ZINC COATED STEEL

Foreword

Steel and zinc make a good marriage during their service life and are easily recyclable.

Zinc coatings lengthen the useful life of steel products and structures and keep the steel performing at its peak condition. When the zinc coated steel is scrapped and recycled the steel and zinc have new lives.

Therefore, the combination of steel and zinc is especially fortunate because it is possible to separate and recover both the original metals.

This means that galvanized steel and electro-zinc coated steel sheet are recyclable materials which can be reused to make further contributions to the life of the community.

The metals can be separated because zinc is naturally much more volatile than steel. When scrap zinc coated sheet is melted in the steel making process, the scrap steel is turned into new steel for reuse. The zinc enters dusts which are recovered from the furnace. They form a resource of zinc which we can use again, alongside other zinc raw materials.

The recycled zinc is also used in zinc coated steel, with a new life in new products, such as cars, buildings and construction products.

This cycle, in which zinc and steel are infinitely renewable, contributes to the virtuous circle of recycling.

Photo: Zinc coated steel manufacturing scrap is recycled into new products

Contents

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1. INTRODUCTION

Zinc is as old as the earth's crust itself and has been used in bronze and brass since ancient times. However, zinc metal was not isolated until about 1400 AD. The galvanizing process - coating steel with zinc to prevent corrosion - was discovered in 1741 and patented in 1837. The use of zinc to protect steel became widespread at the end of the 19th century.

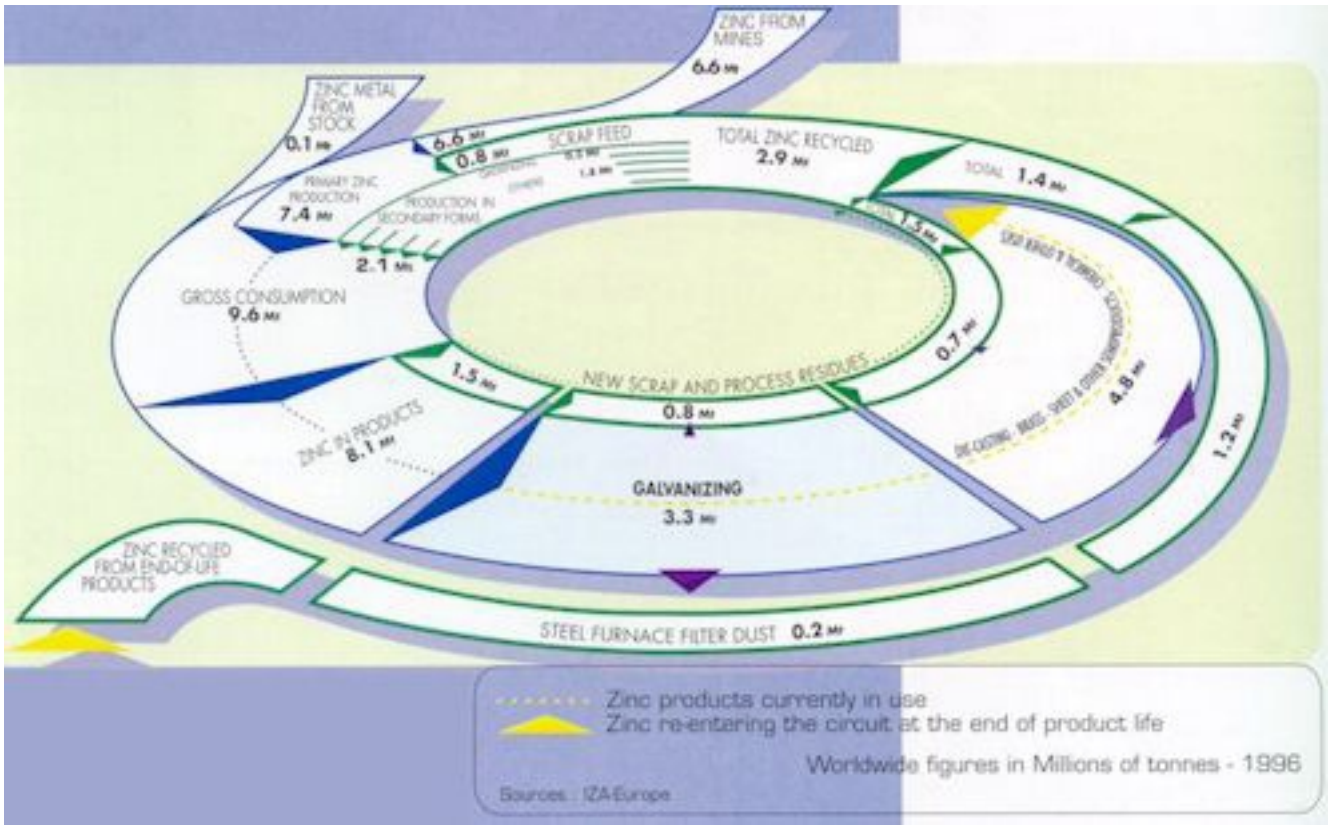
Today, about 140Mt of steel are produced in Western Europe every year and about 25Mt, or 18% of this, are protected against corrosion by galvanizing. Figure 1 shows worldwide zinc consumption through its recycling circuit. Consumption of galvanized steel continues to grow at about 5% each year. As a result, the amount of zinc used in galvanizing has grown steadily,

today representing just under 50% of zinc consumption.

This brochure explains how all zinc coated steel, whether from manufacturing or from the consumption cycle, is recyclable. Recycling zinc coated steel entails recycling both the steel and the zinc. Both components, steel and zinc, keep their original physical and chemical properties after recycling. Technologies and industrial plants have been developed specially to achieve this.

Recycling of the steel-zinc combination conserves natural resources, saves energy and meets the objectives of an increasingly environmentally conscious world.

Fig.1: Recycling circuit for zinc



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This brochure explains how all end-of-life products, by-products, residues, off-cuts and other scrap materials from the manufacturing process - which are accessible and available for recycling - are collected and treated to separate and recover steel and zinc. As a result, recycling zinc coated steel enables the steel and zinc industries to use recovered products instead of new resources.

2. ZINC RECYCLING: THE GENERAL PICTURE

Steel and zinc are both valuable products which are increasingly used together in the production of long lasting steel goods.

Steel and zinc are both recyclable and, today, they are both recycled on an economic basis. The recycling systems for these materials are linked in some ways.

The steel recovery rate from end-of-life steel products in industrialised countries is about 70%. The amount of steel scrap, as opposed to newly produced iron, used in the world steel industry in 1996 was 306Mt. Total steel production in that year was 753Mt. As a result, the proportion of steel which came from secondary sources was about 45% of the total. Steel scrap is recycled into prime liquid steel both by electric arc furnace and the basic oxygen furnace processes.

Similarly zinc is a recyclable metal which is substantially recycled today. The average rate of zinc recovery from scrap and residues is about 80%. Virtually all zinc-containing process and manufacturing scrap is recycled and it is estimated that 66% of zinc from old scrap is recycled too.

The total quantity of zinc recycled world-wide in 1996 was 2.9Mt. At first sight this appears to be a much smaller amount than annual zinc consumption, which was 8.1Mt in that year. But this is due to the fact that the quantity of old zinc accessible and available for recycling depends on the life cycle of zinc- containing products. On average, this is 31 years. When this is taken into account the proportion of zinc from secondary sources which is in new products is more than 30%, close to the contribution which recycled steel makes to new products.

This brochure shows that galvanizing, the major user of zinc, is by far the biggest contributor to zinc recycling, accounting for 1Mt, or 35% of all recycled zinc.

The processes of galvanizing and zinc coating steel generate other zinc-containing materials, known in the industry as residues, and zinc coated steel scrap. Also, the treatment of new and old zinc coated steel scrap in steelmaking produces zinc-containing dusts.

Galvanizing residues, which have a high zinc content, are totally recycled. As a result, these materials, of which 800kt are produced each year worldwide, constitute 54% of zinc-containing materials (new zinc scrap and residues) currently recycled.

Also, substantial quantities of arc furnace dusts are upgraded and used as a raw material for the production of new zinc. The remaining dusts are placed in regulated storage. Processes are being developed to recover the zinc from them. The arc furnace dust currently stored in this way amounts to about 14% of the total zinc available for recycling (see section 4).

3. RECYCLING ROUTES AND LIFE CYCLES

Zinc coated steel scrap

Figure 2 explains the main recycling routes for zinc coated steel scrap.

Scrap comes essentially from two sources :

- process and manufacturing scrap or new scrap
- obsolete scrap.

New scrap is produced either during the production of zinc coated steel sheet or during the production of vehicles construction components and other manufactured parts. Obsolete scrap, sometimes called old scrap, consists of end-of-life vehicles, electrical household appliances, air conditioning ducting taken from redundant buildings, old highway barrier, lamp posts and so on.

Each year the European steel industry produces about 20Mt of zinc coated steel sheet. The amount of scrap produced on continuous galvanizing lines depends on the type of product produced and the nature of the process. It varies between 0,5 and 2% of production, so the tonnage of zinc coated scrap from this source is about 0.2 to 0.6Mt each year. This material is a valuable feed for the electric furnace steelworks.

A second type of process scrap comes from the production and assembly of products such as cars, washing machines, refrigerators and so on. The rate at which scrap is produced varies, depending on the industry and complexity of the product being fabricated. It is between 28 and 30% in the automotive sector and 2 and 3% in the construction sector.

The European automotive sector alone, which consumed 4.9Mt of zinc coated sheet in 1995, generated 1.5Mt of scrap. In all, about 1.8Mt of zinc coated steel scrap was returned via the scrap stream for steelmaking.

The automotive sector and the steel industry are working together to reduce the quantity of scrap which comes from product manufacturing. For example, the development of new technologies known as "tailored blanks" and "hydro-forming" should minimize the scrap production. On the other hand, the use of zinc coated steel sheet in Europe, is expected to rise to 6.8Mt in 2000 as a result of increased demand for corrosion protection and growth in consumption, so the quantity of scrap generated in this sector will still represent about 1.9Mt per year.

European general galvanizing plants, which protect about 5Mt steel products each year, do not generate process scrap. The fabrication brought to the galvanizer's plant already contains a lot of valuable work. The fabrication is galvanized and returned to the fabricator for delivery to the market.

Figure 2 : Flow sheet describing the recycling routes

The useful life of products varies from about 10 years for cars and household appliances to as much as 100 years and more for steel used in buildings.

Most of the products protected by the general galvanizing industry have extraordinarily long service lives. Lamp posts are estimated to remain in service for more than 40 years, and records show that power transmission towers remain in service for more than 70 years. Galvanized steel exposed to wind and rain, in agriculture, may have a service life of up to 80 years.

Even so, when they come to the end of their useful life - usually because the fabrication is obsolete, not because the steel has corroded - they are recovered so that the steel and zinc can be used again.

The amounts of scrap also vary with the recovery rate for end-of-life products depending on the sector, but growing from year to year thanks to a highly developed and efficient collection system. The quantity of zinc and steel contained in old scrap is expected to rise, reflecting continued growth in the automotive sector.

The total zinc coated steel scrap recovered from recycling is likely to increase from 6.5Mt in 1995 to 10Mt in 2005 as shown in figure 3.

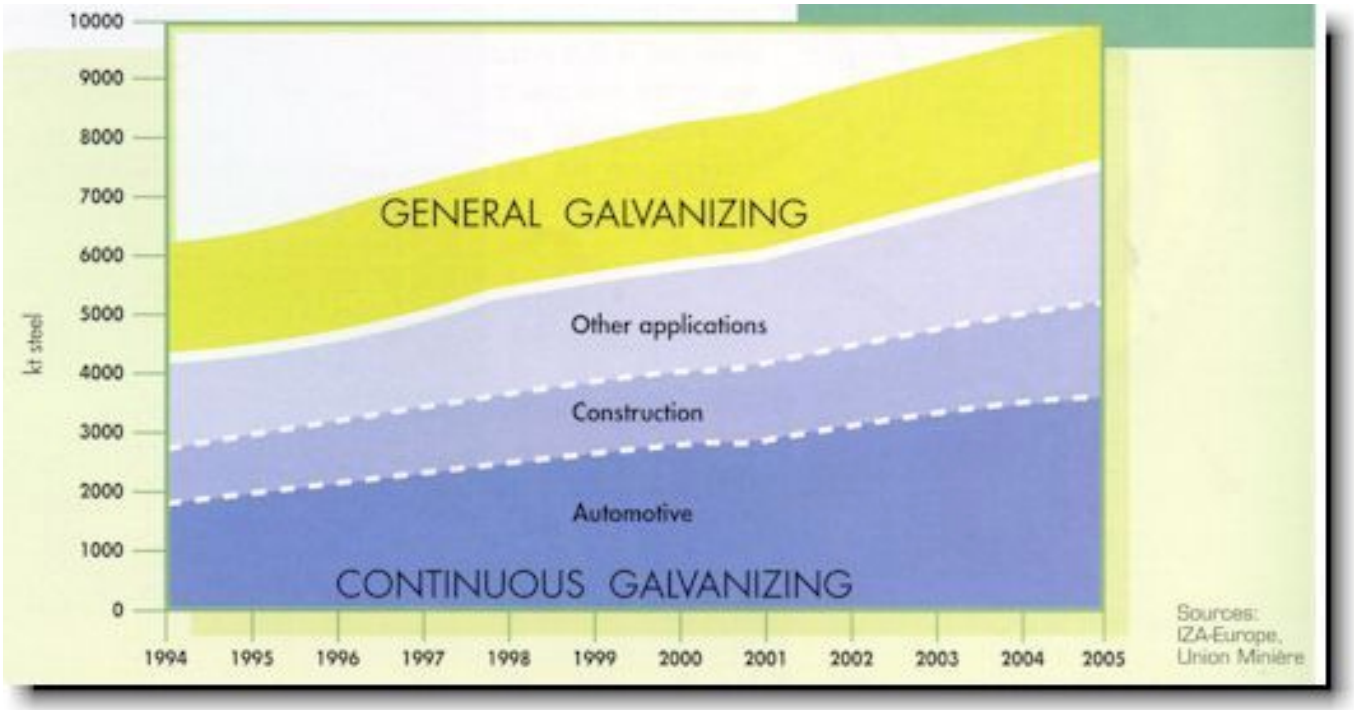

Figure 3 : Recovery potential of galvanized steel scrap

Recycling circuits for galvanizing residues

All galvanizing processes produce zinc-containing materials, or by-products, known in the industry as residues. The first, known as galvanizing dross, comes from the reaction of zinc with the steel which is galvanized. The second, known as skimmings or ash, comes from the oxidation of zinc during the galvanizing process.

The properties of these galvanizing by-products are well known and there are well established technologies to comple-tely recover the zinc contained in them.

Nevertheless, they have a rather high zinc content and so all galvanizing companies try to minimise the quantity of ash and dross which they make because there is a cost to recycling these by-products.

Typically, the quantity of zinc which appears in the bottom dross in the general galvanizing process is between 9 and 13% of the zinc which entered the process. The quantity of zinc which unavoidably appears in skimmings or ash varies from 14 to 18%. In the continuous galvanizing process, which uses a different technology to coat flat steel products, the amount of zinc appearing in the top dross is around 7 to 9% of the zinc which entered the process (see figure 4).

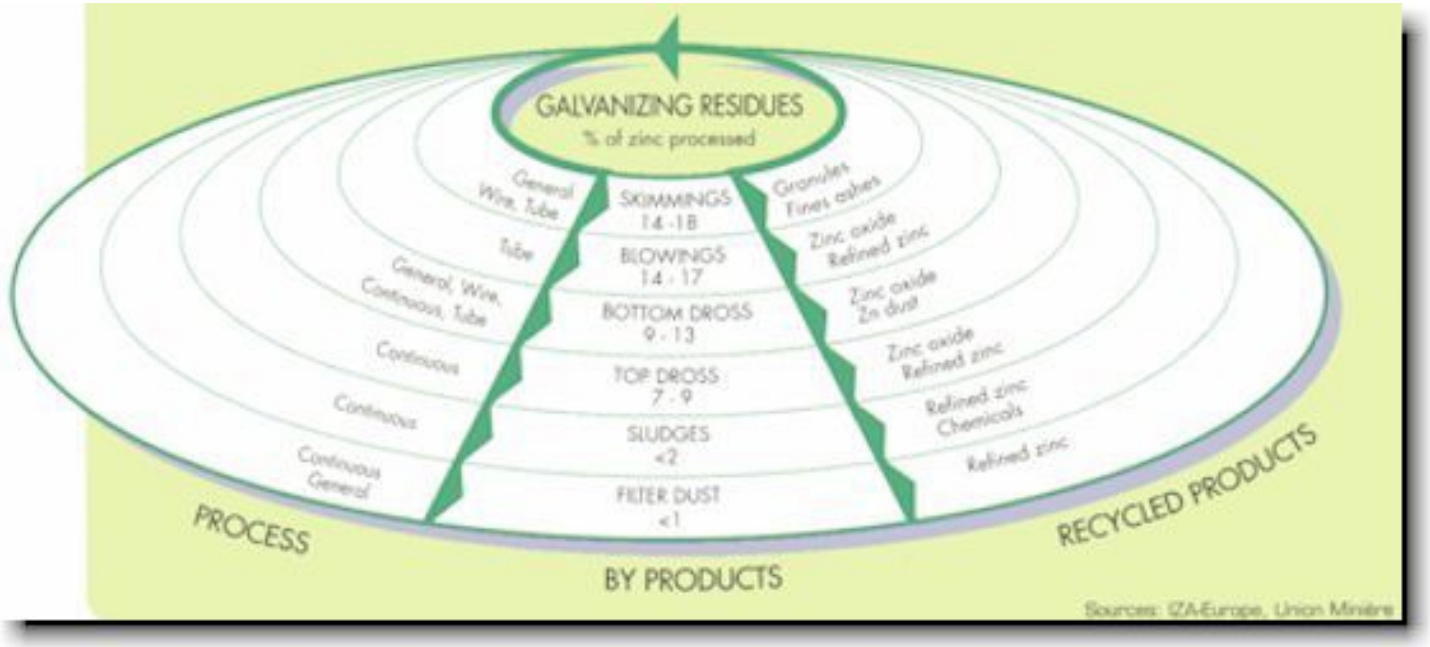

Figure 4 : Recycling of galvanizing process residues

Click here to see a wider view of Fig. 4

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These by-products have a short life because they are valuable raw materials. The galvanizing industry has a strong economic incentive to recover and reuse the zinc which is contained in them.

Some general galvanizers recover metallic zinc from zinc ashes and reuse it directly in their process, although most is recycled into remelted zinc. There is a well established collection system for returning these materials to the zinc production industry and, for the most part, they are treated and the zinc recycled from them within three months of their production (see figure 5).

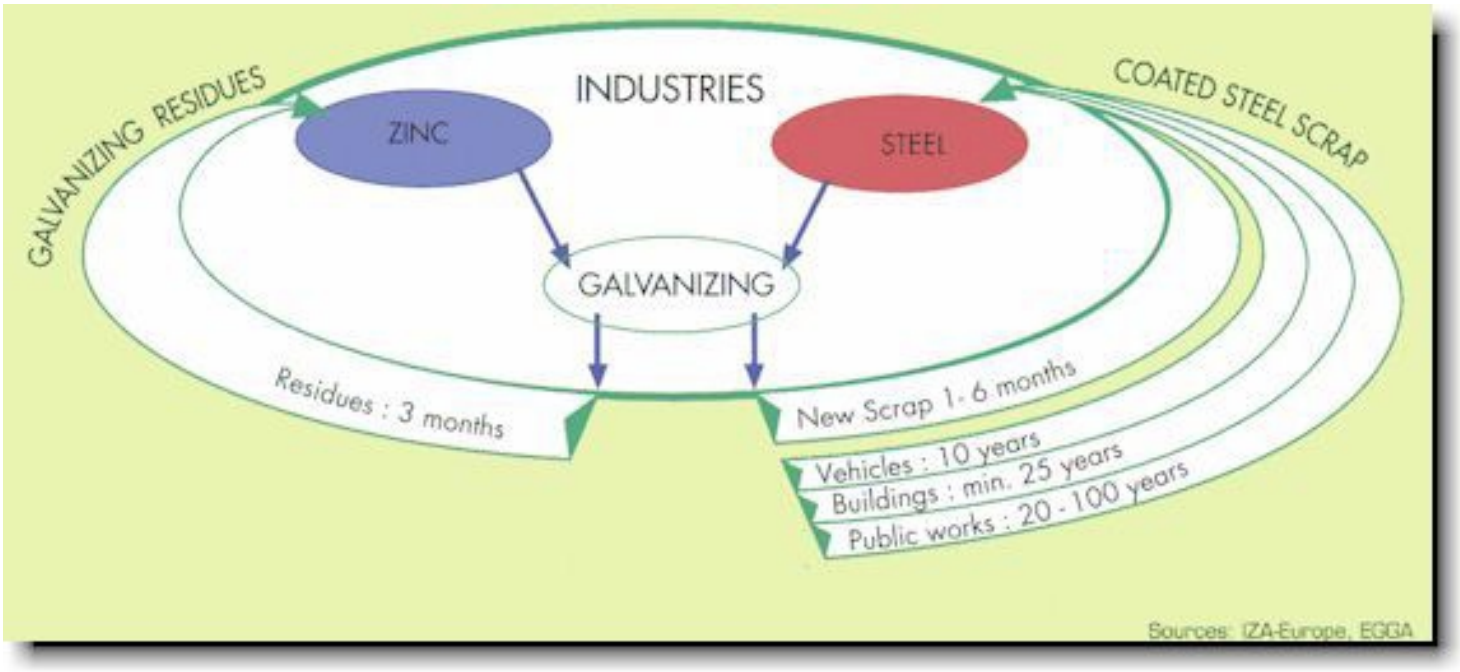

Figure 5 : Life cycles

The zinc products obtained from this recycling system are zinc metal, zinc oxide, zinc powder and zinc chemicals. All of these have important uses in industry, agriculture and everyday life. In a few cases ashes and dross are recycled through primary zinc refineries to become new zinc.

Zinc dross before recycling

4. RECYCLING PRACTICE AND TECHNOLOGY

Recycling zinc and steel in the steelmaking process

When zinc coated steel scrap is recycled, there is a close link between the recycling routes for both the zinc and the steel. But first it is necessary to know something about the way in which steel is produced.

Photo: Electric arc furnace

There are essentially two routes for the mass production of steel. They are the electric arc furnace (EAF) route, for which the raw material is mainly steel scrap, and the blast furnace - basic oxygen (BF-BOF) steelmaking route, for which the raw material is iron ore, liquid iron and steel scrap.

An electric arc furnace is a large refractory brick lined vessel in which electrical power is used to strike an arc between an electrode and the scrap steel. The heat of the arc melts the steel.

The high temperature in the two steelmaking processes causes zinc, which is very volatile at these temperatures, to leave the furnace along with gases.

The gas stream is treated in pollution control equipement and the zinc, which has oxidised, ends up in the dust.

These dusts vary in zinc content and are subsequently recycled at treatment centers.

In the blast furnace-basic oxygen process, iron ore is crushed and made into pellets or sintered in special plants. The pellets are mixed with coke and charged into a blast furnace, which produces liquid iron. The iron is then treated in a basic oxygen furnace to change its composition and produce liquid steel. The chemical reactions in the basic oxygen furnace produce too much heat, so it is necessary to cool the process. This is done by adding steel scrap, which may account for as much as 20% of the steel in the BOF furnace.

Basic oxygen furnaces are even able to charge zinc coated scrap. When working so the dusts leaving the pollution control equipement vary in zinc content and are subsequently recycled at treatment centers.

Although most steelmakers try not to charge zinc coated scrap to the basic oxygen furnace, it is difficult to avoid the presence of zinc in the dust recovered through the pollution control system. The zinc content of those dusts is too low to be recycled and too high to be landfilled. New processes are being in developement to treat those dusts.

Electric arc furnace dust treatment

In the past, all these steelworks dusts were discarded. Today, steelworks increasingly process dust in order to recycle the valuable metals in it. The higher the zinc content, the more attractive is the possibility of treating steelworks dust (figure 6). Therefore, electric furnace steelworks try to raise the concentration of zinc in dust by various technical means. These include increasing the amount of zinc-bearing scrap charged to the furnace and recycling dust until its zinc content reaches 18 to 35%, which makes it an attractive raw material for zinc production. The methods can be combined.

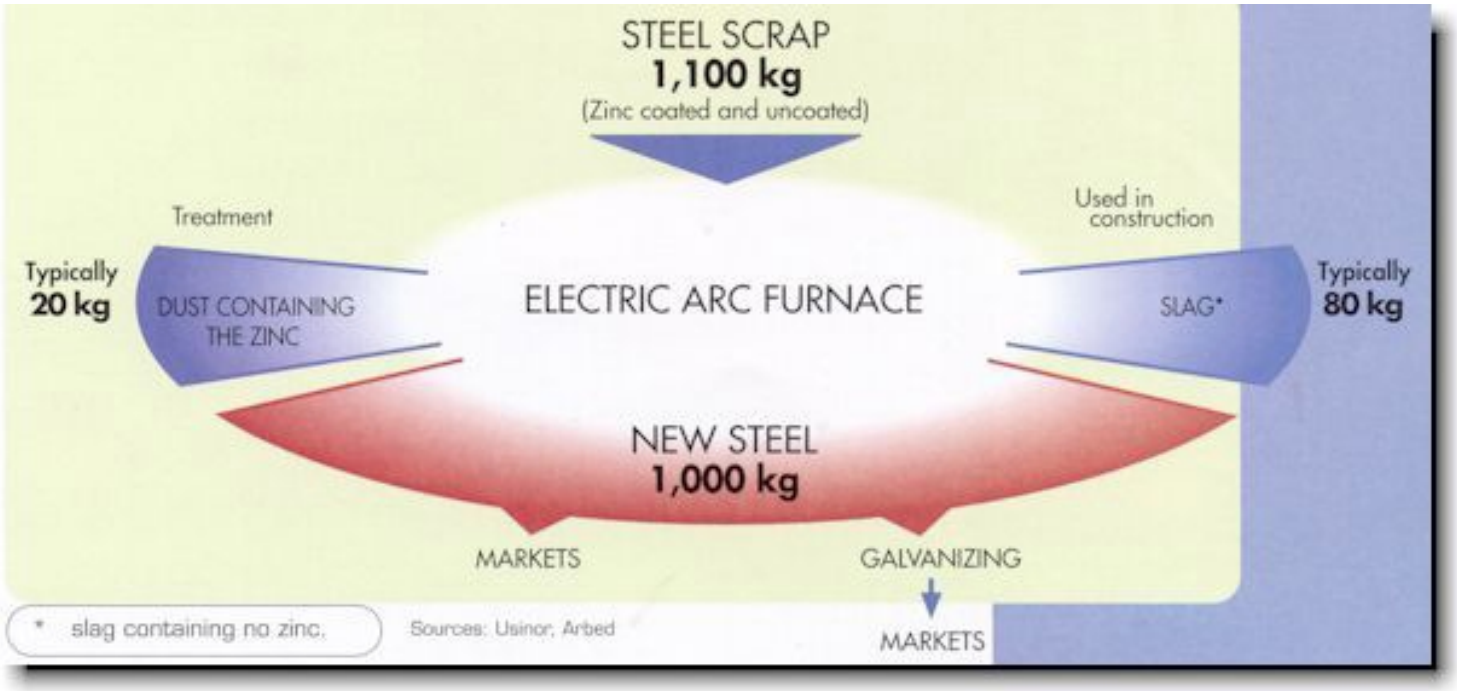

Figure 6 : The electric arc furnace process

Technologies exist for treating electric arc furnace dust which contains from 18 to 35% zinc. These are well established processes already in use in the non-ferrous metals production industries. Zinc producers, who wish to diversify their sources of raw material for zinc production, regard electric arc furnace dust as a valuable alternative source.

However, the zinc industry normally uses raw materials which have a higher zinc concentration. As a result, electric furnace dusts undergo a further process before the zinc can be recovered from them. The most widely used treatment method employs a very large rotary kiln and is known as the Waelz process (figure 7). This raises the zinc content to 55 - 65%, at which point the product can be used as a raw material for primary zinc plants.

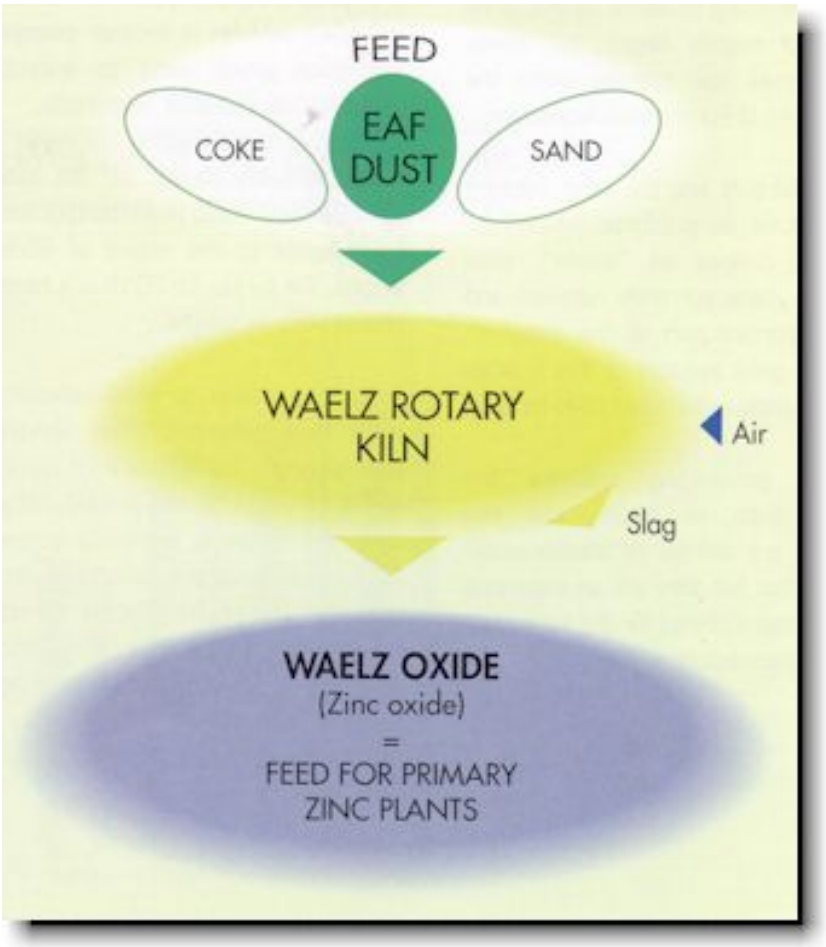

Figure 7 : The Waelz process

Some zinc producers use a blast furnace process for the production of metallic zinc. They are investigating the possibilities of using electric furnace dust without prior Waelz process treatment as part of their raw material. Other processes, which mostly depend on dissolving the dust and recovering zinc metal from solution, are also under development. Some of these have been developed to the pilot plant or small commercial plant scale.

Modern technologies for recycling zinc and steel

Although the most widely used process for treating EAF dusts is the Waelz kiln, which uses high temperatures, other processes are under development. They use chemical methods to recover the valuable metals.

The first new development offers advantages over the old methods and is already operating on an industrial scale. Trials in Europe show that the best capacity for a plant of this type is about 30,000 t/y of dust, roughly equivalent to the dust output of three electric arc furnaces. It seems likely that the process will make a significant contribution to the reduction of recovery costs and thus to the global recycling bill.

Other processes are emerging too. They offer the possibility of treating a range of materials which are rich in iron and zinc. In this process, the first stage separates zinc from steel and recovers the zinc as a material containing zinc oxide. A further chemical treatment of the oxide separates the many other metals, including copper, which appear in small quantities in steel scrap, leading to the production of pure zinc for reuse.

Another process is being developed in Europe and North America. It sets out to separate zinc and steel from zinc coated steel scrap before it reaches the arc furnace. It is an electrochemical dezincing system based on detinning technology which is already used to treat recovered tinplate.

In conclusion, there are several promising industrial scale, cost effective technologies which should enable treatment of zinc enriched steelmaking by-products, such as EAF dust.

5. LEGISLATION ENCOURAGES RECYCLING

Sustainable development

Everybody in Europe supports the idea of sustainable development - the idea that it is better to recycle materials and use them again rather than consume new materials. The European Union has responded by introducing legislation to encourage recycling and sustainable development. But the legislation is complicated, especially when it defines "wastes" and materials which should be recycled.

Metals, including iron and zinc contained in galvanized steel, are chemical elements. They are not degraded or spoiled during the recycling process. As a result, the metals industries have operated recycling systems almost since the use of metals began, but these systems must now operate within the requirements of Europe-wide legislation.

The zinc industry and the steel industry both produce by-products which the legislation defines as "waste", even though they are currently recycled and are an important part of raw materials supply. A good example of this is steel scrap, including zinc coated steel scrap.

Similarly, galvanizing industry by-products such as dross, ash and skimmings are defined as wastes under the legislation but they are an important source of raw material for the secondary zinc production industry.

The Basel Convention

The importance of these materials is recognised in the Basel Convention. This International Agreement protects countries from the unregulated dumping of waste materials in their territory. The Convention places wastes into categories and controls the cross border movement of some materials. Certain wastes are placed on a "Green List", which permits their free movement. Galvanizing by-products (skimmings, dross) are "Green Listed" and may be moved between OECD countries for the recovery of their valuable metallic content.

End-of-life vehicles

The proposed European Directive for end-of-life vehicles is another example of legislation which aims to encourage recycling of valuable materials. The adoption of this Directive will mean that motor vehicles placed on the market after January 2005 must be recoverable or reusable to the extent of 85% by weight. The target for 2015 is a recovery rate of 95% by weight.

Today, the bodies of most vehicles are made from galvanized steel. Galvanized steel protects the vehicle from corrosion during its useful life and is easily recycled when the vehicle is eventually scrapped. As a result designers, who must comply with the end-of-life vehicles Directive, select galvanized steel for vehicle bodies. It offers them an economic solution together with complete recyclability and helps them to comply with the Directive.

6. ZINC COATED STEEL RECYCLING : CASE STUDIES

Recycling end-of-life vehicles

End-of-life vehicles is the name given to cars, trucks and buses - especially passenger cars - which have reached the end of their useful life. ELVs stands for end-of-life vehicles and means the same as scrapped cars.

Cars and other vehicles are made from a wide variety of materials. The proportions vary, depending on the design, but steel is by far the predominant material. The modern car body is built mainly from zinc coated steel sheet. Zinc coating is used to enhance the corrosion resistance of steel. If the steel were not effectively protected from corrosion, the life of the vehicle would be much shorter, leading to increased use of natural resources to make replacement cars. Figure 8 explains how the quantity of zinc coated steel used in the automotive industry has grown.

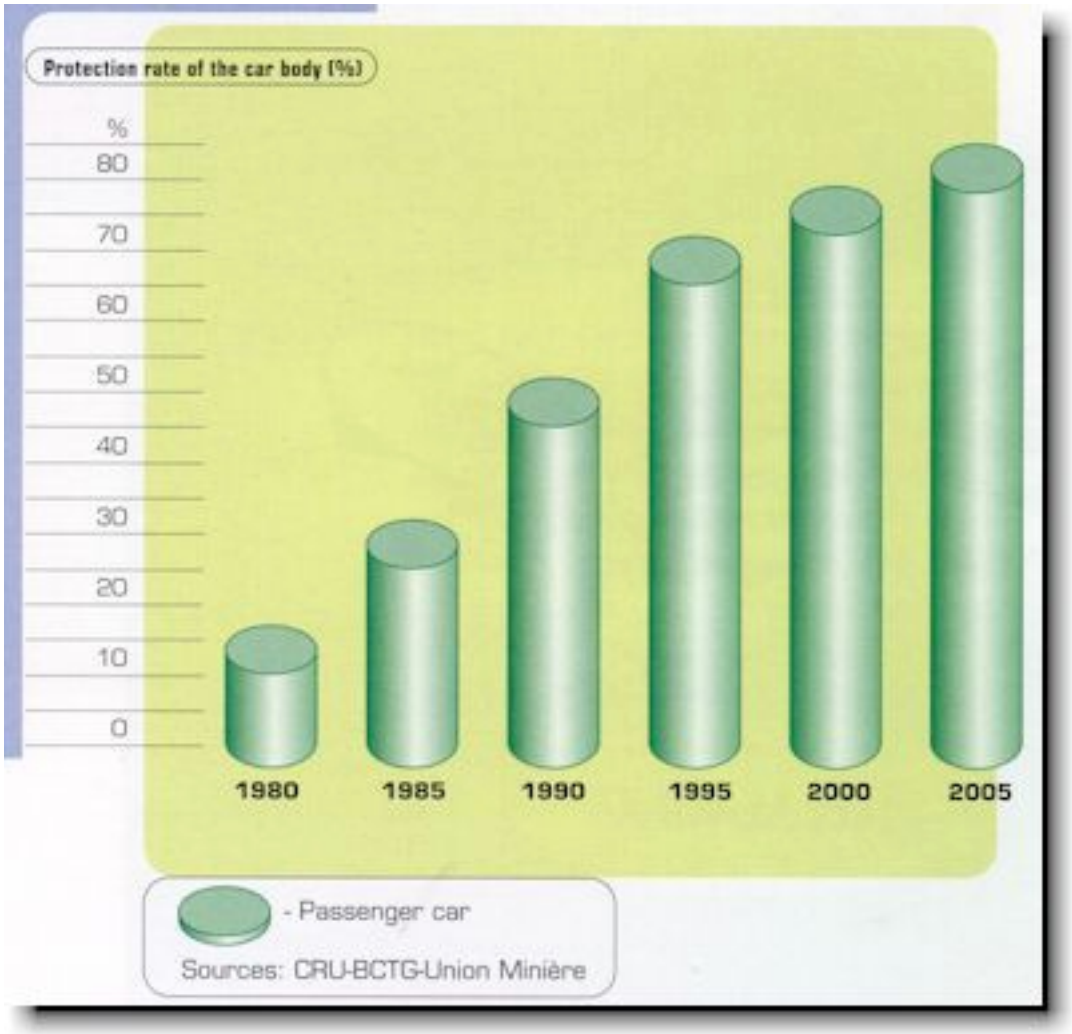

Figure 8 : Trend in the consumption of zinc coated sheet in the European automotive industry

Each year more than 10 million cars are scrapped in Europe. In other words, they become ELVs. The number of cars which are scrapped in each region depends on

the population and the standard of living.

Most ELVs are collected and partly dismantled before delivery to shredding plants. ELVs make up a large part of the material fed to the shredder. The shredder produces zinc coated steel scrap, other metals, rubber and plastics. Figure 9 explains how ELVs are handled in Europe.

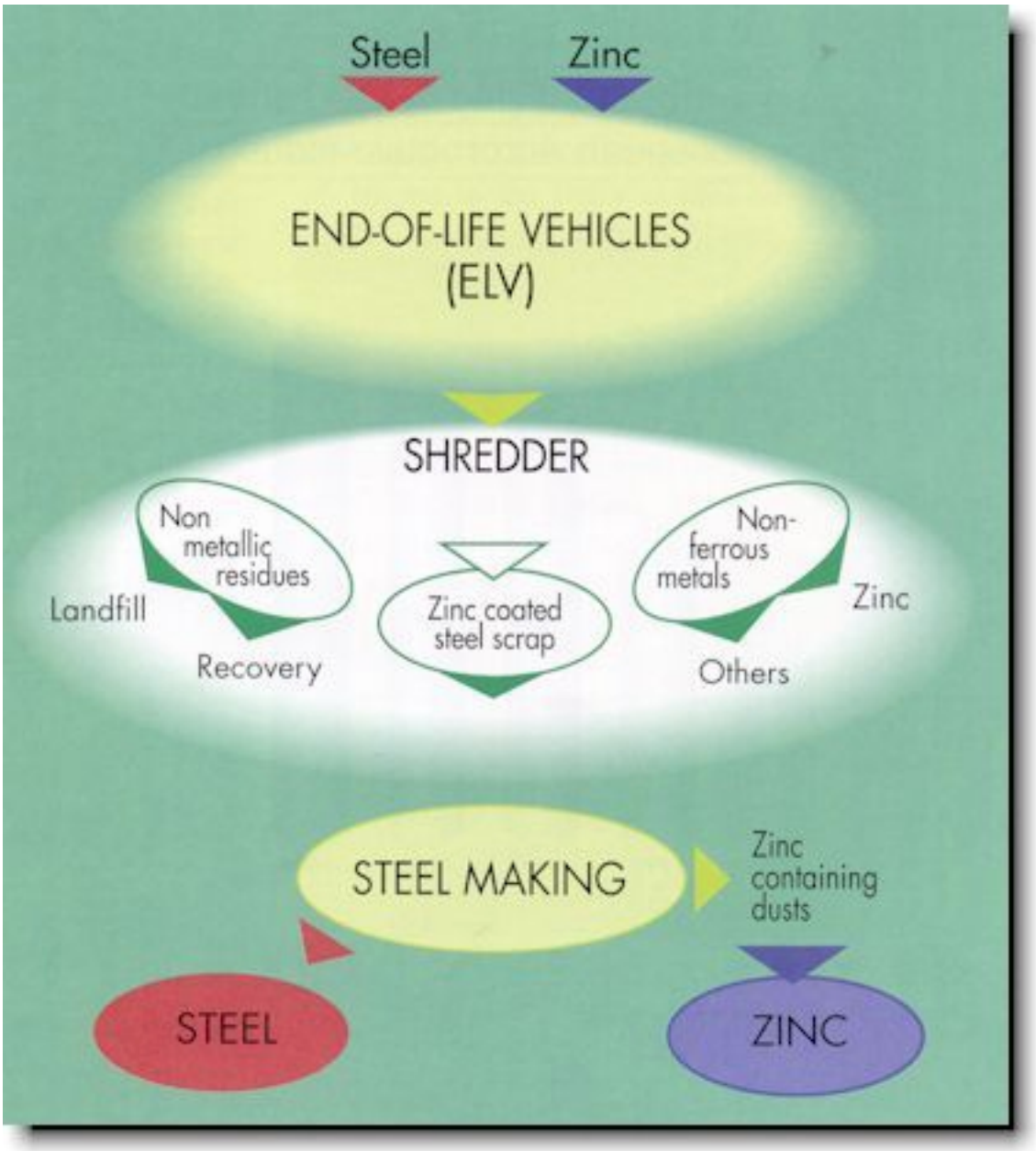

Figure 9 : End-of-life vehicles recycling

The materials produced by the shredder are usually separated into three parts :

- steel scrap containing uncoated and coated steel;
- other metals;
- a mixture of rubber, plastics, foam, woven materials and so on, which is treated outside the metals industry.

The material which consists of "other metals" contains aluminium, copper, zinc alloys and stainless steel. It is processed to recover clean and valuable metals for reuse.

Zinc coated steel recovered by the shredder becomes part of the raw material for steelmaking, where the zinc and the steel are separated to produce new steel products. Zinc is separated from the steel by the process, converted to an oxide form and becomes part of the dust which leaves the furnace. This dust is collected

and becomes a raw material from which zinc or zinc-containing products can be produced (see section 4).

Street furniture product recycling : lighting columns

Many everyday objects which you see on the street are made of galvanized steel. Highway barriers, lamp posts and lighting columns, bus shelters and flower baskets are among them. Galvanized steel is used because it lasts for a very, very long time and provides good value to the community. But even the highest quality products have a finite life, and galvanized steel products are recycled too.

For example, street lighting is indispensable for modern life. Galvanized steel lighting columns and

lamp posts contribute to safety on the roads and security in town centres and residential areas. Most street lighting is purchased and owned by the highway authorities and local authorities. In most cases the life cycle of a galvanized steel lighting column is at least fourty years.

Lighting technology has advanced, and in many cases new lamps have been fitted to columns which have already seen many years of service.

The service life ends due to accidental damage or simply to the passage of time. When the lighting column is taken out of service the highway and local authorities dismantle it and take it back to their maintenance yard. It is then sold to scrap steel merchants, who have an efficient collection system. The merchants cut the column into pieces of convenient size and sell them to the major suppliers of scrap to the steel industry. Eventually, the cut pieces of column form part of the prepared feed for an electric arc furnace. The steel from the column is recovered as steel product from the furnace. The zinc coating oxidises and enters the dust which is recovered from the furnace pollution control equipment. This is a recyclable resource of zinc.

All galvanized street furniture eventually follows the same path. The life of products in use varies from a few months in the case of highway barrier which has been damaged soon after installation to many, many years for barrier in remote places and lighting columns on our streets. Unlike concrete lighting columns, which give rise to a residue of waste concrete, all the content of an old galvanized column enters the recycling stream.

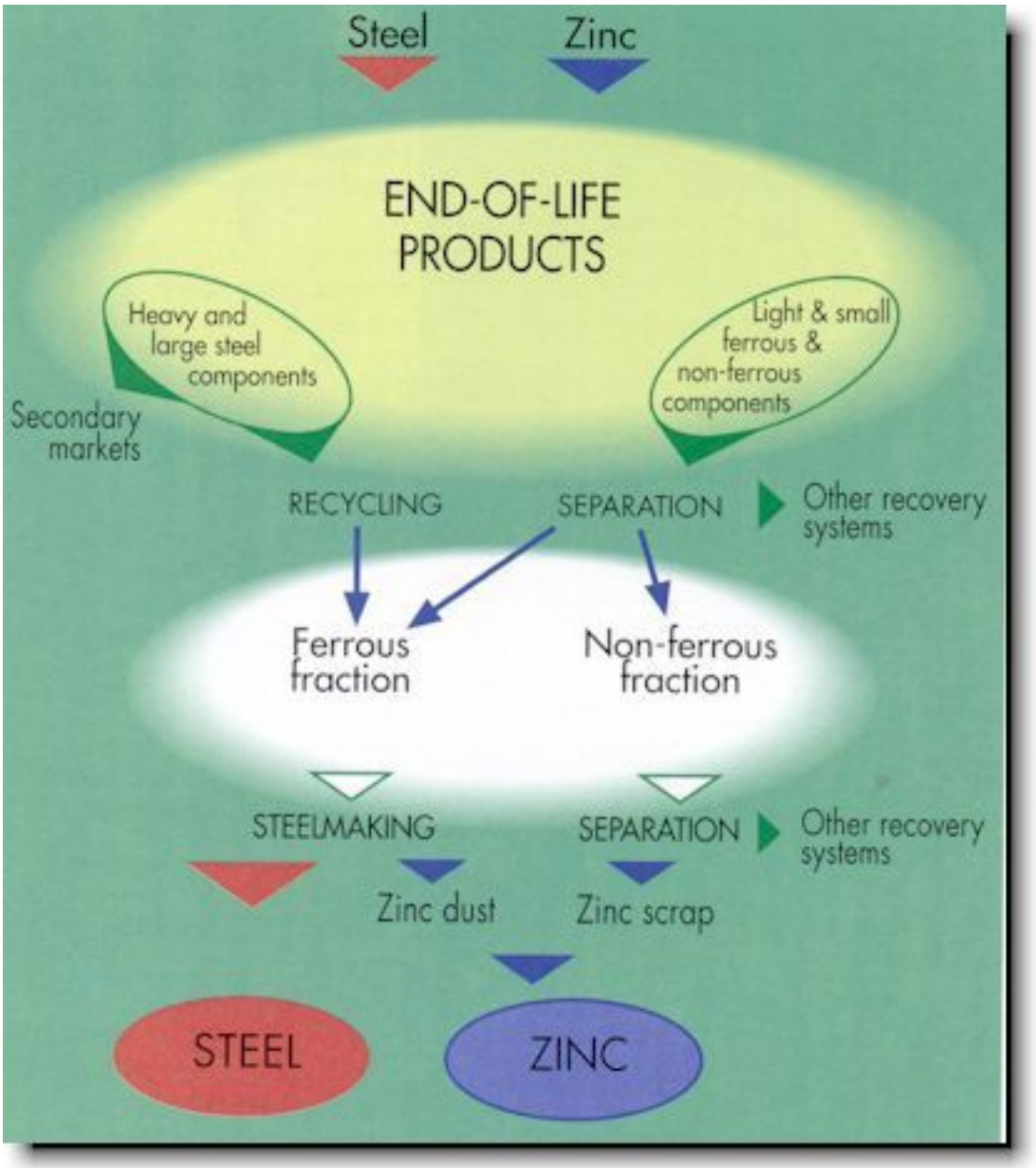

Figure 10 : End-of-life general galvanized products

Figure 10 shows the recovery systems for end-of-life general galvanized products. Lighting columns and lamp posts are recovered by this route.

7. CONCLUSION

The combination of steel and zinc produce products which are recyclable and which are continuously recycled today. Recycling is a long established practice which makes technical, economic and environmental sense.

Both components of zinc coated steel have excellent recycling properties. This means that zinc coatings on steel can compete strongly against other steel corrosion protection systems and against recently developed materials.

Increasing consumption of zinc coated steel leads to an increase in the quantity of zinc coated scrap available for recycling. The zinc and steel industries are working together to improve technologies for treating these materials. Also, new research will result in new technologies with improved performance.

The zinc and steel industries both see recycling of galvanized steel scrap as another source of raw materials, conserving the earth's natural resources.

GLOSSARY
A selection of the terms used in this brochure

GALVANIZING

(steel coating process with zinc)

General galvanizing
A process in which fabricated steel articles are individually dipped into a bath of molten zinc. A zinc coating, which protects the steel from corrosion, forms on all surfaces.

Continuous galvanizing
Hot dip process in which steel strip is moved continuously through a molten zinc bath. A zinc coating, which protects the steel from corrosion, forms on both sides of the strip.

Electrogalvanizing
Process in which a zinc coating is continuously applied to steel strip by means of electrolysis. The coating can be applied either to both sides of the strip or to one side only.

Electrolysis
An electrochemical process for depositing zinc from zinc-containing solutions onto other materials.

GALVANIZING RESIDUES

Blowings
Materials produced during galvanizing of tubes, when an automatic plant using a jet of steam or air is used to blow excess zinc from the surface of the tube. They consist mostly of metallic zinc and zinc oxide and are returned directly to the zinc recycling system.

Bottom dross
A material consisting of an iron-zinc alloy which forms in general galvanizing baths as a result of the reaction between steel and zinc. It is removed from time to time and returned to the zinc recycling system.

Filter dust
A light, powdery material removed from the air pollution control system of general galvanizing plants. It consists mostly of flux with a small amount of zinc oxide, and is recycled in the flux manufacturing industry.

Flux
A material used to prepare the steel surface before galvanizing, to ensure complete coverage of the zinc coating.

Skimmings or ash
Materials unavoidably produced during the galvanizing process. They consist mostly of metallic zinc and zinc oxide and are returned to the zinc recycling system.

Sludges
Materials removed from water circulating in some air and water pollution control systems.

Top dross
A material consisting of metallic compounds of Zn, Fe, Al and zinc oxide which is removed from the surface of the zinc bath in the continuous galvanizing industry. It is returned to the zinc recycling system.

SCRAP

New scrap
Zinc coated steel scrap arising from the zinc coating process, from reject products or off-cuts arising from the fabrication of zinc coated steel products. New scrap comes either from the sheet galvanizing process or from manufacturing processes such as those for car, appliances,…

Old scrap
Zinc coated steel scrap which comes from articles such as cars, washing machines, lamp post and highway barriers which have been used in the end-use market and which are either obsolete or broken.

STEEL

Steel
Alloy based on iron containing carbon and small quantities of other elements.

Basic Oxygen Furnace
A large, brick-lined cylindrical vessel, open at one end, in which liquid iron produced in the blast furnace is refined into liquid steel by oxygen blowing.

Blast Furnace
A tall, brick-lined furnace for the production of liquid iron from iron ore, limestone and coke.

EAF Dust
Materials removed from the air pollution control systems of electric arc furnaces. They are a source of zinc for recycling.

Electric Arc Furnace
A brick-lined furnace in which steel scrap is melted in a furnace heated by electric arc.

Slag
A by-product, which carries impurities away from the iron and steel making process.

ZINC

Zinc
A metallic element, essential to human health, and the most important coating in the corrosion protection of steel.

Electrolytic process
A process for the production of zinc from primary zinc concentrates in which the concentrates are heated and then dissolved to form a liquid containing zinc sulphate. High purity zinc is recovered from the solution by means of electrolysis.

Imperial Smelting Process
A process for the production of zinc, mostly from primary zinc concentrates, in which the concentrates are heated, pelletised and reduced to zinc metal by coke in a blast furnace. The Imperial Smelting Furnace can also be used to treat a limited amount of secondary zinc materials.

Primary zinc
Metallic zinc produced by a chemical or electrochemical reduction process mainly from zinc concentrates.

Secondary zinc
Metallic zinc produced by remelting and, where necessary, chemical treatment of metallic zinc residues.

Zinc chemicals
A variety of manufactured chemicals which contain the element zinc, used in detergents, pharmaceuticals and as animal feed supplements.

Zinc concentrates
Materials produced by zinc mines as the raw material for the primary zinc production industry. They usually contain about 55 per cent zinc.

Zinc dust
Metallic zinc in powder form.

Zinc oxide
The chemical ZnO, widely used in the tyre industry, in pharmaceuticals and as a precursor for zinc chemicals.

Fig.1: Recycling circuit for zinc

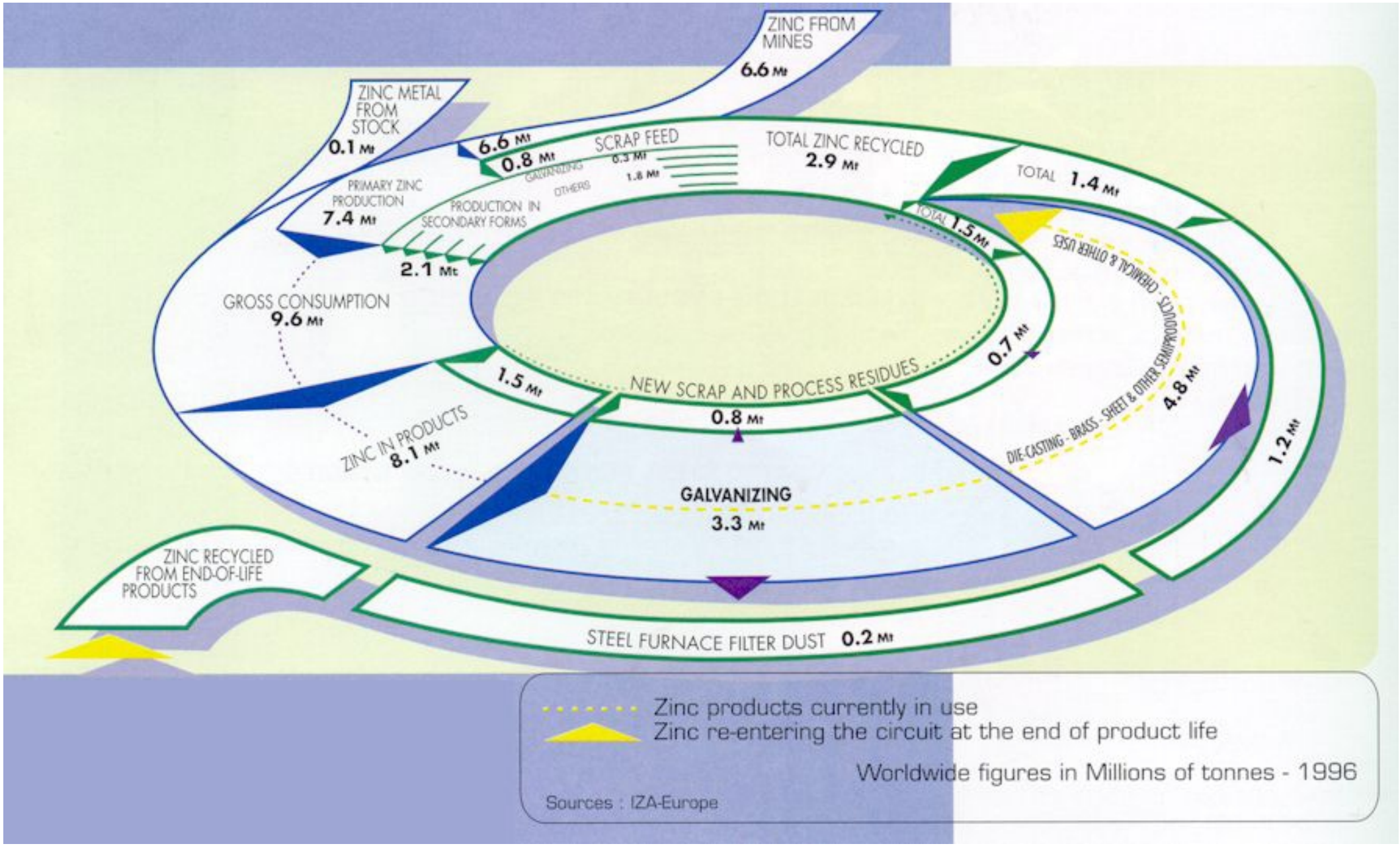

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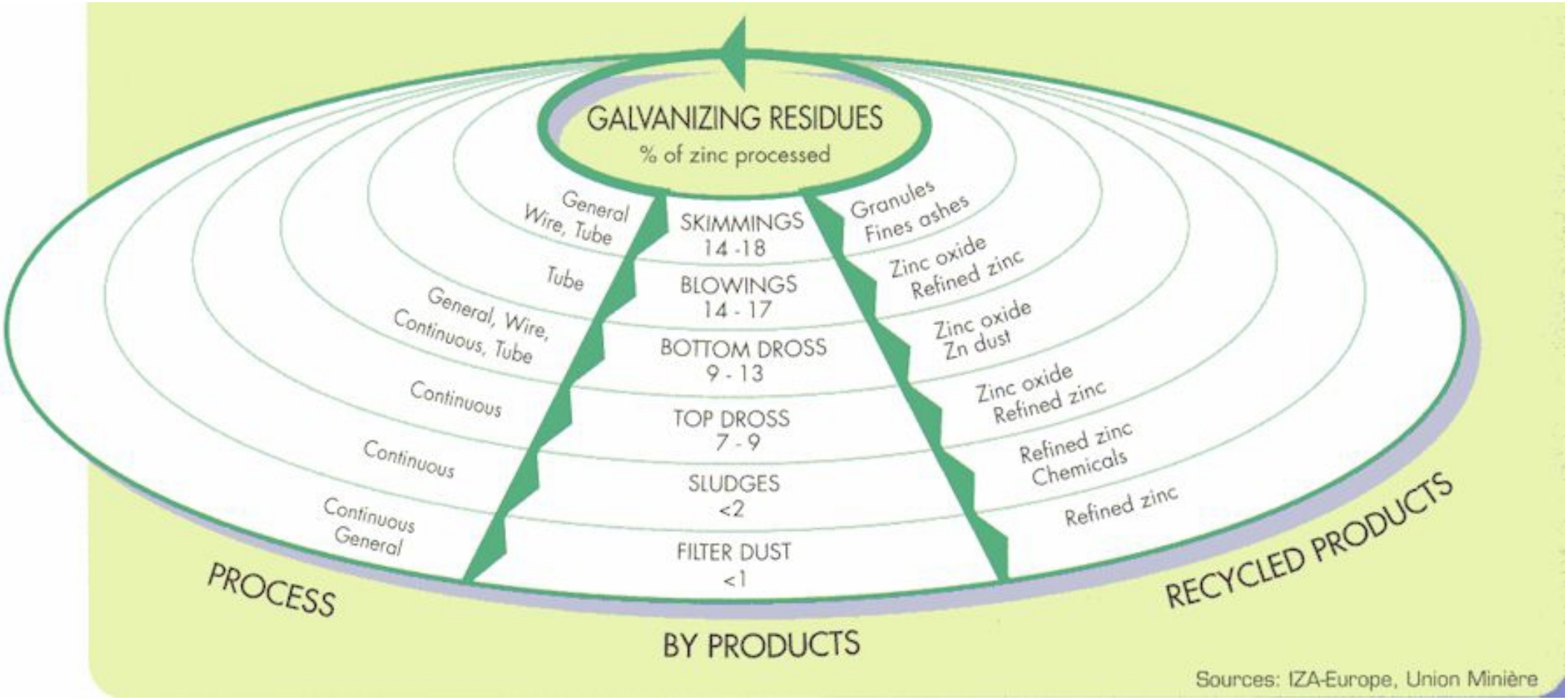
Figure 4 : Recycling of galvanizing process residues



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