Draft White Paper

Municipal Solid Waste Combustion Ash Utilization in the United States

1. Introduction
CDM has recently received several inquiries from our clients in both private and public sectors regarding municipal solid waste (MSW) combustor ash reuse technologies. CDM prepared this DRAFT white paper to address the current status of MSW combustor ash reuse technologies in the United States and to help our clients exploring the best technologies to successfully approach and utilize the ash to achieve their financial and environmental goals.

In the United States, about 450 million tons of MSW are generated annually. Approximately, 130 million tons (29%) of MSW are recycled and 32 million tons are combusted (7%), primarily for energy recovery. Combustion ash residuals comprise almost 8 million tons of material processed. Waste-to-energy (WTE) is becoming a favorable option for many reasons, including use as a diversion from the environmental problems associated with landfilling waste, the excellent volume reduction and sterilization gained by this process and opportunities seen with energy recovery and generation of revenues from the sale of electrical power to help reduce the overall cost of processing MSW.

Landfilling is facing increasing opposition by both regulatory and public agencies due to the emerging paradigm for minimizing waste disposed of in landfills. Landfills in the United States decreased from 8,000 in 1988 to 1,654 in 2004 (74% reduction). Though combustion results in 70-90% volume reduction of waste, a significant portion remains as ash. The remaining ash portion is usually divided into bottom ash fraction which accounts for 90% of the produced ash and fly ash fraction which accounts for only 10% of the total ash generation. Concerns still exist for landfilling of the remaining ash. This generated interest in treating and reusing the ash in a variety of beneficial uses. To date, only 1 million tons (5%) of the annually produced ash is being utilized in beneficial applications within the United States. The majority of applications have been in construction products and as a landfill cover. This white paper provides an overview on the current status of MSW combustor ash utilization in the United States.

2. Regulations
The EPA exempts WTE facilities that combust household and non-hazardous commercial and industrial waste from RCRA Subtitle C requirements for
hazardous waste. However, the rule does not exempt the ash residuals from the subtitle C requirements for hazardous waste and, therefore, the ash is required to be tested for toxicity characteristics (TC) using either the Toxicity Characteristics Leaching Potential (TCLP), as described in 40 CFR sec. 261.24, or by using knowledge of the combustion process to determine if the ash will exhibit TC. In general, the fly ash will have higher possibility to fail the TC more than the bottom ash fraction. Accordingly, most of the WTE facilities combine the fly ash and the bottom ash to dilute the fly ash portion and to avoid dealing with either portion as a hazardous waste. In general, ash reuse has not been subject to strict regulations by the EPA. However, almost half of the states have specific regulations for beneficial ash reuse.

3. Ash Utilization Technologies
Many technologies are available and have proven, either locally or internationally, to be environmentally safe technologies for ash reuse. Nevertheless, some of the technologies for ash reuse need to be verified and permitted for beneficial reuse in accordance with local and state regulations.

3.1 Available Technologies
The following is a list for the major available technologies for ash reuse:

3.1.1 Landfill cover, using combined ash
This is the major current usage for ash and this technology has been approved by every state. The use of combined ash as daily landfill cover reduces the need and cost to obtain soil or other suitable materials.

3.1.2 Road way base and sub-base, using bottom ash or combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale. Both bottom and combined ash exhibits good structural properties for road construction. The presence of an impervious cap in the form of asphalt, along with the fact that roads are typically designed to be above the water table, minimizes the potential for contact of ash with groundwater.

3.1.3 Asphalt aggregate, using bottom ash or combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale. There is a tradeoff which needs to be evaluated for this application, as the use of ash as an aggregate may increase the amount of asphaltic cement that is required to meet the state or local roadway construction specifications. Use of ash in this application is often avoided in the top wearing or friction course of
asphalt to avoid the issues associated with erosion and contact with storm water.

3.1.4 Concrete products aggregate, using bottom and combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale. The use of ash in concrete construction products includes concrete blocks and pavers. Ash is generally avoided in concrete products which contain reinforced steel due to presence of chlorides and other elements which can be detrimental to the long-term performance of steel reinforced structural concrete.

3.1.5 Structural fill under lined landfills, using bottom and combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale.

3.1.6 Soil cement admixture, using combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale. Soil cement can be used for road base or slope protection and is primarily used in locations with high water tables.

3.1.7 Shore protection and erosion prevention, using bottom and combined ash
This technology has been proven to be environmentally safe and it has been applied on small scale in an application that included a long term risk assessment study performed to verify the effect of using fly ash cement blocks within a marine environment. The technology has proven to be environmentally safe with long term (5 years) test data.

3.2 Potential Technologies

There are other potential technologies which need to be explored as options for ash reuse. The following is a list for such potential technologies:

3.2.1 Zeolite synthesis from combined ash
Zeolites are hydrated aluminum silicates that are characterized by high cation exchange capacity. Zeolite materials are used widely in wastewater and water treatment for removal of pollutants, and as a soil amendment. Due to the chemical composition characteristics of the ash, synthesizing zeolite materials from the ash was found to be possible. This technology changes both the chemical and the physical characteristics of the ash and covert the ash into useful materials to be
used for several environmental purposes as adsorbent materials or as a carrier for agricultural plant nutrition. The technology is currently in the research stage and more research needs to be done to commercialize this technology.

3.2.2 Cement manufacture, utilizing bottom ash
WTE bottom ash contains significant amounts of the four primary ingredients necessary for the production of Portland cement (aluminum oxide, ferrous oxide, calcium oxide, and magnesium oxide). Successful tests were conducted in the early 1990s at a South Florida cement manufacturer using the minus 1/2" fraction of screened bottom ash. Portland cement is one of the major construction materials used throughout the industrial world and may be capable of using large volumes of bottom ash.

3.2.3 Blended Roadway Aggregates, using bottom or combined ash
This is an application where processed ash could be blended with virgin aggregates (limerock) or recycled aggregates (crushed concrete and asphalt) to produce an aggregate which meets environmental and structural specifications for use as base and subbase in construction projects.

3.2.4 Flowable fill, use of combined ash
Flowable fill is a lightweight low strength concrete matrix which is often used to backfill excavations for underground pipes and structures. The advantage of this application is that the ash materials are encapsulated in a matrix that minimizes contact with groundwater and leaching potential.

3.2.5 Low Carbon Cement Manufacturing
There is a firm in England which has invented a process to make low carbon cement from waste slag. This may open a new opportunity where mined aged ash from ash monofills (which may have been washed of chlorides) could be integrated into this process.

The technologies mentioned above include several similar process steps starting with recovery of ferrous and non ferrous metals, followed by screening to remove non-burned materials, then the remaining portion is crushed to achieve either 3/8 or 1/2 inch grain size to then be used as an aggregate for roadway, concrete, asphalt, and Portland cement production.

4.2 Corporations/Institutions Active In Ash Reuse and Successful Stories
4.2.1 Active Corporations/ Institutions
The following organizations are the most active Corporations/Institutions working on ash reuse projects in the United States:

1. American Ash Recycling Corporation (AAR)
2. Energy Answers Corporation (EAC)
3. National Renewable Energy Laboratory (NREL)
4. Evergreen Recycling, Inc., which is pursuing the use of WTE ash in Portland cement manufacturing.

Personal communications with the above active firms indicated that the technologies that have been previously developed have proven to be successful and environmentally safe, but their application depends on obtaining permits from the state in which the technology will be used. Though ash reuse technologies are not regulated by the EPA, there are still concerns, and some states have put strict regulation on the ash because it is not exempt from RCRASubtitle C hazardous waste regulations. Therefore, the permitting for ash reuse technologies was found to be cumbersome since it is dependent on state-by-state regulation.

4.2.2 Success Stories
- American Ash Recycling built a 110-ton per hour recycling facility for the metropolitan government of Nashville and Davidson County, Tennessee. This facility operated during the time period between 1994 and 1997, and processed mined ash from an old ash monofill. A wide variety of metals (ferrous and non-ferrous) along with aggregate products were recovered and recycled.

- Rochester, Massachusetts, the SEMASS Resource Recovery Facility manufactures an engineered granular product using bottom ash. In 1994 it produced 29,000 metric tons of products and recovered 3,600 metric tons of metals.

- The city of Commerce, California, has been using the ash from a WTE plant as a road-base at their landfill site.

- Wheelabrator Environmental System developed and patented an ash stabilization technology in 1987 (McKaynite).

- The state of Florida FDEP has previously certified the bottom ash from Tampa's McKay Bay WTE facility to be used for road construction. As a note, this approval was prior to the 1993 Supreme Court decision, which was followed by the issuance of new Beneficial Use Determination (BUD) rules. The FDEP has also previously approved the use of soil cement (Permabase) made from ash from the Hillsborough County, Florida RRF.

- The state University of New York at Stony Brook built a boathouse of hollow masonry blocks made from WTE ash and Portland cement, the boat house showed no adverse environmental effect.

- The National Renewable Energy Laboratory, NREL, Golden, Colorado, a national laboratory of the U.S. Department of Energy, is sponsoring five different studies for ash reuse in construction.

- Energy Answers Corporation has patent an aggregate, called Boiler Aggregate® made from bottom ash.

5.0 Enabling Technologies

Several technical advancements have evolved over the past decade which may help advance the commercial development of ash recycling. One such advance is the use of plasma arc technology for vitrification of ash residue into an inert glass matrix. The ability to process WTE fly ash into an inert glass frit may facilitate the development of options to recycle the greater percentage of bottom ash in a number of beneficial applications.

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Typical Composition of our Garbage

- **28%** Other Paper/Boxes
- **2%** Aluminum
- **6%** Glass
- **2%** Plastic Bottles
- **15%** Yard Waste
- **1%** Other Non-Ferrous
- **1%** Miscellaneous
- **10%** Food Textiles
- **10%** Construction
- **2%** White Goods/Tires
- **10%** Newspaper
- **2%** Other Plastics
- **8%** Non-Ferrous
- **1%** Ferrous Metals
Typical Composition of WTE Ash Residue Composition (After Grizzly and Primary Magnet)
FAIRFAX NON-FERROUS SYSTEM PILOT TEST

TEST NO: 01  DATE: 6/25/92

1. ASH RESIDUE
   THROUGHPUT 232.87 TONS

   FRONT-END LOADER
   VIBRATING FEEDER

   2. ADDITIONAL FERROUS
      10.26 TONS

   3. FINE ASH RESIDUE
      162.63 TONS

   4. NON-FERROUS
      86 TONS

   5. REJECT
      18.28 TONS

   6. FERROUS FINE
      12.39 TONS

   7. REJECT MEDIUM ROCK
      25.76 TONS

   8. NON-FERROUS
      2.69 TONS

   9. REJECT LARGE ROCK
      18.28 TONS

   10. ERIEZ Eddy Current
       SEPARATION PROCESS

   11. FERROUS ROCK
       61.78 TONS

   12. REJECT MEDIUM ROCK
       60.84 TONS

   13. NON-FERROUS METAL
       17.51 TONS

   14. TOTAL WEIGHED
       3.55 TONS

   15. REJ. 9/13 Tons

   16. MATERIAL
       3.55 TONS

   17. %

   18. ASH RESIDUE 100

   19. ADDITIONAL FERROUS 4.90

   20. FINE ASH 69.84

   21. NON-FERROUS 0.31

   22. REJECT Lg 7.85

   23. FERROUS FINE 1.16

   24. REJECT MEDIUM ROCK 11.06

   25. FERROUS ROCK 2.69

   26. REJECT MEDIUM ROCK 5.32

   27. NON-FERROUS METAL 1.53

   28. TOTAL THROUGHPUT 100

   29. WEIGHT INCLUDES MOISTURE, ASH COATING, CERAMICS, GHOST ROCK CONTAMINANTS; DEDUCT 15% TO OBTAIN MARKETABLE MATERIAL QUALITY (.85 x 1.53 = 1.30)