some case studies to illustrate the use of life cycle analysis in evaluating the environmental consequences of different corrosion protection systems are also presented in Section 6.

THE USE OF GALVANIZED STEEL LEADS TO LOWER FINANCIAL AND ENVIRONMENTAL COSTS OF MAINTENANCE.

WALES INSTITUTE FOR SUSTAINABLE EDUCATION
–
Under construction at the Centre for Alternative Technology, Powys, Wales.

ENERGY-EFFICIENT HOUSING
–
Innovative solar-powered housing, Freiburg, Germany



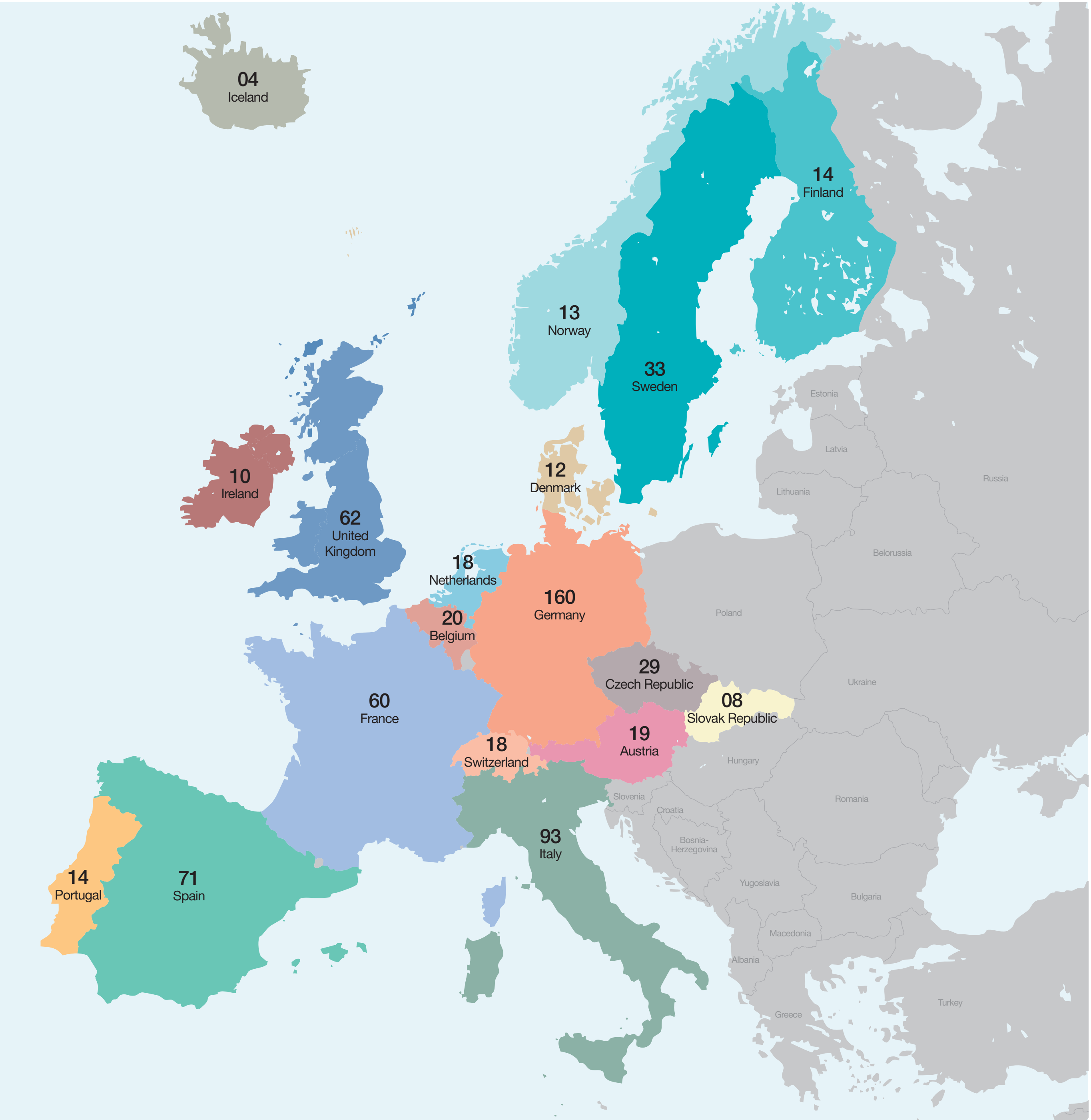
THE WIDE USE OF GALVANIZING

STEEL IS NEVER FAR FROM
A GALVANIZING PLANT

–

There are more than 650 general galvanizing plants in Europe – each making an important contribution to the local manufacturing economy and employment.

Plants are located near to steel fabrication and manufacturing facilities in order to minimise the economic and environmental cost of transport. Smaller customers are normally served by a vehicle service that collects several customers' work on the same transport and returns it in the same way. In many cases, galvanized steel fabrications are delivered directly from the galvanizer to the construction site.



This map shows the number of galvanizing plants in each EGGA affiliated country









ECOBOULEVARD OF VALLECAS, MADRID

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The Eco-boulevard of Vallecas was conceived by Ecosistema Urbano (www.ecosistemaurbano.com) based on three approaches to an existing urban space - the densification of trees, the reduction and asymmetric displacement of the traffic routes and some other superficial interventions which reconfigure the existing situation. Three “air-trees” were installed whilst natural trees are given time to grow. They operate on solar energy and rely on a light weight and flexible galvanized steel structure that can be easily dismantled and re-used elsewhere once the revitalization process of this public space is not needed.

THE EDEN PROJECT

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The Eden Project, a showcase for global bio-diversity, is the largest plant enclosure in the world built with a galvanized steel frame for the lightest and most ecological solution.

SECTION
THREE
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TITLE
ENVIRONMENTAL ASPECTS
OF GALVANIZED STEEL
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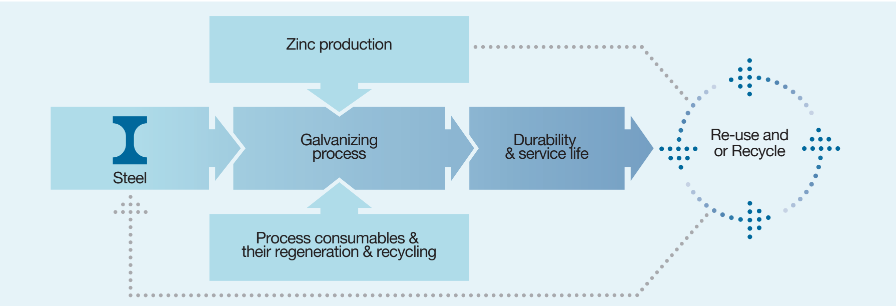

The life cycle of hot dip galvanized steel

GALVANIZING PROCESS
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Galvanizing is always carried out in an industrial works which contains all stages of the process. Steel comes in at one end and the finished galvanized product goes out at the other. There are many galvanizing plants in most countries and steel does not have to travel great distances to a nearby galvanizing plant keeping transport costs and environmental impacts as low as possible. The main process consumable, zinc, is used very efficiently in the process. The dip operation ensures that any zinc that is not deposited on the steel is returned to the galvanizing bath. Zinc that oxidizes on the surface is removed as an ash and is readily recycled (sometimes on site). Dross formed at the bottom of the bath is removed periodically and has a high market value for recycling.

PROCESS ENERGY USE
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Energy is required to heat the hot dip galvanizing bath and this is usually supplied by natural gas. In some countries, baths are heated by electricity or fuel oil. Although the galvanizing industry is not considered to be amongst the most energy-intensive sectors of industry, it has made great efforts to manage its energy use efficiently. In some countries, the galvanizing industry has set targets for energy efficiency and encouraged improved energy management and new technology to achieve these targets.

Examples of these advances are:
- improved burner technology for greater energy efficiency
- more efficient bath lids (used during maintenance and/or down time)
- greater use of waste heat for heating of pre-treatment tanks

EMISSION CONTROL
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Emissions within the plant are carefully controlled to avoid disturbance or problems for the surrounding neighbourhood. Galvanizing plants are regulated under the EU Directive on Integrated Pollution, Prevention and Control[5]. The industry has cooperated in the publication of a Best Practice Reference Note (BREF) for hot dip galvanizing.

The principal requirement of the BREF is to capture the non-hazardous particulates during dipping. These particulates are then filtered using either scrubbers or bag filters.

REGENERATION AND RECYCLING OF PROCESS SOLUTIONS
–

Pretreatment steps in the process are mainly aimed at cleaning the steel articles.

Process consumables, such as hydrochloric acid and flux solutions all have important recycling and/or regeneration routes.
For example:

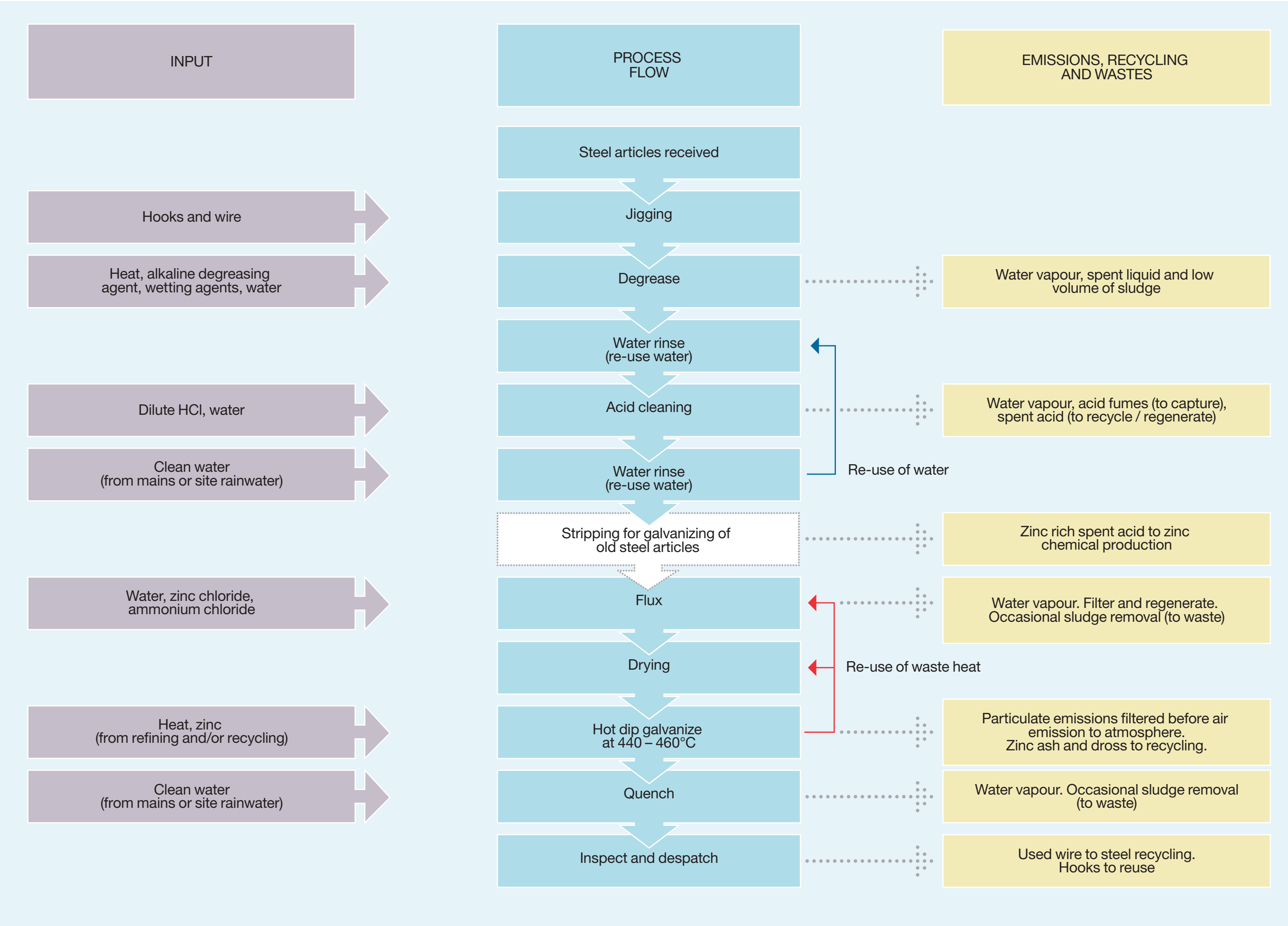
- spent hydrochloric acid solutions are used to produce iron chloride for use in treating municipal waste water. Many plants remove iron and zinc and recycle regenerated acid to the pre-treatment tanks
- improved monitoring and maintenance of flux tanks means that these are rarely discarded to waste and only small volumes of sludge require periodic disposal. Closed-loop flux recycling is used in many plants
- ambient temperature acidic and biological degreasers have been developed

WATER USE
–

Galvanizing plants use relatively low volumes of water compared to other coating technologies[6]. In fact, it is very rare for a galvanizing plant to discharge waste water. Any waste water that is generated can be treated and returned to the process, with only low volumes of stable solids sent for external disposal.

In some cases, it has been possible for galvanizing plants to eliminate the use of mains water by harvesting rain water falling on the site. Rain water can be collected through gutters and stored for later use.

PROCESS CONSUMABLES ALL HAVE IMPORTANT RECYCLING OR REGENERATION ROUTES



THE GALVANIZING PROCESS:

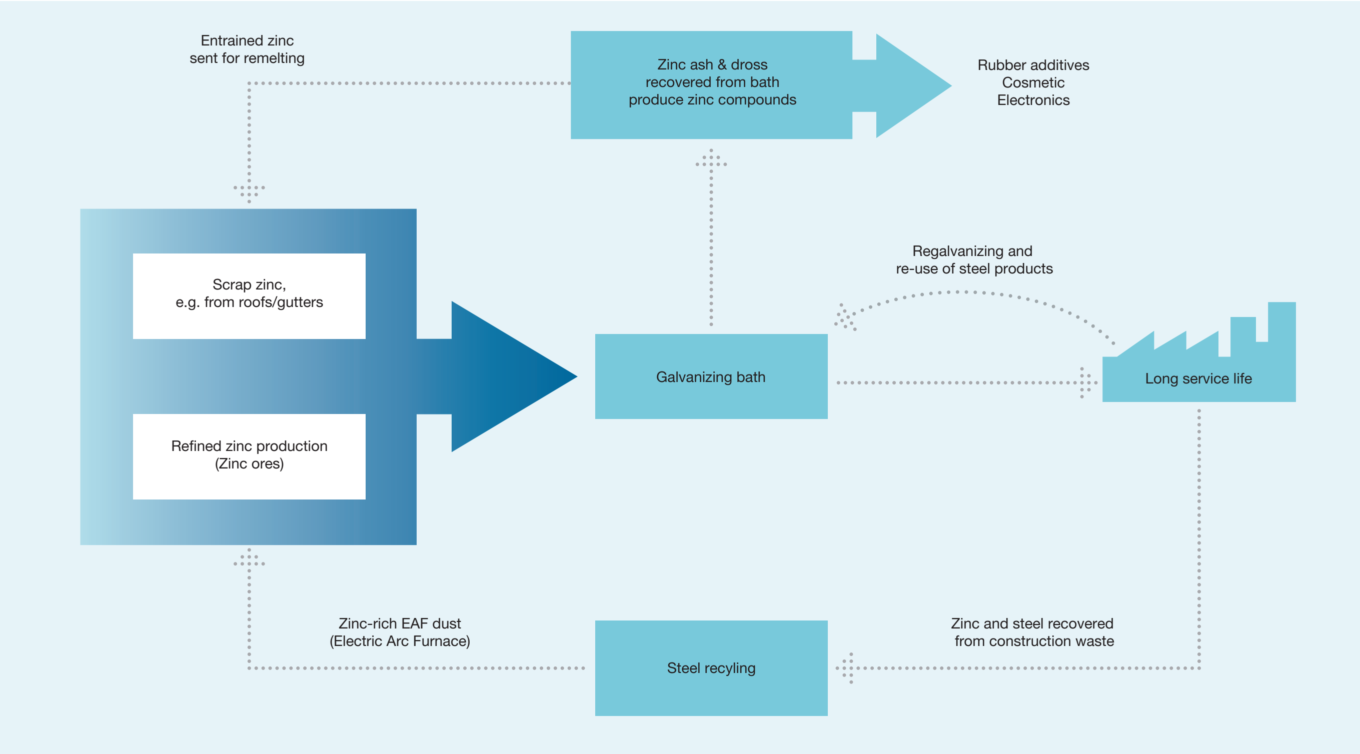
Inputs, emissions, wastes and recycling flows.

Small volumes of water are used to make and top up rinse tanks and other process tanks. In some cases, it is possible to meet all the process water requirements through harvesting of rainwater falling on the site. The water is captured by the gutter system and stored for later use.

The zinc ash (also called skimmings) and dross that is produced at the galvanizing bath can be fully recycled either on site or at specialist recyclers. Some plants operate small furnaces to recover metallic zinc from process ashes. This metallic zinc can be directly returned to the galvanizing bath without leaving the site.

Modern galvanizing furnaces are computer controlled and extremely efficient.

Waste combustion gases are also used to heat pre-treatment tanks or to dry the clean steel prior to immersion in the galvanizing bath. Other advances in process control and efficiency include in-process regeneration of flux solutions and acids.



Flows of recycled zinc within the galvanizing process and at end of life.

USE OF RECYCLED ZINC

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There are two important sources of zinc used in the galvanizing process:

• refined zinc is produced from a mix of both mined ores and recycled feedstocks. It is estimated that, on average, refined zinc contains about 10-15% of recycled feedstock

• galvanizers are also important purchasers of remelt zinc – that is scrap zinc from, for example, old zinc roofs that have been cleaned and remelted into ingot form

So, the refined zinc purchased by galvanizing plants contains a high proportion of recycled zinc and fully recycled zinc is often purchased to supplement use of refined zinc.

The production of one kg of refined zinc (from ore) requires gross energy of 50MJ, although only 20MJ of this energy is used directly in zinc production[7]. Secondary (remelted) zinc used by general galvanizers requires just 2.5MJ to produce[8].

RECYCLING OF PROCESS RESIDUES

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During the galvanizing process, any zinc that does not form a coating on the steel remains in the bath for further reuse. There is no loss of materials that may occur during spray application of other coating types. Zinc ash (from surface oxidation of the galvanizing bath) and dross (a mix of zinc and iron that accumulates at the bottom of the galvanizing bath) are fully recovered. Any zinc metal within the crude ash is directly recycled for further use, often in the same galvanizing process. The fine ash and dross are then sold to make zinc dust and compounds for a variety of applications such as rubber additives, cosmetics and electronic components.

REUSE OF GALVANIZED STEELWORK

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Many galvanized steel products can be removed, re-galvanized and returned to use. For example, highway guard rails are often removed and replaced during routine highway maintenance and resurfacing. The redundant barriers are returned to the galvanizing plant for re-galvanizing and are then used again in similar applications. The zinc-rich acid that is produced by stripping the remaining coating is used for production of zinc compounds for the chemical industry.

RECYCLING GALVANIZED STEELWORK

–

Galvanized steel can be recycled easily with other steel scrap in the electric arc furnace (EAF) steel production process. Zinc volatilises early in the process and is collected in the EAF dust that is then recycled in specialist facilities and often returns to refined zinc production.

In 2006, the European steel industry (EU27) produced 1,290,750 tonnes of EAF dust, which contained 296,872 tonnes of zinc (i.e., 23%). 93% of this zinc (276,920 tonnes) was recycled. (source: Gesellschaft für Bergbau, Metallurgie, Rohstoff - und Umwelttechnik, Germany)

Steel products often have a very long useful life, e.g. many very old steel bridges are still in use. For that reason there is a shortage of scrap and the constant growth in infrastructure will have to be based on primary production of iron ore. The same applies to many other metals that are used in applications with a long useful life.

Steel is the world's most recycled construction material and approximately 40% of all steel production is based on recycled scrap. Steel used in construction has a very high rate of recycling at end of life. For example, in the UK, 87% of constructional steel is recycled; 10% is reused and only 3% goes to landfill[9].

DURABILITY AND SERVICE LIFE

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Hot dip galvanizing to EN ISO 1461 ensures a coating of zinc is applied to protect steel. This is important to provide extended durability, especially in outdoor environments. Thinner zinc coatings will not last so long because the life of a zinc coating is directly proportional to its thickness.

Zinc's resistance to corrosion depends primarily on a protective film (patina) formed on its surface. For atmospheric corrosion, atmospheric contaminants affect the nature and durability of this film. The most important contaminant affecting zinc is sulphur dioxide (SO_2) and it is the presence of SO_2 which largely controls zinc's atmospheric corrosion rate.

It is widely documented that atmospheric SO_2 levels have fallen significantly in most countries over the past decades.

The link between zinc durability and atmospheric SO_2 levels has been illustrated very clearly for Sweden. Similar data have been recorded for other countries[10].

This downward trend and consequent improvements in zinc performance significantly enhance the contribution of galvanized steel to sustainable development by providing, at no additional cost, more durable structures for shelter, infrastructure, transportation and many other applications.

With zinc corrosion rates normally less than 1µm per year in most European countries, a typical 85µm coating can provide many decades of maintenance-free life (in rural and urban environments)[11].

For more aggressive environments, it is possible to achieve thicker coatings on structural steelwork with corresponding increases to coating life.

SECTION
FOUR
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TITLE
GALVANIZING'S
RAW MATERIAL – ZINC
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ZINC PRODUCTION
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80% of zinc mines are underground, 8% are of the open pit type and the remainder are a combination of both. Rarely is the ore, as mined, rich enough to be used directly by smelters; it needs to be concentrated. Zinc ores contain 5-15% zinc. To concentrate the ore it is first crushed and then ground to enable optimal separation from the other minerals.

Typically, a zinc concentrate contains about 55% of zinc, usually in the form of zinc sulphide. Zinc concentration is usually done at the mine site to keep transport costs to smelters as low as possible.

Zinc concentrates are then roasted or sintered to convert zinc sulphide to zinc oxide. Zinc oxides are then processed in either pyrometallurgical, or more commonly, hydrometallurgical processes to produce zinc metal. The most common products are High Grade Zinc (99.95%) and Special High Grade Zinc (99.99%).

THE ZINC PRODUCTION INDUSTRY'S COMMITMENT TO SUSTAINABLE DEVELOPMENT
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In addition to the adoption of their Sustainability Charter in 2001, members of the International Zinc Association (IZA) defined an action plan to bring the zinc industry's activities into harmony with the principles of sustainability. Key elements of IZA's sustainability strategy include:

- assessing future trends and developing zinc sustainability indicators
- developing and communicating a full understanding of the impact of zinc on the environment and its essential contribution to human health and eco-systems, based on a sound scientific risk assessment appropriate for zinc
- ensuring efficient use of resources to produce and recycle zinc
- reducing the energy intensity of all processes along the value-chain
- controlling emissions of zinc from point and diffuse sources
- producing according to appropriate social and environmental standards worldwide
- developing an integrated product policy throughout zinc's life cycle

More information on the implementation of IZA's sustainability strategy can be found at:
www.zincworld.org/sustainable_development

ZINC AND HEALTH
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All living organisms need zinc – it is an essential element. The amount of zinc present in nature varies widely, so living organisms have natural processes that regulate their uptake. Deficiency occurs when the amount of available zinc is insufficient to meet the needs of an organism. This occurs in both the environment and in human nutrition. It has been suggested that nearly half the world's population is at risk from zinc deficiency and efforts are being made to boost the zinc intake of the world's poorest children[12, 13].

Zinc deficiency in agricultural soils is also common on all continents and leads to inefficiencies in crop and livestock production[14].

ALL LIVING ORGANISMS NEED ZINC – IT IS AN ESSENTIAL ELEMENT

Zinc enhances our memory and thinking by interacting with other chemicals to send messages to the sensory brain centre. Zinc can also reduce fatigue and mood swings.

Because zinc is used to generate cells, it is especially important during pregnancy, for the growing fetus whose cells are rapidly dividing.

In women, zinc can help treat menstrualproblems and alleviate symptoms of premenstrual syndrome.

Zinc is vital for taste and smell, it is needed for renewal of skin cells and to keep our hair and nails healthy.

We use zinc in shampoo and sun-block products.

In men, zinc protects the prostate gland and helps maintain sperm count and mobility.

Zinc helps keep us going... and enjoying healthy active lifestyles. Among all the vitamins and minerals, zinc shows the strongest effect on our all-important immune system.

Zinc has proven effective in fighting infections and can even reduce the duration and severity of the common cold.

Zinc is vital in activating growth in infants, children and teenagers.

The importance of zinc for human health

Natural levels of zinc in the environment

Air (rural)	0.01 - 0.2 µg m^3	Ore bodies	5 - >15%
Soil (general)	10 - 300 mg/kg dry weight	Open ocean	0.001 - 0.06 µg/l
Basaltic igneous	28 - 240 ppm	Coastal/inland seas	0.5 - 1 µg/l
Granitic igneous	5 - 140 ppm	Alluvial lowland rivers	5 - 40 µg/l
Shales and clays	18 - 180 ppm	Mountain rivers	< 10 µg/l
Sandstones	2 - 41 ppm	Large lakes	0.09 - 0.3 µg/l (dissolved)
Black shales	34 - 1500 ppm	Streams in highly mineralised areas	200 µg/l

ZINC IN NATURE

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Zinc, like all metals, is a natural component of the earth's crust and an inherent part of our environment. Zinc is present not only in rock and soil, but also in air, water and the biosphere - plants, animals and humans. Zinc is constantly being transported by nature, a process called natural cycling. Rain, snow, ice, sun and wind erode zinc-containing rocks and soil. Wind and water carry minute amounts of zinc to lakes, rivers and the sea, where it collects as sediment or is transported further. Natural phenomena such as:

- volcanic eruptions
- forest fires
- dust storms
- sea spray

all contribute to the continuous cycling of zinc through nature[15, 16]. During the course of evolution, all living organisms have adapted to the zinc in their environment and used it for specific metabolic processes. The amount of zinc present in the natural environment varies from place to place and from season to season. For example, the amount of zinc in the earth's crust ranges between 10-300 milligrams per kilogramme, and zinc in rivers varies from less than 10 micrograms per litre to over 200 micrograms. Similarly, falling leaves in autumn lead to a seasonal increase in zinc levels in soil and water.

Every year an average sized Swedish river transports over ten tonnes of metals to the sea due to natural weathering and leaching from bedrock.

ZINC IN THE ENVIRONMENT

–

Although zinc is well-recognised for its positive effects for humans and ecosystems, it is also important to avoid very high concentrations in the environment. Industrial emissions of zinc have been steadily falling over past decades.

Where locally high zinc concentrations may occur, for example in highly mineralised areas, nature has a remarkable ability to adapt. Nature also has mechanisms to bind zinc to reduce its so-called bioavailability. Bioavailability has been defined as "the amount or concentration of a chemical (metal) that can be absorbed by an organism thereby creating the potential for toxicity or the necessary concentration for survival" (Parametrix 1995).

It is, however, not simply a function of the chemical form of the substance. Rather, it is largely influenced by the characteristics of the receiving environment. Hence, factors such as water hardness and pH have to be taken into account.

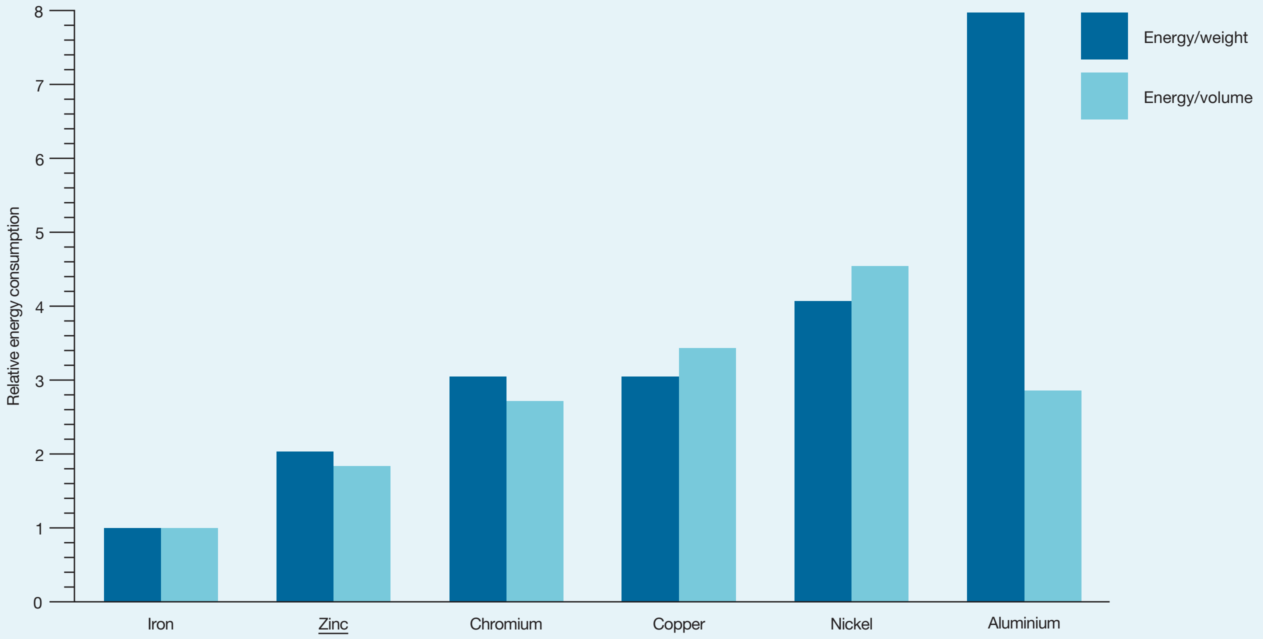
It is these bioavailability effects that explain why the apparently high soil zinc concentrations around large galvanized structures, such as electricity transmission towers, do not produce the toxic effects that may be predicted in the laboratory.

These factors have long been recognized as important, but there was insufficient scientific knowledge to allow a quantitative prediction of zinc's bioavailability in a given set of conditions. To address this, the galvanizing industry has contributed to extensive research to develop clear predictive models to quantify zinc bioavailability in waters, sediments and soils[17].

There have been specific studies of contamination of soil and water from corrosion of galvanized products in the outside environment. Even in locations where many sources of zinc exist, such as at roadsides (where zinc can arise from tyre debris, lubricants, road wear and corrosion), these studies have shown that these releases do not give rise to adverse effects.

The Division of Corrosion Science at the Royal Institute of Technology (KTH) in Stockholm has been studying the environmental impact of zinc, copper and stainless steel roofing materials[18]. When it rains, the substances that are created through the corrosion of the roof surface are released. The amount of metal that can be released depends, on a number of different factors such as the amount of air pollution, the chemical composition and pH of the rain as well as the length and intensity of the rainfall.

The metals that exist in the run-off water leaving the edge of the roof mconsists mainly of free ions. Scientists at KTH found that once water had percolated through soil or had been in contact with concrete or limestone over 96% of its total metal content had been removed. The majority of metals bond very quickly on contact with the soil and the metals that remain in the water have a low bioavailability and therefore low potential for environmental effects.



Although only a small amount of zinc is used to conserve the embodied energy of steel, an important life cycle consideration for galvanizing is the energy used to produce zinc metal.

The Swedish Environmental Protection Agency has compared the relative energy requirements of the common base metals and found that, with the exception of iron (the basis of steel), zinc uses the lowest energy on both a per unit weight and per unit volume basis[19].

The energy used in electrolytic zinc production is approximately 7% for mining and mineral processing; 89% for electrolysis and 4% for casting.

Energy use in primary (refined) production of various base metals in relation to weight and volume.
Energy use for iron/steel is set at one in both cases.
(source: Swedish Environmental Protection Agency)




ZINC RECYCLING

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Zinc is an inherently recyclable non-ferrous metal and can be recycled indefinitely without any loss of physical or chemical properties. At present, approximately 70% of zinc comes from primary refining of zinc ores (including 10-15% from recycled sources) and about 30% comes directly from recycled zinc (representing 80% of the zinc available for recycling). The recycling level continues to increase as technology improves. The long life of zinc coated steel products in construction makes forecast of their emergence in waste streams difficult to model, hence more work will be required on this.

ZINC RESERVES

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Zinc is the 27th most common element in the earth's crust. The world is naturally abundant in zinc. Even a cubic mile of seawater is estimated to contain 1 tonne of zinc. It is estimated that the first mile of the earth's crust under land contains 224,000,000 million tonnes of zinc, with a further 15 million tonnes in the seabed. Such estimates, however, take no account of whether or not it is economic, or environmentally acceptable, to exploit these resources.

Reserves of zinc – like those of any natural resource – are not a fixed amount stored in nature. Reserves are determined by geology and the interaction of economics, technology and politics. The term Reserves denotes the portion of resources that has been mapped and measured and which may be used, now or in the future.

Thus, reserves reflect the state of knowledge, technology and the value of zinc at a given time. These natural resources are increasingly augmented by the supply of recycled zinc. Proven reserves of zinc have increased significantly since the 1950s, as large new ore bodies have been discovered in many areas of the world.

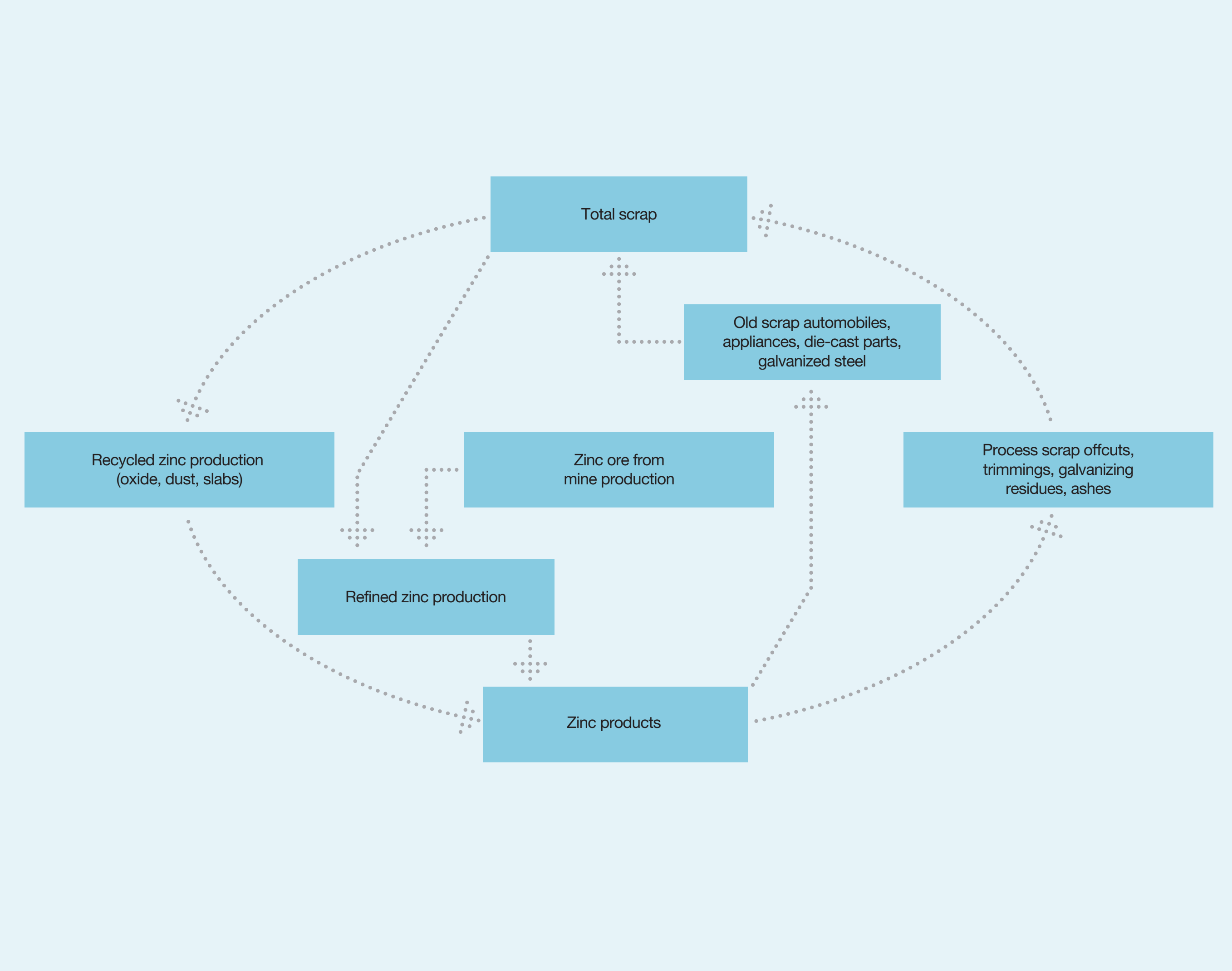
The sustainability of zinc ore supplies cannot therefore be judged simply by extrapolating the combined mine life of today's zinc mines. Despite increasing consumption of zinc from 1995-2005, the world's zinc reserves substantially increased over that same period, as shown in the table.

Year	Reserves[1]	Reserve Base[2]
1995	140,000,000 mt	330,000,000 mt
2005	220,000,000 mt	460,000,000 mt
Increase	57.14%	39.4%

Source: U.S. Geological Survey,

1. Reserves are defined as, "That part of the reserve base which could be economically extracted or produced at the time of determination.
2. Reserve base is defined as, "That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth.

ZINC IS AN INHERENTLY RECYCLABLE NON-FERROUS METAL AND CAN BE RECYCLED INDEFINITELY



The zinc recycling circuit

SECTION
FIVE
–

TITLE
SUSTAINABLE CONSTRUCTION
AN EXPLANATION
–

When choosing building materials and products, architects, specifiers, developers and clients will increasingly be concerned about environmental issues. This may be because rules, regulations and policies enforce this or because of a genuine ethical decision to ensure that buildings are as sustainable as possible.

However, there is a great deal of confusion and misunderstanding of what green and sustainable buildings actually are.

How are informed decisions made about what materials to use and who sets the standards that can validate such decisions? As policies and thinking about sustainable construction are changing so rapidly, can there be any real degree of certainty about the best thing to do?

There are many claims being made by suppliers about the green credentials of their products. Buildings receive awards for being "green" and are then attacked for having poor environmental performance.

Distinguishing between being good for the environment and what has become known as "greenwash" is not always easy.

"The term (greenwash) is generally used when significantly more money or time has been spent advertising being green, rather than spending resources on environmentally sound practices. This is often portrayed by changing the name or label of a product, to give the feeling of nature, for example putting an image of a forest on a bottle of harmful chemicals."(Wikipedia)

Scientific work to evaluate and improve the environmental impact of galvanizing has been based on analysis of genuine data and this avoids greenwash as any claims that are made can be backed up with good peer reviewed science. However, it is not easy to make comparisons between products and materials as there are so many different methods of analysis and claims that are made. A level playing field to compare environmental credentials does not yet exist, though it may come in time.

At an international level, there is a substantial difference between what might be regarded as sustainable in one country and what is sustainable in another.

Some are comfortable with this variation, arguing that local conditions vary and different criteria will apply according to local circumstances. However, we all live on just the one planet, even if we are trying to consume three or four! Excessive consumption of energy and resources in Paris will have just as much impact on pollution of the seas and depletion of the ozone layer as a building in Japan or Rio de Janeiro. Given this, it seems rather surprising that there has been little harmonisation of international standards for sustainable building.

VARIATION OF INTERPRETATION
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A review of the literature on green building will make it clear that there are a wide variety of interpretations available. Some are very technocratic whereas others refer to new age mystical ideas! Rarely is a holistic approach adopted in which every aspect of environmental impacts is considered. Some see environmental issues as only about saving energy or improving building services. Many people associate green building with adding renewable energy to buildings and adopting micro generation. In many cases the materials that are used are fairly low down on the list of concerns for the designer or client. On the other hand some advocate using straw-bales and mud to create low impact buildings with purely natural materials.

This plurality of approach can also be found when looking at environmental assessment tools and methods. Some are concerned with assessment systems for buildings and others for materials as though they are two different things when in fact they are completely inter-related. The other difference is whether assessment tools are to design buildings or assess them once they are built. If assessment systems are not useful as design tools, then they are essentially measuring the impact once the damage has been done. When claims are made, are they properly checked once the building is completed? How useful are these tools and assessment methods for people when they embark on a building project and to decide what to do? Do they help in the selection of materials?

THERE IS A GREAT DEAL OF CONFUSION AND MISUNDERSTANDING OF WHAT GREEN AND SUSTAINABLE BUILDINGS ACTUALLY ARE.

The Hearst Tower is one of America's greenest office buildings to date, built with over ninety percent recycled steel and designed to save 1.7 million gallons of water annually by harvesting and recycling rainwater.

THERE IS A NEED FOR A CONSUMERS' GUIDE TO ENVIRONMENTAL ASSESSMENT TOOLS.

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The European Commission has mandated the European standards organisation, CEN, to develop a standardised system for assessing the environmental performance of buildings[20]. This work began in 2004 and is expected to be completed in late 2009. Meanwhile, several other national schemes have been developed to suit national circumstances, such as Ecoquantum (Netherlands); LEGEP (Germany)[21]; Haute Qualitié Environnementale (France). In Spain, the US LEED system has been used to assess sustainable building in public projects.

In the UK and USA, market leaders such as BREEAM[22] and LEED[23] dominate the field. While these two systems are well known, the selection of building materials and methods represents only a small part of the tool. Generally BREEAM and LEED are seen as making a useful contribution to advancing the cause of greener buildings but they are not without their critics.

Many maintain that a LEED plaque is no guarantee that a building deserves accolades for good green design. Industry professionals commonly complain that the credit system unevenly recognizes energy use. For example, because each LEED credit is worth one point (out of a possible 69), it's possible for a building to receive 26 points - enough for a plaque - without obtaining a single point for energy efficiency.

This is arguably the most important green building metric, and critics note that this loophole allows owners to slap a few green elements - from a green roof to preferred parking spaces for hybrid vehicles - on top of an otherwise conventional building in order to score easy LEED points.

In 2004, the Green Building Alliance, a Pittsburgh-based coalition of environmental groups, compiled an anonymous electronic survey of architects, engineers, contractors, and others who had worked on green building projects. On a recent building, one respondent had received one LEED point for installing a $395 bike rack, the same score as for a $1.3 million heat recovery system that would help save the owner around $500,000 annually in energy costs.

The US Green Building Council promotes the LEED system of assessment and recently in the UK a Green Building Council has also been established. Similar organisations exist in Australia and other countries. In addition to such overall methods of assessing buildings, there is a maze of systems for assessing the environmental impact of materials. These are sometimes taken into account in building design assessment tools, but not always.

In 1988, a Construction Products Directive[24] was adopted by the European Union and is currently being considered for amendment. It had been hoped that this would lead to a harmonisation of environmental standards for building products throughout Europe. Even though many building products now exhibit the "CE" mark, this does not provide any guidance to its environmental provenance. While a number of EU measures have driven forward the agenda for sustainable construction, in particular pressure to reduce pollution and remove toxic chemicals from buildings, there has not been an overall strategy for sustainable construction.

TOOLS FOR ASSESSING ENVIRONMENTAL PERFORMANCE

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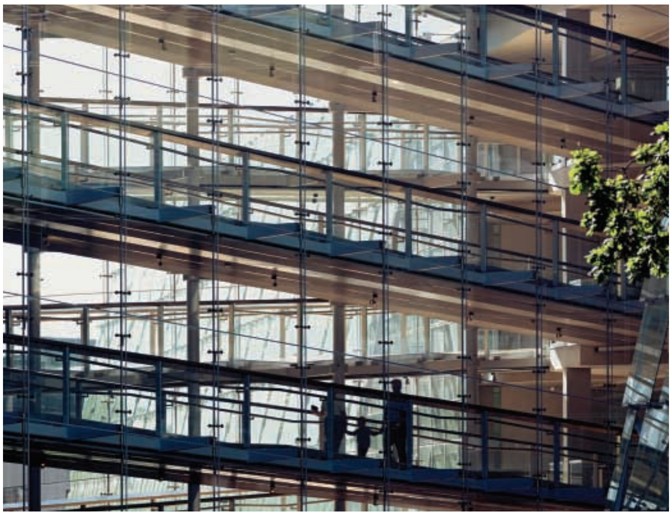
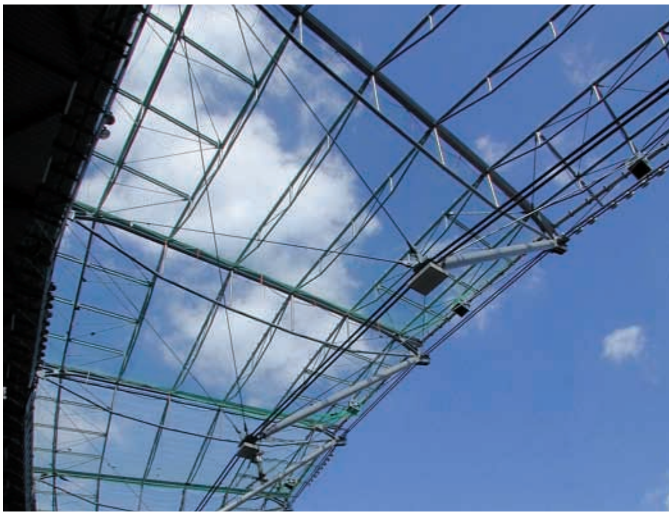
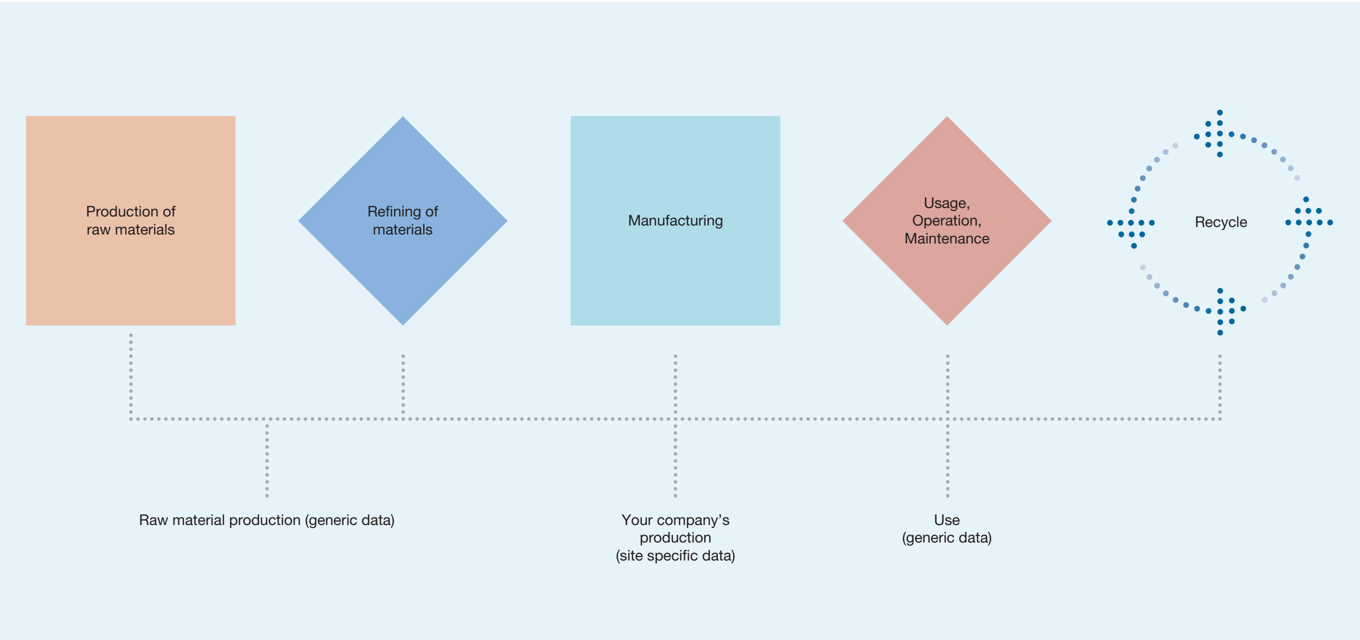
There are two important tools that are used to assess environmental performance of construction products – Environmental Product Declarations (EPDs) and Life Cycle Assessment (LCA).

In fact these two tools are closely linked as an EPD uses LCA to calculate the magnitude of the impact categories that are included in the declaration.

In order for LCAs and EPDs to be generated for a particular process or product, it is necessary to have reliable and representative life cycle inventory (LCI) data.







Key components of a full life cycle inventory for construction products.

WHAT IS LIFE CYCLE ASSESSMENT?

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'Life cycle assessment is a process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements.

The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing; transportation and distribution; use, maintenance; recycling and final disposal.'

LIFE CYCLE ASSESSMENT

–

Life Cycle Assessment (LCA) is defined under ISO 14040[25], whereby a product's resource use and emissions are evaluated from cradle-to-gate or cradle-to-grave, and normalised to a functional unit or one square metre of protection of a steel product for a specified period of time.

LCA's can be costly but they have the advantage of making comparisons over a wide range of potential environmental impacts (not just carbon emissions and energy consumption). The disadvantage is that LCA is time consuming, expensive and complex and that the results are often difficult to interpret. For example, practitioners and customers may be left to make their own decisions on the relative importance of higher carbon dioxide emissions for one product and increased ecological toxicity for another.

LCA can allow comparison between products which serve the same purpose, such as coatings for metal products. However, the use of LCA for coatings is relatively new and there are few instances of directly comparable LCA studies in this field with differing functional units, timescales, operating conditions, boundaries and other variables, being used by commercial organisations, university departments and governmental bodies.

Commercial databases which contain Life Cycle Inventories (LCIs) for manufacturing elements and environmental burdens involved in creating a product may be used to build up LCAs. Transmission of researched LCIs is facilitated by EcoSpold, a common data exchange format that links to proprietary LCA software.

It seems sensible to follow the trends currently underway (or planned) for other building products and to calculate the embodied energy and other environmental impacts for galvanized products.

This would allow the galvanized products to be listed alongside, and compared with, alternatives. However, as noted above, the most informative comparisons are between completed structures providing an equivalent service.

The gradual interest from media of the climate debate has put pressure on the development of comparable and quality-assured environmental information.

This was identified early by the International Standardisation Organisation, (ISO), which has developed a standard for such information about the environmental performance of products and services, so-called environmental product declarations (EPD).

ENVIRONMENTAL PRODUCT DECLARATIONS

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An environmental product declaration, EPD, is defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information"

The most rigorous form of EPD is Type III (according to ISO 14025) - where the product's performance must be backed by LCA, is valid for a fixed period, independently verified, and must be updated if significant process changes occur.

The demand for factual-based and quality-assured environmental information has increased during recent years. This is especially important in the currently heated debate about climate change, where a number of reports have been issued recently conveying quite different messages about the magnitude of our emissions of greenhouse gases and their future consequences for mankind. Managing to reduce emissions of CO_2 has become a highly prioritised issue for many organisations. This trend has led to new methods for reducing CO_2 emissions, e.g, climate labelling of food and of "climate-neutral" products and services and "zero-carbon" buildings.

SOME KEY TERMS EXPLAINED

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Embodied carbon is the total amount of carbon dioxide gas (or equivalents) emissions associated with the energy embodied in a product (C CaLC 2006).

Carbon footprint
A carbon footprint is a measure of the impact of human activities on the environment in terms of the amount of greenhouse gases produced, measured in units of carbon dioxide.

Embodied energy
is the sum of the total primary energy consumed in the manufacture and supply of products. This would normally include the energy used in extraction, processing and refining, transport, production, packaging and delivery to the site in a condition ready to use without further processing. There are two common 'flavours' of embodied energy: cradle-to-gate and cradle-to-site. Here 'gate' refers to the factory gate where the product is manufactured. The difference in the two definitions is the energy associated with transporting the product from factory to site of use. Most references suggest this difference is usually small in comparison to the cradle-to-gate values.

Life cycle embodied energy
is calculated from cradle-to-grave and therefore includes energy use during the useful life of the product, energy associated with end-of-life processes and final disposal and/or recycling.

What is the meaning of non-renewable?
Examples of non-renewable resources are ores and fossil resources like coal and oil. In the EPD®-system, peat is considered a non-renewable resource.

What is the meaning of renewable?
Renewable resources are resources that are being renewed relatively fast. Examples are wood and agricultural products and energy sources such as: wind energy, solar energy, tidal energy, hydroelectric power, marine current energy and biomass energy. Geothermal energy is also considered renewable because there is so much of it, it can hardly be depleted.

Resource, recycled
Recycled resources have already been used at least once. If a product is made of recycled resources, only those environmental impacts associated with recycling the resource is attributed to the product.

Global warming
Global warming is measured in kilogram CO_2 - equivalents. Global warming is the gradual increase, over time, of the average temperature of earth's atmosphere and oceans sufficient to induce changes on the earth's climate. This increase on earth's temperature is related to the increase of the emission of gases, such as, CO_2, methane, water vapour, nitrous oxide and CFC's, among others, from anthropogenic (man made) sources, mainly from the burning of fossil fuels. Europe´s emissions in 1990 corresponded to 8700 kg CO_2 -equivalents per person. Burning 1000 litres of petrol in a car generates approximately 2500 kg CO_2 as a comparison.

Photochemical smog
Potential photochemical ozone creation, or summer smog, is measured in kg ethene equivalents (C_2H_4). Increased levels of ozone at ground level, arise through the reaction of volatile organic compounds, for example ethene, with oxygen compounds or oxides of nitrogen in air and under the influence of sunlight, so called photochemical oxidation. The effects on human health are amongst others irritation of eyes and mucous membranes as well as impaired respiratory function. Ground level ozone also has severe effects on vegetation, resulting in agricultural production losses. Europe´s emissions in 1990 corresponded to 20 kg ethene equivalents per person. Burning 1000 litres of petrol in a modern car generates around 1 kg ethene equivalents as a comparison.

Eutrophication
Eutrophication is measured as the amount of oxygen consumption a substance causes when released in the environment. For example, nutrients like nitrogen released in a lake leads to an increased production of planktonic algae. The algae sink to the bottom and are broken down with consumption of oxygen in the bottom layers, causing a dead environment at the bottom.

The most significant sources of nutrient enrichment are the agricultural use of fertilizers, the emissions of oxides of nitrogen from energy production and waste water from households and industry. Europe´s emissions in 1990 corresponded to 298 kg O_2 per person. Burning 1000 litres of petrol in a modern car leads to the consumption of around 10 kg oxygen as a comparison.

Acidification
Acidification is measured in amount of hydrogen ions (H^+) created when a substance is converted into an acid. These acids (often referred to as acid rain) are best known for the damage they cause to forests and lakes. Less well known are the many ways acid rain damages freshwater and coastal ecosystems, soils and even ancient historical monuments, or the heavy metals these acids help release into groundwater. The most important man-made emissions of acidifying gases are sulphur dioxide (SO_2) and nitrous oxide (NO_X) from combustion processes. Europe´s emissions in 1990 corresponded to 38700 mol H^+ per person.

Ozone depletion
Ozone depletion is measured in CFC-11 equivalents. Ozone existing in the stratosphere (upper layer of the atmosphere) functions as a protective layer against ultraviolet radiation harmful to life on earth. The emission of CFC's and tetraclorомethane gases, among others, is responsible for the decrease of ozone concentration in the upper atmosphere, with negative consequences to life on earth, such as, the increase in skin cancer incidence. Europe´s emissions in 1990 corresponded to 0,2 kg CFC-11 equivalents per person.

Waste to recycling
Waste to recycling includes all waste, for example scrap metal, which is sent away from the manufacturing plant to be used again in another product, often after some form of treatment.

The average European
It is easier to understand what the environmental impact category indicators in an EPD means, if they are compared to something. One possibility is to compare with the average environmental impacts of a person living in Europe in 1990. Europe´s emissions divided by its inhabitants in 1999 were: 8700 kg CO_2 equivalents; 20 kg ethene equivalents; 298 kg O_2; 38700 mol H^+; 0,2 kg CFC-11.

(explanations based on information provided by website of the EU-funded Stepwise EPD project. COOP-CT-20004-513045. http://extra.ivf.se/stepwiseEPD2/)

WHY USE AN EPD?

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From a purchaser´s point of view, EPDs are designed to allow comparisons between similar products' environmental performance. Furthermore, an EPD must be based on a life cycle assessment of the product's significant environmental aspects.

From a producers' or suppliers' point of view, there are two very good reasons to establish an EPD:

- to learn more about a product's environmental strengths, weaknesses and opportunities for improvement
- to communicate a product's environmental profile in an objective and credible way

That a product has an EPD is no guarantee that the product is less harmful to the environment than a competing product. However, it shows that the manufacturing company has an in-depth knowledge about its product's environmental performance and is sharing that information openly.

WHAT IS THE DIFFERENCE BETWEEN GENERIC AND SPECIFIC DATA?

–

One of the difficulties faced by specifiers when making decisions about what to use is that most environmental profiling information is available for specific products and then only for a very limited range. Information on generic materials is much harder to find.

All data used in a life cycle assessment represent the characteristics of the processes in the product system being studied. However, the source of the data can be site-specific - i.e., representing the specific site in which the declared product is manufactured - or generic, i.e. representing an average of data from the process technologies used to manufacture the product in question.

INTERPRETATION OF EPDS.

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There is no one-way of interpreting the values of an EPD. EPDs for two similar products should be based on the same product category rules for the life cycle assessment, thus should be able to determine which of the two is best from an environmental point of view by comparing the data. When there is no similar product to compare with, comparing the data to an average European could make them more understandable. Sometimes the EPD itself contains a comparison with an older version of the product or an alternative way of using the product. This could also facilitate the interpretation.

CREATING AN EPD IN THE EPD® SYSTEM

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The international EPD® system is operated by an international panel and was originally driven by the Swedish Environmental Management Council (SEMCO)[26]. The programme operator is responsible for providing general guidelines for the overall aim and methodological structure.

The system is part of the Global Type III Environmental Product Declarations Network (GEDnet).

The EPD® system is one of several available EPD programmes, however it is the only programme at present with international applicability. From the point of view of a company or an organisation creating an EPD, the overall procedure includes the following steps:

- consider available Product Category Rules (PCR) and create a PCR document
- collect and calculate LCA-based and other types of information to be included in the EPD
- compile information for reporting
- verification and registration

To be able to add up LCA-based information in the supply chain and to compare different EPDs, similar calculation rules have to be used. Groups of products can, however, differ in their inherent environmental performance and these variations need to be reflected in the calculation rules. Because of these differences, rules specific to a certain product group, so-called product-category rules may have to be prepared.

EGGA'S INITIATIVE –
LIFE CYCLE INVENTORY FOR GENERAL GALVANIZING
–

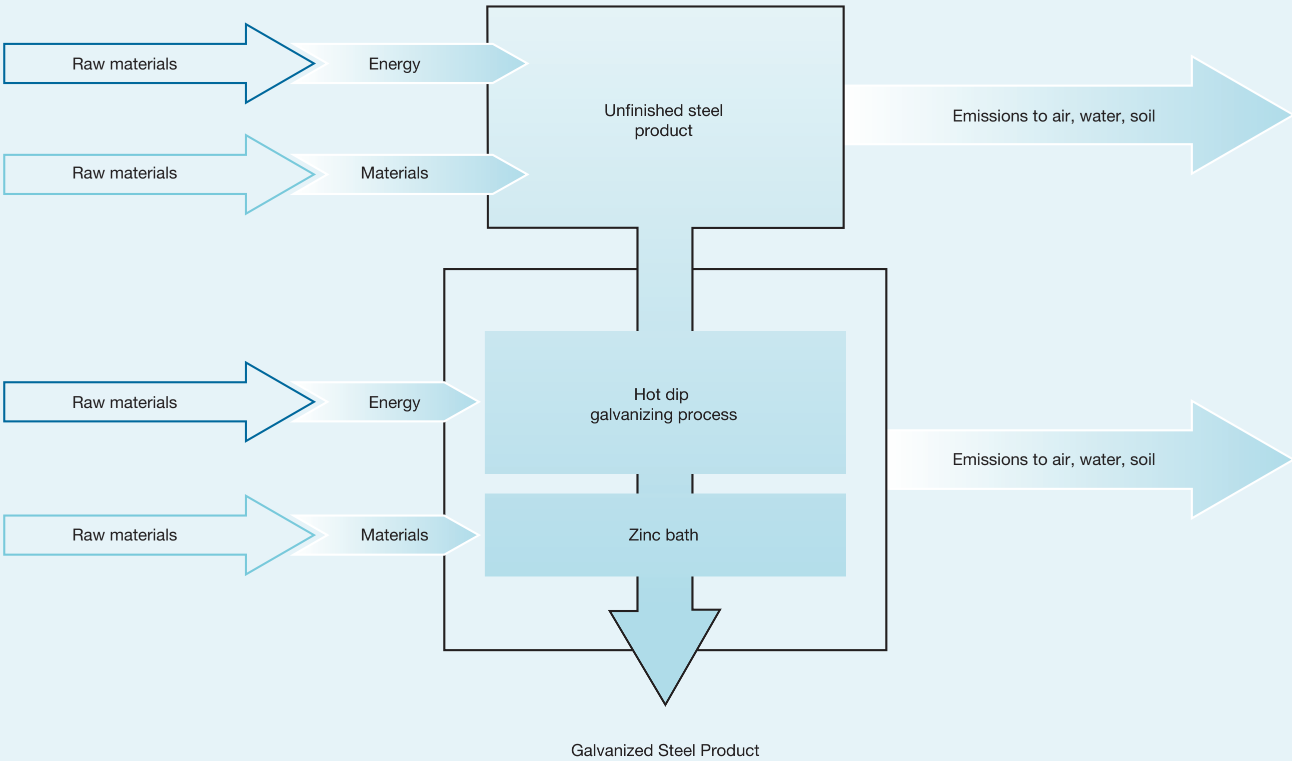
In 2005 European General Galvanizers Association (EGGA) contracted Life Cycle Engineering (LCE), Torino, Italy to perform a pan-European life cycle inventory (LCI) study of hot dip galvanized products. The study considered an average result for typical general galvanized products but a separate product class was identified for highway guard rails.

The objective of the work was to deliver life cycle inventory data sets for the galvanizing process, sometimes known as 'the service', using data submitted by members of EGGA National Associations from their members' operations. This involved quantifying the average energy, resource consumption and emission of substances to the environment, resulting in an LCI of a sample of processes operating in several plants in Europe, according to the defined system boundaries. The sample covered about 937,000 tonnes of steel galvanized by 46 plants.

The systems under consideration have the purpose of processing steel pieces and steel products to protect the surface of the steel from the environment. The functional unit was thus expressed in terms of 1 tonne of averaged zinc coated steel product.

Energy and environmental results are expressed by reference to the functional unit, but an extension of the analysis provides data about the system, independently of the steel product, in order to focus attention on 'the service'. Such results were expressed in terms of '1kg of zinc alloy ready for coating purposes'. This represents a useful measure of the energy and environmental costs of 'the service'.

This LCI data is available, on request from EGGA, to LCA professionals and customers who wish to generate an environmental product declaration for a galvanized steel construction product.



EGGA LCI: system overview

PRODUCT CATEGORY RULES FOR PREPARING AN EPD FOR CORROSION PROTECTION OF FABRICATED STEEL PRODUCTS

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A PCR has been established for galvanized steel in 2006 published by the SEMCO. The PCR is applicable to metallic, inorganic and organic coatings as well as for stainless or weathering steels.

The functional unit is one year of protection for a given geometry of steel plate. The PCR required statement of the following categories in a related EPD:

- use of non-renewable resources
- use of renewable resources
- global warming (kg CO_2 equ)
- ozone depletion (kg CFC-11 equ)
- acidification (mol H^+)
- eutrophication (kg O_2)
- photochemical oxidant formation (kg C_2H_2 equ)

This PCR document is currently being used as the basis for a sectoral EPD for galvanizing, that will soon be published by EGGA.

CLIMATE DECLARATIONS

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As an ambition to tailor-made EPD information for specific environmental issues, the International EPD® system introduces so-called Climate Declarations, concentrating on all aspects of relevance for climate issues including all green house gases and covering all stages of the life cycle from raw material acquisition to final waste handling. A climate declaration is indeed a global concept as it deals with human activities usually occurring in different countries around the world as a result of international trade.

There are many advantages with climate declarations – they are based on scientifically-sound methods for collecting and interpreting life cycle data, are neutral, developed and reported in a similar way, the information is comparable between different declarations and the information is quality-assured through external verification and certification. Through an official registration they are easy-to-access, and thereby available to anyone.

With these characteristics, climate declarations should be a welcomed contribution in the ongoing climate debate, bringing a holistic, factual-based and credible perspective on the market about the climate influence from various human activities and products.

SECTION
SIX
–

TITLE
CASE STUDY ONE
–

LCA EXAMPLE:
BALCONY STRUCTURES

	Hot Dip Galvanized System	Painted System
Balcony Manufacture	Balcony slab, balustrade and roof consisting of various profiled steel sheets, mineral wool and wooden grating. 4 CHS steel stanchions	Balcony slab, balustrade and roof consisting of various profiled steel sheets, mineral wool and wooden grating. 4 CHS steel stanchions
Coating Process	Hot dip galvanizing to EN ISO1461 of 778kg of CHS steel	Electrostatic painting of 39m^2 of CHS steel (external surfaces only)
Service Life	3 maintenance cycles to replace wooden grating and repaint roof every 15 years. No maintenance required for CHS steel stanchions.	3 maintenance cycles to replace wooden grating and repaint roof and repaint CHS steel stanchions every15 years.
End of Life	Steel and zinc recycling	Steel recycling

1. Systems for comparison

This study, completed in April 2004, was carried out by VTT Technical Research Centre of Finland for the International Zinc Association.

The objectives were to:

• provide a basis for future improvements in life cycle performance of zinc products
• establish environmental performance of a hot dip galvanized steel structure and an equivalent painted structure
• identify the relative importance of coating selection to overall life cycle environmental impact of steel structures

VTT has extensive experience with the Finnish building industry in developing Environmental Product Declarations (EPDs) for building products. VTT also carried out earlier work on life cycle assessment for the Finnish galvanizing industry. This provided a valuable basis for the study.

Scope and Data Sources

The "Producta" balcony systems studied in the assessment are produced by Rannila Steel Oy, Finland and have been in production since 1996. This lightweight balcony system is normally manufactured with a duplex coating (galvanized and painted) for its structural circular hollow sections (CHS) and had been previously studied by VTT in producing an EPD for the balcony. In order to assess the impacts of hot dip galvanizing and painting separately, two coating specifications were defined to cover the required 60-year service life (Fig 1).

The environmental issues assessed were those most commonly applied in EPDs and "green building" rating systems – i.e., the use of energy, use of natural resources and the impacts of air emissions on global warming potential, acidification and photochemical ozone creation.

These aspects were estimated using established life cycle impact category indicators from the Eco-Indicator 95 and DAIA methods. Life cycle inventory data was predominantly sourced from Finnish processes and products, although data for paint materials was sourced from published European databases. Recycling of the steel and zinc was considered in the assessment and allocated using a methodology set out by the International Iron and Steel Institute (IISI).

Durability

The durability of the coating systems was estimated using ISO 14713 and ISO 12944 for galvanizing and painting, respectively. Corrosion rates for galvanized coatings in Finnish environmental conditions are reported as 0.5-1.0µm/year. The 100µm galvanized coating would therefore require no maintenance during the 60-year service life. The painted structure would require maintenance painting every 15 years.

The "standard" paint system identified for comparison was a zinc-rich epoxy (40µm DFT)/epoxy primer (2x80µm DFT)/polyurethane (40µm DFT), chemically curing solvent-borne system. In addition to this "standard" paint system, a low-VOC (water-borne) paint system was also considered in the assessment.

A number of assumptions were necessary. Most notably, that the maintenance painting of the structure has the same durability and environmental profile as the original paint application. This was a conservative assumption, but was necessary due to the lack of available environmental data on in-situ maintenance painting.

Results

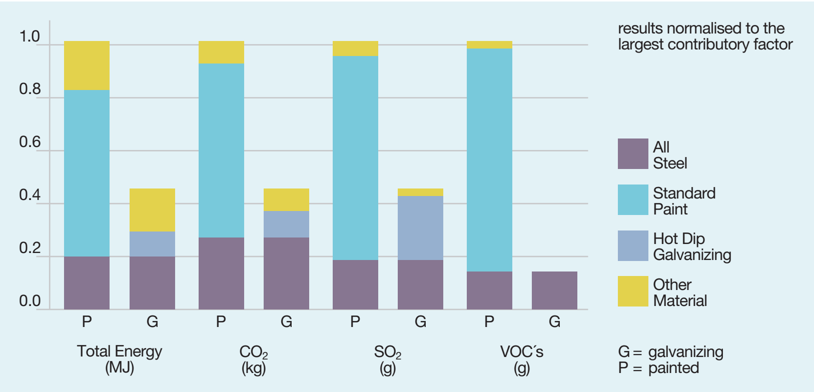
The results of this pilot study are illustrated in Figures 2-4 and can be summarised as:

- the choice of coating has a significant influence on the life cycle environmental profile of the balcony structure
- galvanizing has significantly lower results across all three main life cycle impact categories (global warming potential, acidification and photochemical ozone creation potential)
- durability determines much of the life cycle difference between paint and galvanizing, with the burdens of maintenance painting contributing significantly to the life cycle results of the painted balcony system
- appropriate allocation of the benefits of steel recycling, using the IISI model, is important in estimating the overall life cycle impact

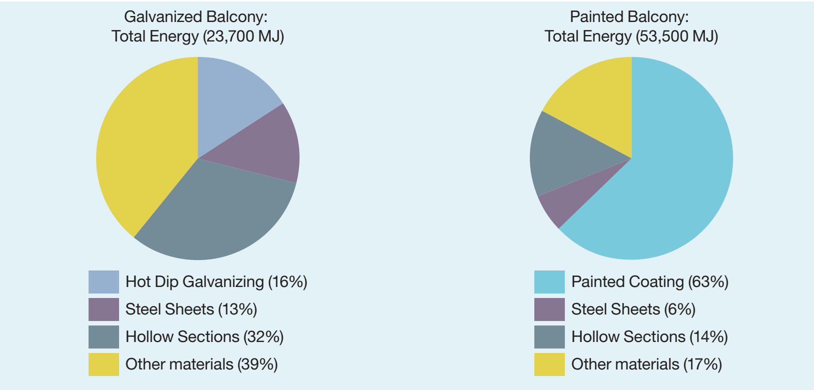
Conclusions

This pilot study quantified the principal environmental impacts of a galvanized steel balcony and a painted balcony. For the impact categories considered, the efficiency and durability of the galvanized coating provided for significantly lower life cycle environmental indicators of the balcony, when compared to the equivalent painted system.

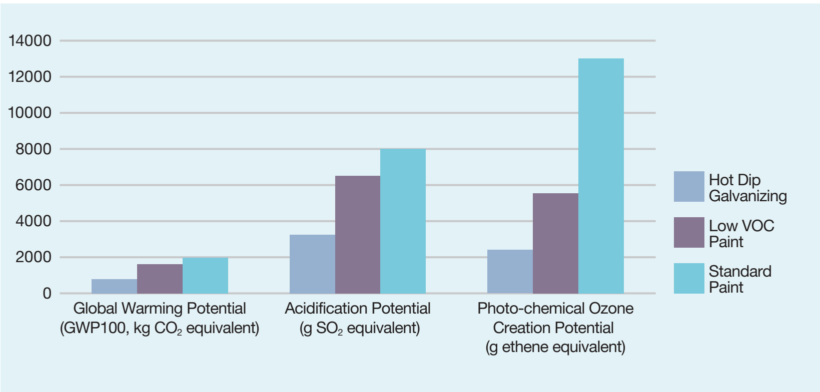
These results require further exploration, in particular to further define the burdens associated with maintenance painting. However, these refinements are unlikely to change the general results.



2. Detailed life cycle inventory results for selected inventory categories



3. Life cycle energy – galvanized balcony compared to painted balcony



4. Life cycle environmental impacts – selected indicators

SECTION
SIX
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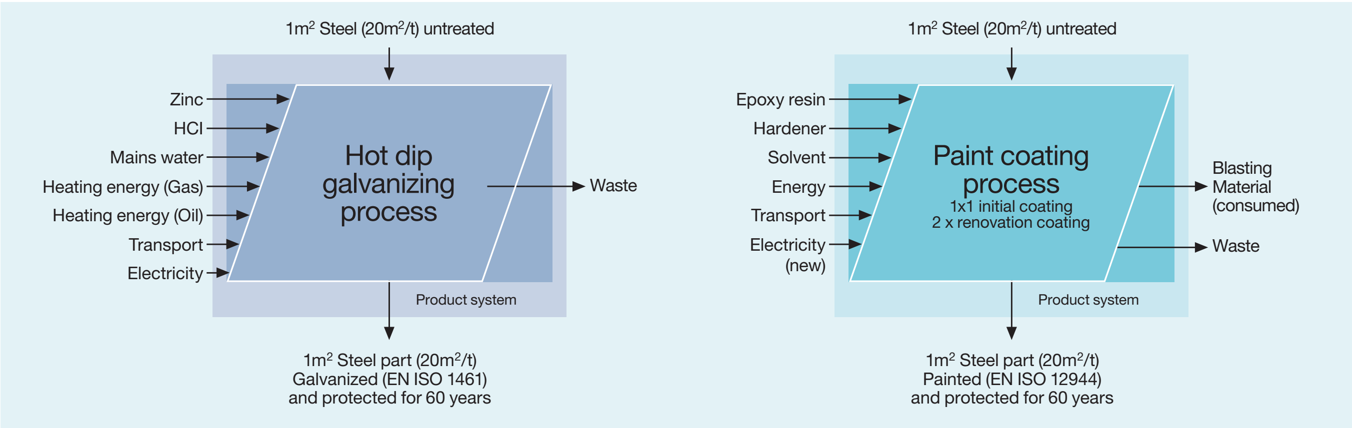
TITLE
CASE STUDY TWO
–

LCA EXAMPLE: CAR PARKS



1. Galvanized system

2. Painted system

A 2006 study by the Environmental Technology Systems Department of the Institute for Environmental Protection Technology at the Technical University of Berlin involved a comparison between a paint coating (as EN ISO 12944) and hot dip galvanizing (EN ISO 1461) for a steel car park on the basis of a life cycle assessment.

The central value for LCA comparisons is the functional unit - the reference quantity for the comparison. An objective comparison cannot be carried out without identical comparison variables. The way these values were defined in the study was that the two systems had to provide corrosion prevention for a steel structure which was to be used for 60 years, and which was applied to a steel structure such as a multi-storey car park with a steel area amounting to 20 m^2/t. It was assumed that the structure was externally exposed to a medium level of corrosion (corrosion category C3 from ISO 9223).

The hot dip galvanizing system is a 'one-off' corrosion prevention treatment by immersion in molten zinc. With a zinc layer thickness of 100 µm and an average corrosion rate for category C3 of 1 µm/year, the calculated durability far exceeds the required 60 years. The environmental impacts connected with this system (resource consumption, energy consumption and wastes) are shown in Fig. 1.

To guarantee corrosion prevention for 60 years using the paint coating system, the components are first abrasion-blasted to remove the rust. Then they are initially coated in the works with a three-coat application with a total coating thickness of 240 µm. On-site maintenance operations are then needed after 20 and 40 years, involving partial cleaning and some renewal of the coating (see Fig. 2).

Results

The results calculated using the recognised CML 2 baseline 2000 method are represented by five different environmental impact categories. Fig. 3 shows these environmental impacts. The results are normalised to the largest contributory factor (consumption of resources). The length of the bars is a measure of the environmental stress.

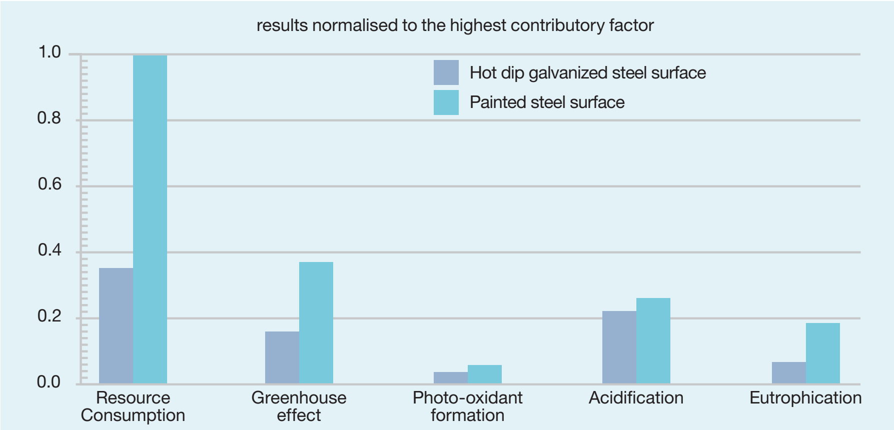
The contributory factors for the hot dip galvanizing system are lower in all effect categories than for the paint system. In several effect categories there are marked differences. In comparison with paint, hot dip galvanizing's score in the category of eutrophication is only 18%, in the resource consumption category it is only 32%, and in relation to the greenhouse effect it is only 38%.

Hot dip galvanizing is distinguished by lower consumption of resources and less pollution throughout its service life.

Conclusions

The study shows that life cycle assessment is a meaningful method, based on actual practice of ecological comparison of products. It brings out marked differences between two established corrosion prevention systems for steel structures.

The hot dip galvanizing corrosion prevention system displays lower environmental impact for a steel structure with a long service life, as against a paint system. Long service life and freedom from maintenance, the well-known advantages of hot dip galvanizing, are the basis for the environmental benefits of the process.



3. Life cycle environmental impacts

Service Life (Yrs)	Hot Dip Galvanized Steel Structure (Kg CO_2 equivalent)	Painted Steel Structure (Kg CO_2 equivalent)	Saving in global warming potential by hot dip galvanizing (Kg CO_2 equivalent)
60	41,500	98,600	57,100
40	41,500	71,600	30,100
20	41,500	60,500	19,000

4. Savings in global warming potential: hot dip galvanized protection for the steel framed car park (500t structural steel)

SECTION
SIX
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TITLE
CASE STUDY THREE
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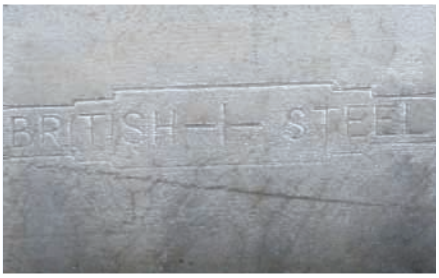
DURABILITY: BRIDGE IN THE NETHERLANDS AFTER 60 YEARS



The durability of galvanized coatings can be reliably predicted using a variety of techniques. One of the most reassuring is the use of case histories such as this Dutch bridge. Galvanized steel structures have been around for many decades and these examples provide real-world demonstrations of coating performance.

The Ehzer Bridge was built quickly by Canadian troops in 1945 in support of the liberation of the Netherlands. It carries a small local road, over the Twente canal, from Almen to Laren which is still being used by local traffic. The bridge is just wide enough to allow cars to pass in each direction but nearby bridges are now starting to take the fast urban traffic leaving mostly cyclists and pedestrians to use the bridge.

Visual inspection

The bridge was recently inspected by technical staff from the Dutch Galvanizers Association (SDV) who were struck by the good appearance of the bridge, which was characterised by a dull grey galvanized coating with only some light rust staining.

Some remedial work had been done in the vicinity of the bolted connections and youngsters with their spray cans had also contributed to the appearance of the bridge! Most importantly, the steel structure itself had not suffered any significant corrosion.

Remaining coating thickness

During the inspection, coating thickness was electromagnetically determined in a number of randomly selected areas, using an average of 10 readings at each location. At three diagonal bracing sections (150 x 150 mm) coatings of 74μm, 115μm and 219μm were found. At two other diagonal sections (130 x 130 mm) coatings of 69 μm and 82 μm were found. Two connecting plates were found to have coatings of 114μm (19 mm steel thickness) and 86μm (9 mm steel thickness).

In comparison with the thicknesses of the zinc layers as reported by Dutch galvanizing expert, Van Eijnsbergen, 25 years after the bridge was built there appears to have been no significant reduction of the coating thicknesses.

Note that the requirements of EN ISO 1461 for new galvanized steel are for 85μm for steel of section thickness > 6mm.

Future for the bridge

The Ehzer bridge at Almen could make it to 100 years without significant maintenance. Whether the bridge will actually last that long is dependent on other considerations. Will the road where the bridge is located remain a quiet local road or will heavier traffic be passing over it in due course? Or will the use of the canal change completely and the bridge clearance need to be changed or the span need to be increased?

SECTION
SIX
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TITLE
CASE STUDY FOUR
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DURABILITY: MARINA IN SWITZERLAND AFTER 38 YEARS

Hot dip galvanizing can provide long-term, maintenance-free corrosion protection in even the harshest of environments. An example of this is the marina and port installations at Arbon and Bottighofen in Switzerland. These two small towns are idyllically situated on the Southern shore of Lake Constance and are very popular with water sports enthusiasts.

Use of galvanized steel

A new port was built in Bottighofen in 1968 and used considerable quantities of steel. The sheet piling used along the 150m long port basin and many other steel elements such as railings, barriers, doors, gates, the landing stages with ship caissons, plus the bollards and heavy tubular jetties, were all protected against corrosion by hot dip galvanizing.

The port installation in Arbon was extended in 1971. Galvanizing was also used as the main system for corrosion protection of the steel components. Over 100 tonnes of sheet piling and fender profiles were used in the project.

Inspection results

When the two port installations were first inspected, in 1983, no significant corrosion was found on the galvanized coating. Even in the most aggressive areas, (sheet piling) no corrosive effects could be detected.

A second inspection of the two port installations took place in the autumn of 2006 about 38 years since the original construction project. The galvanized coating was again shown to be in good condition and fully functional. As expected, the original silvery, glossy zinc appearance had changed into a dull grey surface. This change in appearance occurs as the protective film is built up on the coating surface during reaction with the atmosphere.

The inspection report emphasised the good condition of the sheet piling after so many years of exposure, despite the exposure to abrasion and impact from boats. In fact, it was only on some steel bollards, to which large ships moor up using heavy chains, that the galvanized coating had been damaged.

The electrochemical protection of the surrounding zinc will prevent this damage from spreading through sideways corrosion.

Most importantly, the inspected thicknesses of the remaining coating was still between 50 and 100 µm. So, the galvanized steel elements of these port installations will also remain protected against corrosion for many more years to come.

SECTION
SIX
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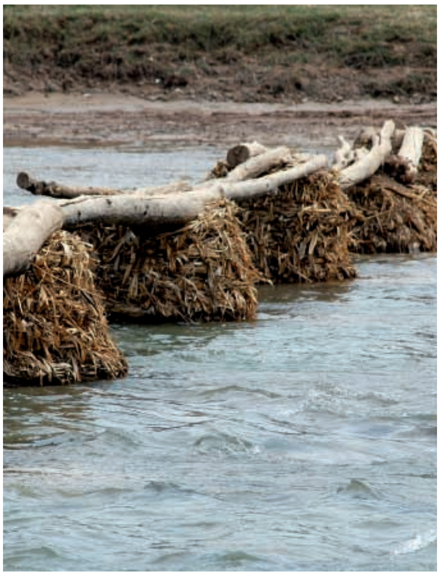
TITLE
CASE STUDY FIVE
–
THE BRIDGE OF SUSTAINABILITY



For years children in a Chinese community divided by the River Po – a tributary of the Yellow River – had to cross the river on a precarious single-log bridge: built on pillars of straw, rock and earth. Among the many accidents, a mother and child were swept to their deaths on the journey to the school on the other side of the waterway from
their homes.

Nearly 400 primary students in Maosi village, Gansu province attend four cave schools on both sides of the Po River, which freezes in winter and can be a raging torrent during summer monsoons, according to Professor Edward Ng Yan-ynug of the Department of Architecture at CUHK, who came across the community and their problem during field work to study the thermal properties of cave dwellings in the area.

This means students do not go to school from November to February for fear of falling into the freezing water and between May and August because the river is flooded.

To make life easier and safer for children and parents, a group headed by professor Edward Ng have designed a special floating footbridge, the project – “A Bridge Too Far” – is part of a campaign to improve education facilities for the local population. Professor Ng said the original plan was to build a submersible bridge, but the forces of nature proved to be a stumbling block.

“We are trying to build a cheap and simple bridge for the villagers that can be easily maintained”, Professor Ng said.

Students and professionals came up with the solution – the 80-metre Wu Zhi Qiao (bridge of sustainability). The structure, which cost just $300,000 to build, was designed to use mainly natural local materials, to be maintained by the villagers and copied for other bridges.

The UK engineers, Anthony Hunt, famed for the Eden Project, helped with the initial conception of the design.

The bridge needed to be cheap, simple to construct, not be swept away by annual floods and be easily reparable by the villagers.

The solution was to construct piers without foundations but fastening pins to attach them to the riverbed. The piers are shaped to minimise resistance and form gabions with sufficient weight so as not to be swept away. The bridge deck consists of a galvanized steel frame, which is in-filled with bamboo planks to form the deck. The bridge is designed in small sections with handles so that each section, if detached, can be easily put back by six villagers. The other intriguing feature of the Zig-Zag design of the deck is to conform to the traditional Chinese belief that evil spirits cannot turn corners but conveniently adds structural integrity to the design.

About 50 students from Hong Kong and 30 from Xian, took five days to build the bridge, working alongside villagers. The galvanized steel bridge has already withstood a flood that submerged the whole structure.

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GLOSSARY

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ASH
Also termed skimmings. A solid by product formed at the surface of the galvanizing bath as a result of the reaction between zinc and air. It is removed from the surface of the bath periodically and recycled.

DROSS
A solid by product of the reaction during galvanizing between iron and molten zinc. Dross contains about 96% zinc and 4% iron and is removed from the bottom of the bath periodically and recycled.

ENTRAINED ZINC
Small globules of zinc can be entrained in the ash that is removed for recycling. This entrained zinc is separated from the ash and remelted for re-use.

FLUX
A pre-treatment solution that provides a final cleaning of the steel surface prior to galvanizing and ensures good wetting of the steel surface by molten zinc on immersion in the galvanizing bath.

HYDROMETALLURGICAL
A process that relies mainly on electrolysis or chemical precipitation for the separation of a metal from its ores.

JIGGING
The hanging of batches of steel articles to be galvanized on hooks or wires.

PATINA
A protective film formed at the surface of the galvanized (zinc) coating when it reacts with carbon dioxide and oxygen from the atmosphere.

PICKLING
The use of a dilute acid to remove rust and other contaminants from the steel article prior to immersion in the galvanizing bath.

PYROMETALLURGICAL
A process that relies mainly on heat for the separation of a metal from its ores.

QUENCH
The rapid cooling of hot galvanized steel articles immediately after removal from the galvanizing bath. This allows handling of the coated steel to take place sooner.

REFINED ZINC
Also termed primary zinc. Metallic zinc produced from both mined ore concentrates or recycled feedstock.

REMELT ZINC
Also termed secondary zinc. Metallic zinc that has been recovered from end-of-life or process scrap and remelted for re-use scrap

GUIDE TO ACRONYMS

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BREEAM
Building Research Establishment Environmental Assessment Method

CML
Institute of Environmental Sciences, Leiden University, Netherlands

DAIA
Decision Analysis Impact Assessment (Finnish Environment Institute)

DFT
Dry Film Thickness

EGGA
European General Galvanizers Association

EPD
Environmental Product Declaration

KTH
The Royal Institute of Technology, Stockholm

LCA
Life Cycle Assessment

LCI
Life Cycle Inventory

LEED
Leadership in Energy and Environmental Design

PCR
Product Category Rules (for an EPD)

SEMCO
Swedish Environmental Management Council

VOC
Volatile Organic Compounds (e.g., solvents)

ACKNOWLEDGEMENTS

Cover — Acoustic barrier,
Utrecht, Netherlands.
OLN [Oosterhuis_Lénárd]
Meijers Staalbouw

Page 5 — NV Afvalzorg headquarters,
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Rob Hoekstra, Kalmthout

Page 6 — Jubilee wharf,
Cornwall, UK.
Zedfactory
www.zedfactory.com

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China.
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CUHK

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Abacus Lighting

Page 9 — Crash Barrier,
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Heneghan.peng in association
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Architekturbüro Schulitz + Partner

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Cork, Eire.
O'Donnell & Tuomey
Denis Gilbert/VIEW

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Eire.
Paul Leech, Gaia Ecotecture

Page 31 — Houses in Constance,
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Schaudt Architects
Reiner Blünck

Page 32 — Case Study One
International Zinc Association

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Institut Feuerverzinken,
Germany.

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Stichting Doelmatig Verzinken
Netherlands.

Page 37 — Case Study Four
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Gackenheimer,
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Page 38 — Case Study Five
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