

# Overview of options for utilization of (biomass) ashes

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## Introduction

Large variations in ( biomass) fuels

Combustion processes:

- direct co-firing: biomass ashes mixed with coal ashes
- indirect co-firing: “pure” ashes, but often high-C
- stand-alone: “pure” biomass ashes

Typically from any kind of thermal installation two main kinds of ashes emerge:

- **bottom ashes**, from below the fire
- **fly ashes**, removed from flue gas

## Diversity in composition of ashes

	Grate stoker Green mix Bottom ash	Grate stoker Green mix Fly ash	CFB comb. Green mix Fly ash	CFB gasif. Demolition wood Fly ash
Ash (wt%)	99.7	98.3	95	35
K (wt%)	7.5	37.5	2.8	0.7
P (wt%)	0.6	1.4	2.7	0.14
Ca (wt%)	16.6	2.5	13.7	4.9
Mg (wt%)	1.7	0.4	1.2	0.6
S (wt%)	0.7	11.6	0.9	0.6
Si (wt%)	22.1	0.23	19.3	7.6
Pb (mg/kg)	440	1300	120	4500
Zn (mg/kg)	450	10800	470	4000
Cd (mg/kg)	6	40	4	8
Cl (mg/kg)	7000	125000	0.3	10000

All numbers are on dry basis

Numbers are indications, real ash compositions show large variations

## Common solutions

Ash recycling to forests

Not all ashes can be recycled

- Landowners are not willing to accept ash
- From unknown origins, blends, e.g. imported fuel
- Unacceptable levels of contaminants
  - from contaminated biomass
  - from clean biomass !!!



Bottom ashes mostly used in building products, in particular road construction, due to low nutrient content.

For fly ash the situation is more difficult.

## Bulk and niche applications

Besides large diversity in qualities, also large diversity in quantities

- Bulk solutions most urgent
- Niche solutions possible for smaller volumes
- Niche applications do not diminish the need for bulk applications.

Three generic bulk applications

- Fertilizer
- Building material
- Fuel



*White pieces from combustion fly ash  
Black pieces from gasification fly ash*

## Search for solutions – KEMA – ECN project

Project of ECN/KEMA consortium resulted in a list of options

- List of 20 ash utilization options
- screened for technologically feasible
- ranked for technical and economically feasibility in Dutch situation



For situation in Netherlands, see also presentation by A. Saraber

## Overview of potential applications for ashes (fly ashes and bottom ashes), Saraber and Overhof, 2009

No	Application	Function	Sector	
1	Binders alternative for standard cement	Component	Building industry and civil engineering	
2	C-fix	Filler		
3	Concrete (products) low quality	Reactive filler		
6	Road Construction material	Binder/Raw material		
7	Sand-lime bricks	Filler		
8	infrastructural works (embankments, fillings)	Filling material		
9	Soil stabilization	Binder		
10	Synthetic aggregates <sup>1</sup>	Raw material		
11	Fuel	Combustion		Energy production <sup>2</sup>
12	Back-filling mining	Filler		Mining
13	Polymers	Filler	Industry	
14	Metals	Filler		
15	Phosphor production	Raw material		
16	Zeolites	Raw material		
17	Metals recovery	Raw material		
18	Mineral fibers	Raw material		
19	Soil improvement and fertilizer	Product/Raw material	Agriculture	
20	Neutralisation of waste acids	Product	Environmental technology	
21	Adsorption material	Raw material		
22	Impermeable layer	Raw material		

1 including synthetic basalt

2 including indirect energy production in industry

## Direct utilization as building material

Utilization as building material is a sustainable form of utilization:

- Saving mineral sources (non-sustainable sources)

Bottom ashes are being utilized as building material

- From fluidized bed combustion/gasification: mainly sand
- From grate stokers in granulate (0-40 mm)
- Generally: replacing other sand, gravel and granulates in road construction and landscaping, possibly used in concrete

Fly ashes are unlikely to find *direct* application as building material

Bottom ash used in road construction



## Standardized application as binder in concrete, cement and mortars

Main application, replacing portland cement

- fly ash from coal have good pozzolan properties
- no burning of lime → smaller carbon foot print
- portland cement minimal emission 760 kg CO<sub>2</sub>/ton
- large market
- pure coal ashes are most attractive, not too much biomass ashes, e.g. due to free lime
- known standards, EN-450, EN-196, EN-197, etc.



## Other application in building products

- clinker production - replacement of clay
- bricks and other ceramics - replacement of clay and fillers



## Low-quality concrete products

### General characteristics

- no reinforcement = no corrosion
- limited forces exerted

### Examples:

- segmented retainer walls (SRW), e.g. “Earth Blocks” or “megablocks”
- concrete pavement tiles



## Special case for non-reinforced concrete

### Artificial reefs and protection of piers and sea barriers

- Trials in USA, Japan, Netherlands, UK
- Slow release of minerals, back into eco-system
- No evidence was found for transfer of heavy metals from the reef blocks to the epifauna



## Vitrification - smelting

- High-temperature treatment into synthetic basalt
  - energy intensive
  - expensive
  - minimal leaching risks → unrestricted use
- Also: Japanese waste incineration



*Test block made at ECN*



*Basalt blocks used to protect sea walls*

## C-FIX and other asphalt-like products

### C-FIX is

- Concrete-like material
- In shaped blocks
- With petroleum residue as binder

### Filler in C-FIX blocks

- 7 wt% carbon rich fly ash
- Good technical quality
- Relatively expensive, but not due to the fly ash
- Market introduction is bottleneck

### Filler in asphalt

- 10 kT/y from AMER-CFB covers 2% of filler needed for new asphalt in NL
- Competition from other fillers, e.g. residues from waste incineration



*C-fix blocks as underlayer in road construction*

## Light-weight aggregates

Most-attractive option, emerging from ECN/KEMA project

Results of ECN/KEMA experiments:

- Good physical and mechanical properties
- High K and Ca content lower production temperature
- When applied in concrete, leaching the same as for regular materials
- less avoided CO<sub>2</sub> emission than for replacement as cement
- Production costs: ca. 45 €/ton (excluding profit from sale of aggregates)
- E.g. Trefoil and Lytag



## Re-use as fuel (gasification fly ash)

- Direct use as fine black powder
- Pelletization/granulation
  - Volume reduction by factor 4 – 6



*Fuel pellets from high-C fly ash*

- Minimum carbon content of 35% or caloric value of over 15 MJ/kg
- Shifting ash utilization problem towards the buyer of the fuel
- Combustion facility needs license according to EU Waste Incinerator Directive, or production with license for processing waste
- Utilization in metallurgical industry → replacing cokes

Preliminary calculations show that - when possible - re-use as fuel is most economic option for carbon-rich ashes

***“Utilization of biomass as fertilizer - as old as agriculture”***

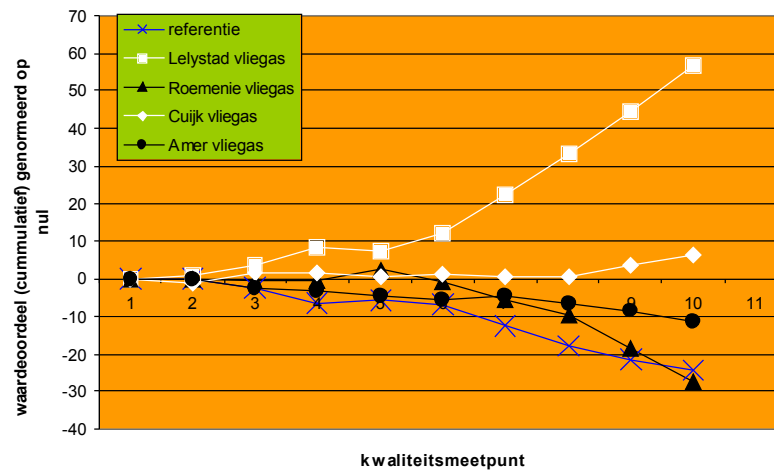


# “Biomass fly ash is an excellent fertilizer”



## Exploratory test

- with added N-fertilizer
- Combustion fly ash from grate stoker was clear winner



## Direct utilization as fertilizer

### Advantages

- Nutrients from a biological source
- Saving mineral (non-sustainable) resources
- Solving waste issue



### Disadvantages

- Ashes are incomplete fertilizers – no nitrogen; less-soluble phosphorus
- Low nutrient content compared to heavy metals (especially Cd, also As, Zn)
- Large content of inerts - sand
- Consistency in quality and quantity needed

Potential use as soil improver, especially when having high Ca and Mg, e.g. when dolomite is used as bed material in combustion/gasification.

Potential use as special fertilizer for energy plantations

## Recycling of wood ash

- Ash from local combustion of wood waste
- Legally possible for clean wood ash
  - Scandinavia, Austria and Germany in forestry
- Sweden is leading
  - Condition for “Whole Tree Harvesting”
  - 30% more fuel in form of forest residue
  - locally used
  - 50% of ashes (technically) suitable
  - Handbook from RECASH Project



## Utilization as raw material in fertilizer production

Replacing (non-sustainable) mineral resources

Utilization as raw material for fertilizer possible when only **end product must comply with legislation**, origin of minerals not relevant.

The same issues apply as for direct utilization:

- Low nutrient content compared to contaminants and inerts
- Mineral sources are cleaner and more reliable
- Consistency in quality and quantity



## Some remarks on utilization as fertilizer

- National legislation apply to direct use or allow it as component in mixed fertilizers. In Netherlands, nobody has petitioned for permission.
- Fertilizer industry interest depends on P and K raw material prices.
- World P shortage will become primary driver
- Consistency is the key to success
- Lucky matches possible, e.g. BMC produces ashes from chicken litter used in fertilizer
- High-carbon ashes may be **biochar**

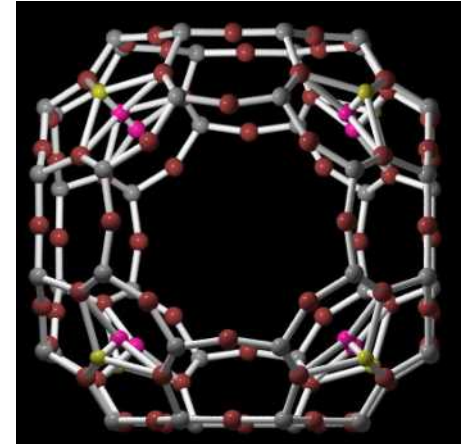


*BMC Moerdijk*

## Other applications

### Zeolites

- hydrothermal synthesis from silico-aluminates
- water treatment → risk for heavy metal leaching
- again: consistency
- virgin raw materials cheap and of predictable quality



### Mineral fibers

- smelting and spinning at 1600°C
- Rockwool has investigated this option
- high level process control required
- again: consistency & virgin materials

### Metal recovery

- treating ashes as metal ore
- not yet a feasible option, but it will come



## Other applications

### Phosphorus production

- elemental phosphorus for industrial application
- Thermphos has investigated this option
- ashes from sewage sludge replacing phosphate ore
- high-P ashes also from meat & bone meal
- problem with Cl and Fe in ashes



### Adsorption of pollutants

- stabilization of hazardous waste → current application
- carbon-rich fly ash replacing activated carbon



### Soil stabilization, also at land fill sites

## Landfill - The bottom-line

Combustion ashes can be landfilled without much difficulties

- costs vary between countries
- classification varies from inert to hazardous waste
- bottom ash or sintered ash: from almost nothing to € 100 per ton
- fly ashes: from € 50 - € 300 per ton

Extremely simplified calculation

- ash content of average biomass: 4% (dry basis)
- gate fee for average biomass ash: € 100/ton
- cost of ash disposal: € 4 per ton dry fuel
- compare: prices for biomass fuel € 0 - 40 per ton



## Concluding remarks

In all applications, consistency is a key factor

- Ash delivered with a predictable, constant quality
- Constant low quality is better than fluctuations in high quality

Quantity is other key factor

- Only a few kiloton ash per year → almost nobody will contemplate using it
- For products with high added value → competition with virgin materials
- Lucky matches may exist

Other conclusions

- Clean biomass does not guarantee clean ashes
- There is no single solution for “biomass ash”, because there is no single biomass ash.
- The best utilization option is a local solution
- Landfill is in many cases the most cost-effective alternative

## THE END

Better... to be continued...

