ASSIGNMENT COVERSHEET FOR PROJECT WORK

Faculty of Design and Creative Technologies

Paper Name	Production Technology	**Paper Code**	116026	**Assignment Due**	26.08.2013
Lecturer 1	Shane Inder	**No Words/Pages**	12 pg	**Date Submitted**	16.08.2013

In order to ensure fair and honest assessment results for all students, it is a requirement that the work that you hand in for assessment is your own work. If you are uncertain about any of these matters then please discuss them with your lecturer.

Plagiarism and Dishonesty are methods of cheating for the purposes of General Academic Regulations (GAR)

Student's Statement:

This assessment is entirely my/our own work and has not been submitted in any other course of study. I have submitted a copy of this assessment to Turnitin, if required.

In this assessment I have acknowledged, to the best of my ability:

- The source of direct quotes from the work of others.
- The ideas of others (includes work from private or professional services, past assessments, other students, books, journals, cut/paste from internet sites and/or other materials)
- The source of diagrams or visual images.

Student ID	Name	Signature	Date
1242332	Samuel Blok	Samuel	28.08.2013

The information on this form is collected for the primary purpose of submitting your assignment for assessment. Other purposes of collection include receiving your acknowledgement of plagiarism polices and attending to administrative matters. If you choose not to complete all questions on this form, it may not be possible for the Faculty of Design and Creative Technologies to accept your assignment.


Zinc

0.3 Contents

1.0 Introduction

A product designer usually considers a list of properties (e.g. strength, density, stiffness, aesthetics, working temperature etc.) when choosing a material to meet his/her design purpose and comply with the constraints of production (Simões, Costa Pinto & Bernardo, 2012). Other constraints, such as low carbon emissions, low energy consumption and recyclability are also growing in significance so it is important we understand patterns of consumption, manufacture and recycling so that we choose appropriate materials.

Given that 40-50 % of the global use of zinc is consumed in hot –dip galvanising (HDG) (Chivers & Porter, 1994), this report focuses primarily on zinc within the galvanising process. Lighting columns (also known as lamp posts) are used as a 'vehicle' to describe the uses of zinc, characteristics, relative cost, aesthetics, mechanical specifications and manufacturing process. A life cycle analysis is then conducted with similar materials used to produce lighting columns to establish zinc's relative sustainability.

1.1 Product Overview

Lighting columns are iconic structures on our street scape. They are generally constructed of galvanised steel (Figure 1), glass reinforced polymer composites (Figure 2) and aluminium (Figure 3) (Simões et al, 2012).

Figure 1. Galvanized Lamp Post. Author's private image. Reprinted with permission.

Figure 3. Glass Fibre Lamp Post. From Lighting Styles. Retrieved from http://www.lightingstyles.co.uk. Reprinted with permission.

Figure 2. Aluminium Lampost produced by CNFR. Retrieved from http://www.cnfrp.net/. Reprinted with permission.

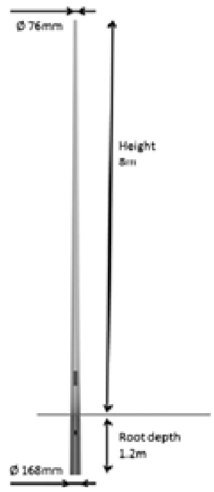


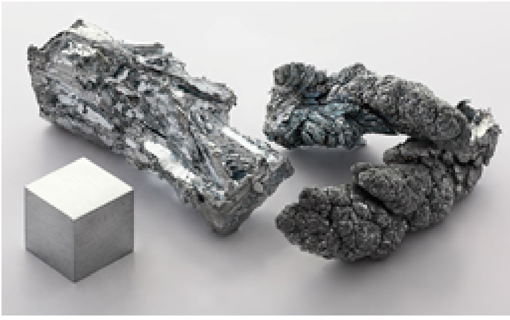
Figure 4. Schematic of a lighting column. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission.

Galvanised steel is the most dominant form of lighting column, mainly because of its ease of application, low-cost and high corrosion resistance. Zinc is the core metal used when galvanising these columns. In New Zealand they are produced by companies such as Steelgal Industries who sell a single seam welded steel Octagonal Pole with 2.5mm thick sections (Steelgal Industries, 2008).

In recent years there has been an increase in the production of lighting columns due to the shift towards hidden power services. As shown in Figure 4, a significant portion of the product is located underground.

2.0 Material Description

Uses of Zinc	Building industry (houses, commercial and industrial properties), infrastructure (roads and lighting columns, bollards etc.), automotive industry, furniture making and communications industry (Kong & White, 2010; Thompson, 2007)
	Protects products ranging from 8mm (nuts and bolts) to 30 meters by 3 meters (Thompson, 2007)
	Post galvanisation, products can be combined to make larger structures including hollow and open sided vessels (Thompson, 2007)
	Suitable for one-off to mass production.
	Effective as an alloy so used in combination with many other elements (Thompson, 2007).
	Applied mainly through galvanising. Other processes include spraying, plating, sherardizing and painting with zinc rich paints (Chivers & Porter, 1994).

Characteristics of zinc	Metallic element traditionally mined with lead (Van Beers, Kapur & Graedel, 2007)
	Stored and used in several different chemical and physical forms (Van Beers et al, 2007)
	Final form is often a molten layer or a roll (VM Zinc, n.d.)
	Low viscosity and relatively low melting point (420 °C) - well suited for casting (Thompson,2007)
	Strong anti-corrosive properties - continuous, impervious metallic barrier that does not allow moisture to contact with underlying steel (Simões et al, 2012).
	Protective nature varies depending on base material
	Depending on application, typical coating between 50 and 150 microns (Thompson, 2007)
	Hot dip galvanising provides thickest coatings however can be made thinner or thicker by adding silicon to the steel using centrifuged galvanising process (Thompson,2007)
Relative cost of zinc	Moderate in cost (Thompson, 2007). As a galvanising material, high economic value because it controls corrosion. Effective galvanising is estimated to lower the monetary loss of steel parts due to corrosion up to 20-30% (Kong & White, 2010).
Aesthetic qualities of zinc	 Figure 5. Aesthetic Qualities of zinc. Retrieved from http://www.payer.de/. Reprinted with permission.
Material specifications of zinc	Zinc (Zn) in raw state presents as a metallic conglomerate rock
	Final appearance depends on application process
	Quality of steel quality impacts on galvanising so that outcome ranges from bright and shiny to dull and grey (which is formed by high silicon content) (Thompson, 2007)
	Patina develops over time due to air quality (such as carbon dioxide and weathering) (VM Zinc, n.d.)
	Ratio of roughly 1:15 zinc to metalwork is usual (Thompson, 2007)
	Typical coating is between 50 and 150 microns depending on application (Thompson, T. 2007)

3.0 Manufacturing Process

Manufacturing a steel lighting column involves primary material extraction, production of the steel column and galvanising with zinc.

3.1 Primary material extraction

The main process routes for mining zinc are given in Figure 1. Refined zinc metal (which is part of the electrolytic zinc process) is produced using smelting (Norgate, T., Jahanshahi, S. & Rankin, W., 2007).

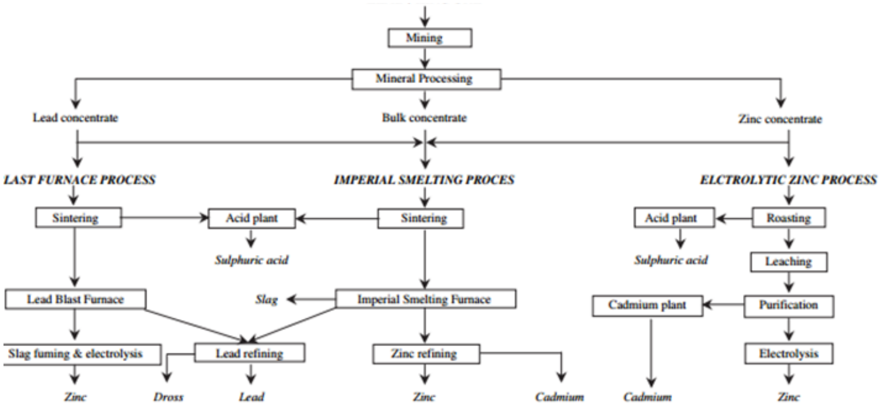


Figure 6. Zinc/ Lead refining process. From Copper and zinc recycling in Australia: Potential quantities and policy options. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.023. Reprinted with permission.

3.2 Steel column manufacturing

A steel lighting column is traditionally produced by cold rolling and hot-dip galvanisation. The steel is manufactured either by a blast furnace (basic oxygen) or an electric arc furnace and involves deforming, grinding, cutting, sawing and welding processes which result in a welded or seamless pipe (Simões et al., 2012).

3.3 Galvanizing Process

After the preparation stage, the columns are submitted to a corrosion protection process involving hot-dip galvanising with a layer of zinc (Simões et al., 2012). This is a rapid cycle production process which can typically complete within 10 minutes (Thompson, 2007).

Galvanising consists of main phases:

1. Degreasing and pickling with a weak solution of hydrochloric acid.
2. Fluxing using a solution of ammonium chloride and zinc chloride.
3. Immersion in molten zinc at 450◦ C (DCE Limited, 1997).

The process is described in more depth in the following section.

4.0 Life Cycle Analysis

Zinc is not biodegradable and has an unlimited life span so "great potential for unlimited recycling" (Jahanshahi, S., & Rankin, W., 2007, p. 56). Given that our future resources may be limited, it makes sense to critically examine how zinc is used. The following Life Cycle Analysis (LCA) assesses Zinc's potential environmental impact during the entire life cycle of a lighting column. Metals are associated with a high number of feed streams, by-product and waste streams plus energy inputs so this is not a straight forward exercise (Norgate et al., 2007). Focus is placed mainly on the HDG process for the steel lighting column but the data is compared with aluminium and glass fibre reinforced polymer composite lighting columns. These columns share common life cycle patterns (Figure 7) but have different inputs and outputs at each point in the life cycle - although there is some overlap in on-site installation, maintenance and dismantlement (Table 1).

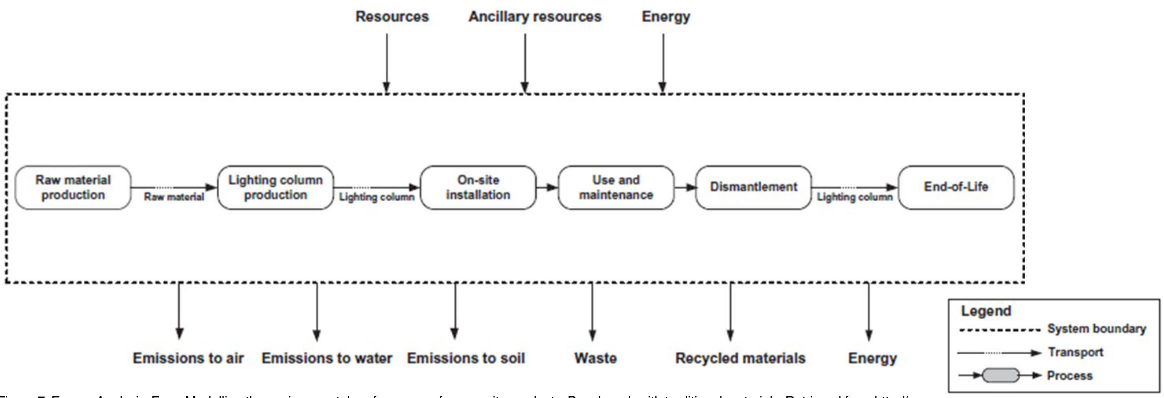


Figure 7. Energy Analysis. From Modelling the environmental performance of composite products: Benchmark with traditional materials. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission

Table 1
Input data for the three systems and data sources for each life cycle stage.

Life cycle stage	Composite	Steel	Aluminium
Raw materials production	Polyester resin Polyester resin transport Glass fibre Glass fibre transport Grey pigment Grey pigment transport Ancillary materials	Steel Steel rolling Steel pipes transport	Aluminium Aluminium transport
Lighting column production	Glass fibre multiaxial fabric weaving Curing agent, pigment and resin mixing Vacuum infusion Incineration of flash Incineration of waste Waste transport	Deforming, grinding, cutting, sawing and welding Hot-dip galvanising Recycling of steel scrap Steel scrap transport	Aluminium extrusion Machining
On-site installation	Truck with a crane Lighting column transport from production to site installation	Truck with a crane Lighting column transport from production to site installation	Truck with a crane Lighting column transport from production to site installation
Use and maintenance	None	Transport to lighting column site Truck with a crane	Transport to lighting column site Truck with a crane
Dismantlement	Truck with a crane Lighting column transport from site installation to incineration site	Truck with a crane Lighting column transport from site installation to recycling site	Truck with a crane Lighting column transport from site installation to recycling site
EoL	Incineration with energy recovery	Recycling	Recycling

Table 1. Products, inputs and outputs. From Modelling the environmental performance of composite products: Benchmark with traditional materials. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission

4.1 Primary material production

Production of metals often contains trace levels of toxic/hazardous chemicals, some of which are captured and others are dispersed through tailings, slags, and fumes, making environmental assessment difficult. However, one recent life cycle assessment found Zinc to have relatively low cradle to gate environmental impact. Steel produced by the blast furnace process was lower still (Norgate et al., 2007). Light metals like aluminium have the greatest “cradle to gate” impacts. Smelting of Zinc has less impact that the electrolytic process and the lower grade the ore, the greater the impact on the environment because extraction involves more energy (Norgate et al., 2007). Like most metals, zinc mining is an energy intensive process (Dodson, Hunt, Parker, Yang & Clark, 2012). Environmental impacts are given in Table 2 and Figures 8 & 9.

Environmental impacts for “cradle-to-gate” metal production

Metal	Process	GER (MJ/kg)	GWP (kg CO_2e/kg)	AP (kg SO_2e/kg)	SWB (kg/kg)
Zinc	Electrolytic process	48	4.6	0.055	29.3
	Imperial smelting process	36	3.3	0.036	15.4

Table 2. Energy inputs and outputs. From Assessing the environmental impact of metal production processes. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.018. Reprinted with permission.

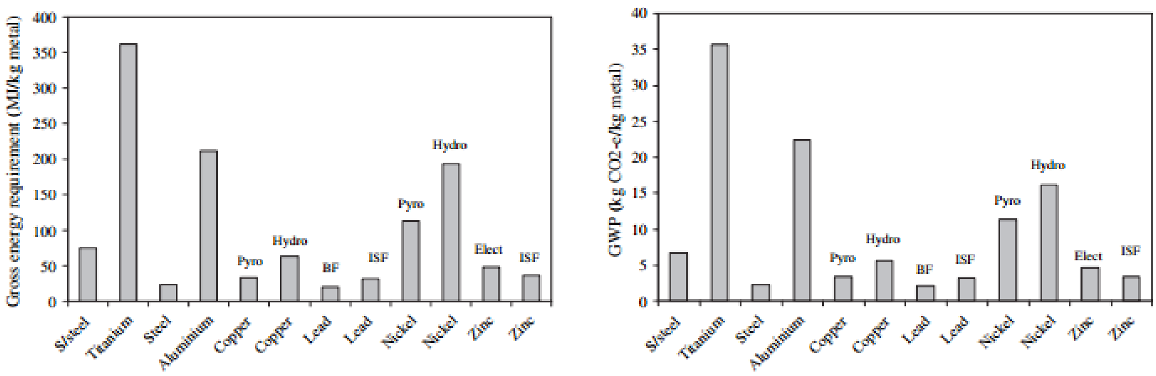
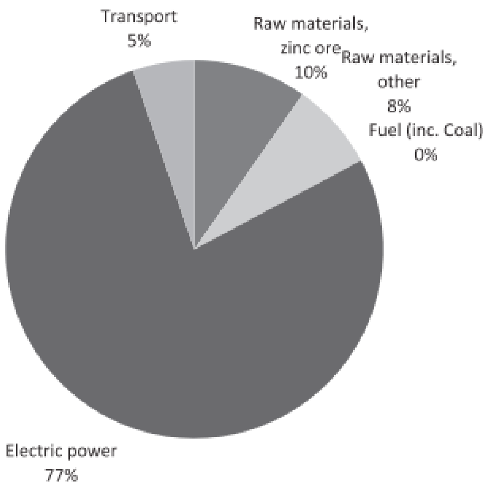


Figure 8 and 9. Gross Energy Requirements. From Assessing the environmental impact of metal production processes. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.018. Reprinted with permission.



One of zinc’s main contributors to Global Warming Potential is power consumption (Norgate et al., 2007) Environmental impact appears to be strongly dependant on the type of power supply the zinc plant uses.

Figure 10. Gross Energy Distribution. From Assessing the environmental impact of metal production processes. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.018. Reprinted with permission.

4.2 Secondary material production

The aluminium lighting columns (ALC) are made of aluminium pipes produced by extrusion and machining. The waste is controlled through a recycling process, managing 80% of the environmental burden. The composite lighting columns (CLC), by contrast, are composed of unsaturated polyester, E-glass fibres and pigment produced by vacuum infusion. To make E-glass, liquid glass is drawn into fibres which are coated for protection from atmospheric and physical damage then a weaver makes the fabric with a specific fibre orientation. The production of glass fibre and oil to produce the polyester is the main contributor to the CLC’s environmental burden (Simões et al, 2012).

4.3 Summary

The production of the alternative materials - aluminium and glass fibres - is much more energy intensive than steel however the steel lighting columns (SLC) have worst performance for fossil fuel consumption. Production of the raw material is the greatest contributor to the environmental burden of all the columns (Table 3) (Simões et al, 2012).

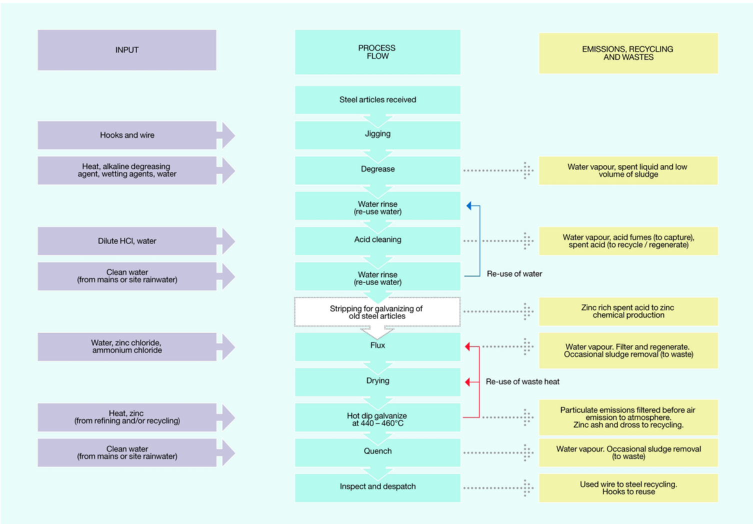
Impact category	Life cycle stage	CLC	SLC	ALC
Fossil fuels (MJ surplus)	Raw material	160	113	287
	Production	1.1	24.2	45.5
Resp. inorganics (DALY)	Raw material	7.78E−5	7.1E−5	2.63E−4
	Production	5.24E−7	7.1E−5	2.05E−5

Table 3. Energy consumption. From Modelling the environmental performance of composite products: Benchmark with traditional materials. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission.

The most significant environmental burden for the SLC are fossil fuels and emissions from inorganic chemicals which pose a health risk (Resp.inorganics). These are nitrogen oxides (36.7%), particulates (<10 l) (21.3%) and ammonia (14.7%) (Simões et al, 2012)

4.4 Product manufacture

“There are few more aggressive industrial processes than that of a galvanising plant” (DCE Limited, 1997, p. 341). The main environmental impacts are atmospheric emissions, contaminated waste waters and solid waste emissions (Kong, G. & White, R., 2010). When metal components are immersed and extracted from the hot zinc, a white plume is given off which produces a number of fine pollutants (Hosokawa MikroPol, 1995). Table 4 gives CO2 emissions from a typical galvanising plant (DCE Limited, 1997) and the inputs and outputs of the galvanising process are described in Figure 11.



CURRENT EMISSION LEVELS

Total particulate matter (from galvanising baths)	15mg/m³
Chlorides (as hydrogen chloride excluding particulate matter)	30mg/m³
Lead and its components (as lead)	2mg/m³

Table 4. Energy consumption. From Filtration and control of fume emissions from the galvanising process. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/S0015-1882(97)90557-7. Reprinted with permission.

Figure 11. Energy consumption. From Galvanizers Association. Retrieved from http://www.sustainable-galvanizing.com/media/main/sustainability/cases/EAGS-1.jpg. Reprinted with permission.

The level of zinc’s environmental impact varies between countries. China, for example, tends to use obsolete technology and fuels its plants with coal so has a very high energy emission rate compared to the States. Galvanising baths (zinc kettles) are, in general, the largest user of energy (Table 4) (Kong & White, 2010).

Specific energy consumption in a HDG plant (MJ/ton of steel galvanized).

	Natural gas		Electricity			Total
	Zinc kettle heating	Caustic and flux tanks heating	Cranes	Process equipment and lighting	Other peripheral uses	
Average	1785	797	6	95	5	2688
Percentage	66.4%	29.6%	0.3%	3.5%	0.2%	100%
Range	1150–2740	460–1200	4–9	56–120	3–12	

Table 4. Specific energy consumption. From Toward cleaner production of hot dip galvanizing industry in China. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j. Reprinted with permission.

Zinc’s environmental impact can be reduced by recovering zinc dross and zinc ash. Between 60-70% can be reused for coating product and 60-80% as an additive in paint and agricultural fertilizers (Kong & White, 2010).

In terms of each of the lighting columns, the manufacturing phase is “responsible for most of the impacts in all systems, with the production of the raw materials being the largest contributor for that phase” (Simões et al, 2012 p. 124).

4.5 Product useful life

The estimated residence life for zinc is about 25-40 years for infrastructure such as lighting columns (Van Beers, Kapur & Graedel, 2007). In comparison to painted surfaces, HDG rates lower in environmental impact, particularly resource depletion and greenhouse emissions (Figure 12) (Galco House, 2008).

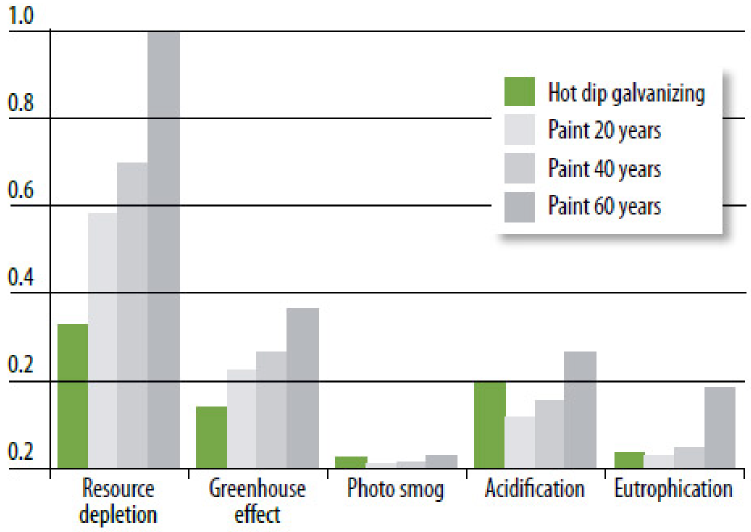


Figure 12. Environmental Effects. From Galco. Retrieved from http://www.galco.ie/hot-dip-galvanizing-sustainability-life-cycle-assessment. Reprinted with permission.

Simões et al (2012) indicate that the life span of the SLC and ALC is significantly shorter by 50% than the CLC, based on the assumption that lighting device and wiring are the same (Table 5).

Product	Lifespan (Years	Conditions
Steel lighting column	20 years 30 years if maintained	Dependent on quality of steel & zinc Dependent on atmospheric conditions such as moisture and sea air
Aluminium lighting column	20 years 30 years if maintained	Dependent on atmospheric conditions such as moisture and sea air
Composite lighting column	60	

Table 5. Expected Life Span. Adapted from Modelling the environmental performance of composite products: Benchmark with traditional materials. Retrieved from 39,121-130. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission.

On-site installation, use and maintenance and dismantlement stages account for 45.6% of the noxious chemical emissions (Resp. inorganics) for the SLC while, at 64.8%, the loading is even greater for the ALC (Simões et al, 2012). The use of a truck with a crane appears to significantly impact on the Product Useful Life Cycle. In contrast, the long life span of the CLC avoids consumption of new materials and it has very little maintenance.

4.6 End of Life

Technically, zinc is 100% recyclable because the content is the same at the end of life as the start (Norgate et al, 2007). In reality, around 25-30% of global zinc consumption is currently being generated from recycling sources (Dodson, Hunt, Parker, Yang, & Clark, 2012) and, in Australia, 40% of all discarded zinc is being recycled (van Beers et al, 2007).

Some scholars argue that galvanised steel is relatively easy to collect, treat and recycle. This is not the case. The most widely used process for recycling zinc-coated steel is the electric arc furnace (EAF) where high temperatures cause zinc to leave the furnace (Simões et al, 2012). The furnace dust (EAFD) is potentially hazardous so disposal is a major problem for the steel industry. Other processes can be used to recover zinc but, because of their high cost, large proportions of EAFD end up in landfill (Figure 13). The low figure for zinc recycling is therefore due to the high recovery costs (Van Beers, et al, 2007).

Overall calculations for inputs and outputs of the lighting columns are described below however most columns are sent to recycling facilities. The SLC and ALC are recycled through smelting and EAFD processes. The CLC is difficult and expensive to recycle therefore it tends to be incinerated at energy recovery facilities with the inert produce being sent to landfill (Simões et al, 2012).

Figure 13. Outputs of EAFD. Retrieved from http://www.zinc.org/general/electric_arc_furnace.jpg. Reprinted with permission.

4.6 Conclusion: Relative Sustainability

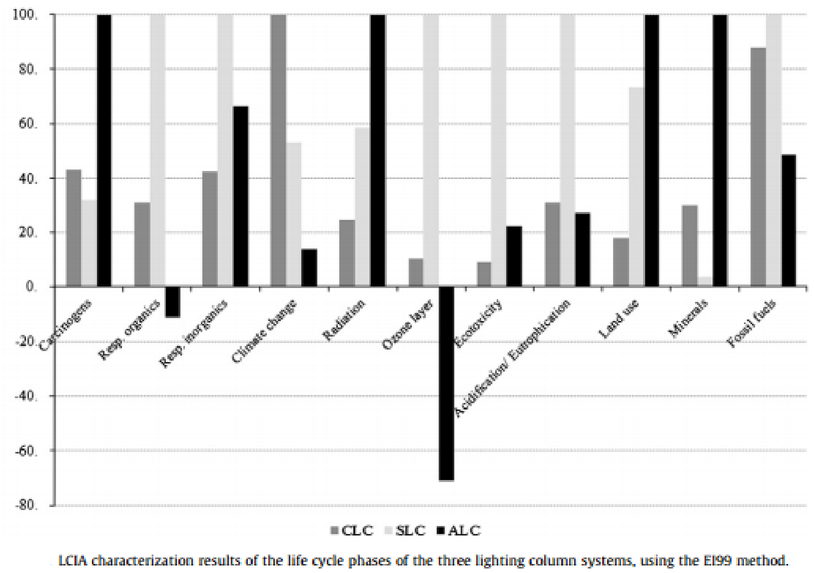


Figure 14. Environmental outputs of lamppost types. From Modelling the environmental performance of composite products: Benchmark with traditional materials. Retrieved from http:http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027. Reprinted with permission.

In terms of the relative sustainability of the lighting columns, it appears that:

1. “The composite lighting column is environmentally preferable due to its extended life span and lack of maintenance” Simões et al., 2012, p. 121) despite its recycling challenges.
2. The product **containing zinc**, the Steel Lighting Column, presents the most negative environmental profile despite less energy intensive production therefore is the least recommended product.
3. The SLC has higher environmental impact in all categories except Carcinogens, Climate Change, Radiation, Land Use and Minerals.
4. The CLC performs worse in only one environmental performance category - Climate change
5. If jute replaced the glass fibre production (which is the main contributor to the overall environmental burden of the CLC) then there would be more environmental gains.
7. With its high environmental loading, the ALC must also be discounted. (Simões et al, 2012)

5.0 Recommendations/ Implications

Zinc is a flexible material used mainly for its anti-corrosive properties. As a galvanising product, it plays an important role in extending the life of steel and lead. However, as shown in this report, it is not necessarily the best material to use when considering the life cycle of a lighting column.

To improve zinc's overall sustainability it is necessary to:

Primary Material Production
Seek other routes for sourcing zinc:
i. "Urban mining" from existing landfill sites.
ii. Extraction from low grade ores and mining operations containing zinc.
iii. Recovery from aqueous waste-waters such as the nuclear industry.
(Dodson, Hunt, Parker, Yang,& Clark, 2012)

Manufacturing
Reduce environmental burden by developing:
i. Advanced operating technology (such as improved process flow, low acid pickling, zinc stripping
ii. Advanced energy technology (covering tanks, insulating walls, improving combustion systems)
iii. Focus environmental protection at cradle point not end-of-pipe treatment and pollution technologies.
(Kong & White, 2010)

Useful product life
i. Ensure regular maintenance of the product.
ii. Control inputs - installation/maintenance and dismantlement.

End of life/disposal
i. Locate zinc recycling depots in urban areas (Van Beers et al., 2007)
ii. Seek other ways to recycle the product than the Electric Arc Furnace.

Factors to consider if using zinc as a galvanising material:
1. Check whether the galvanising company has a policy of Cleaner Production (CP) and how it is implemented
2. Check on zinc' country of origin with awareness that, if the material is sourced from China then the company may not comply with CP processes (Kong & White, 2010).
3. Explore alternative material options such as composites using jute.
4. Be aware that, in terms of the life cycle, product useful life has a big environmental impact so the potential impacts of installation, maintenance and dismantlement.
5. Check about recycling processes and avoid use of an EAF where possible.

6.0 References

Chivers, A. & Porter, F. (1994). *4.7 - Zinc and Zinc Alloys: Corrosion* (3rd ed.), 168-174. Oxford: Butterworth-Heinemann. http://dx.doi.org/10.1016/B978-0-08-052351-4.50049-2.

DCE Limited. (1997). Filtration and control of fume emissions from the galvanising process. *Filtration and Separation, 34*, 341-343. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/S0015-1882(97)90557-7

Dodson, J., Hunt, A., Parker, H., Yang,Y., & Clark, J. (2012). Elemental sustainability: Towards the total recovery of scarce metals. *Chemical Engineering and Processing: Process Intensification*, *61,* 69-78. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.cep.2011.09.008e/article/pii/S0261306912000842

Galco House. (2008). *Life cycle assessment*. Retrieved from http://www.galco.ie/hot-dip-galvanizing-sustainability-life-cycle-assessment.php

Galvanizers Association. (2013). *Sustainable galvanising.* Retrieved from http://www.sustainable-galvanizing.com/media/main/sustainability/cases/EAGS-1.jpg

Hosokawa MikroPol. (1995). Hot dip galvanising. *Filtration and Separation*, *32*(6), 509-511. Retrieved from http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/S0015-1882(97)84089-X

Kong, G. & White, R. (2010).Toward cleaner production of hot dip galvanizing industry in China. *Journal of Cleaner Production, 18*(10-11), 1092-1099. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2010.03.006

Norgate, T., Jahanshahi, S., & Rankin, W. (2007). Assessing the environmental impact of metal production processes. *Journal of Cleaner Production*, *16*(8-9), 838-848. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.018

Van Beers, D., Kapur, A., & Graedel, T. (2007). Copper and zinc recycling in Australia: Potential quantities and policy options. *Journal of Cleaner Production*, *15*(8-9), 862-877. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.jclepro.2006.06.023.

Simões, C., Costa Pinto, L., Bernardo, C. (2012). Modelling the environmental performance of composite products: Benchmark with traditional materials. *Materials and Design*, *39*,121-130. http://dx.doi.org.ezproxy.aut.ac.nz/10.1016/j.matdes.2012.02.027,

Steelgal Industries Ltd. (2008). Product Range. *Steelgal*. Retrieved from: http://www.steelgal.co.nz/products.html

Thompson, T. (2007). *Manufacturing processes for design professionals*. New York: Thames & Hudson.
VMZinc. (n.d.). Passionate about zinc. Retrieved from http://www.vmzinc-us.com/