Coal combustion products – A global perspective

Craig Heidrich, Hans-Joachim Feuerborn and Anne Weir

Kurzfassung

Kraftwerksnebenprodukte – Eine globale Betrachtung

Durch den hohen Anteil der Kohle an der Energieerzeugung werden große Mengen von Kraftwerksnebenprodukten hergestellt, für den bedeutende Absatzmärkte entwickelt wurden.

Bestehende und geplante Absatzmärkte für Kraftwerksnebenprodukte sind nicht nur von entscheidender Bedeutung für die Wirtschaftlichkeit der Stromerzeugung, sondern auch für die Beteiligten in den entwickelten Zulieferketten, die in die Verwendung von Kraftwerksnebenprodukte investiert und diese beforscht, entwickelt und gefördert haben. So werden zum Beispiel große Mengen an Kraftwerksnebenprodukten in der Bauindustrie genutzt. Neben Qualität und Produkteigenschaften hängt die stetige Zunahme der Verwendung der Kraftwerksnebenprodukte weltweit von vielen Faktoren ab. Geeignete Rechtsvorschriften und Gesetzgebungen verbunden mit der Entwicklung internationaler Klassifizierungssysteme, Normen und Richtlinien sind nur einige der wichtigsten Grundvoraussetzungen, um eine höhere Verwendung und „Rechtssicherheit" für laufendende Investitionen zu gewährleisten.

Der Bericht beinhaltet eine globale Betrachtung zur Rolle der Kohle in der Weltenergieerzeugung und der sich ändernden Paradigmen zum Energiemix. Die aktuelle globale Produktion von Kraftwerksprodukten und deren Anwendung einschließlich Volumen und Wert des internationalen Handels werden betrachtet. Ein Überblick über länderspezifische Einstufungssysteme für Kraftwerksnebenprodukte wird diskutiert, außerdem die wichtige Rolle der Gesetzgebung bezüglich Rechtssicherheit für laufende Investitionen in Management und Marktentwicklung von Kraftwerksnebenprodukten. l

Authors

Craig Heidrich
Ash Development Association Australia
Wollongong/Australia

Hans-Joachim Feuerborn
European Coal Combustion Products Association
Essen/Germany

Anne Weir
Association of Canadian Industries Recycling Coal Ash (CIRCA)
London/Canada

Introduction

Whenever coal is burnt, coal combustion products are produced by the thermal transformation of the mineral matter present into amorphous inorganic oxides. Large-scale use of coal in power generation gives rise to significant quantities of coal combustion products from which important "hard won" end use markets have been established.

Existing and proposed end use markets for coal combustion products (CCPs) are not only of critical importance to the economics of power generation, but also to the established supply chain participants which have invested, researched, developed and promoted CCPs into various end use markets, for example the construction sector uses large quantities. Globally, the continued growth in utilisation of CCPs is dependent on many factors beyond the quality and characteristics. Appropriate legislation and regulation coupled with the development of international classification systems, standards and codes of practice are only a few of the important enablers for easing the way towards increasing utilisation and securing the "legal certainly" for continued investment.

The paper provides a global perspective on the role of coal in worldwide energy production and changing paradigms in the energy mix. Current global CCP production and utilisation including volume and value of international trade will be discussed. An overview of country-specific classification systems for CCPs will be discussed, moreover the important role of legislation in creating legal certainty for the ongoing investment in CCPs management and market development.

The paper has been jointly written by members of the World Wide Coal Combustion Products Network (WWCCPN[1]) and is the result of an ongoing, international collaboration between respective country industry associations, being non-governmental organisations (NGOs), to inform the public, industry and governmental entities about the beneficial environmental, technical and commercial uses of CCPs.

[1] The WWCCPN is a coalition of international Associations interested in information exchange concerning management and use of CCPs, http://www.wwccpn.org/.

Changing operating environment

Coal is used worldwide in the production of energy and heat in power plants. Over the last decade, a number of changes have occurred globally in the coal-fired power generation sector that has impacted on coal combustion products (CCPs[2], Table 1) production, physical and chemical characteristics and resultant environmental legislation. In a report by the International Energy Agency 2010 [1], a number of factors were identified as having significant impacts in respect to CCP quality and quantity. These changes include:

- the increasingly common practice of co-firing coal with other fuels, especially biomass
- modifications to coal-fired power generation plants to reduce emissions (in-boiler and post combustion)
- the development of more fuel-efficient and more operationally flexible boiler plants
- fundamental changes to the basic combustion process to prepare for carbon-capture technologies (for example oxy-fuel combustion)
- changed legislative operating environment, e.g. imposition of carbon tax, renewable energy targets, alone or together impacting of base load demand

In addition to the impacts identified in [1] with respect to CCP quality and quantity, other recent developments [2] include:

- increased use of renewables
- changed operating conditions for coal mining which leads to increased imports

Set within the content of this changing operating environment, it would be prudent to explore implications for established utilisation pathways (i.e. current markets) and the need for changes to standards to enable possible future pathways (i.e. new markets).

This paper reports on current CCP production and utilisation by selected countries, including typical properties to the main resulting CCPs by coal types. The paper also

[2] Coal combustion products (CCPs) include fly ash, bottom ash, boiler slag, fluidised-bed combustion (FBC) ash, or flue gas desulfurisation (FGD) material produced primarily from the combustion of coal or the cleaning of the stack gases. The term coal ash is used interchangeable for the different ash types.

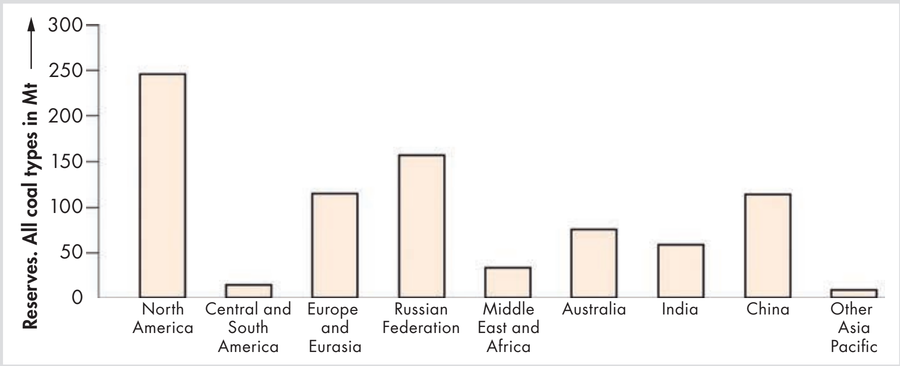

Fig. 1. Proven coal reserves worldwide (adapted [1]).

explores implications for established utilisation pathways (i.e. current markets) and the need to incorporate this experience in standards to safeguard possible future pathways (i.e. new markets) in countries around the world.

Coal: an extensive resource

It is estimated that there are over 850 Giga tonnes of proven coal reserves worldwide; which is enough to last more than 130 years at current rates of production [3]. Coal reserves are available in almost every country worldwide, with recoverable reserves in over 70 countries. The largest reserves are found in North America, Russia, Europe, China and Australia respectively which account for more than 80 % of global reserves. Australia is currently ranked fifth globally in terms of known coal reserves.

The largest coal producing countries are China, the USA, India, Australia and the Russian Federation. Much of the global coal production is used within the country of origin, with approximately 16 % of hard coal production traded on the international coal market. The vast majority of this coal is used for power generation, largely by pulverised coal combustion [4]. Australia is currently ranked fourth globally in terms of coal production. Figure 1 illustrates proven coal reserves by country for the top 9 countries or regions.

Coal is a major fuel for energy and steam production in coal-fired power plants across the globe. “Coal currently supplies around 30 % of primary energy and 41 % of global electricity generation. Coal use is forecast to rise over 50 % to 2030, with developing countries responsible for 97 % of this increase, primarily to meet improved electrification rates” [3].

Following the Fukushima nuclear accident in April 2011, the future of nuclear power use within advanced industrialised countries (e.g., Germany and Japan) has come under considerable scrutiny resulting in political decisions to reduce nuclear power dependency. For Japan this results in future increased dependence on coal [5]. Energy blackouts across India during 2012 signal more coal power plants will be necessary to serve the growing energy needs in India and other countries.

In 2011, global coal trade amounted to just over 1.142 billion tonnes or 15 % of world coal production of 7.2 billion tonnes. Coal is traded all over the world, with coal shipped huge distances by sea to reach markets. Seaborne trade in steam coal has increased on average by about 7 % and seaborne coking coal trade has increased by 1.6 % each year over the past 20 years. [3] reports lignite is mainly used in the vicinity of deposits. Coal from mines with low production costs and favourable locations near to seaports can be delivered competitively to overseas consumers. For example, imported hard coal to Europe makes a significant contribution to the EU’s security of energy supply and offers a competitive fuel which can be easily and safely transported and stocked.

Coal resources are significant with more than 130 years at current production rates. Demand for coal use in energy generation continues to grow within developing and developed economies. Policy shifts towards clean coal technologies are contributing factors, but these technologies identified are likely to have significant impacts in respect to CCP quality and quantity.

Coal combustion products: a recoverable and valuable resource

Globally, 86 % of coal used in thermal generation is currently black coal with 14 % of brown coal/lignite making up the balance. The vast majority of this coal is used for power generation, largely by pulverised coal combustion [4].

CCP utilisation can be dated from the advent of widespread pulverised coal combustion for electricity generation in the 1920s when large amounts of CCPs began to become available. The first published use of fly ash in concrete was for sulphate resistant concretes exposed to seawater. These investigations date back over 10 years of exposure were first published 1953 in a report from the American Concrete Institute Advisory Committee, Long-Time Study “Ten-Year Report on the Long-Time Study of Cement Performance in Concrete” [6].

The earliest recorded use in the Australian construction materials industry dates back to the 1950s, with fly ash imported from the US for use in concrete to construct the Snowy Hydro Scheme (Dam) and other significant projects since the early 1960s [7 and 8]. Internationally, the first significant use of CCPs in construction is generally acknowledged to have occurred in the 1930s, with published papers that established the groundwork for many of the specifications and formulations which are still in use today.

CCPs produced today, by modern coal-fired power stations, have extensive supply chain opportunities. Following the combustion of pulverised coal in the furnace, in its molten state, the majority (80 to 85 %) of the non-combustible materials remain in the furnace gases. Transported by the combustion gases (now the “flue gas”) through the boiler and captured, usually, in an electrostatic precipitator at the boiler outlet. Conventionally known as fly ash (FA), sometimes referred to as PFA (pulverised fuel ash) especially in the UK, this fine material represents the largest volume. The remaining 15 to 20 % of the coal ash produced in the boiler falls to the bottom of the furnace where it is removed as bottom ash (also furnace bottom ash FBA) and partly processed, prior to transportation.

CCPs have two primary pathways; storage in on-site repositories[3] and beneficial use. Globally, methods of storage vary considerably from wet, slurried or dry repositories, with dry repositories becoming increasing preferred. The other pathway results in beneficial use after capture behind the furnace in electrostatic precipitators or filter systems, partly also further processed for various end uses.

The valued added benefits of CCP utilisation are well established within the technical literature across many regions of the globe within construction material sectors addressing the need to save natural resources, energy, emissions of pollutants to the air, CO_2 emissions and repository space. Within modern coal-fired power stations, when appropriate collection and management systems are implemented, CCPs have extensive supply chain opportunities.

Coal combustion products: definitions

The combustion of pulverised coal in the furnace of a power station boiler results in the production of a number of solid products traditionally regarded as wastes but more accurately classified as coal combustion products (CCPs). This latter terminol-

[3] a receptacle where coal combustion products are managed and stored

Tab. 1. Draft global definitions for coal combustion products.

Term	Definition
Coal combustion products	Coal combustion products (CCPs) include fly ash, bottom ash, boiler slag, fluidised bed combustion (FBC) ash, or flue gas desulphurisation (FGD) material produced primarily from the combustion of coal or the cleaning of flue gases. The term coal ash is used interchangeable for the different ash types.
Fly ash	The finer ash produced in a coal-fired power station, which is collected using electrostatic precipitators. Sometimes spelt as "fly ash". This is also known as pulverised fuel ash (PFA) is some countries. About 85+% of the ash produced is fly ash.
Bottom ash	The coarse ash that falls to the bottom of a furnace. The molten ash adheres to the boiler tubes, eventually falling to the base of the furnace. In many furnaces there is a water system that rapidly cools this ash, so-called "wet bottomed" ash. Usually <15 % of the ash produced is bottom ash (BA), in some countries also known as furnace bottom ash (FBA)
Cenospheres	Hollow ash particles that form in the furnace gas stream. Sometime these particles will contain smaller ash spheres. They float on water and are usually collected from lagoons, where ash/water disposal systems are being used. Only 1 to 2 % of the ash produced are cenospheres and with the reduction in ash/water transportation, fewer are collected/available
Conditioned ash	Where fly ash is mixed with a proportion of water (10 to 20 % by dry mass typically) in order that it can be transported in normal tipping vehicles without problems with dust for sale or disposal or interim stockpile.
Flue gas desulphurisation	Where a source of Calcium is injected into the furnace gas stream to remove sulfur compounds. In wet systems a slurry with ground limestone is sprayed in the gas stream. After decomposition of the limestone, the sulphur reacts with lime and after oxidisation forms calcium sulphate. This flue gas desulphurisation gypsum (FGD) is used in the gypsum industry as replacement for natural gypsum.

Tab. 2. Typical range of elemental composition for CCPs from different coals, wt% [9].

Element	Bituminous	Sub to bituminous	Lignite
SiO_2	20 to 60	40 to 60	15 to 45
Al_2O_3	5 to 35	20 to 30	10 to 25
Fe_2O_3	10 to 40	4 to 10	4 to 15
CaO	1 to 12	5 to 30	15 to 40
MgO	0 to 5	1 to 6	3 to 10
SO_3	0 to 4	0 to 2	0 to 15
Na_2O	0 to 4	0 to 2	0 to 6
K_2O	0 to 3	0 to 4	0 to 4
LOI	0 to 15	0 to 3	0 to 5

ogy is a more positive view and is in keeping with the concept of industrial ecology, an approach which seeks to reuse one industry's by-products as another industry's raw material.

Globally various terms to describe CCPs have arisen over time. Coal ash, pulverised fuel ash, CUBs, CCBs, CCRs, and CWR with an ever-extending list of new terms. Whilst researchers, organisations and government agencies have adopted/created terminology specific to their needs, members of the World Wide Coal Combustion Products Network ("WWCCPN" or "Network")[1] are working together to harmonise terminology and promote consistent nomenclature which can be employed by all stakeholders.

Based on input and suggestion provided from WWCCPN Associations across the globe, "draft" definitions are provided in Table 1.

Depending on the coal type siliceous and calcareous ashes are produced. In siliceous ashes three predominant elements present: silicon, aluminium and iron. The oxides account for 75 to 85 % of the material. It consists principally of glassy spheres together with some crystalline matter and unburnt carbon. Reactive lime content for these ashes is restricted by definition to less than 10 %. Calcareous ashes constitute the same oxides but contain more than 10 % of reactive lime.

Numerous standards produced across the globe provide guidance and definitions for their use for example European EN 197-1, EN 450-1, US ASTM 618, South African SANS 1491-2, Canadian CSA 3000, Australian AS3582.1 and Indian 3812 parts 1 & 2. The nature and properties of fly ash are dependent on a variety of factors that include the coal's mineral composition, furnace/boiler temperature, type and fineness of the coal and the length of time the minerals are retained in the furnace/boiler.

Some of the more important properties of fly ash which are addressed in the specifications are the carbon content, the chemical and mineralogical properties, with the former, as assessed by measuring loss on ignition (LOI), potentially experiencing wide variation. Some typical compositions of fly ash produced by the main coal types are given in Table 2.

Coal combustion products are well defined. There are definitions within numerous standards across the globe. The adoption of a harmonised terminology will promote consistent nomenclature which can be employed by all stakeholders that differentiates coal combustion products for other ashes.

Coal combustion products: global production

Originally organised in 1999 as the World Wide Coal Combustion Product Council, the organisation changed its name to World Wide Coal Combustion Products Network or "WWCCPN" which more accurately reflects it's nature of voluntary cooperation towards international collaboration to promote, coordinate and inform the public, industry and governmental entities about the beneficial environmental, technical and commercial uses of CCPs. Members of the network have consulted with each other for several years to identify common problems and more effectively to communicate the results of their continuing research and implementation of new beneficial CCP applications. Goals for the network are broadly defined as

- Stimulate the international transfer of technical information related to CCP management and use that can be benefited from by planners, designers, specifiers, regulators, purchasers, manufacturers, and constructors or other stakeholders;
- Coordinate the international development of appropriate codes, specifications and guides for the use of CCPs on par with competing materials and products;
- Promote the international development of appropriate regulations for the management of CCPs on part with competing materials and products; and
- Facilitate awareness and understanding of the environmental, economic, engineering, manufacturing and societal benefits derived from the use of CCPs.

In recent years the Network has grown and become increasingly active given the speed and internationalisation of information and inter-jurisdictional activities of environmental agencies. The Network meets twice a year. Issues discussed are shown in Figure 2.

During the course of 2012 the Network agreed to gather, collate and publish production and utilisation data provided by members or from publically available and proven sources. Table 3 reports on Estimated Annual Production, Utilisation Rates by Country 2010 and compares selected countries CCPs production, and reported utilisation volumes.

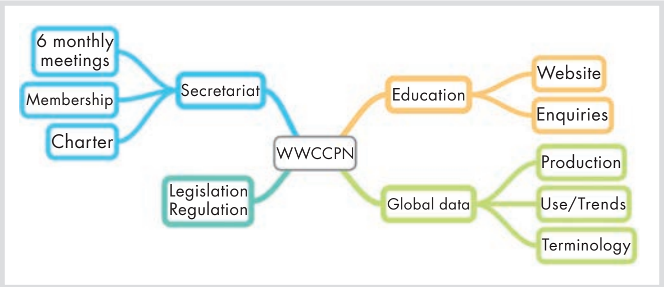

Fig. 2. Cooperation activities of world wide coal combustion products network.

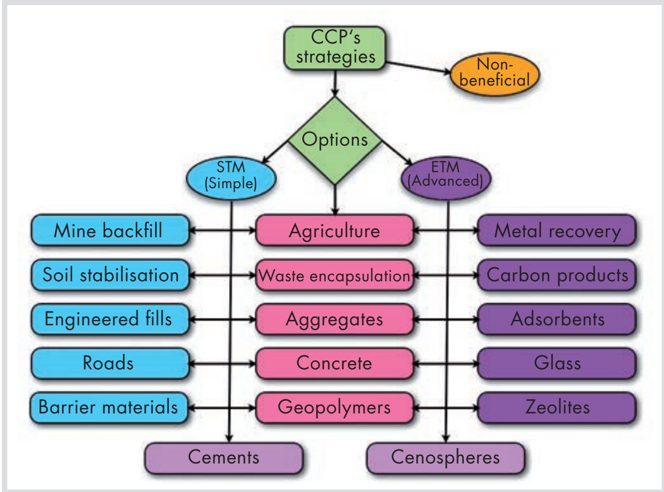

Fig. 3. Coal combustion products utilisation STM vs. ETM strategies [5].

From the data in 2010, the worldwide production of coal combustion products was approximately 780 million metric tonnes (Mt), as shown in Table 3 (880 Mt with updated poduction figures for Europe). The largest coal combustion product producing countries were China 395 Mt, North America 118 Mt, India 105 Mt, Europe (EU15) 52.6 Mt (update: Europe (EU) 145 Mt-only for production), Africa 31.1 Mt and Middle East as a minor contributor. Australia contributes approximately 2 % to global production of CCPs. From the 780 Mt produced, some 415 Mt or 53 % were reported as utilised. Utilisation varies widely in the countries discussed in this paper.

Japan had the highest reported effective utilisation rate of 96.4 % and Africa/Middle East with the lowest at 10.5 %. Countries ranked with the highest coal combustion product utilisation rates were Japan 96.4 %, Europe 90.9 %, China 67 % and other Asia 66 %. The Australia coal combustion product utilisation rate was 45.9 % or just below the global average of 53 %.

One interesting observation that can be drawn from Table 3 is the relative carbon intensity or reliance of power coal for energy within each of the industrialised countries based on CCPs generated on a per capita basis. That is, countries ranked in order of the highest CCPs generated on a per capita basis were: Australia at 600 kg, North America at 340 kg, China at 290 kg, Canada and Russia at 200 kg and 190 kg respectively. Countries such as the EU, Japan and India generated less than 100 kg per person. While Australia generated the highest amount of CCPs on a per person basis, 600 kg, it also had the highest effective utilisation rate on a per person basis at 270 kg, followed by the USA at 160 kg.

Tab. 3. Estimated annual production, utilisation rates by country 2010. (All reported volumes have been converted to metric tonnes, for example North America published data is reported in US short tones. Data is based on provided copies membership survey results for the 2010 calendar period. Where data is not available, secondary sources have been used, coupled with thermal coal consumption data and typical ash contents).

Country/Region	CCPs Production (Mt)	CCPs Utilisation (Mt)	Utilisation Rate %	CCPs Production/ person (Mt)	CCPs Utilisation/ person (Mt)
Australia	13.1	6.0	45.8	0.60	0.27
Canada	6.8	2.3	33.8	0.20	0.07
China*	395.0	265	67.1	0.29	0.20
Europe (EU15)	52.6**	47.8	90.9	0.11	0.10
India*	105.0	14.5	13.8	0.09	0.01
Japan	11.1	10.7	96.4	0.09	0.08
Middle East & Africa	32.2	3.4	10.6	0.02	0.01
United States of America	118.0	49.7	42.1	0.37	0.16
Other Asia*	16.7	11.1	66.5	0.05	0.03
Russian Federation	26.6	5.0	18.8	0.19	0.04
Total/s	777.1	415.5	53.5		

* Non-members of WWCCPN
**Total production in Europe >145 Mt. No verified figures on use other than for EU15.

Worldwide production of coal combustion products was approximately 780 Mt tonnes in 2011. Effective utilisation was 415 Mt or 53 % of total production varies widely within countries reported. The highest reported effective utilisation rate was 96.4 %, the lowest 10.6 %.

Global: resource utilisation options

As defined previously, CCPs include fly ash and bottom ash but can also include other by-products termed boiler slag (BS), fluidised bed combustion (FBC) ash, or flue gas desulphurisation (FGD) material produced primarily from the cleaning of the stack gases through the injection of lime slurry to remove sulphur from flue gas emissions or spray dry absorption product (SDA product) resulting from a dry process. Not all regions/countries generate flue gas desulphurisation material, for example Australian coals commercially used for power generation have very low sulphur contents, therefore not requiring these flue gas clean techniques. Interestingly, FGD materials are highly sought after by-products in countries where they are generated. The main user is the gypsum industry who combine virgin materials with FGD gypsum. It is also used in the cement industry as a retarder.

Fly ash and bottom ash are the primary materials generated globally and accordingly have been used in a variety of applications over the past 70 years. Across the globe numerous reviews of CCPs utilisation strategies have been undertaken to identify different utilisation options available for exploitation and attempts to categories strategies according to value.

A summary of CCP utilisation strategies and their potential role towards full utilisation is summarised below. Utilisation strategies can be classified into three main groups according to their usefulness and economic value, i.e. non-beneficial, simple and advanced.

- Non-beneficial use or placed into onsite repositories are viewed as having limited value add and is generally an economic burden to the generator.
- Simple Transform Manufactures (STM) or simple utilisation strategies may require limited processing or blending or are directly produced for value added products.
- Elaborate Transform Manufactures (ETM) or advanced utilisation strategies typically will require significant processing to extract a high value add products.

The major reported coal combustion product utilisation strategies are illustrated in Figure 3.

Whilst waste generators, processors and users of CCPs are eager to explore utilisation strategies as illustrated, the one common constant paradigm inhibiting value-adding pathways are national, regional and jurisdictional environmental legislators and regulators who continue to be hesitant in adopting more progressive and modern international definitions and categorisations of traditionally defined "waste" materials. As an example, Europe has defined "by-products" and "end-of-waste" materials in the revised Waste Directive with all requirements met by ashes but implementation into national law is behind schedule.

Given the need for some paradigm change in international definitions and categorisation systems we discuss in the following section efforts by the WWCCPN and first proposed during WOCA 2011 [9].

Utilisation strategies can be broadly classified into three main groups according to their usefulness and economic value, i.e. non-beneficial, simple and advanced.

Coal combustion products: globally traded commodity

Firstly recap to context reported in [9], since the late 1800s, trade administrators have been working to establish and maintain a comprehensive trade nomenclature to capture all goods with a view to facilitating international trade. The "Harmonized System" (HS), as it is known, classifies goods for the benefit of border and customs agencies charged with administration of trade in accordance with international agreements. The history of the Harmonized Systems is summarised as follows:

- 1853 to 1922 (186 commodities) approved by international convention, signed by 29 countries
- 1922 international bureau of statistics established
- 1931 Geneva Nomenclature (991 headings, in 86 Chapters)
- 1950 Brussels Convention: renamed Brussels Tariff Nomenclature
- 1974 renamed Customs Cooperation Council Nomenclature (1241 headings, in 99 Chapters, 21 Sections) supported by Explanatory Notes
- 1983 replaced by the Harmonised commodity description and coding System
- 1988 Harmonised System entered into force[4]

Developed through prolonged international efforts under the auspices of the [now] World Customs Organization (WCO), the HS entered into force in 1988. The HS has legal status, classifying over 98 % of the merchandise in international trade. With an estimated 179 signatories, more than 200 countries as a basis for Customs tariffs and the collection of international trade statistics use the HS. It has evolved into a "universal economic language and code for goods, and an indispensable tool for international trade, used by governments, international organisations and the private sector for a variety of policy, legislative and economic purposes".

Within the HS, coal ash is currently classified under the HS Heading 26.21 and Subheading 2621.90 – Other. Materials classified under subheading 2621.90 include the following five products, which are listed in the Explanatory Notes to heading 26.21:

- ash and clinker of mineral origin (e.g., coal, lignite or peat ashes)
- kelp and other vegetable ash
- bone ash
- crude potassium salts
- ash and residues resulting from the incineration of municipal waste

[4] Source: Customs Tariff Nomenclature Classification (Harmonized System) United States Agency for International Development: http://pdf.usaid.gov/pdf_docs/PNADL092.pdf

Tab. 4. Environmental classification systems adopted by country.

Countries	Defined as waste	Defined as hazordous waste	Basel conv. adopted	REACH adopted	International treaty on mercury	Utilis. env. condit
United States	Yes	No	Yes	No	No	Yes
Australia	Yes	No	Yes	No	No	Yes
Canada	Yes	No	Yes	Ref	Yes*	Yes
Europe	Yes	No	Yes	Yes	No	Yes
Israel	No	No	Yes	No	No	Yes
Japan	Yes	No	Yes	No	No	Yes
Russia	Yes	No	Yes	No	No	Yes
South Africa	Yes	No	Yes	No	No	Yes

* International treaty on Hg, under UN environment programme

Suffice to say that given the discussion above about the proposed tightly developed definitions, it is clear that CCPs can be differentiated from other materials listed under heading 2621.90, both in terms of chemical composition and physical properties. The general "pooling" of materials under this heading can be misleading, as CCPs whose commercial reuse and value are demonstrable, are grouped with general waste materials.

Weir [9] advised that for any proposal to be considered by the WCO HS Committee and its Review Sub-Committee, the value of annual global trade in CCPs must be more than USD $50 million just to secure a separate "Sub Heading". Where trade exceeds USD $100 million, a HS Heading could be considered. Since 2011 Network members have been working to compile international statistics needed to quantify international trade, moreover to mount a case for differentiating coal ash or more appropriately coal combustion products. This exercise of data collection also yielded a better understanding of the degree to which national legislation and regulation may effect trade and use of CCPs in various jurisdictions around the world.

Based on trade data provided by contributing network members, global trade of coal ash for 2010 equated to more than 3.5 Mt of CCPs traded globally or cross border which generated over USD $101 million annually. From the 6 countries reporting trade of CCPs, only 4 countries were able to determine value attributable for these transactions. In other words the revenue generated is highly underestimated. The long-term trend in trade and value are both increasing.

Through the cooperation and efforts of Network members, a submission was provided to the WCO through one of the signatory countries (Canadian Boarder Services) in 2012 for consideration. Consultation is continuing between Network members and WCO HS Committee to clearly define CCPs using methods/tests to correctly differentiate it from other materials listed under 2621.90.

Overview of country classification of CCPS

The development of sound legislation, regulations and other necessary measures designed to provide industry with the level of "legal certainty" are a minimum requirement for capital investment in modern economies. These investments provide for the efficient and effective recovery or value-adding and "best use" of CCPs for beneficial ends. The identification of actual, potential and ultimate removal of unnecessary "contingent liabilities" attributable to the generation, processing or sale of coal combustion products must be a key goal for all stakeholders [10].

This concept of "legal certainty" and its importance should not be underestimated.

Essentially, it underpins all corporate commercial decision-making processes where investments lead to secure associated "property rights" arising from investment to develop resources. Where a substance accrues property rights, they become tradeable goods or commodities based on changed perceptions of value. Ambiguity associated the materials classification will only result in hesitancy for further investment into future utilization technologies.

The concept of "contingent liabilities" can be broadly applied in relation to the generation, processing and or use of materials defined as wastes, and relates to the potential for use of these materials under the relevant regulation. Ultimately, any substance defined as a "waste", regardless of its economic, social or environmental value, continues to be subject to strict controls and reporting requirements [11 to 14] exposing participants to the use of CCPs therefore leads to legal uncertainty.

In the absence of legal certainty, generators, investors, business owners and customers operating in highly-competitive commercial markets typically avoid regulatory uncertainty or risks associated with an activity, resulting in the widespread loss of current and future beneficial utilisation opportunities for CCPs. On the other hand, the securing of legal certainty for CCPs supports sustainable industry development, whilst protecting the environment and human health – both of which are implicit in the community license to operate obligations for society today.

Predictably, different jurisdictions across the globe have adopted various classification systems for CCPs. These classifications broadly are non-hazardous wastes, solid waste, inert waste and resources or products. Obviously the assigned classification has a direct bearing on how and where CCPs are used from a legal certainty perspective. In the majority of network countries CCPs are reported as non-hazardous, solid or inert wastes and used widely in construction applications as shown in Table 4.

For example, in Europe, the non-hazardous classification has just been renewed with appropriate tests for the Regulation Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), which entered force in 2006. The registration required comprehensive information about toxicology and ecotoxicology of the substances.

Conclusions

This paper reported on current CCP production and utilisation by selected countries, including typical properties to the main resulting CCPs by coal types. The paper also explored implications for established utilisation pathways (i.e. current markets) and the need to incorporate this experience into standards which safeguard possible future pathways (i.e. new markets) in countries around the world.

Coal resources are significant with more than 130 years at current production rates. Demand for coal use in energy generation continues to grow within developing and developed economies. Policy shifts towards clean coal technologies are contributing factors, however, the technologies identified are likely to have significant impacts in respect to CCP quality and quantity.

The valued added benefits of CCPs are well established within technical literature produced across many regions of the globe within construction material sectors. Within modern coal-fired power stations, when appropriate collection and management systems are implemented, CCPs have extensive supply chain opportunities.

Coal combustion products are well defined by the definitions in standards and the adoption of a harmonised terminology will promote a consistent nomenclature for use by all stakeholders.

Worldwide production of coal combustion products was approximately 780 Mt tonnes in 2011. Effective utilisation was 415 Mt or 53 % of total production and varies widely within countries reported. The highest reported effective utilisation rate was 96.4 %, the lowest 10.6 %.

Utilisation strategies can be broadly classified into three main groups according to their usefulness and economic value, i.e. non-beneficial, simple and advanced. Factors potentially inhibiting reported value-adding pathways remain in the domain of national, regional and jurisdictional environmental legislators and regulators who continue to be hesitant in adopting more progressive and modern international definitions and categorisations.

Global trade or cross border transport of coal ash for 2010 equated to more than 3.5 Mt of CCPs which generated over USD $101 million. Through the cooperation and efforts of World Wide Coal Combustion Products Network members, consultation is continuing between Network members and WCO HS Committee to define CCPs clearly for a unique HS Heading or Sub Heading under 2621.

Different jurisdictions across the globe have adopted various waste classification systems for CCPs. These classifications broadly are non-hazardous wastes, solid waste, inert waste and resources, by-products or products. For the majority of the Network member countries CCPs are reported as non-hazardous, solid or inert wastes and used widely in construction applications.

The members of the World Wide Coal Combustion Products Network will continue to promote, coordinate and inform the public, industry and governmental entities about the beneficial environmental, technical and commercial uses of CCPs.

In conclusion it has been argued the securing of legal certainty for CCPs supports sustainable industry development, whilst protecting the environment and human health both of which are implicit in the community license to operate obligations for society today, being a common goal of World Wide Coal Combustion Products Network members.

References

[1] *Barnes, I.:* Ash Utilisation - impact of recent changes in power generation practices. In I. E. A. C. C. Centre (Ed.), Vol 1: pg. 51. London, England: International Energy Agency Clean Coal Centre, 2010.

[2] *Caldas-Vieira, F., and Feuerborn, H. J.:* Impact of Political Decisions on Production and Use of Coal Combustion Products in Europe World of Coal Ash 2013: pgs 17. Lexington, Kentucky USA: WOCA, 2013.

[3] *WCA, Vol. 2012:* World Coal Association, 2012.

[4] *IEA:* Coal Information 2009: 498 pp. Paris: International Energy Agency, 2009.

[5] *WNA:* Nuclear Power in Japan, Vol. 2013. United Kingdom: World Nuclear Association, 2013.

[6] *ACI, American Concrete Institute:* Advisory Committee, Long-Time Study. Ten-Year Report on the Long-Time Study of Cement Performance in Concrete. Journal of the American Concrete Institute Vol. 49 pp. 601-616. 1953.

[7] *Baweja, D., and Nelson, P.:* Supplementary Cementing Materials: Their Acceptance in Australian Specifications. Paper presented at the Sixth CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Bangkok, Thailand, 1998.

[8] *Sirivivatnanon, V., Ho, D. W. S., and Baweja, D.:* The Role of Supplementary Cementitious Materials in Australian Concrete Construction Practice. Paper presented at the Supplementary Cementitious Materials in Concrete, A Practical Seminar on the Specification, Use and Performance of Ground Granulated Blast Furnace Slag, Fly Ash and Condensed Silica Fume in Concrete, Perth, Adelaide, Melbourne, Canberra, Sydney and Brisbane, 1991.

[9] *Weir, A.:* World Customs Organization's Harmonized System can put Coal Ash in a Class of its Own, World of Coal Ash: pgs 9. Denver, Colorado USA: WOCA, 2011.

[10] *Heidrich, C.:* Summary of Technical Options for Coal Combustion Products Utilisation in Australia Ed. 1 ed.: pgs 6. Wollongong: Ash Development Association of Australia, 2005.

[11] *Heidrich, C.:* Legal certainty: why we need to change the waste paradigm, World of Coal Ash 2011, Vol. Vol 1: pgs 15. Denver, CO ACAA/CAER, 2011.

[12] *Heidrich, C., and Ritchie, S.:* Possible inter-jurisdictional approaches to Waste reclassification. Paper presented at the Sustainability, Construction Materials and your Bottom Line, Sydney, NSW, Australia, 2007.

[13] *Heidrich, C., Ward, C. R., French, D., and Bowman, H.:* CCP - Waste or Resource: Breaking the regulatory paradigms. Paper presented at the World of Coal Ash, Covington, Kentucky, USA, 2007.

[14] *Heidrich, C., Ward, C. R., and Gurba, L.:* Coal Combustion Products Handbook (Ed 1. ed.). (Vol 1). Brisbane, Australia: Cooperative Research Centre for Coal in Sustainable Development, 2007.

InfoExpert

InfoExpert

VGB PowerTech-DVD

More than 12,000 digitalised pages with data and expertise
(incl. search function for all documents)

Please fill in and return by mail or fax

I would like to order the VGB PowerTech-DVD 1990 to 2012 (single user license).

- ☐ Euro 950.–* (Subscriber of VGB PowerTech Journal [1]
- ☐ Euro 1950.–* (Non-subscriber of VGB PowerTech Journal [2]
  Plus postage, Germany Euro 7.50 and VAT
- ☐ Network license (corporate license), VGB members' edition (InfoExpert) and education license on request (phone: +49 201 8128-200).

* Plus VAT.
Annual update [1] Euro 150.–; [2] Euro 350.–
The update has to be ordered annually.

Return by fax or in business envelope with window to
VGB PowerTech Service GmbH
Fax No. +49 201 8128-329

Name, First Name

Street

Postal Code City Country

Phone/Fax

Date 1st Signature

Cancellation: This order may be cancelled within 14 days. A notice must be sent to to VGB PowerTech Service GmbH within this period. The deadline will be observed by due mailing. I agree to the terms with my 2nd signature.

Date 2nd Signature