Australasian (iron and steel) Slag Association

Benchmarking Report

Prepared for the

Benchmarking Module: Sustainability Capacity Building Program

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Executive Summary

Electric arc furnace slags (EAFS) are a valuable but underutilised mineral resource. There are several reasons for this underutilisation that include lack of awareness, lack of understanding of the resource properties and characteristics, barriers to entry (exclusion from major specifications designed for natural materials), and unidentified areas for reuse and associated commercial and environmental benefits.

With specialist assistance of Link Strategy, the Australasian (iron and steel) Slag Association (ASA) has, through a refined supply chain approach to sustainability and low carbon product development, worked closely with Victorian steel companies and supply chain partner industries to explore, in some cases re-explore, opportunities to utilise EAFS. Various end use applications in road construction and building products afford the greatest potential starting point.

This benchmarking report captures and adds to the current 'knowledge base' about EAFS with the participant companies in the EAFS supply chain. The EAFS supply chain is analysed from three perspectives;

- Energy use or "carbon footprint" associated with EAFS (Quantitative),
- Products and potential end use applications for EAFS (Quantitative & Qualitative), and,
- Participant attitudes to issue/s that impact on effective utilisation of EAFS in Victoria.

The integration of these three perspectives into the benchmarking report enabled participants to conceive a rich and balanced picture of the current state of the industry in 2009/10, and has contributed to a more thorough, comprehensive evaluation of relevant issues for the supply chain and reuse opportunities for those participants involved.

Victorian steel companies and supply chain partners explored opportunities to utilise EAFS in appropriate, sustainable and environmentally beneficial applications. This report benchmarks the current knowledge base.

Contents

Key benchmarking facts

This benchmarking report establishes that from the 90,000 tonnes of EAFS produced annually in Victoria there have been limited volumes effectively utilised[1]. Many factors uncovered are due to lack of awareness of the resource, misunderstandings of the resource properties and characteristics, and major barriers to entry from state agency controlled specifications which historically preference natural materials. Areas for alternative reuse and associated commercial and environmental benefits were generally unexplored.

The results of the benchmarking study analysed from three perspectives are summarised below:

- Limited volumes of EAFS were effectively utilised at the commencement of this program, when sold 'low value add' was attributed
- Energy carbon analysis results were very encouraging;
  - Feedstock material emissions are 0.004 tCO_2-e/tonne product
  - Aggregates material emissions are 0.006 tCO_2-e/tonne of product
  - Blended products material emissions are 0.002 tCO_2-e/tonne of product
  - Combined product materials emission are 0.012 tCO_2-e/tonne of product
  - Total water used is 2.61 kL to process and manufacture one tonne of EAFS
- Technical - EAFS are poorly understood; moreover, VicRoads held negative perceptions initially. EAFS were NOT currently addressed or specifically allowed for in key material specifications
- Competence - there are insufficient projects and case studies demonstrating the environmental and performance characteristics of EAFS to provide confidence to VicRoads
- Acceptance - Local Government were identified to be technically risk averse to new products - default to VicRoads specifications and approved products

EAFS are not currently addressed or specifically identified in key VicRoads material specifications. Participants indicated that simple performance standards, opposed to prescriptive standards, would aid communication and utilisation of product options.

[1] "Effective utilisation" is the sale or utilisation recoverable mineral resources into a value added construction application that provides both commercial returns [revenue] return on investment or an economic profit [avoided expense], and use is consistent with the criteria of ecologically sustainable development (ESD) principles

Combined product materials emission are 0.012 tCO_2-e/tonne of product the emission reduction for products containing EAFS could be up to 0.034 tCO_2-e/tonne of product or 73 percent emission reduction when compared to natural quarried products. Natural aggregate associated emissions are 0.046 t CO_2-e/tonne of product[2].

Potential total annual emissions reductions for Victoria, if EAFS were used to displace natural quarried aggregates, would be between 3,000 to 3,500 tCO_2-e from the 90,000 tonnes of EAFS produced.

Development time is considered a major commercial risk from a business perspective. Low value add is typically associated with low technical risk, whereas high value add is likely to be associated with higher technical risk.

The processors and value adders consider the technical specification barriers, low economic value add and waste stigma as key impediments to increasing utilisation. The customers consider the lack of performance specifications for different applications as a barrier.

The complexity of the technical information requirements makes it difficult to establish what materials are required for specific sites. All participants indicated that simple performance standards, opposed to prescriptive standards, would aid communication and utilisation of product options.

Development time is considered a major commercial risk from a business perspective. It can take extensive time, funding and resources up front for product development, and results are not known for a couple of years.

[2] Flower, D. J. M., J. G. Sanjayana, et al. (2007). Environmental Impacts of Concrete Production and Placement. Concrete 07, Adelaide, Concrete Institute of Australia.

Introduction

The Australasian (iron & steel) Slag Association Incorporated (ASA) was formed in 1990, nationally represents the leading steel, cement, quarrying and slag processing companies, who have a common interest of increasing community, business and government awareness of the superior construction properties, environmental and value added benefits derived from the various iron and steel furnace slags (ISS). Association activities are primarily focused on conducting research and development, understanding and educating users, stakeholders and engaging regulators with regard to the uses and benefits arising through the effective utilisation of ISS, which is a valuable recovered resource.

The association has previously identified that in Victoria, up to 90,000 tonnes of ISS produced annually has not been effectively utilised[3] due to the poor understanding within the supply chain in regards to the resource, areas for reuse and associated benefits [commercial & environmental] that can be derived through assisting in developing current and new market opportunities for Electric Arc Furnace Slags (EAFS) use.

Electric arc furnace slag (EAFS) is the by-product from the manufacture of molten steel within an arc furnace.

Increasing the effective utilisation of EAFS materials produced in Victoria by 50 percent through identified potential associated industries, such as cement, concrete, road construction and water treatment applications - could provide up to 30,000 tCO_2-e emission reductions from high value add, high technical risk applications, e.g. cementitious applications.

Using a refined supply chain approach[4] we have aimed to identify a range of options from low value add to high value add applications. Interestingly, there is a corresponding technical and commercial risk factor for each of these value add options. That is, low value add is typically associated low technical risk, whereas high value add is likely to be associated with higher technical risk.

The electric arc furnace (EAF) steel production process used at OneSteel, Laverton has potential to generate up to 90,000 tonnes of EAFS annually. EAFS is the by-product after steel scrap and fluxes are added to a refractory lined cup-shaped vessel. This vessel has a lid through which carbon electrodes are passed. An arc is induced between the scrap and electrodes and the resultant heat generated melts scrap and fluxes. The molten steel and EAFS [by-product] are separated before processing the molten steel into various finished products.

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[3] "Effective utilisation" is the sale or utilisation recoverable mineral resources into a valued added construction application that provides both commercial returns [revenue] return on investment or an economic profit [avoided expense] and use is consistent with the criteria of ecologically sustainable development (EDS) principles

[4] Woodhead, A. Guidelines to Sustainability in Supply Chains (2009) www.linkstrategy.com.au

As by-products from the steel making processes, EAFS products are a result of the same quality process controls and modern technology used to achieve high quality metal products. As products of an industrial manufacturing process the consistency of chemistry and quality of slag products is an important characteristic.

This study establishes baseline information about low carbon opportunities for EAFS, the current state of the industry and barriers to market development.

From a national perspective, first tier revenues between the generator and processor are reported to be >$140 million annually from so called 'wastes'. The reuse and/or recovery of 2.71 Mtpa of ISS across Australia is a success story that has not translated into Victoria. Challenging participants and potential users about the 'low carbon' opportunities which could be exploited from processing EAFS into new-use opportunities which maximise their inherent qualities requires significant understanding of the barriers to entry. This benchmarking study establish a baseline.

The participants

The benchmarking modules involved several sectors of the ISS supply chain and are defined in the groupings below. These groups are not discreet with some participants representing interests that cross sectors.

- **Producer** – means a company whose primary business is to produce steel products, and EAFS as a by-product – who supplies EAFS to a value adders or customers.
- **Value adder** – means a company who processes, mixes, blends, or otherwise incorporates EAFS into a material for supply to customers. A value adder brings intellectual property to EAFS.
- **Customer** – use or manufacture products that incorporate EAFS for their unique physical or chemical properties.
- **Researchers** – provide research support to the sector at various stages of the supply chain

Other participants that are not represented in the following table include Sustainability Victoria, ECO-Buy and EPA – Environment Protection Agency. These participants were viewed as 'enablers' and span across all parts of the supply chain.

Producer	Value adder	Customer	Researchers
- OneSteel	- Harsco Metals Pty Ltd - Cement Australia Ltd - Blue Circle Southern Cement - Independent Cement & Lime Pty Ltd - Australian Steel Mill Services	- VicRoads - Holcim Pty Ltd - Wyndham City Council - Geoploymer Alliance	- University of Technology, Sydney - The University of Melbourne - CSIRO - Monash University - ARRB Group - Swinburne University of Technology

Table 1 - Participant Groups

Benchmarking Scope

The methodology

The objective of the benchmarking analysis[5] is to;

- Establish data about current practices in 2009/10.
- Increase capacity of business to understand the impacts of their current product streams and potential efficiency opportunities
- Inform decision-makers about options for product diversification and low-carbon products

The quantitative benchmarking data is also supported by qualitative data developed during the workshops. Data definitions are drawn from Sustainability Victoria's performance KPIs. The benchmarking study incorporates data from both *primary* (Producers) and *secondary* sources (external studies and industry reports). *Primary data sources* and associated externalities include:

- Raw materials, transport, fuels and electricity from operations in Victoria.
- Association data and anecdotal knowledge gained during the workshops (energy use, business drivers, characteristics of geography / production / materials etc.)
- Invited experts with specialist presentations to the group.

This benchmarking report incorporates data from both primary and secondary sources.

Secondary data sources are associated energy, transport and material inputs used. The data analysis is categorised into three (3) benchmarking factors, namely an Emission analysis, Product analysis and Perspective analysis:

- **Emissions analysis:** EAFS are categorised into three groups: feedstock, aggregates, blended products. For each of these groups an analysis of energy, water, and transport is reported as carbon emissions per tonne of EAFS. Emission analysis identifies energy use during EAFS production, collection and metal recovery resulting in feedstocks prior to the value adding process. (Blue boundary line).
- **Product analysis:** The product and market data are distinguished on the basis of their extent of value adding attributes, categorised as high, medium or low value add and are further classified into associated product categories. Product analysis identifies the EAFS supply chain boundaries including the processor/value adder sector (Grey boundary line).
- **Perspective analysis:** The participants' assessment of key economic, social and operational issues based on workshop data and captured from participants.

[5] Woodhead, A., Cornish, P. Slavich, P., (2000) Multi-stakeholder Benchmarking. Australian Journal of Experimental Agriculture 40: 595-607

Perspective analysis draws on participant views from the entire supply chain (defined by participants who attended workshops above) (Green boundary line).

Each sector has data based on a defined supply chain boundary (see Figure 1, Benchmarking groups below).

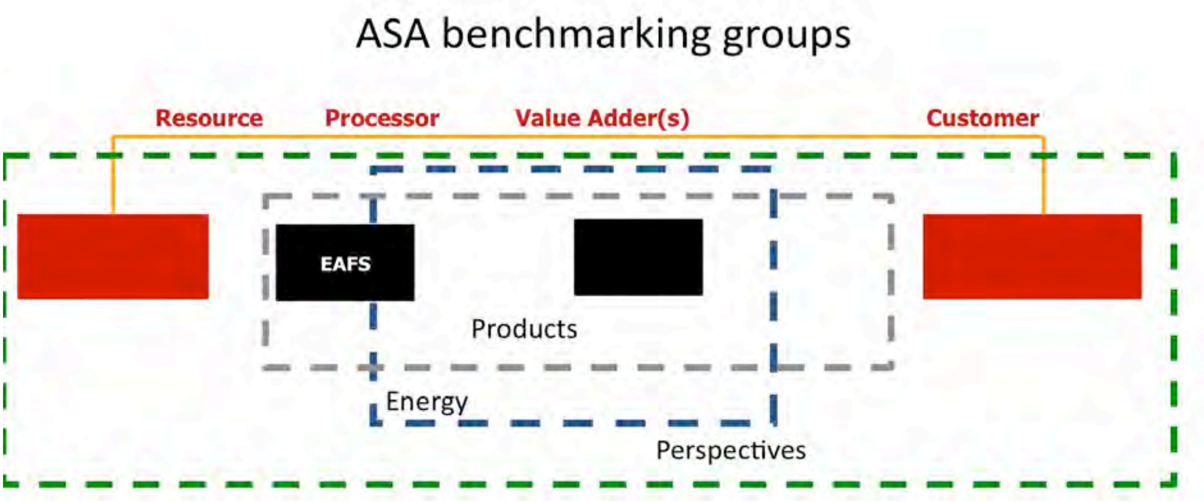

Figure 1 - ASA Benchmarking Groups

Electric arc furnace slags

Production Process

For EAFS to be of value to the generator, processor, value adder or consumer, there must be an economic reuse for the material, and the material must be price-competitive and offer some other benefit (e.g. reduced environmental impacts) against more conventional raw materials for potential applications. This information can be used to compare resource processing options, e.g. how EAFS processes and associated emissions compare against natural materials and the associated energy and processing inputs' "carbon footprint."

Processes and associated emissions of the steel mill's (Generator's) primary products are beyond the scope of this study, accordingly not relevant to the project aims of this partnership program for EAFS being by-products.

The following figure illustrates the typical flow for the manufacturing process. Figure 2 – *Typical EAFS production process* focuses on the EAFS processing and handling systems and emissions attributable for each step in the process.

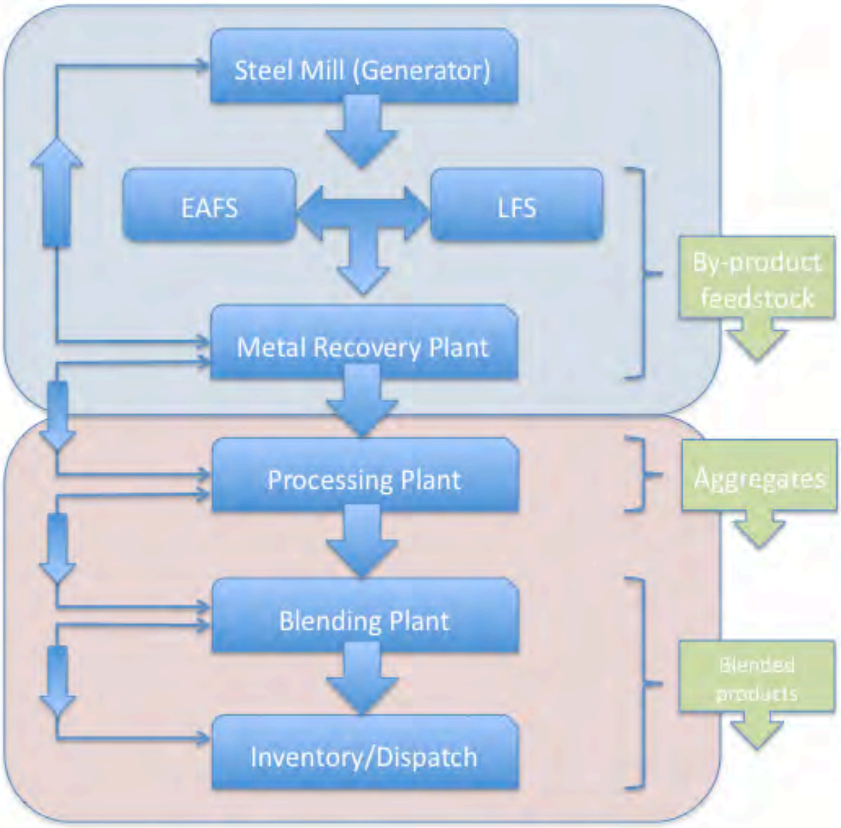

Figure 2 - EAFS Production Process

Stages of EAFS production

During the primary stages of the electric arc furnace (EAF) process, steel scrap, lime (fluxes), coke (fuel) and Magnesium Oxide (MgO) are added to a refractory lined cup-shaped vessel. An arc is induced between the scrap and electrodes and the resultant heat generated melts scrap and fluxes. Molten slag, being a by-product of the steel mill process needs to be removed from the steel.

EAFS (by-product) are separated before further processing the molten steel into various finished products. The slag generated in the EAF processes accounts for approximately 120 — 150 kg per tonne of steel produced. Another by-product in relatively small quantity is Ladle Furnace Slag (LFS) which is equal to 30 kg per tonne of steel produced.

Metal Recovery Plant

EAFS and LFS process flows are show in Figure 2. Processes within the blue shaded boundary are generally attributable to the primary operations. During the removal of the

EAFS, a small quantity of steel will be poured off at the same time. This practice ensures no slag or impurities remain in the steel prior to further processing into various finished products. Accordingly, small but valuable quantities of steel need to be recovered from the EAFS.

EAFS and LFS are collected from the tipping bays and processed through the 'Metal Recovery Plant' (MRP). As the process name suggests, metal contained within the slag is removed after crushing in metallic separation plant using magnets. Metal recovered is recycled back to the steel mill furnace.

Aggregate Processing Plant

Once through the MRP, EAFS is referred to as the primary 'feedstock', which can be further processed into smaller size fractions through the next crushing and screening plant. The product outputs of this process are referred to as sized 'aggregates'. These aggregates can be blended into various finished products to customer specifications or requirements. These processes are show in Figure 2, contained within the red process boundary.

As by-products within the steel making processes, EAFS products are a result of the same quality process controls and modern technology used to achieve high quality metal products. As products of a manufacturing process the consistency of chemistry and quality of slag products is a feature.

EAFS products are a result of the same quality process controls and modern technology used to achieve high quality metal products.

Characteristics and Properties

The typical chemistry of EAFS, after appropriate conditioning and weathering, is shown in following table with ranges of 2 standard deviations. These results generally compare well with other natural quarried materials used widely throughout Australia[6]. Chemical testing conducted by the association over the past 15 years highlights the low co-efficient of variation inherent in slag[7].

[6] ASA (2002). A Guide to the Use of Slag in Roads. Revision 2. Wollongong, Australasian (iron & steel) Slag Association Inc.
[7] Heidrich, C. and S. Ritchie (2007). Possible inter-jurisdictional approaches to Waste reclassification. Sustainability, Construction Materials and your Bottom Line, Sydney, NSW, Australia, Australasian (iron & steel) Slag Association Inc.

Constituents as oxides Oxides	Symbol	EAF Slag (%)
Calcium Oxide	(CaO)	30 - 35
% Free Lime		1 - 2
Silicon Oxide	(SiO2)	10 - 12
Iron Oxide	(Fe2O3)	22 - 29
Magnesium Oxide	(MgO)	5 - 8
Manganese Oxide	(MnO)	4 - 7
Aluminium Oxide	(Al2O3)	4.5 - 5.5
Titanium Oxide	(TiO2)	0.5 - 1.0
Potassium Oxide	(K20)	0.1 - 0.3
Chromium Oxide	(Cr2O3)	1 - 2
Vanadium Oxide	(V2O5)	0.5 - 1.0
Sulphur	(S)	0.1 - 0.3

Table 2 - EAFS Chemistry

Focusing on the largest by-product volume – EAFS – this benchmarking study set out a system boundary rationale to identify the baseline 'carbon footprint' attributable to the production of 1 tonne EAFS. Using the above 'EAFS Production Process' diagram the study focuses on the three stages: metal recovery plant, feedstock and aggregates (which incorporates proportions of LFS).

EAFS produced in Victorian steel mills are typically grey in colour. Once processed, crushed particle 'aggregates' can range in size or a combination of <70mm, 20mm, 14mm, 10mm and <7-0mm. Aggregates have a vesicular appearance or honey-comb structure – providing a higher surface area than traditional quarried aggregates.

Figure 3 - Typical EAFS products

When compared with natural aggregates, EAFS are approximately 10-20 percent heavier due the material's particle density of between 3,300 to 3,400 kg/m^3. Wet/Dry strength is higher at between 240 to 300 kN which results in increased durability features for road construction pavement surfacing applications. Further technical details, characteristics, properties and test results can be found in the associations published guides downloadable from the ASA website[8].

[8] http://www.asa-inc.org.au/techguides.shtml

Benchmarking Analysis

National Production and Utilisation Data

The association annually collects information regarding ISS – namely production and sales by members and non-members for each calendar year. Information provided by members and non-members is collated and then aggregated into a national set of results and include ISS production levels, and nominated uses for all slag products.

For the calendar period January to December 2009, 80 percent of all ISS produced were utilised within various civil and construction applications throughout Australasia. The survey results include all generators (iron & steel plants), marketers (processing and value adding companies), and customers for the total production and resulting sales by each end use. Where required, data is supplemented with importation data and other secondary data sources for accuracy purposes

For the period, 3.4 Mt (million tonnes) of iron and steel slag products were produced within Australasia (Australia and New Zealand).

- From the ISS produced, some 2.71 Mt or 80 percent has been effectively utilised [sold or reused for some beneficial use]
- On per capita basis, this equates to 123 kgs per person recycled or reused
- 20 percent or 0.671 Mt was used in cementitious applications – 'high value add' [HVA][9]
- 48 percent or 1.64 Mt was used in non-cementitious or road construction applications –'medium value add' [MVA][10]
- 12 percent or 0.39 Mt was in general civil or fill applications – 'low value add' [LVA][11]

Recovery and reuse of EAFS provide significant positive environmental impacts.

In summary the recovery and reuse of ISS provide significant positive environmental impacts, including resource conservation and in this case, the reduction of greenhouse gas emissions[12] from the processing of virgin resources. For example from the use of 0.671 Mt in cementitious applications – 'high value add' [HVA] approximately 440,000 tCO_2-e were abated in 2009 from the use of ISS.

Placing the above national production and utilisations data into a Victorian state context, from the 690,000 tonnes or 20 percent not effectively utilised across Australasia the estimated 90,000 tonnes produced in Victoria contributes to this underutilised volumes. Reasons for this poor utilisation level are further discussed in the following sections such as

9 HVA – High Value Add – means where ISS materials are sold for > (more than) $100/tonne
10 MVA – Medium Value Add – means where ISS materials are sold for between $10-$100/tonne
11 LVA – Low Value Add – means where ISS materials are sold for < (less than) $10/tonne
12 Heidrich, C., I. Hinczak, et al. (2006). GGBFS lowering Australia's greenhouse gas emissions profile. Global Slag Conference, Bankok, Thailand, GBC.

products and potential end use applications and participant attitudes to issue/s that impact on effective utilisation of EAFS in Victoria.

Energy analysis

For the **energy carbon analysis**, EAFS are categorised into three groups based on chemical and physical characteristic differences:

- Feedstock (MRP)
- Aggregates
- Blended products

For each of these groups an analysis of energy, water, transport, reported as carbon emissions, is provided based on the different processing stages and inputs required.

The energy carbon analysis is based on diesel, electricity and other energy activity data for the period 2009. It should be noted these data have not been 'third party verified' being beyond the scope of the study. Sources of greenhouse gas emissions identified included:

- Diesel consumption (Scope 1 emissions)
- Electricity consumption (Scope 2 emissions)

No heat recovery or associated energy production data has been provided under the scope of the operations, which could be used, to further offset emissions. Using provided energy use data for the production year for 2009, calculated for direct and indirect emission factors, the average emission associated with the collection, processing and transport up to a distance of 10 kilometres within the manufacturing/processing site one tonne of EAFS is shown in *Table3 – Weighted average emission factors for one tonne of EAFS*.

Electric Arc Furnace Slag (EAFS)								
	Feedstock (MRP)		Aggregates		Blended mix		Combined	
Inputs	**CO_2-e/t**	**%**	**CO_2-e/t**	**%**	**CO_2-e/t**	**%**	**CO_2-e/t**	**%**
Transport emissions	0.001	35.37%	0.002	36.86%	0.001	46.69%	0.005	38.28%
Electricity emissions	0.003	64.63%	0.004	63.14%	0.001	53.31%	0.007	61.72%
Total tCO_2-e/tonne	0.004	100.00%	0.006	100.00%	0.002	100.00%	0.012	100.00%
Water usage KL/tonne	1.89		0.61		0.11		2.61	

Transport (fuel) = transport emissions, up to 10kms (FIB)
Electricity (kWh) = energy emissions used to collect/transfer/process materials

Table 3 - Weighted average emission

The methods and calculations for all greenhouse gas emissions are as specified in the National Greenhouse Accounts (NGA) Factors, June 2009. The system boundaries methodology is based on *Heidrich, C., I. Hinczak, et al. (2006). Case study: GGBFS Lowering Australia's Greenhouse Gas emissions profile.*

Water use

For the purpose of this study, water used within the operating site as been captured and reported as kL per tonne of product. Water use for each processing stage has been calculated per tonne of material for the following groups:

- To process 'Feedstocks' approximately 1.89 kL/tonne is used. Water is used to initially quench solidifying EAFS materials prior to further processing
- To process 'Aggregates' approximately 0.61 kL/tonne is used. Water is used to minimise dust generation within the operating site.
- To manufacture 'Blended Products' approximately 0.11 kL/tonne is used. Water is used to pre-condition blended products prior to sale

Water use relates mainly to initial cooling, dust suppression and pre-conditioning of blended products prior to sale.

Emissions associated with water management and handling have been included in Table 4. That is, only the calculated energy attributable 'electricity use' for management and handling. To this end, energy and associated emission have been accounted for in the analysis use water pumps onsite. Water use per tonne of product manufactured is captured in this benchmarking report for future water efficiency or reduction programs.

Energy analysis findings

As discussed previously, processes and associated emissions of the steel mill's (Generator's) primary products are beyond the scope of this study and accordingly not relevant to the project aims of this partnership program for EAFS being by-products.

The information contained in Table 3 can be used to compare resource processing options, e.g. how EAFS processes and associated emissions compare against natural materials and the associated energy and processing inputs 'carbon footprint.'

Feedstocks

EAFS (unprocessed) are collected and transported to the 'Metal Recovery Plant' for processing. Metal contained within the slag is removed using magnets after crushing in metallic separation plant. Metal recovered is recycled back to the steel mill furnace. For 'feedstocks' the material process emissions that can be attributed are diesel for local transport and electricity for the crushing and screening plant.

- **Feedstock material emissions are 0.004 tCO_2-e/tonne product**

Aggregates
The primary 'feedstock' can be further to processed into smaller size fractions through the next crushing and screening plant. The product outputs of this process are referred to as sized 'aggregates'. For 'aggregates' the material process emissions that can be attributed are diesel for local transport and electricity for the crushing and screening plant.

- **Aggregates material emissions are 0.006 tCO_2-e/tonne of product**

Blended Products
These aggregates can be blended into various finished products to customer specifications or requirements. For 'blended products' the material process emissions that can be attributed are diesel for local transport and electricity for the crushing and screening plant.

- **Blended products material emissions are 0.002 tCO_2-e/tonne of product**

For illustrative purposes the following figure 3 shows emission associated with each processing stage. It is arguable that process emissions during the production of 'feedstocks' are primary to the steel mill operations, that is, metallic's are recovered for recycling within the furnace. The subsequent processing stage emissions for 'Aggregates' and 'Blended Products' are attributable to the developed finished or value added products discussed in the next section.

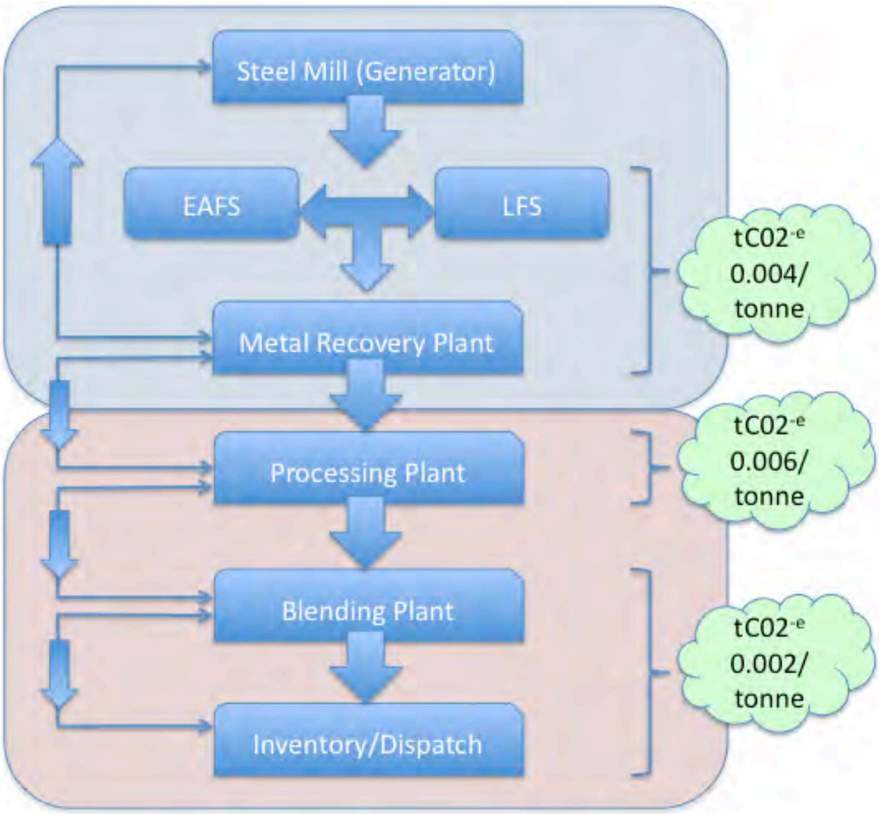

Figure 3 - Process Emission Groupings

Combining these emissions, in the areas shaded blue and red including 'metal recovery plant emission', result in total process **material emissions of 0.012 tCO_2-e/tonne of product** or **material emissions of 0.008 tCO_2-e/tonne of product** for the processing stages of 'aggregates and 'blended products' which exclude the 'metal recovery plant' emissions.

For the purposes of this report the authors have adopted a conservative approach and use the combined emissions **of 0.012 tCO_2-e/tonne** of product for the purposes of comparison.

EAFS compare well to natural quarried materials on energy analysis for 'carbon footprint'.

As discussed previously, when compared on the basis of physical and chemical properties with natural quarried products, EAFS compares well. On the basis of this report's energy analysis findings for 'carbon footprint', EAFS perform better.

In a study conducted by Flower et al. (2007) at Monash University[13], the environmental impacts of concrete production and placement were investigated for environmentally sustainable design (ESD) issues. The carbon emissions associated with construction materials were used as an environmental impact indicator. The paper quantified the carbon emissions associated with the embodied energy of concrete, in particular raw materials data was collected from two coarse aggregates quarries, one fine aggregates quarry, six concrete batching plants and several other sources. The findings for the study report the material process emissions that can be attributed are diesel for local transport and electricity for the crushing and screening plant of natural quarried aggregates are **0.046t CO_2-e/tonne of product**[14].

The average weighted emission reduction for products containing EAFS could be up to **0.034 tCO_2-e/tonne** of product, or 73 percent emission reduction when compared to natural quarried products. Estimated total annual emissions abated, if EAFS is used to displace natural quarried aggregates, could be between **3,000 to 3,500 tCO_2-e** abated from 90,000 tonnes of EAFS.

Summary findings are:

- Comparing these natural aggregate results with EAFS 'aggregates' associated emissions, the average weighted emission reduction for products containing EAFS could be up to 0.036 t CO_2-e/tonne of product or 84 per cent.

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[13] Flower, D. J. M., J. G. Sanjayana, et al. (2007). Environmental Impacts of Concrete Production and Placement. Concrete 07, Adelaide, Concrete Institute of Australia.
[14] Flower, D. J. M., J. G. Sanjayana, et al. (2007). Environmental Impacts of Concrete Production and Placement. Concrete 07, Adelaide, Concrete Institute of Australia.

- Using the more conservative approach of combined emissions, the average weighted emissions reduction for products containing EAFS could be up to 0.034 tCO_2-e/tonne of product or 73 per cent.
- Base on the above conservative emission findings, potential savings projected for Victoria on the basis of full effective utilisation of available EAFS in similar 'aggregates' product applications from 90,000 tonnes of EAFS manufactured and used equates to (0.034 x 90,000) = 3,060 tCO_2-e abated

Product streams: EAFS utilisation

The benchmarking of products streams and perspectives identifies current knowledge about options, and the current state of EAFS utilisation in products.

Using the workshop collected data [primary sources] and other industry association data [secondary sources], product options and risk assessment data is presented below - see *Table 4 Product options and risk analysis*. The data has been grouped as follows:

- Application
- Sector
- Potential volume/s
- Company/Industry in product supply chain
- Risk factors/Commentary

All supply chain sectors agreed that there are significant knowledge gaps about performance in applications; this has hindered greater utilisation of EAFS in new and existing products.

Each application is attributed to a) economic: high value add, medium value add and low value add, and b) industry sector: construction, building products and agriculture.

Opportunities to utilise the EAFS products are diverse – construction aggregates, geoploymers and mineral extraction are some options.

High value add (low EAFS volume) products identified were rock wool, metal recovery, sealing aggregate and grit blasting. Quantities of EAFS utilised for all these applications are unknown. Metal recovery was considered to be high commercial risk due to variability in metal prices and high technical risk due to process and IP required. Other value add applications such as sealing aggregate, require further technical and performance data before standards to meet customer (e.g. VicRoads) procurement requirements are met. All high value add applications can be broadly associated with either high technical or commercial risk.

Medium value add products identified included use of EAFS in cement feedstock, water treatment and use in blended cements. Competition with natural sands and processing costs were barriers to increasing utilisation, included technical suitability. Quantities of EAFS utilised in products, cement feedstock etc. were unknown. Geopolymer concretes have proven to provide significant CO_2 reduction advantages, but logistics and handling issues required further research and investigation.

Low value add (high EAFS volume) are very sensitive to transport costs. Soil stabilisation (using free lime properties) and engineered fills were identified as having potential given the medium and high value add focus from natural quarry materials. All low value add applications can be broadly associated with either low technical or commercial risk. Correspondingly, environmental risk was potentially high and will be discussed further in the 'Participant Perspectives' of this benchmarking report.

The workshop collected data (primary sources) and other industry association data (secondary sources), product options and risk assessment data identified a range of barriers to increasing utilisation, for example – historic, economic, social and geographic. These issues are benchmarked in the next section.

Participant's perspective on the EAFS supply chain

This section outlines participants' perspectives on the opportunities and barriers to increasing utilisation of EAFS. A summary of issues is shown in Table 5 – *Perspectives on social, economic, environmental and operational issues*.

As discussed above the processors' core business is steel production. EAFS and metal recovery are the value adders' core business. While the customer, VicRoads for example, is interested in lowering its greenhouse gas emissions from operations and materials use. Each position in the supply chain brings different perspectives on EAFS as shown in Table 5. All supply chain sectors agreed that there are significant knowledge gaps about performance in applications and this has hindered greater utilisation of EAFS in new and existing products. Participants at the workshops also noted that current knowledge is restricted because there are specialist silos of data and information and this has not been effectively shared or communicated to customers. There is limited knowledge about the market and economic drivers to develop products. There is also limited knowledge about engineering characteristics.

The processors and value adders consider the low economic value add as a key impediment to increasing utilisation. The customers consider the lack of performance specifications for different applications as a barrier. The complexity of the technical information also makes it difficult to establish what materials

> **The processors and value adders consider the low economic value add as a key impediment to increasing utilisation. Long development time, financial resources and staff allocation are considered a major risk from a business perspective**

are required for specific sites. All participants indicated that simple performance measures would aid communication about product options.

Development time is considered a major risk from a business perspective. It can take extensive time, funding and resources up front for product development, and results are not known for a couple of years. Financial support and staff time allocated to developing new markets and alignment of sustainability and performance standards with customer needs must be a primary focus for all supply chain participants.

Table 4 - Product options and risk analysis

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Product value	**Product type**	**Volume**	**Quantity (tonnes) used in Victoria (2009)**	**Company Name (s) in product supply chain**	**Rank / Priority**	**Risk factors**
High Value Add						
Rock wool	Building Products	Low	Unknown	CSR Bradford		Product substitution, unique properties required
Metals Recovery - zinc	Minerals Processing	Low/med	Unknown	Unknown		Risk from metal price fluctuations, logistics/processing costs
Sealing aggregate, Asphalt aggregate	Construction Products	Med	Unknown	Asphalt companies	1	VicRoads significant influencer. Requires greater technical understanding to reduce risks
Grit blasting	Cleaning products	Low	Unknown	Unknown		High processing costs

Table 4 - Product options and risk analysis (continued)

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Product value	**Product type**	**Volume**	**Quantity (tonnes) used in Victoria (2009)**	**Company Name (s) in product supply chain**	**Rank / Priority**	**Risk factors**
Medium Value Add						
Cement feedstock	Mineral Processing	Low	Unknown	Cement Companies		Competing against low cost fee stocks [clay/limestone] available locally
Water treatment sub-soil drains	Industrial waste	Low	Unknown	Agricultural, water treatment, processing	3	Promising research, low cost solution to chemical treatment
Aggregates	Building Products	High	Unknown	Quarrying Companies	3	Some treatment issues w/ free CaO and MgO
Geopolymer	Building Products	Med	Unknown	Concrete Companies	3	Emerging technology, significant C02 advantages, logistics and handling issues
Blended Cements – (LFS)	Building Products	Med	Unknown	Concrete Companies	2	Low cost binder solution, potential pre-calcined feedstock

Table 4 - Product options and risk analysis (continued)

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Product value	**Product type**	**Volume**	**Quantity (tonnes) used in Victoria (2009)**	**Company Name (s) in product supply chain**	**Rank / Priority**	**Risk factors**
Low Value Add						
Soil Stabilisation	Civil	Med	Unknown	Soil Stabilisation Companies		High volume, LVA. Requires significant RD&D to build Regulator confidence.
Engineered Fills, Road' Bases	Civil	High	Unknown	Civil Companies	2	Mature markets, some logistics impediments, regional focus, customer approval and sustainability focus required

Table 5 - Perspectives on social, economic, environmental and operational issues

	OneSteel	Harsco	Transport	VicRoads
Social	Positive community and customer perception	Positive environmental benefits, avoid landfill	Amenity, congestion	Release of premium material for higher use
Economic	Road construction cost – capital approval Value add R&D Find partners (government, university, VS to verify process)	Cost vs revenue balance, having our own transport	Limited scope for delivery vs cost	Priced appropriately to competing Sources e.g. recycled crushed concrete, fine crushed rock, cement treated crushed rock
Environmental	EPA classification of CLS? EREP	Watering regimes (environmental safety), Lifecycle analysis of impacts	Fuel use, noise, dust	DBR (beneficial reuse), life cycle impacts
Resource / Operations	Segregation and handling Quality control	Resource: Develop sales at specs to manufacturers demand and maintain customers Marketing and sales Density (factors) Operation: Controlling moisture and engineering – potentially needs capital Tramp contamination from melt shop Slag operation area	$0.20/T/K >50K	Work with other recycle materials operators. Experience of construction contractor
Knowledge	Limited to locally 100m trial road X 3 materials	Developing training procedures Optimisation		Lack of laboratory testing Lack of field trial Try several combinations of material (100m in length) Field trial – increased testing and construction supervision.