Ash characteristics and utilisation

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Outline

- Current and potential future ash utilisation options
- Result of Joint Measurement Campaigns
- Conformity of ashes with EN specifications
- Conclusions and recommendations
Objectives

- Utilisation of bottom and fly ash essential for economic and environmental performance of biomass co-firing
- Different DEBCO Joint Measurement Campaigns cover broad biomass co-firing spectrum, and associated potential ash utilisation routes
- Increased biomass co-firing scenarios lie beyond the scope of existing EN specifications
- DEBCO results aim provide substantial base to evaluate needs and limitations for future specifications
Types of ashes

• **Bottom ashes:**
  - Slag, dry bottom ash and bed materials
  - Drop from flame and collected at bottom of thermal conversion installation
  - Common characteristics:
    - Bulk formed by inert sand and sand-like materials
    - Low loss-on-ignition (LOI), low carbon content, low volatile content, and low concentration of leachable contaminants

• **Fly ashes:**
  - Fine powders, low bulk density, entrained by flue gas
  - Contain volatile elements that condense upon cooling
  - Characteristics:
    - Large variation in composition, LOI, carbon content
    - Typically higher volatile content and display increased leaching
Approach to identify ash utilisation options

EU Waste Management Hierarchy

- Ash value is zero or slightly positive
- Avoidance land fill costs
- Strongly influenced by local conditions

Ash utilisation options
Ash utilisation options (1)

• Consistency and quantity are the keys to successful ash utilisation:
  – Ash to be delivered with predictable and constant quality
  – Low constant quality is preferred over fluctuating high quality
  – Profitable niche utilisation options may exist locally
  – No “of the shelf” solutions for bulk biomass ashes that do not comply with EN-450

• Established bulk applications:
  – Construction materials and products
  – Mine back-filling
  – Fertilizer
  – Fuel (carbon-rich ash)

• Ash is the starting point → appropriate utilisation option to be identified
# Ash utilisation options (2)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Application</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td>Construction and Civil Engineering</td>
<td>Cement, concrete, mortar</td>
<td>Binder, filler</td>
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<td></td>
<td>Low quality concrete products</td>
<td>Reactive filler</td>
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<td></td>
<td>Synthetic aggregates</td>
<td>Raw material</td>
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<td></td>
<td>Road construction</td>
<td>Binder/Sand replacement</td>
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<td></td>
<td>Landscaping/embankments</td>
<td>Filler</td>
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<td>Soil stabilization</td>
<td>Binder</td>
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<td>Sand-lime bricks</td>
<td>Filler</td>
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<td>Carbon concrete (C-fix)</td>
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<tr>
<td>Energy production</td>
<td>Re-burning</td>
<td>Fuel</td>
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<tr>
<td>Mining</td>
<td>Mine back-filling</td>
<td>Filler</td>
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Derived from: Saraber and Overhof (2009)
### Ash utilisation options (3)

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<tr>
<td>Agriculture/Forestry</td>
<td>Soil improvement/Fertilizer</td>
<td>Product/Raw material</td>
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<td>Industry</td>
<td>Polymers</td>
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<td>Zeolites</td>
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<td></td>
<td>Metals</td>
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<td>Phosphor production</td>
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<td></td>
<td>Metals recovery</td>
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<td>Mineral fibers</td>
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<td>Environmental technology</td>
<td>Impermeable layer (landfill)</td>
<td>Raw material</td>
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<td>Waste acids neutralisation</td>
<td>Product</td>
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<td></td>
<td>Adsorption material</td>
<td>Raw material</td>
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</tbody>
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Direct use as construction material

Bottom ashes are directly used as construction material or filler:
- From coal-fired power plants: little or no restrictions (sometimes CO₂ uptake through aging to reduce basicity)
- From fluidized bed combustion/gasification: predominantly sand
- From grate stokers in granulates (0-40 mm)
- In general: replacing mineral sources (sand, gravel and granulates) in civil engineering (EN-13055) or landscaping

Fly ash not likely suitable for direct use

Bottom ash used during road construction
Binder in concrete, cement and mortars

Main use of coal-derived fly-ash: (partially) replacing Portland cement:

- Good pozzolanic properties
- Less lime calcination → reduced carbon foot print
- Minimum emission Portland cement 760 kg CO₂/ton
- Large market
- “Pure” coal ashes are most attractive; biomass co-firing ashes to a limited extent due to free lime
- Existing standards, EN-450, EN-196, EN-197, etc.
- Allows clean wood co-firing up to estimated 25-40% (energy basis)
- Landfill typically more expensive than utilisation in concrete or cement

- Developments in fly-ash based geopolymers as binder to replace cement
Low-quality concrete products

- Absence of reinforcement → no corrosion vulnerability alkali metals & Cl
- Limited forces exerted; fly ash mainly used to obtain volume
- Examples:
  - Segmented retainer walls (SRW), e.g. “Earth Blocks” or “Megablocks”
  - Concrete pavement tiles
  - Artificial reefs
Lightweight aggregates

- Replace mineral aggregates in lightweight concrete with improved thermal insulation
- Appropriate physical and mechanical properties
- High K and Ca content lower operating temperature during sintering
- Leaching comparable with mineral aggregates when used in concrete
- Less avoided CO₂ emissions than replacement for cement
Fertilizer/soil improvement

Both direct utilisation and use as raw materials for fertilizer feasible

• Nutrients from a biological source
• Saving mineral (non-sustainable) resources

• Ashes are incomplete fertilizers – no nitrogen and less-soluble phosphorus
• Low nutrient content compared to heavy metals (especially Cd, also As, Zn)
• High inert content (sand)

• Use as soil improver possible especially for high Ca and Mg content; e.g. when dolomite is used as bed material in combustion/gasification
Ash recycling in forestry

• Whole Tree Harvesting (WTH) became more lucrative during past decades:
  – Increased use of forest residues as cheap and clean fuel
  – Nutrients mainly present in roots, bark, branches, leaves and needles; therefore WTH poses risk of nutrient depletion

• Ash recycling can also counteract acidification

• No common European standard but regulated by certain individual states:
  – Sweden, Finland, Austria, Germany, Slovakia

• Sweden is a frontrunner:
  – Ash recycling condition for WTH
  – Specified minimum nutrient and maximum contaminant content
  – Locally used in combustion installation
  – 50% of ashes (technically) suitable