Ash Development Association of Australia

Benchmarking Report

Prepared for the
Benchmarking Module: Sustainability Capacity Building Program

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EXECUTIVE SUMMARY

Coal combustion products (CCPs) are a valuable and poorly understood mineral resource. There are several reasons for this underutilisation, including a lack of awareness and understanding of the properties and characteristics of the resource, inadequate research of the reuse potential of the resource, and associated commercial and environmental benefits.

With the specialist assistance of Link Strategy, the Ash Development Association of Australia (ADAA) has, through a refined supply chain approach[1] to sustainability and low carbon product development, engaged Victoria-based generator members[2] in the Latrobe Valley and supply chain partner industries to explore and identify opportunities to utilise various types of CCPs, (fly ash, furnace bottom ash and char) in appropriate and environmentally beneficial applications. Applications explored include road construction, agriculture and building related areas.

This report benchmarks the current knowledge base of CCPs produced from Victorian power stations in the Latrobe Valley and known supply chains. The CCPs supply chain is analysed from three perspectives:

- Energy use or "carbon footprint" for CCPs (Quantitative)
- Product opportunities for CCPs (Quantitative & Qualitative), and
- Participant attitudes and perceptions that undermine the effective utilisation of CCPs in Victoria (Qualitative)

The integration of these three perspectives into the benchmarking program has enabled participants to conceive a rich and balanced picture of the current state of the industry in 2010, and has contributed to a more thorough, comprehensive evaluation of relevant issues and moreover reuse opportunities for those involved in the program.

Victorian based generators and supply chain partners explored opportunities to utilise coal combustion products in appropriate, sustainable and environmentally beneficial applications. This report benchmarks the current knowledge base.

Contents

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

[2] http://www.adaa.asn.au/membership.htm [accessed May 2010]

Key benchmarking facts:

In Victoria, more than 1,300,000 tonnes of CCPs are poorly understood by the majority of the program participants. In particular by potential users, as a recoverable resource in identified areas for reuse and associated benefits (commercial & environmental) that can be derived. The results of the benchmarking study analysed from three perspectives are summarised below:

- Fly ash (dry) material emissions are 0.026 $tC0_2^{-e}$/tonne
- Fly ash (wet) material emissions are 0.064 $tC0_2^{-e}$ /tonne
- Furnace bottom ash material emissions are 0.064 $tC0_2^{-e}$ /tonne
- Char material emissions are 0.019 $tC0_2^{-e}$ /tonne
- Between 180 and 291 KL of recycled water is used to transport one tonne CCPs on site to final storage
- Understanding about the Victorian end use market and local economic drivers to develop product was limited
- Published technical information on CCPs, produced in Victoria, was more than 20 years old

Long-term stewardship costs for continued storage in onsite ash dams and storage limitations, are major incentives to increase utilisation for the generators.

Opportunities identified to utilise CCPs are diverse and include potential CO_2 sequestration, manufactured aggregates, fillers in carpets, geopolymer products, cement products, agriculture products, biochar and mineral extraction. Based on discussions within the workshops over 2009/10, current knowledge about CCPs was demonstrated to be restricted due to a range of reasons including limited information about materials characteristics and environmental benefits of CCPs, competition and confidentiality concerns and failure to establish rigorous trials of CCPs to meet customer performance criteria.

Engagement with participants revealed there is limited financial support and staff time allocated[3] to developing new markets by the generators because CCP markets are not considered a key focus, rather their focus is the generation of energy. CCPs are historically treated as waste, with a low market value. Long-term stewardship costs for continued storage in onsite ash dams and storage limitations, are major incentives to increase utilisation for the generators. Increasing CCPs utilisation is consistent with business and government objective to enhance utilisation and regional “sustainability” objectives.

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[3] Compared with similar studies conducted with black coal fired power stations. See - Heidrich, C. (2001). Ash Utilisation - production, uses and barriers. 18th Annual International Pittsburgh Coal Conference, Newcastle, NSW, Australia, Annual International Pittsburgh Coal Conference.

Introduction

The Ash Development Association of Australia (ADAA) is a national organisation representing Australian generators and marketers of coal fired power station ash. The primary objectives of the Association are to conduct research and technology transfer on behalf of members and to assist in developing current and new market opportunities for coal combustion products (CCPs) use.

The ADAA is an industry association with a long history in the development and reuse of CCPs, more commonly known as "fly ash'' (FA) or "furnace bottom ash'' (FBA) – being the main by-products from burning coal within coal fired power stations to produce more than 85[4] percent of Australia's energy needs. The Association encourages and supports the development of industry-focused research designed to lead to the responsible and increased utilisation of CCPs as a valuable, recovered and recycled resource.

… the concept of industrial ecology - seeks to reuse one industry's by-product (or waste) as another industry's raw material or input resource

More than 1,300,000 tonnes of CCPs generated in Victoria are poorly understood, by other potential users, as a recoverable resource within areas for reuse and associated benefits (commercial & environmental) that can be derived. Effective utilisation[5] by other users (associated industries) of these resources could potentially provide significant carbon reductions when used to displace other traditional natural resources. For example, CCPs have considerable potential to substitute, where appropriate, finite natural quarried materials in – road construction, civil and structural applications, drainage and pipe bedding materials[6].

The combustion of pulverised (black and brown) coal in the furnace of a power station boiler results in the production of a number of solid by-products traditionally regarded as wastes, but should be more accurately classified CCPs. This terminology adopts a more positive view of the material and appropriately adheres to the concept of industrial ecology - an approach which seeks to reuse one industry's by-product (or waste) as another industry's raw material or input resource.

[4] Heidrich, C., I. Hinczak, Ryan B.. (2005). Case study: CCP's potential to lower Greenhouse Gas emissions for Australia. World of Coal Ash 2005, Lexington, Kentucky, USA, American Coal Ash Association & University of Kentucky.
[5] "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
[6] http://www.adaa.asn.au/literature.php [Accessed June 2010] lists various technical and reference data sheets demonstrating the range of current and potential applications

The participants

The benchmarking module involved several sectors of the CCPs supply chain and are defined in the groupings below. It should be noted that these groups are not discreet, that is, some participants represent interests across various sectors.

- **Resource –** means a supplier of raw materials, such as coal, to the power sector
- **Generator –** means a company who generates coal powered electricity and produces CCPs as a by-product. CCPs can be supplied to a processor, consumers or value adders.
- **Value adder** – means a company who processes, mixes, blends, or otherwise incorporates CCPs to produce products for supply to consumers or other value adders. [A value adder typically incorporates owned intellectual property]
- **Customer** – use products that incorporate CCPs for their unique physical or chemical properties
- **Researchers** – provide research support to the sector at various stages of the supply chain

Participants of the program can be broadly grouped under the following headings. Other participants that are not represented in the following box include – Sustainability Victoria, EPA – Environment Protection Agency and KPMG.

Box 1 – Participants groupings

Resource	**Generator**	**Value adder**	**Customer**	**Researchers**
- Loy Yang coal - TRUenergy coal - Rio Tinto	- TRUenergy - International Power Australia - Loy Yang Power	- Holcim Pty Ltd - Flyash Australia Pty Ltd - Cement Australia Ltd - Blue Circle Ash Pty Ltd - Independent Cement & Lime Pty Ltd - Zeobond Pty Ltd - Blue Circle Ash Pty Ltd - Cement Australia Pty Ltd	- VicRoads - LaTrobe City Council - Geoploymer Alliance	- ARRB Group - HRL Technology Pty Ltd - DMC Advisory - Swinburne University of Technology - The University of Melbourne - CSIRO - Monash University

Victorian Generators of CCPs

TRUenergy, a wholly owned subsidiary of CLP Group. TRUenergy operates gas-fired and brown coal-fired power stations in the Latrobe Valley (Yallourn) in Victoria, in Jamestown (Hallett) in South Australia and near Wollongong in NSW (Tallawarra). At the moment, TRUenergy relies on coal resources for approximately 80 percent of the energy it generates and sells. In 2007 TRUenergy committed to reduce its emissions by 60 percent by 2050, to assist its customers reduce their environmental footprint through changes to its products and services over time.	**International Power Australia** has a majority interest in Hazelwood (including Hazelwood mine) and Loy Yang B and is a subsidiary of International Power plc, a global company which has business in 21 countries. International Power entered the Australian energy industry in 1996 and has grown to become the country's largest private generator of electricity with 3,723MW (gross) of renewable, gas-fired and brown coal-fired generating plants in Victoria, South Australia and Western Australia.	**Loy Yang Power** owns and operates a 2,200 megawatt power station and adjacent brown coal mine in Victoria's Latrobe Valley. The Power station is the largest in Victoria, capable of providing approximately one third of Victoria's electricity demand. The open cut brown coal mine is the largest in Australia, also supplying the nearby Loy Yang B power station. The mine's annual coal excavation of 30 million tonnes fuels ~50% of Victoria's power requirements. Loy Yang Power is owned by the Great Energy Alliance Corporation.

Benchmarking Scope

The methodology

The objective of the benchmarking analysis is to:

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

The quantitative benchmarking data is 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* [generators] and *secondary* sources [external studies and industry reports]. *Primary data sources* and associated externalities include;

- Raw materials, transport, fuels and electricity from the various operations in Victoria.
- Association annual membership survey data
- Industry knowledge base (business drivers, characteristics of geographic locations / production / materials etc.), coupled with
- Invited experts with specialist presentations to the group workshops

Secondary data sources are associated energy, transport and materials inputs used.

The data analysis is categorised into three (3) benchmarking factors, namely an Emission analysis, Product analysis and Perspective analysis:

1. **Emissions analysis:** CCPs at power stations are categorised into four groups: fly ash (dry), fly ash (wet), furnace bottom ash, char. For each of these groups an analysis of energy, water, transport and carbon is aggregated across the four power stations.
2. **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 and are further classified into associated product categories – construction, building products and agriculture.
3. **Perspective analysis:** the participant's assessment of key economic, social and operational issues based on workshop data.

Each sector has data based on a defined supply chain boundary (see Figure 1 – ADAA supply chain benchmarking analysis below) The *Emission analysis* identifies energy use during the production of CCPs, prior to further processing (Blue boundary line). In order to compare CCPs-based products to traditional products they may substitute, the impacts from any additional processing required will need to be added.

The *Product analysis* identifies the CCPs supply chain boundaries including the processor/value adder sector (Grey boundary line), while the *Perspective analysis* draws on participant views from the entire supply chain (defined by participants who attended workshops above) (Green boundary line).

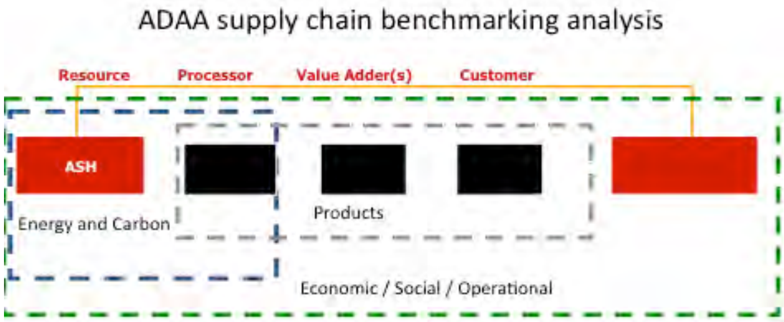

Figure 1 – ADAA supply chain benchmarking analysis

Coal combustion products

For CCPs 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.

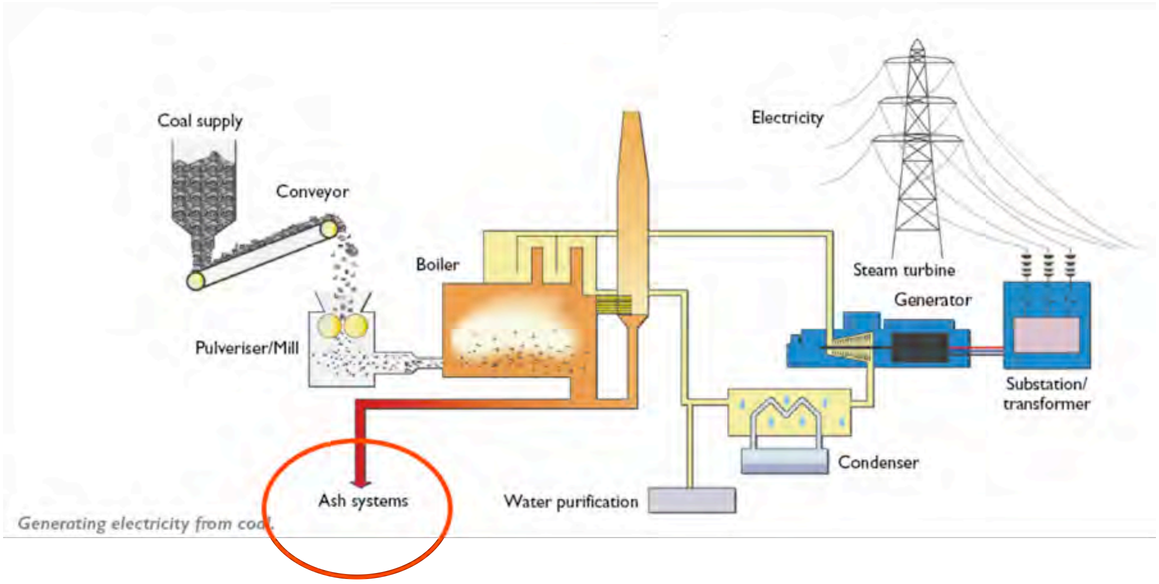

Figure 2 – Schematic of Coal fired Power Station

The above schematic, *Figure 2 - Schematic of Coal fired Power Station*, of a typical coal fired power station is used to illustrate that the focus of the benchmarking study will be on the "Ash Systems" or CCPs. Other aspects of the coal fired power station are beyond the scope of this study and have limited relevance to the project aims of this partnership program on CCPs. Focusing on the "Ash Systems", this benchmarking study set out a system boundary to identify the base line "carbon footprint" attributable to the production of one (1) tonne

CCPs. The study focuses on largest volume CCPs, in particular fly ash and furnace bottom ash.

The system boundary includes the capture, collection processing, provision of fuels and associated consumables (electricity, diesel etc) and transportation to a distance up to 10 kilometres within the generation site to its storage location (ash repository) (*see Figure 3 - Main stages and processes to produce one (1) tonne CCPs)*. This information can be used to compare resource options, e.g. the use of CCPs against other recovered or natural materials and the associated energy and processing inputs to develop a "carbon footprint".

The following figure illustrates the typical energy and process inputs to produce one (1) tonne of CCPs.

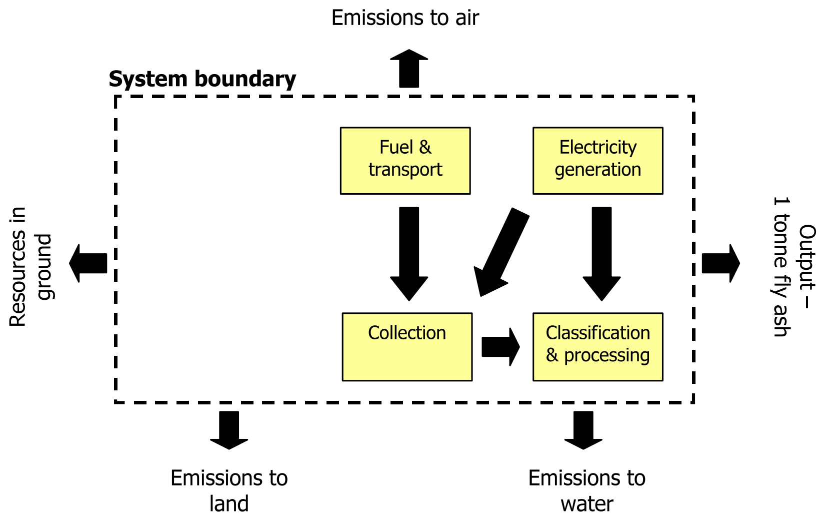

Figure 3 – Main stages and process to produce one (1) tonne CCPs

Characteristics of CCPs

CCPs are the solid inorganic particulates that remain after the combustion of coal within the furnace of a coal fired power station. They are composed of many types of non-combustible components, of which fly ash, furnace bottom ash, boiler slag and cenospheres are the most common[7].

The CCPs produced in Victorian coal fired power stations are typically mid-grey -ochre or reddish in colour. Fly ash particle sizes range from less than 1 µm (micrometer) to 200 µm and are irregular to spherical in shape. Fly ash consists essentially of the oxides of silicon, aluminium, iron and some calcium. Fly ash typically represents 80-90 percent of the total CCPs volume.

[7] Heidrich, C., C. R. Ward, et al., Eds. (2007). Coal Combustion Products Handbook. Brisbane, Australia, Cooperative Research Centre for Coal in Sustainable Development.

Figure 4 – Fly ash colour variation

Fly ash is typically separated from flue gas by mechanical collectors (e.g. cyclone), electrostatic precipitators, filter bags or wet scrubbers. In Australia, electrostatic precipitators and fabric filters are the dominant forms for collection. The main difference between electrostatic precipitators and filter bags is that electrostatic precipitators classify particles according to size, where as filter bags collect all particles together[8].

Furnace Bottom ash (FBA) can comprise 10 to 20% of the CCPs produced and range in grain size from fine sand to coarse lumps. They have chemical compositions similar to fly ash but may contain greater quantities of carbon and are relatively inert.

[8] Heidrich, C., C. R. Ward, et al., Eds. (2007). Coal Combustion Products Handbook. Brisbane, Australia, Cooperative Research Centre for Coal in Sustainable Development.

Benchmarking Analysis

ADAA Data

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

For the calendar period January to December 2009, approximately 31% of all CCPs produced were utilised within various civil and construction applications throughout Australasia[9]. The survey results consist of information derived from generators, marketers (processing and marketing companies) and users of CCPs and calculate the total production and resulting sales by each end use.

National key results for the 2009 calendar period survey were:

- Approximately 14.6 Mt (million tonnes) of CCPs were produced within Australasia. On a per capita basis, this equates to about 664 kg/person
- Some 4.584Mt (or 31%) of CCPs have been effectively utilised in various value-added products or to some beneficial end over the period. On a per capita basis, this equates to about 208 kg/person recycled or reused.
- Approximately 1.787 Mt (or 12%) was used in high value-added applications such as cementitious applications or concrete manufacture.
- About 0.5 Mt (or 3%) were used in non-cementitious applications
- Some 2.3 Mt (or 16%) was used in projects offering some beneficial use (e.g. onsite mine site remediation, local haul roads etc.). These uses typically generate no economic return, that is, cost recovery only
- Surplus CCPs (10.1 Mt) are typically placed into onsite storage dams awaiting some future opportunity for economic reuse
- More than 27 million tonnes of CCPs (fly ash) have been used in cementitious applications or concrete manufacture from 1975 to 2008 (33 years)

In summary the recovery and reuse of CCPs provide significant positive environmental impacts, including resource conservation and in this case, the reduction of greenhouse gas emissions from the processing of virgin resources as noted in the published paper by Heidrich, C., I. Hinczak, Ryan B.. (2005). Case study: CCP's potential to lower Greenhouse Gas emissions for Australia – greenhouse gas savings of up to 60% can be realised when CCPs are used to displace ordinary Portland cement.

Energy analysis

For the **energy carbon analysis**, CCPs from the three power stations were categorised into four main groups based on chemical and physical characteristic differences:

[9] Includes Australia and New Zealand

- fly ash (dry)
- fly ash (wet)
- furnace bottom ash (wet)
- char (wet)

Using the collected energy use data from the generators and direct emission factors[10], the calculated average energy inputs to capture, process and transport up to a distance of 10 kilometers is shown in *Table 1 – Weighted average emission factors for one tonne of fly ash*.

Currently, all power stations operate wet CCPs processing systems. CCPs are collected and discharged continuously from the mechanical collection systems and at less frequent intervals from the bottom of the furnace hoppers. Materials are mixed with recycled/recovered water to create a slurry (approximately 3% CCPs, 97%water). The slurry is then transported, via a pipeline, to the interim storage site.

The following Figure 5 provides an example flow chart which illustrates one of the three generator's handling stages for CCPs located in the Latrobe Valley – from the coal mining operation through to the final placement site of unutilised CCPs.

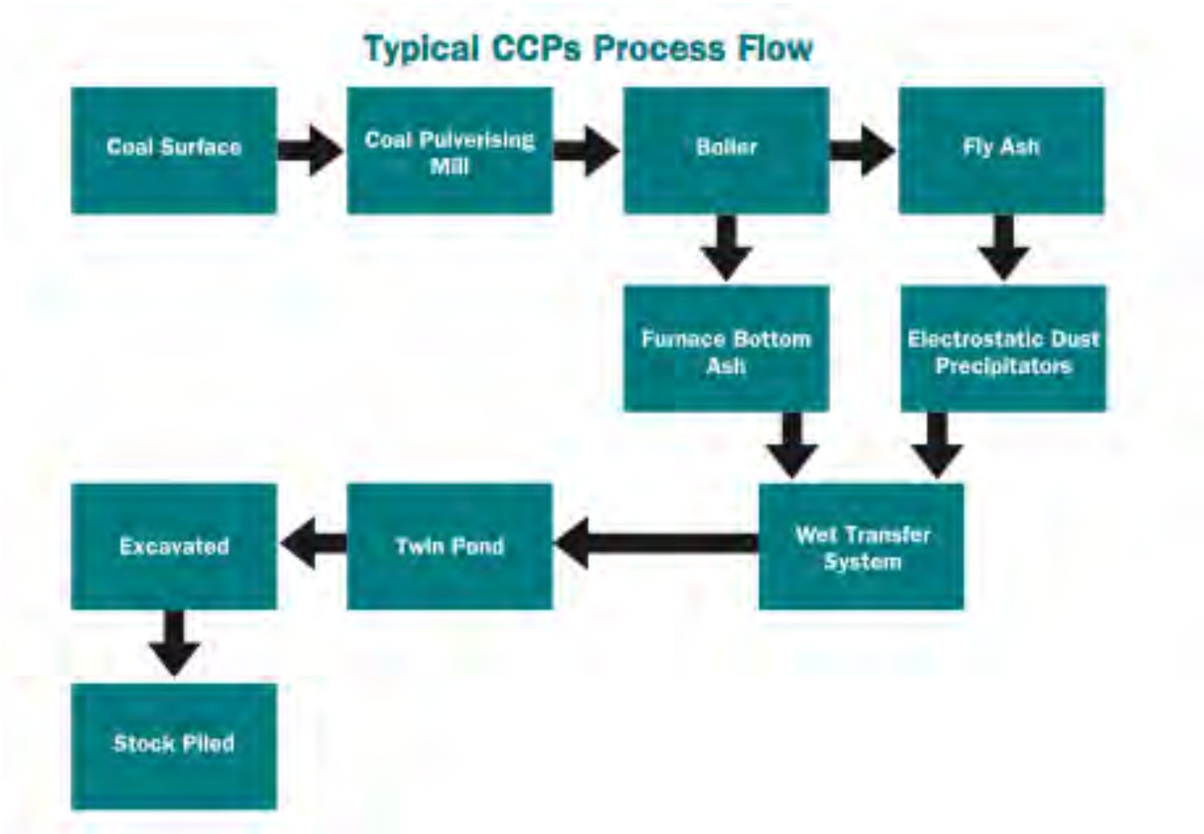

Figure 5 – CCP process flow

[10] DCC (2009). National Greenhouse Accounts (NGA) Factors. DCC. Canberra, Department of Climate Change. Vol 1: pgs 67.

Water use

Water used in the pumping operation, transporting CCPs to storage, is principally sourced from the brown coal mining operations. Having 60% higher water content than black coal, the brown coal is dewatered once removed form the mine site. This recovered water is used within the pumping operations and recycled back from the storage ponds to the station.

Across all sites approximately 10.4 megalitres per day is used to transport CCPs to the final placement site. It should be noted, the majority of this water is recovered and reused prior to being released via the Saline Waste Outfall Pipeline (SWOP) to the ocean. The SWOP is a dedicated wastewater system for the power industry and is used to dispose of excess recovered waters from Yallourn Energy, Hazelwood Power, Loy Yang B and Loy Yang A Power Stations.

For the purpose of this study, water per tonne of material used to transport CCPs to final storage is estimated for the following groups:

- fly ash (dry) 0 kL/tonne,
- fly ash and furnace bottom ash (wet) ~291 kL/tonne and
- char where removed before pumping to storage ponds is ~180 kL/tonne due to differences in physical properties and reduced transport distances

Approximately 10.4 megalitres of water per day is used to transport CCP's to final placement site.

Surplus process water to meet the needs of the three power stations is approximately 34 megalitres per day[11]. This surplus water is piped via the SWOP to the ocean.

Energy analysis findings

Fly ash (dry) is separated from flue gases by mechanical collectors. From these collectors, material can be further "classified" using cyclones to separate out specific particle size range. This material, once classified, can be stored in silos ready for dispatch to processors or customers. For **fly ash (dry)** the material emissions that can be attributed are fuel for local transport and electricity to classify the material prior to storage in silos.

- **Fly ash (dry) material emissions are 0.026 $tC0_2^{-e}$/tonne**

Fly ash and furnace bottom ash (wet) handling differs in that once the material is removed from the mechanical collectors, the material is combined with large quantities of water (>95% by volume) and pumped via pipelines into large collection ponds. Once these ponds are full the materials are recovered and transported to a final storage destination within the site. For **fly ash and furnace bottom ash (wet)** the material emissions attributable are electricity to pump materials to interim collection ponds and fuel for handling and transport.

- **Fly ash (wet) material emissions are 0.064 $tC0_2^{-e}$/tonne**

[11] http://www.powerworks.com.au/swop.asp [Accessed 2010]

- **Furnace bottom ash material emissions are 0.064 $tC0_2{}^{-e}$/tonne**

Char, having been mixed with fly ash and furnace bottom ash (wet) can only be collected prior to pumping to large interim collection ponds. Given their physical characteristics, char - when mixed with water - floats to the surface where these materials can be recovered prior to pumping to the large collection ponds. For char (wet) the material emissions attributable are electricity and fuel for local transport.

- **Char material emissions are 0.019 $tC0_2{}^{-e}$/tonne**

NOTE: Each generator's analysis of energy, water, transport and carbon has been aggregated across the power stations.

Coal Combustion Products								
	Fly ash (dry)		Fly ash (wet)		Char		Furnace Bottom Ash	
Inputs	**tCO2-e/t**	**%**	**tCO2-e/t**	**%**	**tCO2-e/t**	**%**	**tCO2-e/t**	**%**
Transport emissions	0.008	29.02%	0.009	14.06%	0.010	51.53%	0.009	14.06%
Electricity emissions	0.018	70.98%	0.055	85.94%	0.009	48.47%	0.055	85.94%
Total CO2/tonne	0.026	100.00%	0.064	100.00%	0.019	100.00%	0.064	100.00%
Water usage KL/tonne	0		2.91		0.8		2.91	

Transport, ltrs fuel = emissions transport distance of 10kms (fuel)
Electricity (kWh/tonne) = emission to classify/transfer/process materials

Table 1 -- Weighted average emission factors for one tonne of CCPs

The methods and calculations for all greenhouse gas emissions are as specified in the National Greenhouse Accounts (NGA) Factors, June 2009 [ibid]. The system boundaries methodology is based on *Heidrich, C., I. Hinczak, et al. (2005). Case study: CCP's potential to lower Greenhouse Gas emissions for Australia.*

Product streams: CCP utilisation

The benchmarking of product streams and perspectives identifies current knowledge about options, and the current state of CCPs utilisation in products. Using the workshops, collected data (primary sources), and other industry association data (secondary sources), product options and risk assessment data is presented in -- *Table 2 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

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 CCPs products are diverse – CO_2 sequestration, aggregates, carpet underlay, geopolymer products, magnesia cement products, agriculture products, biochar and mineral extraction are some options.

High value add (low CCPs volume) products identified were carpet underlay, metal recovery, blended cements and biochar. Quantities of CCPs utilised for metal and biochar were unknown. Metal recovery of MgO was considered to be high risk due to variability in metal prices. Geopolymers can potentially provide significant CO_2 advantages, but logistics and handling issues require further research.

Opportunities to utilise CCPs products are diverse and include CO_2 sequestration, aggregates, carpet underlay, geopolymer products, magnesia cement products, agriculture products, biochar and mineral extraction

Medium value add products identified included use of CCPs in concrete, being a substitute for natural quarried fine aggregates (sand). From some 5.8 million[12] cubic meters of concrete used annually in Victoria, sand use for this application only represents more than 3 million tonnes of natural sand. Competition with natural sands and processing costs were barriers to increasing utilisation, which included factors regarding technical suitability. Potential quantities of CCPs utilised in other products, cement feedstock and aggregates were unknown.

Low value add (high CCPs volume) are very sensitive to transporting distance and associated costs. Road base and engineered fills were identified as having most potential given the limitations on expanding local natural quarries. Limited knowledge about engineering characteristics of local CCPs and relative low value add were considered key impediments to increasing utilisation.

[12] ABS – Sector data for 2008/9

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 perspectives.

Participant perspectives on the CCP supply chain

The benchmarking of participant perspectives on the opportunities and barriers to increasing utilisation of CCPs are discussed in this section. A summary of these issues is shown in Table 3– Perspectives on social, economic, environmental and operational issues.

Based on the feedback of participants during the workshops, it can be said the CCP supply chain is highly segmented and has significant knowledge gaps that hinder the utilisation of CCPs in new and existing product applications. In particular, key participants (value adders and users) were strongly of the view during our workshops that there is limited knowledge about:

- The market and economic drivers to develop products
- Published technical information on CCPs produced in Victoria
- Potential CCP utilisation volumes for several products

Key participants such as value adders and users also noted many of the potential end use applications held significant technical risks, which needed to be satisfied with technically sound published data.

The marketing and promotion of CCPs are not the generators' core business, their primary focus being the generation of electricity. Based on workshop discussions, current knowledge about CCPs was demonstrated to be restricted because:

- **Intellectual property and confidentiality**: There is a lack of collaboration, new information is confined to individual organisations and is generally not made available to a broader audience. This is restricting the generation of new knowledge within the industry and the development of new products with supply chain partners.
- **Material characterisation of products and their physical properties**: There is limited information on the beneficial environmental and social outcomes from the use of CCPs in products.
- **Environmental Classification**: The unclear classification status of CCPs is hindering the alignment of CCPs with potential product applications.
- **Uncoordinated Strategy**: The industry (power generators) are unsure where to focus their product development activities. For example, previous attempts to develop CCPs with the construction sector have had very limited success. This is partly due to limited knowledge about customers needs and processes, as well as the market and product opportunities.
- **Trial and error**: Historically, unstructured experimental applications have had a negative impact on efficacy of the CCPs applications. This continues to impact on the ability of the generators to develop new product options.

There is limited financial support and staff time allocated to developing new markets by the generators because CCP markets are not considered a key focus, rather their focus is the generation of energy. CCPs are historically treated as waste, with a low market value. Long-term stewardship costs for continued storage in onsite ash dams are a major incentive to increase utilisation for the power sector. Increasing CCP utilisation is consistent with business and government objectives to enhance utilisation and regional “sustainability” objectives.

Table 2 Product options and risk analysis

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Application	**Sector**	**Volume**	**Potential CCPs Utilisation (tonnes)**	**Company Name (s) in product supply chain**	**Rank/Priority**	**Risk factors/Commentary**
High Value Add						
Carpet Underlay	Building Products	low	7,000	Blue Circle Ash		Product substitution [lime], cost benefit analysis
Metals Recovery	Minerals Processing	low/med	Unknown	Unknown		Risk from metal price fluctuations, capital intensive
Biochar	Agriculture/ fuel	low	Unknown	Unknown		Capital intensive, unknown impacts of CPRS
Geopolymers	Building Products	Med	Unknown	Various, Cement & Concrete Companies	1	Emerging technology, significant C02 advantages, logistics and handling issues
Blended Cements	Building Products	Med	> 300,000	Cement &Concrete Companies		Mature market, technically well understood properties of CCPs. Total cementitious use > 1.5 mtpa. 20% + cement market share could equate to 300,000 to 400,000 tonnes annual. Note: ~150,000 tonnes of CCPs used in Victoria <10% -- Black Coal CCPs

Table 2 Product options and risk analysis (Continued)

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Application	**Sector**	**Volume**	**Potential CCPs Utilisation (tonnes)**	**Company Name (s) in product supply chain**	**Rank/Priority**	**Risk factors/Commentary**
Medium Value Add						
Cement feedstock	Mineral Processing	Low	Unknown	Cement Companies		Competition against low cost feed stocks [clay/limestone] available locally
Concrete (aggregates)	Building Products	High	> 7.0 mtpa	Quarrying Companies	2	Varied options for binding, some issues w/ ASR, Generally has strong promise, medium term
Concrete (sand)	Building Products	Med	> 3.0 mtpa	Concrete Companies	3	Sand substitute, lower bound of MVA, competing against natural sands. Some processing costs

Table 2 Product options and risk analysis (Continued)

	PRODUCT OPTIONS / SUPPLY CHAIN PARTICIPANT				RISK FACTORS & RANKING	
Application	**Sector**	**Volume**	**Potential CCPs Utilisation (tonnes)**	**Company Name (s) in product supply chain**	**Rank/Priority**	**Risk factors/Commentary**
Low Value Add						
Agricultural Lime substitute & Agrichemicals	Agriculture	High	> 10,000	Unknown	3	High volume, LVA. Requires significant RD&D to build regulatory confidence. Haz good agri results
Soil Stabilisation	Civil	Med	Unknown	Soil Stabilisation Companies		Logistics costs main impediments
Engineered Fills	Civil	High	Unknown	Civil Companies		Logistics costs main impediments, Some local low hanging fruit. Requires sound engineering properties
Road Bases	Civil	High	Unknown	Civil Companies		Logistics costs main impediments, Some local low hanging fruit. Requires sound engineering properties

Table 3 Perspectives on social, economic, environmental and operational issues

Perspectives	Processor	Transport	Value Adder
Social	Good for society or Brown coal is “Bad” Consistent with business and government objective “sustainability” Community expectations are evolving Potential for job creation	Potential for rail – studies undertaken – currently no rail transport	N/A
Economic	Capacity expense, opportunity expense Direct / Indirect licensing costs Already a cost > revenue opportunity CPRS opportunity	Define feasible distance (economic and environmental) Potential for job creation Fuel use/transport impact	Potential job creation More opportunity for fine aggregates >5mm supply than coarse aggregate
Environmental	Reduce risk long term Reduce regulatory costs Offset other resources - Quarry licences contracting Build long term stewardship cost – improved resource efficiency – inputs and outputs	Volume – rail vs road Spur line - Intermodal	Resource efficiency - inputs and outputs

Perspectives	Processor	Transport	Value Adder
Resource / Operations	Diversity of materials – Market streams / Market X? Fine aggregates opportunities increasing (1/2 market of sm(?) market Look at AS2758 for aggs specifically Require new equipment – Deck Screen	Integrated operations – back loading 24/7 availability Densities – bulk, specific gravity Moisture content Similarity with other by-product (synthetic) aggregates	Opportunities: • Concrete (Boral, Hanson, Holcim, Independent – currently using local quarry?) • Structural Fills • Road Base (specification – Vic Roads; design – civil designers; application – contractors, Abigroup, Leighton) • Filler material • Non structural Fills • Dust Suppression • CMAR removal /use – downstream mkt • Concrete products – blocks, pavers • Partitioning of FA / BA • Drainage material – plumbing • Freeways – sound barriers • Termite guard
Knowledge	Collection methods and processes Capacity Extent (economic vs alternatives) Potential for knowledge from Institute of Quarry Assoc. Need R&D development strategy	Metrics understood Define optimum distance to optimum markets	What is the limit of local application – industry housing? Feasibility of Melbourne market? Wanthanggi desal plant?