LIFE CYCLE ASSESSMENT OF HOT-DIP ZINC GALVANIZING

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ABSTRACT

Nowadays the attention of people and authorities is getting more and more focused on the environmental performance of the industrial products as well as on the sustainability of the productive activities. The market could be soon influenced by rules for which a product has to be more 'eco-compatible' than another to gain the chance to be used by galvanisers' main customers. That situation makes it necessary to perform analysis on the entire life of the galvanised steel product from the extraction of the raw materials through the production processes up to the end of their life and over, taking into consideration also the recycling and wasting environmental costs. The most recent indications by the European Commission are in line with such an integrated approach whose natural tool is the Life Cycle Assessment – LCA. It includes an assessment of the environmental and energetic loads of a process by the means of a method by which energy and raw material consumption, different types of emissions and other important factors are to be measured and analysed to give exhaustive description of the process/products entire life cycle.

The first results of a Life Cycle Assessment on a hot-dip batch galvanising process for generic steel products are here reported in order to present some environmental sustainability indicators of that industrial sector.

The study has been carried out according to ISO 14040 standard and the system referred to an average process resulting from two Italian medium-size plants (about 12.000 metric tons of galvanised steel per year for each plant). Different frameworks, poles and pylons for energy transportation and ancillaries have been considered from a cradle-to-gate (eco-profile) point of view adding up to energy and environmental results also on the basis of the steel product service lifetime within different corrosion scenarios.

Those results allow weighing most important activities in terms of environmental burdens with a special consideration of contribution due to different type of zinc (SHG, GOB, secondary zinc, zinc alloys).

End of life considerations are finally included to consider the recycling of hot-dip galvanised steel.

The research has been strictly monitored by AIZ – Italian Galvanisers Association, with the goal of providing a methodological approach which could be usefully extended to other Italian producers.

Next steps of the activity are expected to be in direction of the Environmental Product Declaration (EPD) according to the ISO TR 14025 and that would be certified by accredited certification bodies.

INTRODUCTION

Industry involved in steel surface treatment, such as Hot-Dip Galvanising, is currently facing increasing challenges to provide solutions for reducing its own environmental impact both at direct and indirect level and for supporting Steel Industry to purchase final products with high degree of environmental sustainability. To make choices, good quality and reliable information are required for the ‘environmental design’ of buildings. Now the knowledge of materials performance in terms of their consequences on the environment is commonly considered necessary by designers. Moreover crucial importance is assumed by the targets of CO_2 reduction fixed by the European Commission which follows the decisions taken during the Kyoto Earth Summit and the following initiatives in that direction.

For instance the implementation of the EU IPPC Directive (Integrated Pollution Prevention and Control – 96/61/CE) that is to be applied to different industrial sectors, including Hot-Dip Galvanising, requires the development and adoption of continuously updated Best Available Techniques (BAT) for reducing the emissions and the environmental loads of plants and activities.

At a national level as well, Italian authorities are encouraging actions addressed to energy saving and emissions reduction.

Bearing this in mind, two Italian galvanizing companies in co-operation with AIZ - Italian Galvanisers Association agreed on the need of an eco-profile study with the aim to provide quantitative information about the use of energy as well as the consume of raw materials and the generation of solid, liquid and gaseous emissions and wastes due to the hot dip galvanising process. Their final purpose would be issuing a report on the environmental sustainability of their products from a ‘life-cycle’ point of view.

METHODOLOGY

The study applies *Life Cycle Assessment* (LCA) methodology to the hot-dip zinc galvanising process aiming at both quantifying its environmental burdens and assessing the eco-*sustainability* associated to the use of galvanised steel product.

Hot-dip galvanising is a coating process obtained by dipping steel in a molten zinc bath to give the product a tough and long lasting protection against corrosion. Protective coating is developed by the means of a reaction by which the zinc of the bath and the iron of the substrate give place to a layer made of Zn-Fe alloys. The LCA of the galvanising process has been carried out according to the indications and protocols set out in the ISO 14040 series (ISO 14041, ISO 14042, ISO 14043). About the software model and data base for secondary data, the Bousted Model (version 4.4, updated June 2001) has been used in this project. Another source of data has been the I-LCA - Italian LCA Data Base recently published by

ANPA - Italian Governmental Environment Protection Agency. Primary data have been collected by using ad hoc questionnaries compiled by the two plants involved in the study.

THE CONSIDERED SYSTEM AND ITS BOUNDARIES

The variability in shape and quality of the product processed at the considered manufacturers facilities do not allow a direct characterisation of a relevant product-type of average mass and surface. Therefore it has been decided to express the results in terms of 1 kg of mean galvanised steel (called 'white') with no reference to a specific shape.

The industrial system considered in this paper comprises in a special way, together with all the operations inside the process facilities, also the raw materials extraction and the unfinished steel production as well as the production and delivery both of the energy carriers and of the final product.

A complete study would take into account also the use phases and the end of life scenarios but here only the 'eco-profile' (from cradle to gate) results are reported.

A flow chart with a generic production scheme of galvanised steel production process is shown in Figure 1 where also the secondary metallurgical process for a generic unfinished steel product is pointed. It's important to stress that the system pattern takes into account the production of the unfinished steel product in order to obtain the evaluation of the whole environmental burden related to the selected functional unit that allows assessing the weight of the galvanising process during the lifetime of the steel product itself in terms of its environmental sustainability.

As shown in the same scheme in Figure 1 to correctly describe the process it could be worth considering that the zinc used for the coating, the so called 'adhered zinc', is the real product of a galvanizing plant. Besides this the special skills of hard zinc and ashes (the two main by-products) should be also taken into account. Particularly the hard zinc generated by the process is actually a secondary raw material with a high content of zinc which doesn't require any treatment to be externally recycled for production of zinc oxide (in an open loop recycling system), while the ashes are subjected to a proper external treatment in a closed loop recycling system to be re-used in the galvanising process. Therefore particular attention has been paid to the partitioning of environmental burdens among product and by-products.

MAIN RESULTS

The output of the study consists in a set of parameters each of them describes a specific skill in the system total behaviour.

Energy Results

Energy results can be broken down into:

- Energy production represents the energy that is used by the fuel producing industries in extracting the primary fuel from the earth, processing it and delivering energy to the ultimate consumer. This will also include the energy associated with the production of any non-fuel materials (such as steel) that are taken into the fuel production process.

- Energy use represents the energy that is received by the final operator who consumes energy (the hot dip galvanising plant).
- Transport energy refers to the energy associated with fuels consumed directly by the transport operations as well as any energy associated with the production of non-fuel bearing materials, such as steel, that are taken into the transport process.
- Feedstock energy represents the energy of the fuel bearing materials that are taken into the system but used as materials rather than fuels.

The total energy consumption (Gross Energy Requirement – GER) is given by the sum of these four single items. Figure 2 and 3 report the contribute in percentage to the GER value respectively of the zinc coated steel and of the direct energy consumption in each process step which is aimed at obtaining “useful zinc” i.e. the final product as a zinc coating actually applied on steel surface.

Figure 3 clearly shows the importance of the zinc deposition operation. That is why Figure 4 is deeper focused on the results analysis of that phase.

Environmental results

Primary energy sources are listed in Table 1: they refers to the primary fuels actually extracted from the earth as the mass of different fuels that are taken into the system. About the emissions to the environment (to air, to water and solid), the complete list is not here reported due to the limited space. However, the classification and characterisation of these emissions is proposed according to ISO 14042 Standard. This operation is based on the definition of some environmental impact potentials: for instance, the Global Warming Potential (GWP), that is usually expressed for a time horizon of 100 years, is calculated in terms of CO_2-equivalents using specific weighting factors for all substances with a greenhouse potential (CO=2, CH_4=21, N_2O=310, etc.) (Table 2).

In addition to the analysis performed for the Inventory energy results, also environmental impacts have been partitioned (allocated) among main production phases: the most important indicators (GWP_{100} and acidification) are shown in Figure 5 and 6 for the zinc coated steel.

FINAL CONSIDERATIONS

The research has been strictly monitored by AIZ – Italian Galvanisers Association with the goal of providing a methodological approach which could be usefully extended to other Italian producers.

The study adds up to some objective quantification of the environmental burden of the zinc coating process by hot-dip galvanising and could be considered as a first step to provide for information designers and final users by giving them indications about the environmental performance of different building components which could be made of galvanized steel.

The described methodology could be used for making comparison among different steel corrosion protection technologies, competitors to galvanizing, taking into account specific applications with a reliable service time. For instance, a steel product when treated with hot dip batch galvanising process could stand protected against corrosion for an average time of about 35 years in certain aggressive conditions without any need of maintenance but, when an organic coating is alternatively applied to the same one, it would remain in service only for 9 or 12 years maximum depending on the applied paint process.

A possible future step of the activity could be the Environmental Product Declaration (EPD) according to the ISO TR 14025 in order to diffuse environmnetal information following the advice of a third party verified system.

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FIGURES AND TABLES

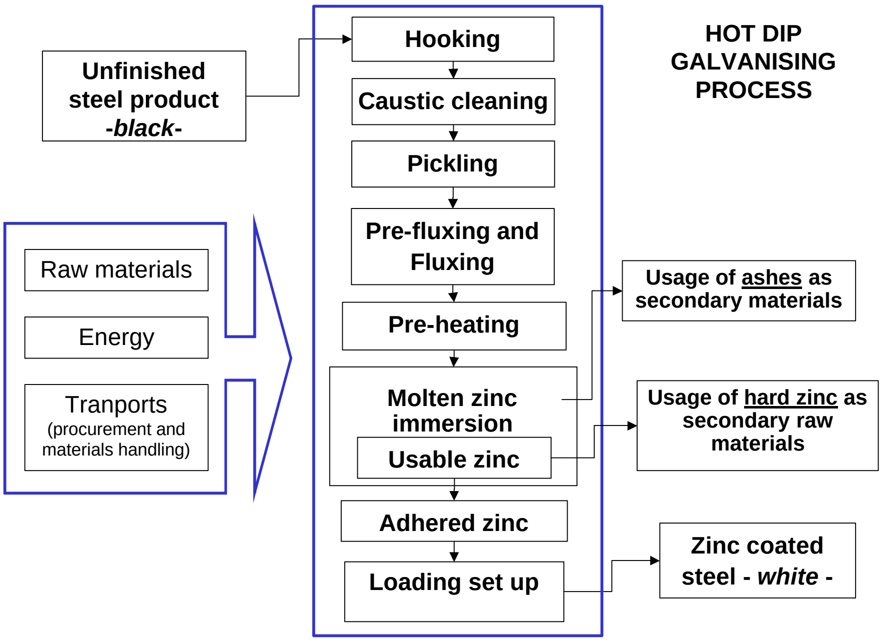

Figure 1 – Simplified scheme of the hot dip galvanising process.

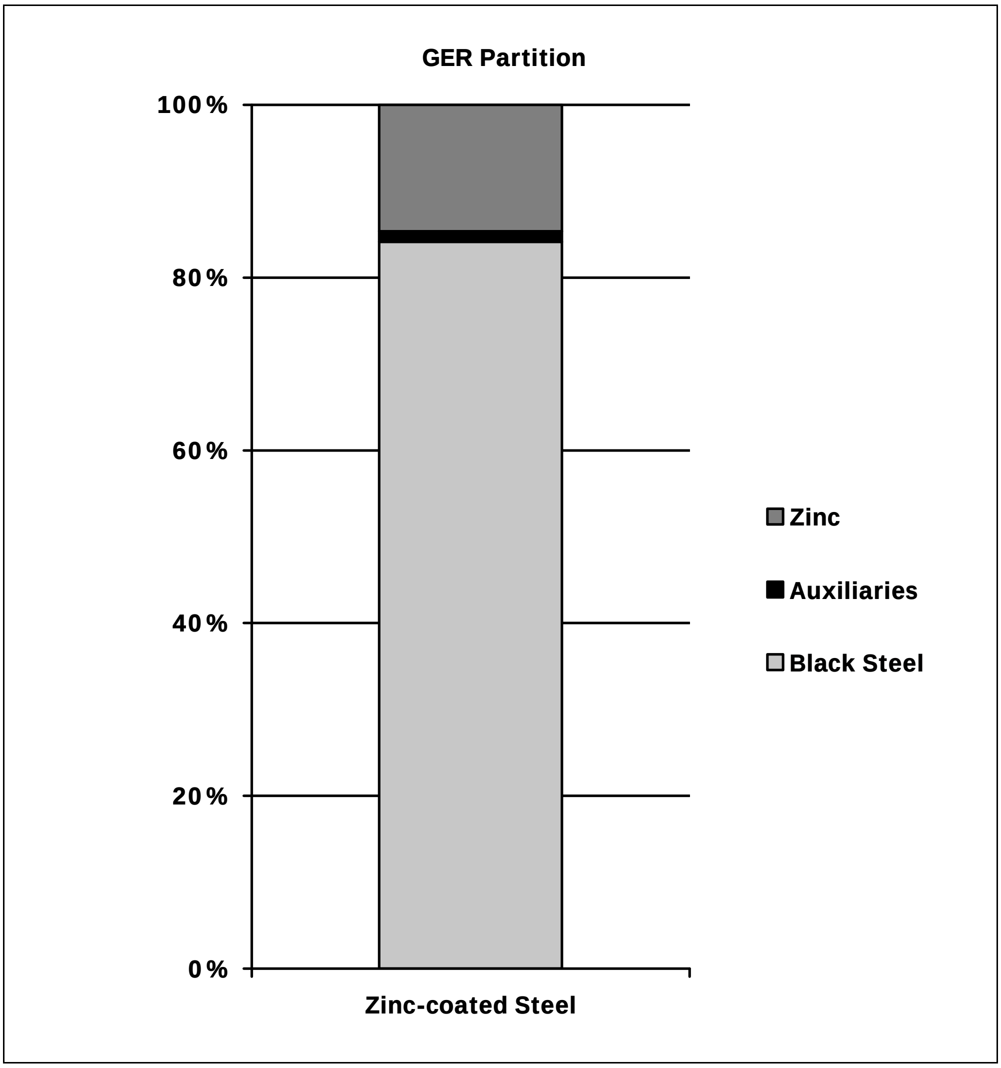

Figure 2 – Contributors to GER for the production of coated zinc

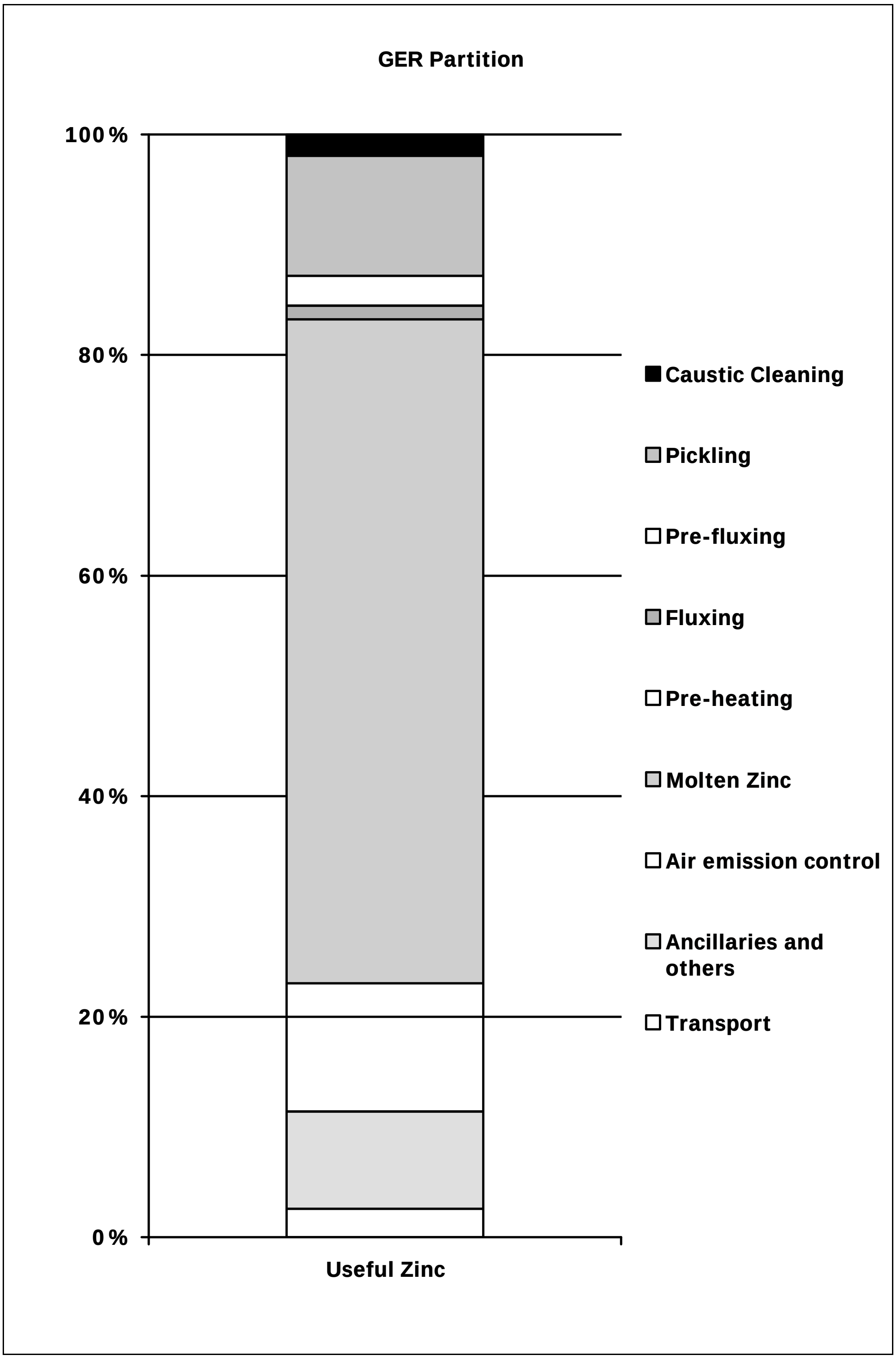

Figure 3 – Contributors to GER for the production of “adhered zinc”

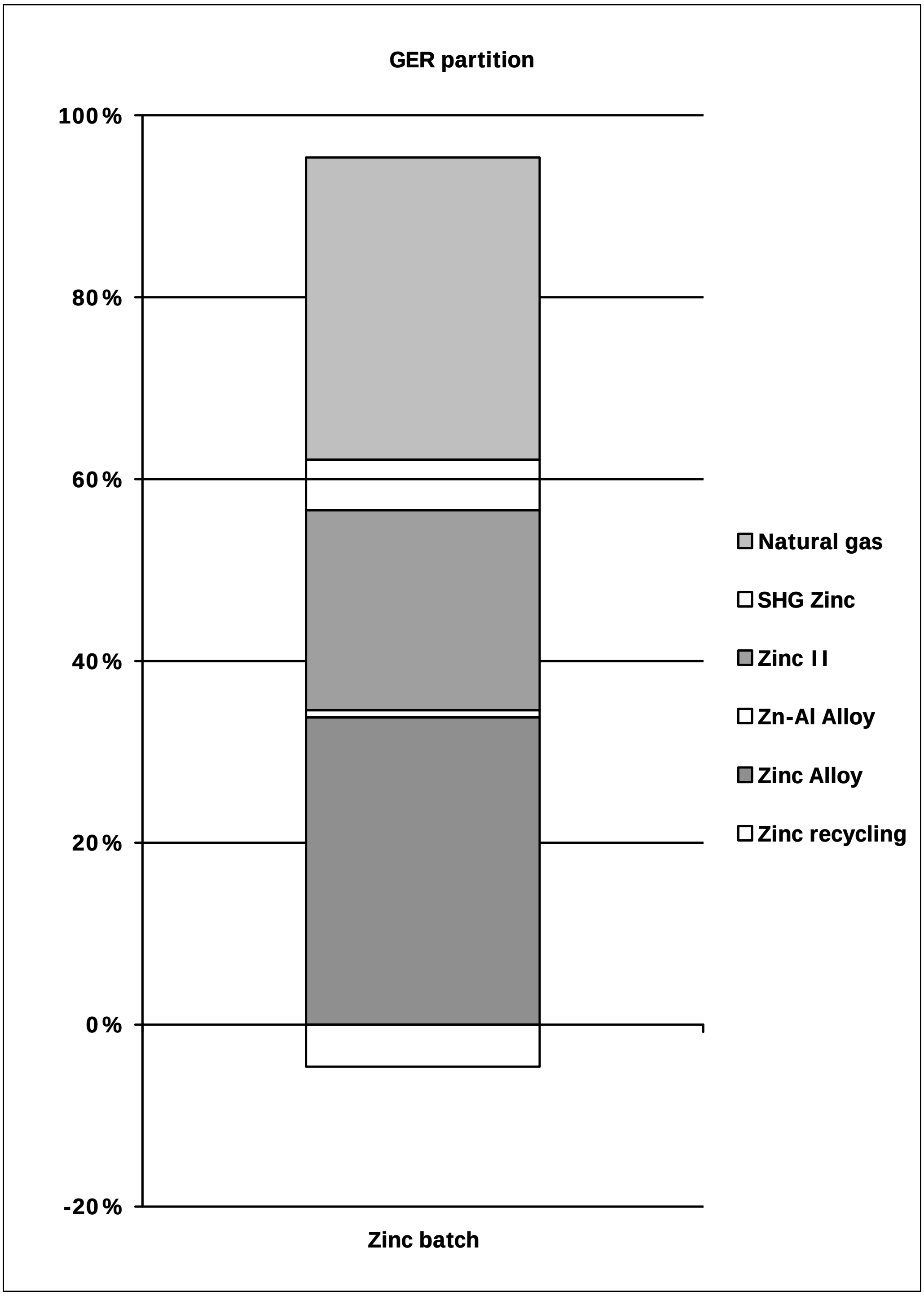

Figure 4 – Contributors to GER in the zinc batch[1] ("Zinc II" means zinc from secondary metallurgy)

[1] The negative sign of the secondary zinc comes from the methodology used to take into account the environmental benefit of recycling.

Table 1 – Primary energy sources (data in g/kg).

Natural resource with energy content	Zinc coated steel	Useful zinc
Crude oil	173	314
Natural gas	184	801
Coal	96	399

Table 2. – Classification and characterisation of total emissions (data per kg)

Indicator	Units	Zinc coated steel	Useful zinc
GWP_{100}	g CO_2	1.460	4.740
Acidification	mol H^+	0,72	2,57
	g SO_2	20	80
Eutrofization	g O_2	50	280
	g PO_4^{3-}	Negligibe	10
Ozone depletion	g CFC11	Negligibe	Negligibe
Photo-smog	g C_2H_4	Negligibe	5

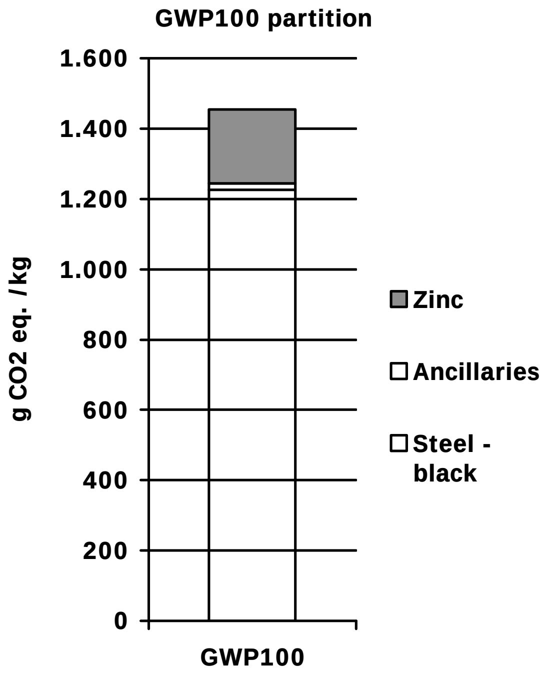

Figure 5 – Contributions to GWP_{100} for zinc coated steel.

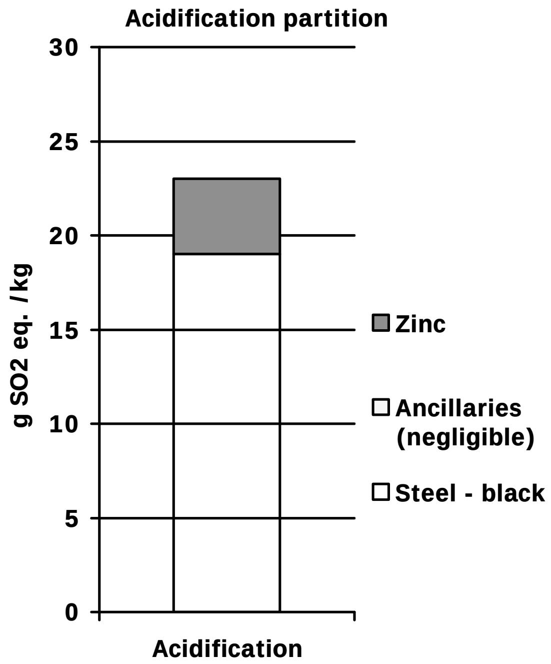

Figure 6 – Contributions to Acidification potential for zinc coated steel.

AUTHORS BIOGRAPHIES

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Mining engineer with a Ph.D. and Post Doc in Life Cycle Assessment. At present he is the responsible and senior consultant at Life Cycle Engineering, grant researcher at Dept. of material science, Faculty of Engineering, Politecnico di Torino, lecturer in "Economy of Energy Sources" for energetic engineering course. He has a considerable experience in national and international research projects, published more than fifty papers and two books on LCA in Italian language. He is a member of the Editorial Board of the Int. Journal of Life Cycle Assessment.

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With a 20 years experience in the Hot-Dip Galvanizing sector, he is environment and safety manager in Metalzinco and in Zincheria Toscana. He is also a member of Environmental and Technical Committee of AIZ – Italian Galvanisers Association.

Carmine Ricciolino

More than 25 years experienced man in the Hot-Dip Galvanizing sector as a director of plants. At present he is the director of AIZ – Italian Galvanisers Association.

Stefano Rossi

Mechanical engineer with a good experience in design for environment. At present he is a junior engineer at Life Cycle Engineering and he is the most skilled and experienced project leader for some projects in the field of materials selection and eco-design.