HB 648 Section2: Coal ash markets investigation program
Report by the Research and Information Services Bureau at the MT Department of Commerce to the MT Legislative Energy and Telecommunications (ETIC) and the Environmental Quality Council (EQC) Interim Committees.

Background

House Bill 648 was codified in 2021 under statute MCA §90-2-202. The statute states the "the department of commerce shall establish a coal ash markets investigation program to determine the existence of economically viable markets to reuse coal ash."

MCA §90-2-202 Section 2 goes on to state "The Department may start an investigation when it has sufficient funds to conduct an investigation or in other circumstances the department determines is appropriate."

As reported in September of 2022 to the ETIC and EQC Committees, the research staff at the Department of Commerce determined a quality study will require, at a minimum, $50,000 in grant funding. HB 648 provided an initial $25,000 to Commerce in 2022, and an additional $25,000 was received in July 2023.

HB 648 directs, that within one (1) year of starting the investigation, the department shall present the results of the investigation in the form of maps and text to:

(i) the economic interim affairs committee; and

(ii) the environmental quality council.

At this time, Commerce anticipates issuing an RFP before year end to hire a consulting firm to determine the feasibility of coal ash utilization including possible uses of the rare earth/critical minerals contained in the ash. The chosen organization will be charged with conducting or reviewing analyses done by the state or company experts of various ash samples, evaluating various business opportunities, and determining any profitable market opportunities.

Previous work to date

Although we have not spent any appropriations to date that would trigger the one-year completion requirement for reporting, Commerce has been actively researching this topic and pursuing opportunities over the past two years. These activities are attached as report "HB 648 - Coal Ash Markets Investigation Program, Activities to Date, MT Department of Commerce, Research & Information Services Bureau".

Current efforts by RIS regarding Coal Ash, Rare Earth Elements (REE) /Critical Minerals (CM)

In 2023, Commerce staff continued to hold collaborative meetings with economic development organizations, specifically Southeast Montana Development Corporation (SEMDC) exploring opportunities to develop rare earth / critical minerals extraction in Montana. The staff also continues to work with prospective mining operations to help support the basis of this supply chain and lead initiatives to secure funding for research and development based in both the academic and private sector to aid this homegrown technology sector of the future. Commerce is currently looking at potential grant opportunities and coordinating responses with private and public partners.

In December of 2022, the RIS staff joined the planning work for a Critical Resource Summit sponsored by the Department of Defense National Security Innovation Network. This Summit was held in May 2023, and was attended by representatives from Commerce, including Director Osterman., Leaders from the United States government, defense agencies, academia, and private industry met for three days in Montana to discuss the future of critical resources, with an emphasis on rare earth elements. Discussion at the summit focused on technical innovations and infrastructure development needed to make the US more independent in its current and future REE needs, and the outsized emphasis China current holds in this crucial sector.

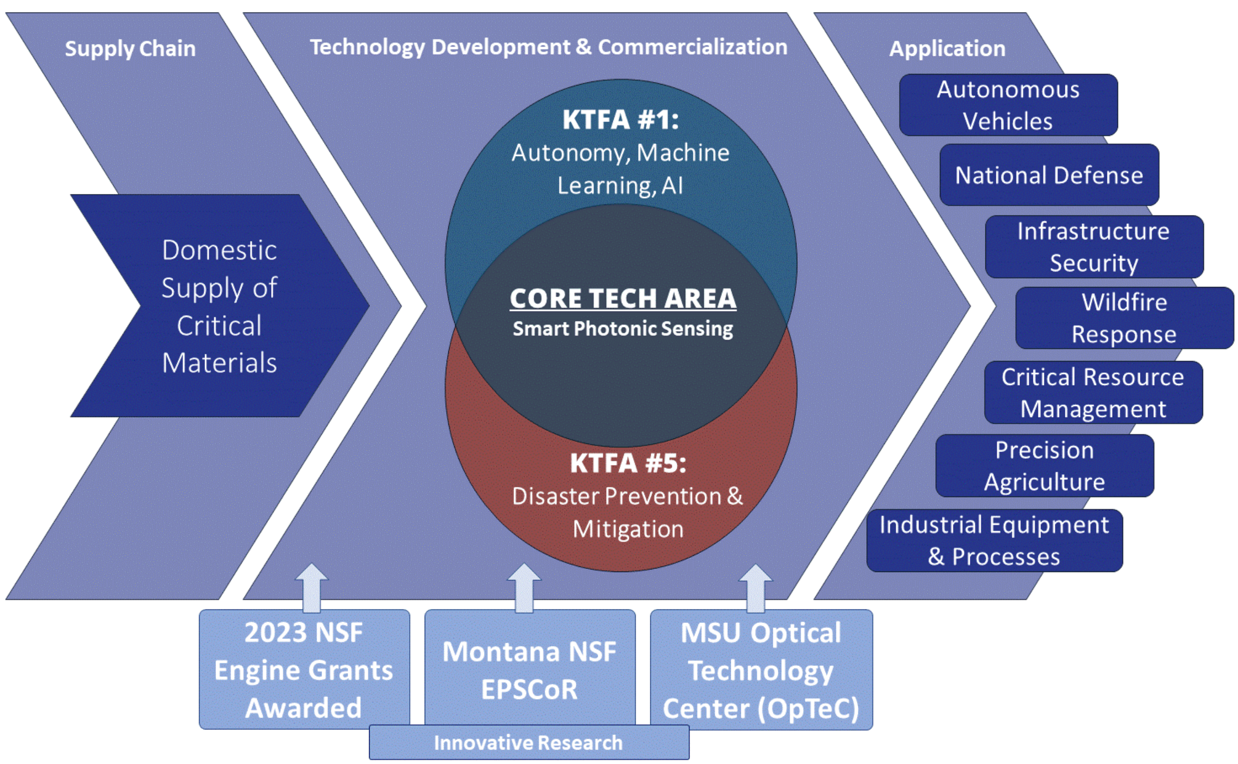
Montana has geological and waste resources that position it in a place of opportunity as the REE industry develops in the US. The Sibanye-Stillwater is currently looking into extraction of REE in the tailings and US Critical Metals released information earlier this year about their rich deposits of elements in their Sheep Creek claims. The Sheep Creek site includes elements such as neodymium, praseodymium as well as lesser amounts of cerium, dysprosium, europium, gadolinium, lanthanum, niobium, scandium, strontium, and gallium. Although the initial samples taken are promising, more extensive sampling needs to be done to determine more accurate deposits and mining potential. RIS staff continue to work with both companies to explore opportunities. A National Security Showcase site visit to the Sibanye-Stillwater Metallurgic Complex will be held September 27, 2023. This tour is co-sponsored by the Montana Chamber and the Department of Commerce and part of ongoing partnership development from the Regional Headwaters Technology Hub application.

HB 648 - Coal Ash Markets Investigation Program
Activities to Date
MT Department of Commerce, Research & Information Services Bureau

Activities To Date Researching coal ash uses and markets:

- IDP prepared an internal report on the Beneficial Uses of Fly Ash (attached).
- Staff held several HB 648 coordination meetings with DEQ.
- Reviewed an analysis of the chemical make-up of the coal ash at Colstrip.
- Have had several meetings with industry representatives to discuss opportunities in both the fly ash and rare earth elements (REE) / critical minerals (CM).
- Commerce continues the work on a data platform funded with an ARPA grant from the EDA to plan Fly Ash/ REE / CM development in Montana. An RFP will be released this fall for the final stage which will build the interactive platform into a data lake to be created using the Snowflake Data Cloud technology. Information for this was gathered from 111 surveys and 30 in-depth interviews with planners and economic developers about their requirements for the site.
- In coordination with Industry, IDP responded in late March 2022 to this DOE request for information (RFI); the purpose of this RFI is to demonstrate the feasibility of a full-scale integrated rare earth element extraction and separation facility and refinery. The companies were not successful in obtaining this funding but continue to look for other opportunities.
- Commerce obtained information from respected data sources on the scale and projected growth of the markets for rare earth elements and other critical minerals. Two reports were purchased since the focus of the reports was different but also complementary. Funding from the IDP program was used to make these purchases.
  - Obtained the March 2022 report from Wood Mackenzie Global Rare Earths Strategic Planning Outlook - Q1 2022. Wood Mackenzie, headquartered in Edinburgh, Scotland is a market research company that specializes in the natural resources industry. They have been providing quality data, analytics, and insights used to power the natural resources industry for over 50 years. https://www.woodmac.com/. The Wood Mackenzie report provided a global outlook for all uses. One key observation is the world REE supply is expected to exceed demand out to 2050 – albeit China/Asia is expected to dominate especially REE refining and magnet production. This observation underscores the importance of the US federal government establishing a market if, for national security purposes, it wants to create a domestic supply chain.
  - Obtained an April 2022 report prepared by the Toronto, Ontario consulting firm Adamas Intelligence entitled "Rare Earth Magnet Market Outlook to 2035." The Adamas report focused on the use of rare earth in electric vehicle magnet use which is expected to triple by 2035 from $15.1 billion to $46.2 billion.
- RIS acquired NAICS code info from the MT Department of Revenue in order to identify MT businesses that could support REE supply chain development.
- Staff chaired/presented at a panel regarding REE/CM supply chain the University of Wyoming (UW) CORE-CM (Carbon Ore- Rare Earth- Critical Mineral) annual meeting.
- Facilitated a phone call MSU and UW on bio-leaching of minerals which MSU has expertise in and served to bring MSU into the PRB CORE CM project spearheaded by UW.

- Promoted the Colstrip Business Incubator as a technology innovation center for REE/CM to UW.
- Established a RIS lead program to pursue grant opportunities in partnership with the Montana Chamber and the Montana University system that would provide funding for Montana industries and businesses. The program Grant Exploration Tied to Industry Team or GET IT works to identify federal funding opportunities primarily in Energy, Mining, and Agriculture.
- Compiling a report for UW of companies, university programs, tribal college resources, non-university educational resources, and other organizations in Montana that are involved in REE/CM development.
- Coordinated the response by the Montana University System, State Government, and the Montana Chamber/Montana business community to the Regional Technology Hub program. The Tech Hubs Program is an economic development initiative designed to drive regional technology and innovation-centric growth by strengthening a region's capacity to manufacture, commercialize, and deploy critical technologies. The U.S. Economic Development Administration (EDA) is authorized to spend $10 billion over 5 years. The Montana team applied for both a planning grant of $500,000 and a designation as a hub. If designated, the Montana hub can submit a proposal for $500 million+ over the 5 years. Announcements on the application are expected this fall. A core part of the hub proposal was the potential of a Montana-based domestic REE/CM supply chain and the application of the promoted technology of photonics and autonomous systems to seven industry areas including National Defense and Critical Resource Management.



DP Report- Beneficial Uses of Coal Fly Ash

In Response to Montana HB 648

ABSTRACT

Coal fly ash (CFA) can be used in different products and materials. It can be beneficially used to replace fresh materials removed from the earth, thus conserving natural resources. It is a good idea to encourage the beneficial use of coal ash in an appropriate and protective manner, because this practice can produce positive environmental, economic, and product benefits such as:

- reduced use of fresh resources,
- lower greenhouse gas emissions,
- reduced cost of coal ash disposal, and
- improved strength and durability of materials.

While the beneficial use of coal ash has these potential benefits, the environmental impacts associated with their use should also be considered.

Types of CFAs generated from coal combustion include fly ash, bottom ash, boiler slag, flue gas desulfurization (FGD) waste, and fluidized bed combustion (FBC) waste. All coal-fired electric utility plants in the United States generate at least one of these types of CFAs. Each different type of CFA has unique properties and, as a result, different potential uses. *It is environmentally and economically advantageous to maximize commercial use of this by-product.*

According to the latest survey, the US electric utility industry generates approximately 120 million tons of CFAs each year. Approximately 40 million tons of these CFAs were identified by the American Coal Ash Association (AACA) as beneficially used in either encapsulated or unencapsulated products. An additional 12.8 million tons were placed in mine-fill operations, while the remaining 57.8 million tons were disposed of in landfills and surface impoundments.

There are two types of beneficial use categories for CFAs, encapsulated and unencapsulated. Over 60 percent of coal fly ash is used in its encapsulated form.

Encapsulated Beneficial Use

Encapsulated uses of CFAs involve binding the coal ash, such as in wallboard, concrete, roofing materials, and bricks in a way that minimizes the CFA from escaping into the surrounding environment. There are important benefits to the environment and the economy from the use of coal ash in encapsulated form. The two largest encapsulated uses reported by the ACAA in 2018 are fly ash used in "concrete/concrete products/grout" (13.4 million tons) and flue gas desulfurization (FGD) material gypsum used in "gypsum panel products" (12.3 million tons), making up over 60 percent of the total amount of coal ash beneficially used.

In 2013, EPA developed a methodology for evaluating encapsulated beneficial uses of CFA. This methodology can support beneficial use determinations by allowing the user to demonstrate whether releases from an encapsulated beneficial use of coal ash are comparable to or lower than those from analogous products made without coal ash or are at or below relevant regulatory and health-based benchmarks, during use.

EPA used the methodology to evaluate the potential environmental impacts associated from fly ash used as a direct substitute for Portland cement in concrete, and from FGD gypsum used as a replacement for mined gypsum in wallboard. EPA's evaluation concluded that the beneficial use of encapsulated CFA in concrete and wallboard is appropriate because environmental releases are comparable to or lower than those from analogous non-CFA products or are at or below relevant regulatory and health-based benchmarks.

Unencapsulated Beneficial Use

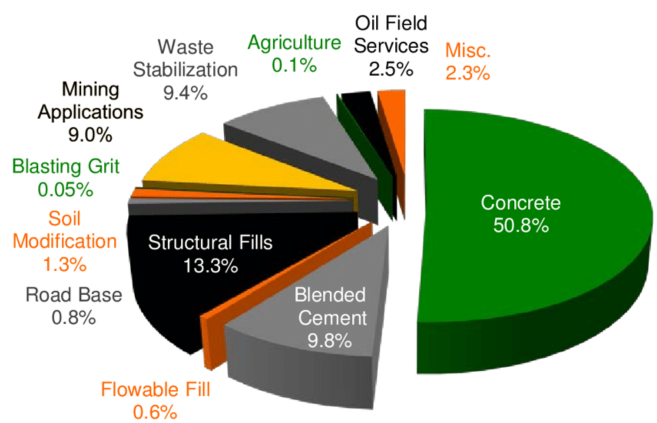
Unencapsulated uses of coal ash are those where coal ash is used in a loose particulate, sludge, or other unbound form. In 2018, ACAA reported about 20 percent of CFA (8.1 million tons) are beneficially used in unencapsulated uses. The largest unencapsulated use is CFA used in "structural fills/embankments" (4.6 million tons).

The ACAA indicates that the largest encapsulated beneficial uses of CFAs, by more than a factor of two, are fly ash used in "concrete/concrete products/grout" (11.8 million tons) and FGD gypsum used in "gypsum panel products" (7.6 million tons). That is, these two beneficial uses make up nearly 50 percent of the total amount of CFAs beneficially used on an annual basis. There is a myriad of additional beneficial uses of coal fly ash, to include soil modification.

Industrial Applications of Coal Fly Ash

The varied industrial applications of fly ash include:

- Construction and engineering materials: concrete, bricks, blocks and geopolymers. Incorporation of ash into construction materials leads to a product possessing enhanced strength that is especially important in complex engineering projects such as bridge, tunnel, and dam structures, and as a structural road-fill material.
- Agriculture: ash possessing low levels of contaminants is suitable for agricultural use, to improve key soil indicators such as carbon content, water retention and fertility.
- Mineral extraction: The extraction of valuable elements (such as rare earths and germanium) from fly ash is significant to the renewable energy and aerospace industries, while fly ash can also be a source of aluminum.



- Advanced materials: composites, ceramics, fillers, zeolites, and proppants. Fly ash is increasingly applied in the manufacture of advanced composite materials to extend the material properties and replace valuable metals.

CFA IN CONSTRUCTION

The dominant use of CFA is in the construction industry where it can substitute for cement clinker, replace cement in production of flowable fill and foamed concrete; and form low density manufactured aggregates, bricks, cement, and geopolymers. Projections indicate an unsustainable increase in demand for construction materials and the production of cement is the largest industrial greenhouse gas emitter. CFA substitution for cement is one way to reduce the environmental impact of the construction industry. Another reason for the increasing proportion of CFA, especially for concrete, is due to the enhanced properties of the final products that contain CFA. A key benefit is the reduction of microcracking due to thermal stress which leads to a longer lasting product that resists freeze-thaw erosion. Low density ash-based materials are suitable for the construction of passive high-rise buildings that require 16-inch-thick walls, aimed at reducing the need for heating and cooling in cities.

CFA can act as a pozzolan reactant, partially replacing Portland cement in concrete production. The inclusion of fly ash enhances the durability and strength of concrete, essential to build large structures such as bridges, high rise buildings and dams. This method reduces energy use associated with cement kilns and provides substantial reductions in greenhouse gas emissions. In brick manufacture, CFA offers important environmental benefits as it can replace clay taken from fertile soils and at the same time reduce energy usage and pollution by avoiding the use of brick ovens. CFA is an effective engineering filler material in road building and mine backfilling by replacing soil or sand (Li and others, 2017).

Concrete is the principal manmade construction material; production exceeds 10 billion tons each year, making it the second most consumed material after water. Ready mix concrete sales are estimated at over US$395 billion per year with the market anticipated to grow at over 5% per year. Cement is the most important constituent in concrete, it forms about 1/7th of the final concrete when mixed with aggregate and sand. Given the scale of the industry and its associated energy intensity, OPC manufacture is a major contributor to greenhouse gas emissions as approximately 4% of total atmospheric emissions arise from cement kiln operation. The cement industry is now the focus of efforts to reduce industrial CO_2 emissions which exceeded 1.45 $GtCO_2$ in 2016.

Cement production is energy intensive involving high temperature processing to convert calcium carbonate to calcium oxide. To manufacture OPC, limestone and clay are heated in a rotary kiln at up to 1500°C to form a clinker, at conditions just below the melting temperature. Clinker consists of lime (CaO), sand (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3); the small diameter balls formed are then milled, and gypsum ($CaSO_4$) is added to prevent the cement setting. At this point CFA may be combined with the cement clinker product.

Portland Cement Concrete

Fly ash has been successfully used as a mineral admixture in PCC for nearly 60 years. This is the largest single use of fly ash. It can also be used as a feed material for producing Portland cement and as a component of a Portland-pozzolan blended cement.

Fly ash must be in a dry form when used as a mineral admixture. Fly ash quality must be closely monitored when the material is used in PCC. Fineness, loss on ignition, and chemical content are the most important characteristics of fly ash affecting its use in concrete. Fly ash used in concrete must also have sufficient pozzolanic reactivity and must be of consistent quality.

Asphalt Concrete – Mineral Filler

Fly ash has been used as a substitute mineral filler in asphalt paving mixtures for many years. Mineral filler in asphalt paving mixtures consists of particles, less than 0.075 mm (No. 200 sieve) in size, that fill the voids in a paving mix and serve to improve the cohesion of the binder (asphalt cement) and the stability of the mixture. Most fly ash sources can meet the gradation (minus .075 mm) requirements and other pertinent physical (non-plastic) and chemical (organic content) requirements of mineral filler specifications.

Stabilized Base – Supplementary Cementitious Material

Stabilized bases or subbases are mixtures of aggregates and binders, such as Portland cement, which increase the strength, bearing capacity, and durability of a pavement substructure. Because fly ash may exhibit pozzolanic properties, or self-cementing properties, or both, it can and has been successfully used as part of the binder in stabilized base construction applications. When pozzolanic-type fly ash is used, an activator must be added to initiate the pozzolanic reaction. Self-cementing fly ash does not require an activator. The most used activators or chemical binders in pozzolan-stabilized base (PSB) mixtures are lime and Portland cement, although cement kiln dusts and lime kiln dusts have also been used with varying degrees of success. Sometimes, combinations of lime, Portland cement, or kiln dusts have also been used in PSB mixtures.

The successful performance of PSB mixtures depends on the development of strength within the matrix formed by the pozzolanic reaction between the fly ash and the activator. This cementitious matrix acts as a binder that holds the aggregate particles together, similar in many respects to a low-strength concrete.

Brick, Block and Ceramic & Reinforced Concrete

Fly ash bricks are made by combining fly ash, pigment, cement, and sand in the required proportions, mixing with water, and then passing to an automatic brick press, before curing for two weeks. Although ash bricks are not fired, one of the constituents, OPC at 1/7th of the mix, is manufactured in a kiln, so comparative carbon emission assessments would have to take this into account.

Due to the cement needed, the cost of a fly ash brick is likely to be higher than a traditional clay brick, but there are technical benefits, lower use of natural resources, reduced energy consumption and lower carbon emissions. Clay bricks are typically more variable in quality and often have crevices. These are largely absent from fly ash products which results in an approximately 50% greater compressive strength than red clay brick. Clay brick is highly porous whereas a fly ash brick will resist water penetration which can weaken the structure; this together with the inherent higher strength may be important in regions affected by earthquakes and flooding. Compared to clay bricks the fly ash product also offers better heat and sound insulation and resists damp penetration.

Autoclaved aerated concrete (AAC) is a lightweight load-bearing durable product offering good insulation. AAC is made using milled aggregates (clay), cement that contains CFA, gypsum and an expansion agent that introduces air producing a block that is approximately a third of the density of traditional bricks. The mixture is prepared at ambient conditions in an autoclave and then molded and cut into precise blocks. The main advantage of the material is that it resists water penetration in much the same way as CFA bricks, while the strength of AAC blocks is comparable to that of traditional bricks. CFA-AAC exhibits similar benefits to those outlined for CFA bricks, although this aerated product is much lower density (20% of concrete) and hence easier to handle as well as offering higher thermal insulation.

The use of carbon fiber, such as pitch based fiber, is attracting interest as an alternative to steel in reinforced concrete. It possesses comparable strength to steel but the drawback is that fiber costs are an order of magnitude higher (Reid, 2018). However, the benefits of using carbon fiber include the avoidance of corrosion, which is the main cause of reduced life in major construction projects; thus, it could substantially extend the life of structures avoiding rebuilding costs. There is research in the USA which aims to reduce the cost and improve the strength of carbon fiber produced from coal products (Anderson, 2019). A significant extension in the useful life of infrastructure projects such as bridges would far outweigh the additional cost of carbon fiber – fly ash – concrete construction materials.

The rise in demand for construction materials includes minerals used for ceramic tiles, such as kaolin and feldspar which are in increasingly short supply. CFA is primarily an alumina silicate material and resembles the chemical and physical characteristics of the mixture used to make tiles. Historically, the CFA content in tiles has been limited to less than 20% to maintain quality standards. More advanced processing techniques that select specific ash particle size, such as for super pozzolans, synthesize ceramic tiles with the requisite properties that possess a much greater CFA content.

DAM CONSTRUCTION

Hydroelectricity is the world's main renewable energy resource utilized today. However, large dam construction projects are now viewed less favorably due to increased awareness of the impact on local environments. Despite this growing resistance to new projects, the BP energy outlook to 2024 predicts a rise in hydro power to 7–9% of total energy consumption, which itself is set to increase by between three and five billion tons of oil equivalent.

In huge structures such as gravity dams, where the mass of the dam counteracts the force of the water reservoir, the role of ash is to limit peak temperature during concrete setting, developing full strength over a longer period to avoid microcracking, and enhance strength prior to the critical first fill period where the full load of the reservoir is applied.

EXTRACTION OF METALS

Certain deposits of coal can be relatively rich in rare earth elements, recognized as critical elements for the energy transformation to renewable power and for aerospace industries. Once combusted, the elements are concentrated in fly ash and there are current demonstration programs seeking economic extraction as a substitute to restricted supplies of REE from China. In addition, CFA can be a commercial source of aluminum from alumina-rich CFA, an industrial process practiced in China. CFA is also an established source of germanium and new facilities are under construction to extract magnesium from lignite ash.

AGRICULTURE AND LAND RECLAMATION

The UN has supported initiatives concerned with the loss of arable soils and desertification, building upon the 2015 'International Year of Soils'. Given the increasing demand for food and water, the addition of CFA to soils, especially if combined with manure, has positive benefits: controlling soil acidity; improving texture; and water retention among others. A subject of current research is the addition of CFA to soil to improve its CO2 retention. The suitability of CFA for land use depends on the concentration of toxic elements, chiefly arsenic and lead, and application should be supported by leachate analysis. Practical precautions include modest deposition rates, monitoring, and application intervals of several years. There is considerable experience in the use of CFA for land reclamation and mine fill; the use of CFA improves stabilization of embankments and avoids consumption of fresh materials such as river sand.

OTHER CFA APPLICATIONS

As an alumina silicate, the composition of CFA is close to that of zeolite catalyst supports and can be adjusted to match specific crystalline structures. Zeolite catalysts account for about half of all catalysts and are important in water and gas purification. Current research is examining CFA as a suitable low-cost CO2 adsorbent in pressure swing technologies to reduce the cost of CCS. Metal composites are deployed for the protection of armored vehicles and lightweight bodyshells for electric vehicles. CFA can directly replace metals such as aluminum to lower the weight; up to 30% of the metal can be CFA while retaining the original properties of cast materials. Addition of metal filings or carpet fibers to improve certain concrete strength characteristics is already practiced. The availability of new forms of carbon, such as graphene oxide (GO), takes this to a new level as the GO can chemically bond to ash and cement materials, greatly enhancing strength and crack resistance. The inclusion of nanomaterials may mean less material is needed and the lifespan of concrete is extended.

CFA can be used as a superior proppant in shale gas recovery, where the ash can lubricate the flow into a well and offer enhanced crush resistance. CFA paper is another new product with potential.

Cenospheres are a valuable low-density ash product in demand as a filler material already exhibiting sales exceeding US$170 million per year.

The benefits of incorporating CFA into products by preserving resources, lowering material costs, building more robust structures, and perhaps most significantly reducing pollutant and CO2 emissions, are highly advantageous and align with UN Sustainable Development Goals to mitigate the impact of urbanization and population growth.

FLOWABLE FILL – AGGREGATE OR SUPPLEMENTARY CEMENTITIOUS MATERIAL

Flowable fill is a slurry mixture consisting of sand or other fine aggregate material and a cementitious binder that is normally used as substitute for a compacted earth backfill. Fly ash has been used in flowable fill applications as a fine aggregate and (because of its pozzolanic properties) as a supplement to or replacement for cement. Either pozzolanic or self-cementing fly ash can be used in flowable fill. When large quantities of pozzolanic fly ash are added, the fly ash can act as both fine aggregate and part of the cementitious matrix. Self-cementing fly ash is used in smaller quantities as part of the binder in place of cement.

The quality of fly ash used in flowable fill applications need not be as strictly controlled as in other cementitious applications. Both dry and reclaimed ash from settling ponds can be used. No special processing of fly ash is required prior to use.

EMBANKMENT AND FILL MATERIAL

Fly ash has been used for several decades as an embankment or structural fill material, particularly in Europe. There has been relatively limited use of fly ash as an embankment material in this country, although its use in this application is becoming more widely accepted.

As an embankment or fill material, fly ash is used as a substitute for natural soils. Fly ash in this application must be stockpiled and conditioned to its optimum moisture content to ensure that the material is not too dry and dusty or too wet and unmanageable. When fly ash is at or near its optimum moisture content, it can be compacted to its maximum density and will perform in an equivalent manner to well-compacted soil.

Fly ash must be in a dry form for use as a mineral filler. Fly ash that is collected dry and stored in silos requires no additional processing. It is possible that some sources of fly ash that have a high lime (CaO) content may also be useful as an antistripping agent in asphalt paving mixes.

Conclusions

The beneficial use of CFAs, when conducted in an environmentally sound manner, can contribute significant environmental and economic benefits. Environmental benefits can include reduced greenhouse gas emissions, reduced need for disposing of CFAs in landfills, and reduced use of fresh resources. Economic benefits can include job creation in the beneficial use industry, reduced costs associated with CFA disposal, increased revenue from the sale of CFAs, and savings from using CFAs in place of other more costly materials.