Report.

IEA Bioenergy Task 32
Deliverable D4

Options for increased utilization of ash from biomass combustion and co-firing

Arnhem, March 5, 2012

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SUMMARY

In the near future, the demand for biomass-based heat and electricity will increase because of targets for generating energy from renewables and decreasing the emission of fossil CO_2. Because of increase of biomass conversion, there will be an increase of biomass ash production. Thus, there is increased interest in biomass ash utilization.

Several options exist or are possible for utilization of ashes. Technical feasibility is usually not an issue. However, in practice, there is only a limited amount of biomass ashes utilized and a large part is still disposed of in many countries.

Coal and co-firing bottom ashes (for up to 20% (m/m) biomass/coal) have successfully been applied in road construction and as a concrete aggregate, replacing natural stone, while fly ashes from co-firing with up to 20% (m/m) biomass/coal are used as an additive in cement or as a concrete and asphalt filler. Regarding the use as coal fly ash as cement replacement, the European technical standard for the use of fly ash for concrete, EN-450 is currently revised to include the use of ashes obtained from co-firing percentages up to 50% (m/m, fuel input) for clean wood. A common application for bottom ashes or mixtures of bottom and coarse fly ashes from clean biomass fuels currently used is direct use as fertilizer on agricultural or forest soils. These ashes are also used as additives for compost production in Austria and as a liming agent for forest soils in Austria and Germany. Fly ashes are used as raw material in the cement and brick industry in a few countries. In some countries, the ashes are used for grouting mines or used as asphalt or concrete filler. In Sweden, some ashes are used as construction material for landfills. In many countries however, most of the ashes are still disposed.

Next to applications currently in use, many other options for ash utilization exist. Research is in progress to find more ways of utilization of pure biomass ashes. Promising ways for biomass ash utilization include the more widespread use in the building industry (e.g. cement clinker production, production of bricks), civil engineering (e.g. binding material for soil stabilization, landscape management) as well as the use as raw material for the production of synthetic aggregates, fertilizers or liming agents.

The current study shows that the main reasons for this situation relate to environment, sustainability, low market volumes and differences and variations in ash quality. In addition, there are limitations in technical and regulatory regulations as well as logistics. Finally, there is a lack of awareness, knowledge and willingness of plant operators, potential end-users and authorities alike to improve utilization.

In order to overcome the barriers for more widespread ash utilization, it is advised to perform additional research and development on ash utilization options, take measures too provide a constant ash quality, intensify collaboration between producer and end-user, increase awareness with market actors and harmonize national regulations and technical standards.

1 INTRODUCTION

Biomass is one of the sustainable sources of energy that is used for today's production of electricity and heat. In the near future, its share will increase significantly as a result of national policy targets for renewable energy and CO_2 mitigation. By all means, biomass will be an important source in the future for power, heat and transport fuels. Biomass based energy supply can in many cases be reliable, affordable and sustainable.

In the near future, the demand for biomass-based electricity will increase as a result of targets for generating energy from renewables and decreasing the emission of fossil CO_2. For example, the European Union has set a target to reach 20% energy from renewable sources in 2020. Thermal conversion of biomass produces ashes, which may contain a significant part of the elements (nutrients) that were present in the biomass, like P, K and Ca. So, as a result of increase of biomass conversion, there will be an increase of biomass ash production.

In general, the residues from 100% (natural or contaminated) biomass thermal conversion feature different physical and chemical characteristics compared to coal ashes and therefore they usually do not fulfil the requirements of well established utilization options, which were originally developed for coal residues. Consequently, there is a need to identify and develop other utilization possibilities for biomass ashes.

The goal of this report is to support policy makers with knowledge on biomass ash utilization and options for future use. The report should also support and provide information for plant owners and operators.

2 APPROACH

This report has been written by order of IEA Bioenergy Task 32: Biomass combustion and co-firing. The results are based on information that has been collected by sending out a questionnaire on ash utilization to the country representatives of Task 32. They were asked to provide data on ash production and ash utilization in their country and suggestions on potential applications, limitations and ways to improve ash utilization.

Responses were received from representatives from Austria, Denmark, Finland, Germany, Ireland, Italy, the Netherlands, Norway and Sweden. All input has been used for this report.

3 ASH FORMATION AND PROPERTIES

3.1 Combustion/co-firing technology and fuels used

The scale of the boilers in use in Europe vary significantly from large scale co-firing units, medium- and small-scale stand-alone biomass energy plants down to domestic stoves. The most common combustion technologies are the following (Van Loo and Koppejan, 2008):

Co-firing:

- Bubbling fluidized bed furnace: 5 up to 120 MW_{th}
- Circulating fluidized bed furnace: 25 up to 150 (Finland up to 560 MW_{th})
- Pulverized combustion furnace: 100 to 700 MW_{th}.

Dedicated Biomass combustion plants:

- Grate furnace and underfeed stoker: 20 kW_{th} up to 100 MW_{th}
- Bubbling fluidized bed furnace: 5 up to 120 MW_{th}
- Circulating fluidized bed furnace: 1 up to 50 MW_{th}
- Pulverized combustion furnace: 1 to 350 MW_{th}
- Stove: 2 to 15 kWth (household), 20 to 500 kW_{th} (utility buildings or industrial)
- Rotary kiln, 0.5 – 10 MW_{th}

There is a wide variety of biomass fuels utilized, depending on plant size, local availability and combustion technology chosen. In co-firing plants, besides the standard fuels like hard coal, lignite or peat, biomass fuels like wood pellets, forestry waste, husks or shells are utilized. In dedicated biomass plants, a wide variety of fuels are used, such as clean wood, bark, waste wood, husks, straw, grasses, black liquor, and waste streams such as municipal solid waste, sewage sludge, poultry litter, meat and bone meal, and paper sludge. The composition of the fuel has a strong impact on the utilization options available for the ashes produced.

3.2 Ash production

Based on the response from the questionnaire for Task 32 member countries, an indication of amounts of different types of ashes produced in these countries has been compiled. Some figures are estimated, while others were derived from biomass consumption figures. The results are given in table 1.

Table 1. Indication of amounts of ash produced per country per type of source (kton/year)

		Austria	Denmark	Finland	Germany	Ireland	Italy	Netherlands	Norway	Sweden
Biomass	Wood	141*	> 32	100	137	1.2	nq	26	75	155
	Wood pellets	3	nq	nq	12	0.13	nq		0.43	nq
	Wood (households)	53	nq						7	nq
	Bark	nq	nq		nq					nq
	Waste wood	nq			270				nq	27
	Husks						nq		nq	
	Straw	5	nq		nq	0.08				0.5
	Grass		nq							nq
	Miscanthus	1			nq					
	Wood briquettes				3.5				0.4	
	Black liquor	135		nq						70
	Forest chips	12		nq						
	Forestry waste		nq	nq			nq			
	Timber waste		nq						nq	
Peat	Total			350		199				32
Coal (cofiring)	Total						200	840		383
	Bottom				nq			*100*		
	Fly				nq			*740*		
Waste	Total	710	nq					1,602	200	680
	Bottom	*380*						*1,514*		
	Fly	*330*						*88*		
	Sewage sludge							61	nq	
	Poultry litter							67		
	Meat and Bone Meal					nq		nq		

*) including bark and timber waste

nq = mentioned as fuel source, but amount of ash was not quantified

3.3 Physical and chemical properties of biomass ashes

Based on several studies of ECN, KEMA, BIOS and others [Obernberger, 1996a, 1996b, KEMA, 1998; ECN, 2004, Obernberger, 2009a first indication could be produced on residue properties, , as well as possible recycling and utilization options. The main conclusions were:

- Characteristics of biomass ashes from bio-energy plants (BEP's) differ strongly from those of coal ashes. Ashes from the combustion of ligneous fuels feature high amounts of Ca, Si, Mg and K while ashes from herbaceous fuels are dominated by Si, K and Ca. Moreover, ashes from herbaceous fuels have lower heavy metal contents (due to significantly shorter rotations periods, higher pH values of and lower heavy metal depositions on agricultural soils, a lower heavy metal uptake occurs). The high contents of alkali metals, phosphorus and calcium make them unsuitable for the established applications for powder coal and current co-combustion fly ashes.
- Residues from direct co-firing and co-gasification are dominated by ash from the coal. They mainly contain Al and Si and are therefore considered unsuitable as a viable source of nutrients.

Apart from the biomass fuel type and the presence of fossil fuel in the combustion process, the combustion technology as well as the type of ash fractioning determine the chemical composition of the ashes.
Ashes from fluidized bed furnaces (bubbling fluidized bed or circulating fluidized bed furnaces) contain significant amounts of bed material (usually SiO_2). Due to this dilution, the concentrations of other elements in the ashes are usually lower compared to ashes from fixed bed furnaces.

Usually, different ash fractions are generated in biomass combustion and co-firing plants. The main ash fractions are:

- Bottom ash (collected from the combustion chamber; main ash fraction of fixed bed furnaces)
- Coarse fly ash (boiler fly ash, cyclone fly ash)
- Fine fly ash (e.g. from electrostatic precipitators or baghouse filters; main ash fraction of fluidized bed furnaces).

The mass ratio between the individual ash fractions is dependent on the combustion technology. In fixed bed furnaces, the bottom ash usually accounts for 60 to 90% and the coarse fly ash for 2 to 30% of the total ash generated, whereas the fine fly ash fraction amounts only to 2 to 15%. In fluidized bed furnaces, usually the fine fly ash fraction accounts for the largest fraction of the total ash. Depending on the plant size, the combustion technology and the plant design some of the ash fractions may be also collected together (bottom and coarse fly ash or coarse and fine fly ash).

There are significant differences in the nutrient and heavy metal content between bottom ash, coarse fly ash and fine fly ash. Volatile heavy metals such as Zn, Pb and Cd as well as the semi-volatile nutrient K exhibit highest concentrations in the fine fly ash, while non-volatile elements like Ca, Mg, Si, show the highest concentrations in the bottom ash. Due to the fact that the combustion temperature in fluidized bed furnaces is usually lower (between 800 and 900 °C) than in fixed bed furnaces (900 to 1,050 °C) the enrichment of volatile elements in the fly ash fractions of fluidized bed furnaces is less pronounced compared to fly ashes from fixed bed furnaces.
The presence of Cadmium (Cd) and to a lesser extent Zink (Zn) in ash is of particularly relevance due to its potential environmental impacts. Based on the current state-of-the-art, about 35 to 65% of the total amount of Cd and 35 to 55% of Zn in the ash is concentrated in the fine fly ash fraction of fixed bed furnaces.

4 ASH UTILIZATION

4.1 Current and potential future practice

4.1.1 Current practice for coal ashes

Coal ash utilization can be dated from the advent of widespread pulverized coal combustion for electricity generation in the 1920s, when large amounts of fly ash became available. The first significant work on the use of coal-derived ashes in construction products is generally acknowledged to be that carried by Davies and others in the 1930s, and published in a series of papers that established the groundwork for many of the specifications and formulations still in use today (Davies 1935, 1937, 1941).

Fly ash and furnace bottom ash can be used in a variety of applications. In many of these applications, the fly ash is mixed with some form of binding agent such as cement, lime, bitumen, etc. Common applications for coal fly ash include (UKQAA, 2009 and www.ecoba.com):

- Aerated concrete blocks – Here, fly ash forms the primary material within the blocks, which are widely used in house and office buildings.

- Ready mixed and precast concrete – Fly ash that has been classified or selected to appropriate standards is widely used as an addition in concrete partially replacing the Portland Cement.

- Grouting of mines and caverns – Fly ash is widely used for stabilizing large voids in the ground, allowing it to be returned to productive use and remediating problems of subsidence. It compares favorably in this application with naturally occurring aggregates.

- Fill and ground remediation – Fly ash has been extensively used for building embankments, restoring old quarries, etc., for over fifty years.

- Blended cement and cement raw material – Fly ash is increasingly used by cement manufacturers both as a source of silica, and as a blend material. This enables them to produce more environmentally friendly and cost effective cements, reducing overall CO_2 emissions, energy and use of natural aggregates.

An important development in the use of coal fly ash as cement replacement has been the development of the EN-450. This is the technical standard for the use of fly ash for concrete. It is now under revision (Sarabèr et al., 2009) to include the use of ashes obtained from higher co-firing percentages up to 50 % (m/m, fuel input) for clean wood.

4.1.2 Current practice for ashes from co-firing biomass with coal

Bottom ashes from co-firing up to 20 % (m/m) biomass/coal are currently used as concrete aggregate. Fly ashes from co-firing up to 20 % (m/m) biomass/coal that fulfill the requirements of the EN-450 are used as additive in cement. Fly ashes are also used as concrete filler or as asphalt filler.

4.1.3 Current practice for biomass ashes

A common application for bottom ashes or mixtures of bottom and coarse fly ashes from clean biomass fuels currently used is direct use as fertilizer on agricultural or forest soils.

These ashes are also used as additives for compost production in Austria and as a liming agent for forest soils in Austria and Germany. Fly ashes are used as raw material in the cement and brick industry in a few countries. In some countries the ashes are used for grouting mines or used as asphalt or concrete filler. In Sweden some ashes are used as construction material for landfills. In many countries however, most of the ashes are still disposed.

Considering the nutrient and heavy metal concentrations and distributions among the different ash fractions, it seems reasonable to recycle the bottom ash or a mixture of bottom and coarse fly ash (proportional to the actual amount generated at the combustion/CHP plant) to soils. The utilization of bottom ash only has the advantage of lower heavy metal concentrations but results in higher nutrient losses (due to the cut-off of both fly ash fractions only about 40 to 60% of K, P and Mg can be used sustainably). If a mixture of bottom ash and coarse fly ash is utilized, a better closure of the nutrient cycle can be achieved, against the backdrop of somewhat higher heavy metal concentrations in the ash.

4.1.4 **Current practice for municipal solid waste incineration ashes**

As the ashes from combustion of MSW are characterized by relatively high amounts of heavy metals, most of the ashes produced from MSW incineration are currently disposed off. Bottom ashes can only be used as foundation material for road construction when insulation measures are taken. Fly ash may be used for mine stabilization.

4.1.5 **Overview of ash utilization**

The table below gives a more detailed overview of the current utilization practices, based on the type of ash.

Table 2. Current utilization practices for biomass ash, co-firing ash and municipal solid waste incineration ash

Ash description	Current Utilization
Bottom ash/coarse fly ash from (wood fired) grates, BFB[1)] or CFB[2)]	– Fertilizer – Liming agent on agricultural and forest soils (Austria and Germany only) – Additive to compost production (Austria only) – Cement production (Austria) – Disposal
Filter fly ash from (wood fired) grates, BFB or CFB	– Cement production (Austria and The Netherlands only) – Brick production (Austria and The Netherlands only) – Construction material at landfills (Sweden only) – Concrete filler – Asphalt filler – Mining (back-filling) – Soil stabilization – Disposal
Bottom ash from co-firing peat and biomass in BFB or CFB	– Disposal
Fly ash from co-firing peat and biomass in BFB or CFB	– Fertilizer – Grouting mines – Soil stabilization – Disposal
Ashes from straw fired CHP plants	– Fertilizer – Disposal
Ashes from domestic fireplaces, stoves and pellet boilers	– Land spreading on gardens – Composting own garden – Disposal own garden – Disposal household waste – Disposal (landfill)
Bottom ashes from co-firing up to 20 % (m/m) biomass/coal	– Concrete aggregate
Fly ashes from co-firing up to 20 % (m/m) biomass/coal	– Additive in cement – Concrete filler – Asphalt filler
Bottom Ashes from Municipal Solid Waste Incineration	– Disposal
Fly Ashes from Municipal Solid Waste Incineration	– Mine stabilization – Disposal

1) Bubbling Fluidized Bed

2) Circulating Fluidized Bed

4.1.6 Potential applications

Several potential applications in agriculture, building industry, civil engineering and industry/energy were identified by the Task 32 members. The below table gives an overview of alternative applications, which are currently in the R&D or demonstration phase:

Agriculture and forestry

- Raw material (source of nutrients) for production of fertilizers to be used in forest, agriculture, short rotation coppice, horticulture, in-house plants, green houses.

Building industry

- Cement clinker production, as raw material (current practice in Austria and Netherlands only)
- Production of bricks as sand replacement (current practice in Austria and Netherlands only)
- Production of alternative binders (e.g. geopolymers)
- Production of synthetic aggregates by cold bonding or sintering
- Sand replacement in non-reinforced prefab concrete

Civil engineering

- Building material that increases bearing capacity in forest road construction (demonstration phase in Austria, Finland and Sweden)
- Binding material for soil stabilization in road construction, where it substitutes lime as a binding material (demonstration phase in Austria, Finland and Sweden)
- Landscape management (walls, embankments, hills, back-filling)
- Stabilizing dredged material.

Industry and Energy

- (Trace) metal recovery by chemical or electrochemical treatment
- Filler in metals or polymers
- Phosphor recovery for fertilizer production.

4.2 Application requirements

4.2.1 Technical feasibility

The ashes need to have a minimum technical suitability for the intended application as well as a constant quality. The application can be particularly attractive if ashes have a special property which provides an added value for using these ashes. An example is the pozzolanic behavior, which provides a higher durability to concrete. Different properties of the biomass ash are of relevance, dependent on the application. Examples are the physical properties (particle size, density), chemical properties (pozzolanic behavior in concrete, amount of nutrients, e.g. N, P, K, amount of macro elements Al, Si, Ca, amount of unburned carbon), ecological properties (amount of heavy metals, leaching behaviour).

4.2.2 Technical regulations

Technical regulations, standards and/or contracts have to be available as frame of reference for ash producer and customer. Standards exist for coal and co-firing ashes. An example is the EN 450-1, which gives a set of requirements to assess the quality of fly ash for use in concrete and the EN 13055, which gives such requirements for the use of bottom ash in civil engineering. These standards however do not apply to biomass ashes. For applications with a limited number of end-users, technical requirements of the ash are not established in standards but in contracts, for example on the use of fly ash as raw material for the production of Portland clinker. In the U.S., there is a similar regulation, the ASTM standard (C-618) on the utilization of fly ash in concrete industry. However, this regulation explicitly states that the fly ash shall be completely derived from coal.

There is a broad range of concrete or concrete-like products where less strict requirements are possible as the main function of fly ash is to act as inert filler to improve grain size distribution, to increase the paste content and/or to improve workability.

Regulations also apply when ashes are used as fertilizer. These regulations differ per country. Limit values are usually set on minimum content and availability of nutrients (N, P or K) or (Ca, Mg, or S). Note that ashes usually will not be used as a source of nitrogen (N) since this element is missing in ash. In addition, a maximum content of heavy metals (e.g. Cd, Cr, Cu, Pb, Zn) may be set.

In Austria and other countries, there are guidelines for the practical use of biomass ashes on agricultural and forest soils. The guidelines are not always legally binding but often serve as a basis for the application of biomass ashes as a fertilizing agent for ash producers, ash users and authorities alike. Requirements consist of limiting values for concentrations of certain heavy metals or organic compounds in the ash; limiting values for the maximum amount of ash applied per year and ha, based on the quality of the ash as well as on the type of soil (agriculture, grassland, forest); recommendations for the proper application of biomass ashes on agricultural (farmland and grassland) and forest soils. In Sweden for example, only ash from clean biomass fuels is allowed for agriculture or forestry applications.

The Austrian Compost Ordinance manages the use of various organic and inorganic wastes as basic materials and additives for the production of compost. Requirements include limiting values for concentrations of certain heavy metals in the ash; the maximum addition of biomass ash to compost materials is limited to 2% (w/w; w. b.) related to the material weight before the composting begins.

The German Fertilizer Decree (Düngemittelverordnung) enables the use of biomass ashes as fertilizer. Different conditions are set based on different types of fertilizer. For all fertilizers there are limit values for heavy metals.

In Denmark the Ordinance on the use of bio-ash for agricultural purposes was updated in 2008. This regulation also includes limitations on concentrations of polycyclic aromatic hydrocarbons (PAH).

In Sweden the Swedish Forest Agency recommended minimum and maximum levels of substances in ash products for distribution on woodland. The recommendations relate to solids concentrations in the ash product used in the forest, ie. after the addition of plant nutrients and a binder. The stated guidelines relate to ash residues only.

In Finland the Decree of the Ministry of Agriculture and Forestry on Fertilizer Products came into force in 2011. Wood, peat or agrobiomass ashes can be used as fertilizers as such. There are two possible type names:

- "Agroash": to be used in agriculture, horticulture, landscaping and forestry
- "Forest ash": to be used only in forestry.

For both types, there are minimum values for content of nutrients and maximum values for the content of minor elements. In additional there are limit values for maximum loads (g/ha/year) for As and Cd. Addition of nutrients in the form of inorganic fertilizers product is allowed to improve granulated ash fertilizers

In the Netherlands, there are no specific regulations for the use of biomass ash or wood ash in forestry. This means that the use in forestry should be qualified as spreading of waste, which is forbidden.

Table 3 gives an overview of the limits for heavy metals and nutrients in biomass ash for the application on agricultural and forest lands in Germany, Austria, Denmark, Sweden and Finland.

Table 3. Overview of existing limiting values (required min and max values) for heavy metals and nutrients in biomass ash for the application on agricultural and forest lands in different countries

	Germany[1]	Austria[2]	Denmark[3]	Sweden[4]	Finland[5]
Nutrients (% min)		**Class A/B**			**AGR/FOR**
Ca	15[1] (CaO)			12,5	10[5] / 6
K	3[1] (K_2O)			3,0	-/2 (K+P)
Mg				1,5	
P	2[1] (P_2O_5)			0,7	-/2 (K+P)
N	3[1]				
Zn				0,05	
Heavy metals (mg/kg max)					
As	40	20/20		30	25/40
B				800	
Cd	1,5	5/8	5[a]/20	30	2,5/25
Crtot		150/250	100	100	300/300
Cr (VI)	2				
Cu		200/250		400	600/700
Hg	1		0,8	3	1,0/1,0
Ni	80	150/200	60	70	100/150
Pb	150	100/200	120/250[b]	300	100/150
Tl	1				
V				70	
Zn		1200/1500		7000	1500/4500

[1] Germany: only bottom ash may be used as a fertilizer; limits are not relevant for wood ash which is solely recycled to forest land. "K-fertilizer" should contain a minimum amount of 10 % K_2O, "Ca-fertilizer" should contain 15% CaO, "P-K fertilizer" should contain minimum amount of 2 % P_2O_5 and 3% K_2O and "N-P-K fertilizer" should contain minimum amount of 3 % N, 2 % P_2O_5 and 3% K_2O . "Nutrient-fertilizer" should contain minimum amounts of nutrients (B, Co, Cu, Fe, Mn, Mo, Zn).

[2] Austria: Class A/Class B: ashes which meet the limiting values of Class A may be applied without a chemical analysis of the soil, ashes with heavy metal contents between the limiting values of Class A and Class B may only be applied after a chemical analysis of the soil shows that the application of ashes is harmless in terms of heavy metal input.

[3] Denmark: left Cd limit for straw ash/right Cd limit for wood ash. a: for both straw ash and the mixture of straw ash and wood ash. b: for wood ash used in forestry

[4] Sweden: limits only valid for the application on forest soils.

[5] Finland: left values for application on agricultural soils (AGR) / right values for application on forest soils (FOR). The minimum value for nutrients used in forestry is 2 % (K + P) and 6 % Ca. For other uses, including agriculture, horticulture and landscaping, the only limit value is the one for neutralizing value, which should be at least 10% (Ca).

4.2.3 Occupational health and safety aspects

Occupational health and safety regulations have to be met. According to the Threshold Limit Value (TLV) list, fly ashes are classified as nuisance dust. This is similar to many other powders that are used in the building industry, such as cement and limestone filler.

When ashes are sold as a product in the EU, the producer needs to register the ashes according to REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals). REACH however is not applicable to waste. Several utilities and ash traders in Belgium, Finland, Germany, Poland, The Netherlands and other countries already have registered their hard coal ashes, lignite ashes, peat ashes, co-firing ashes and 100 % biomass ashes in 2010. As a follow-up to this registration procedure, safety information has been compiled and made available to downstream users of the ashes.

4.2.4 Environmental and sustainability aspects

Applicable environmental regulations on ash utilization relate to waste handling and classification, waste disposal, soil and water quality.

General guidelines exist regarding the management, monitoring, collection and treatment of waste, i.e. ashes. Within the EU, the Waste Framework Directive has recently come into force. This framework defines criteria on which to decide whether a residue is a by-product or when it is considered an end-of-waste product.

When land filling is carried out in the EU, it has to be done according to the regulations set in the Landfill Decree. This decree sets limiting values for concentrations of certain elements and components in the waste (i.e. ash) as well as in the leachate. In most cases, taxes need to be paid for each ton of waste disposed. In the Netherlands there is a landfill ban and fly ash disposal is not allowed. There may also exist a landfill ban or limitations for disposal of biodegradable or organic waste fractions. Such limitations will automatically make reuse of ashes compulsory in the country. Another practice is permanent storage under controlled conditions, as is the cased with fly ash from waste-to-energy plants.

Furthermore, ashes have to be classified according to the European Waste Catalogue whether it is hazardous waste or not. Hazardous waste may only be used by processing plants that have a special permit.

For utilization of ashes in civil engineering, national legislation applies. In the Netherlands, the National Decree on Soil Quality gives limits for leaching behavior for inorganic compounds and compositional requirements for organic compounds. In Germany, the application of ashes has to satisfy the LänderArbeitsgemeinschaft Abfall (LAGA), which is the German regulation for application of mineral by-products. This regulation sets limits on leaching behaviour. In Finland, the Government decree on recovery of certain wastes in earth construction is applicable. This decree limits the use of ashes to certain constructions (public roads, pavements, parking areas, sports ground, etc.).

Sustainability is a widely used term and compasses many aspects. In the Netherlands, CROW has developed a model to assess the sustainable use of materials in civil engineering (CROW, 2007).

Water management laws have no direct reference to the utilization of ashes but are relevant for the utilization of biomass ashes on agricultural and forest soil in terms of water protection areas (no application allowed).

4.2.5 Market Perception

Market perception is an important aspect for utilization of secondary materials. In fact there is a dynamic balance between waste and product perception. This balance can easily shift due to accidents and reactions of the media. If the perception is negatively influenced, market volume can decrease dramatically.

4.2.6 Sales price and market volume

The sales price is the result of many aspects like potential added value of the ash, ratio supply-demand of the ashes and the competitive products, fulfilling of regulations and the phase of the life cycle of the product.

4.3 Limitations and bottlenecks

Based on the application requirements listed in the previous sections, the IEA Bioenergy Task 32 country representatives were asked to list and prioritise limitations for improved ash utilization. An overview of the responses is given below:

Technical feasibility

Several utilization options are technically possible and were proven at least on lab-scale. The technical properties of the ash determine where and how it can be utilized. Even low quality ashes can be used as raw materials for some applications.

One issue relates to spreading the ashes as fertilizer. Ashes often do not meet the requirements of fertilizer spreading devices regarding particle size and dust formation. Therefore, ash pre-treatment (e.g. metal separation, milling screening, wetting) as well as the appropriate selection of a suitable spreading technology is necessary, if direct ash application on soils shall take place. The lack of application technologies optimized for biomass ash leads to problems at the interface between plant operators and farmers and during application regarding ash logistics and appropriate transport and spreading techniques.

Regulatory issues

Although regulations exist for the use of ashes in concrete or fertilizer in some countries, they often do not (fully) cope with the possibility of using biomass ashes.

An example is the EN-450 regulation for use of fly ash in cement. Only co-firing ashes up to 50% m/m (green) wood can fulfill the revised EN-450. A 100% biomass will not comply by definition.

Only very small fractions can be used as an additive in compost production in Austria which limits the utilization potential significantly. This is despite the results from several studies that indicate otherwise, only 2% of total wet weight are allowed, according to the Austrian Compost Ordinance.

Legislation for ash utilization as fertiliser is relatively strict in Finland. All biomass ashes do not fulfil the requirements of the Finnish fertiliser decree. In Germany, only some specific wood ashes can be used as fertilizer.

Lack of suitable legislation

The legislation on the utilization of biomass ashes for practical use as fertiliser is far from optimal. Only in some countries there are some (legally not binding) guidelines regarding the application of biomass ashes on agricultural and forest land, or as an additive in compost production.

This situation often leads to a complex approval procedures for the application of biomass ashes on soils which leads to delays, causing problems with potential users of the ash. Generally, the lack of sufficient legislation causes uncertainty for both plant operators and authorities.

Occupational health and safety aspects

In general, occupational health and safety aspects are not mentioned as main limitation for ash utilization. However, biomass ashes consist of fine particles and dust formation during transport and handling could be an issue. Proper prevention measures should be taken to avoid health risks related to exposure of workers to inhalable airborne dust.

Environmental and sustainability aspects

When ashes are used in agriculture or civil engineering applications it has to be proven that the application is environmentally safe. This particularly relates to the leaching behavior of the ash.

Market perception (image)

The market perception strongly relates to the fuel source from which the ash was formed. Wood ashes have a more positive perception compared to waste incineration ashes. Coal or co-firing ashes perception probably lies in between these two. Perception also depends on whether the ash is classified as a waste or as a by-product, where the latter has the more positive perception. The public may receive land spreading as a form of uncontrolled disposal of waste, if no clear guidelines or legal regulations are available.

Market volume

The relatively low market value of biomass derived ashes inhibits reuse activities or development of new applications.

Logistic problems (pre-treatment, storage, transport)

If the ashes are used as a fertilizing agent, usually large storage areas are required since the main part of the ash is often produced during the winter season whereas ash application usually takes place during spring and summer. Therefore, a logistic concept considering intermediate storage sites is necessary. When ash is to be used in infrastructural works it also has to be available in large quantities.

Lack of supply chains for ash utilization.

Ashes are produced from a large number of dispersed sites around a country. In many cases ashes are mixed and stored at intermediate sites by ash trading organizations. It is difficult to trace the ashes back to the origin, which would be a requirement for quality assurance.

Variation of ash quality

Ash quality and composition differs greatly between different plants. In many plants, the quality of the ash also varies over time. In co-firing plants, for instance, co-firing shares and the fossil fuels may change significantly, which leads a large variation in ash composition and ash quality (different qualities of fossil fuels like hard coal, lignite, peat are co-fired with different types of biomass like green wood, wood pellets, bark, waste wood, waste, sludges). But also in biomass only energy plants the quality of the fuel often changes over time (due to different fuel sources, seasonal variations, etc.), leading to changes in the ash quality. The different types of boilers used also cause differences in ash properties. Examples are the presence of bed material from the use of fluidized bed boilers and the higher shares of unburnt carbon from the use of smaller, less efficient heating systems.

Awareness, willingness, knowledge

Currently biomass ash is not always recognised as a secondary raw material with fertilising and liming properties, which leads sometimes to the resistance of authorities to approve biomass ash application on soils. The same is true regarding the technical suitability of ashes for civil engineering applications and concrete production. Many operators are not aware of the possibilities of ash utilization and/or lack the knowledge of proper ash treatment necessary for ash utilization. As a consequence, the ash produced does not meet the requirements for ash utilization and must therefore be disposed of.

Sales price

Considering the fertilising value of the ash based on actual fertiliser prices and the average nutrient contents as well as the nutrient availability, the potential value of biomass ashes as fertiliser is considerable [BIOS, 2009]. However, application of the ashes as fertilizer is typically hindered by the rather low perception of the ashes as well as the lack of knowledge of potential end-users of the ash. As a consequence and due to administrative barriers as well as logistic and technical problems ash utilization is often more expensive than its disposal in landfills. Upgrading biomass ashes by chemical or thermal processes (e.g.

sintering) is energy intensive and expensive and is usually not an option under current framework conditions.

5 HOW TO IMPROVE ASH UTILIZATION

The barriers for widespread ash utilization discussed above show that improvements and adjustments in different areas are required in order to further promote the utilization of biomass ashes. Improvements are required in research and development, logistics, ash quality, collaboration, marketing, regulations and policy.

5.1 Research and development

5.1.1 Current research

Currently, research projects in some of the participating countries are ongoing (see Appendix I), which address one or several of the bottlenecks mentioned in chapter 4.3.

Based on a comprehensive study performed by BIOS Bioenergiesysteme GmbH in Austria (Obernberger, 2009), the Austrian R&D project "Development of innovative processes for wood ash utilization" was initiated and started in December 2009. The project deals with the chemical and physical characterization of different wood ashes, the ash balances for different biomass combustion plants and the theoretical and practical investigation of different utilization technologies. Examples of utilization of wood ashes investigated are on short rotation coppice sites, as an additive to the composting process (Obernberger, 2010), as a binding material in road construction (Supancic, 2011) and as a building material in forest road construction.

In the Netherlands research has been carried out to identify bulk and niche applications of ashes from co-combustion, co-gasification and biomass combustion (Kiel et al., 2009). More information can be found on http://www.biomasscofiring.com.

In Sweden there is the Värmeforsk's Ash programme. The aim is to find the most environmentally friendly way of using all sorts of different non-coal ashes from fuel for heating and electricity boilers. More than 30 different companies are involved and several authorities; for example Swedish EPA, Swedish Energy Agency. More than 100 different projects are running from 2002-2011. More information can be found on http://www.varmeforsk.se/files/english/.

In Ireland, research is being carried out to examine the physical, chemical and ecotoxicological properties of wood ash and to investigate the potential sustainable use of the end product as a forestry fertilizer.

5.1.2 Further research needed

Research on ash utilization should continue on new utilization technologies (e.g. in soil stabilisation, road construction, building industry), and on the development of improved guidelines for proven utilization methods (like the utilization in compost production) as well as the preparation of new guidelines for new utilization technologies, in order to provide appropriate framework conditions for ash producers, end users and authorities. Preferably, such guidelines should be harmonized internationally.

Specific research topics to be extended in future include research into cheaper ways of upgrading biomass ashes, research into metal recovery and research into improving nutrients (e.g. phosphorus) availability for plants or separation of nutrients.

5.2 Logistics

An improvement of the process technology and logistics between the operator of the biomass energy or co-firing plant and the user of the ash regarding ash removal, treatment, storage and transport is required. Tailor made application techniques (especially for the utilization of ashes as a fertilizing agent) are needed in order to reduce costs and to increase the acceptance of ash as a valuable secondary raw material at the end-users. More detailed knowledge about the exact volumes of available ashes is also required, in order to explore new ways for utilization.

5.3 Ash quality

It is recommended to avoid mixing of different ash fractions and ashes from different fuels in power plants; however, this is not always possible. For example, in Finland biomass is usually co-fired with peat and in the Netherlands wood is co-fired with hard coal in variable shares varying from 5 to 30 % and intention to go higher up to 50 %. This means that fuels and portions of fuels are varying which affects on ash quality. Variation of quality (environmental and technical) hinders ash utilization and should be avoided.

If possible, significant changes in the fuel quality used in biomass energy plants should be avoided in order to keep ash quality as stable as possible. An application of standard fuels in standard furnaces would avoid extensive ash analyses and may simplify permit procedures. However, this simplification would require a change of current regulations and is also not always feasible, since changes in price and availability of fuels may require the change to other fuels.

5.4 Collaboration

There is lack of knowledge of the technical suitability of various ashes for various applications.A closer cooperation between bioenergy plants and other industries is required for developing, testing and introducing new biomass ash applications or biomass ash based products.

5.5 Marketing

Proven utilization technologies should be promoted by respective marketing programs to enhance the awareness of the value of biomass ash for various applications. This would increase the market, increase ash utilization and reduce costs, making ash utilization more favourable over disposal.

5.6 Regulations

A revision of existing and the initiation of new general legal guidelines for the utilization of biomass ash on federal and provincial level in many countries is necessary in order to establish legal certainty for operators and ash users for potential application technologies. For example, the possible use of biomass ash as a fertilizer or as ingredient for compost shall be incorporated in the respective national regulations.

One important task will be the preparation of guidelines based on the results of the R&D work. Although this document forms a start, experiences from different countries should be better compiled as a basis for international guidelines and internationally harmonized regulations. .

5.7 Policy

Besides the scientific and practical investigation of the utilization of biomass ashes and ashes from co-firing, authorities also need to be made aware of options for recycling biomass ashes in order to encourage changes to legislation and or technical guidelines, which would promote ash utilization.

On the long term, a harmonization of legislation and guidelines on the European level regarding ash utilization is recommended. This would lead to a bigger market for ash utilization and thus would promote more research and development on this field.

6 CONCLUSIONS

Several options exist or are possible for utilization of ashes. Coal and co-firing bottom ashes (for up to 20% (m/m) biomass/coal) have successfully been applied in road construction and as a concrete aggregate, replacing natural stone, while fly ashes from co-firing with up to 20% (m/m) biomass/coal are used as an additive in cement or as a concrete and asphalt filler.

A common application for bottom ashes or mixtures of bottom and coarse fly ashes from clean biomass fuels currently used is direct use as fertiliser on agricultural or forest soils. These ashes are also used as additives for compost production in Austria and as a liming agent for forest soils in Austria and Germany. Fly ashes are used as raw material in the cement and brick industry in a few countries. In some countries the ashes are used for grouting mines or used as asphalt or concrete filler. In Sweden some ashes are used as construction material for landfills. In many countries however, most of the ashes are still disposed.

Next to current applications, many new options for ash utilization are under development. Promising ways for biomass ash utilization in the future include the more widespread use in the building industry (e.g. cement clinker production, production of bricks), civil engineering (e.g. binding material for soil stabilization, landscape management) as well as the use as raw material for the production of synthetic aggregates, fertilizers or liming agents.

Although technical feasibility is usually not an issue, only a limited amount of biomass ashes is utilized in practice and a large part is still disposed of in many countries. The current study shows that the main reasons for this situation relate to environment, sustainability, low market volumes and differences and variations in ash quality. In addition, there are limitations in technical and regulatory regulations as well as logistics. General issues are also the lack of awareness, lack of knowledge and lack of willingness of plant operators, potential end-users and authorities alike to start or increase utilization.

In order to overcome the barriers for widespread ash utilization, improvements and adjustments are required in the following areas: Research and development, ash quality, logistics, collaboration, marketing, regulations and policy.

More research and development is needed on technical, ecological and economic evaluation and performance of field tests regarding new and innovative utilization technologies or ways of upgrading biomass ash.

Ash quality should be monitored to guarantee the satisfaction of criteria of its application field. If possible, significant changes in the fuel quality used in biomass energy plants should be avoided in order to keep ash quality as stable as possible.

Better logistical preparations between the operator of the biomass energy or co-firing plant and the user of the ash are required.

Closer cooperation between bioenergy plants and other industries is required for developing, testing and introducing new biomass ash applications or biomass ash based products.

Proven utilization technologies should be promoted to enhance the awareness of the value of biomass ash for various applications. This could increase the market, increase ash utilization and reduce costs, making ash utilization more favourable over disposal.

Regulations and technical standards should take into account and enable the use of biomass ashes. Intensification of the international exchange of know-how between European countries with the long-term goal to prepare a European guideline for ecologically and economically feasible utilization options for biomass ashes is required.

On the long term a harmonization of legislation and guidelines on the European or even global level regarding ash utilization is recommended. This would lead to a bigger market for ash utilization and thus would promote more research and development in this field.

REFERENCES

Davis R E, Kelly J W, Troxell G E, Davis H E (1935) Proportions of mortars and concretes containing Portland-pozzolan cements. ACI Journal; 33; 577-612 (1935)

Davis R E, Carlston R W, Kelly J W, Davis H E (1937) Properties of cements and concretes containing fly ash. ACI Journal; 33; 577-612 (1937)

Davis R E, Davis H E, Kelly J W (1941) Weathering resistance of concretes containing fly ash cements. Proc. American Concrete Institute; 37; 281-296 (1941)

ECN, 2004. Pels, J.R. et al. "Askwaliteit en toepassingsmogelijkheden bij verbranding van schone biomassa (BIOAS), ECN Report ECN-C—04-091, september 2004.

KEMA, 1998. Zekerstelling van kolenreststoffen. Fijnmazige selectie van toepassingsmogelijkheden. KEMA-rapport 98570110-KST/MAT 98-6608. In opdracht van COP.

Kiel J H A, Ciepilk M K, Pels J R, Van de Kamp W L, Saraber A, Van Eijk R J (2009) Biomass cofiring in high percentages - Dutch R&D consortium pushing the limits. Presented at: 4th International Conference on Clean Coal Technologies in conjunction with the 3rd International Freiberg Conference on IGCC & XtL Technologies, Dresden (18-21 May 2009)

Loo, S. van, and Koppejan, J. (2008). The handbook of biomass combustion and co-firing. Earthscan, UK, 2008.

Obernberger, I., Holzer, H., Ruckenbauer, P. (1996a) Zusammensetzung, Verwendungsmöglichkeiten und Umweltverträglichkeit von Aschen aus Biomassefeuerungen - Teil 1, "Der Förderungsdienst" - Heft 2, pp. 50-54, 1997, Bundesministerium für Land- und Forstwirtschaft (Hrsg.), Vienna, Austria

Obernberger, I., Holzner, H., Ruckenbauer, P. (1996b) Zusammensetzung, Verwendungsmöglichkeiten und Umweltverträglichkeit von Aschen aus Biomassefeuerungen - Teil 2, "Der Förderungsdienst" - Heft 3, pp. 86-92, 1997, Bundesministerium für Land- und Forstwirtschaft (Hrsg.), Vienna, Austria

Obernberger I, Supancic K (2009) Possibilities of ash utilisation from biomass combustion plants. In: Proceedings of the 17th European Biomass Conference & Exhibition, June 2009, Hamburg, ISBN 978-88-89407-57-3, pp. 2373 - 2384, ETA-Renewable Energies (Ed.), Italy

Obernberger, I, Supancic K (2010) Einsatz von Holzasche als Zuschlagsstoff in der Kompostierung - Empfehlungen für verfahrenstechnisch und ökologisch sinnvolle Zuschlagsmengen für Holzaschen in der Kompostierung, study within the collective research project „Entwicklung von innovativen Verfahren zur Holzascheverwertung“, Project-Nr.: 825675, of the Austrian Research Funding Agency (FFG), Graz, Austria

Saraber A J, Feuerborn H J, Berg van den J W (2009). Fly ash for concrete. CEN TC 104MIG 4 DOC 83-2009. Backgrounds to the revision of EN 450-1: 2005/A1:2007 and EN 450-2:2005 (May 2009)

Supancic K, Obernberger I (2011) Wood ash utilisation as a stabiliser in road construction – first results of large-scale tests. To be published in the proceedings of the 19th European Biomass Conference & Exhibition, June 2011, Berlin, Germany, ETA-Renewable Energies (Ed.), Italy

UKQAA, 2009. United Kingdom Ash Association. http://www.ukqaa.org.uk/

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APPENDIX I RESEARCH ACTIVITIES IN BIOMASS ASH UTILIZATION

Austria

Name of project 1
Development of innovative processes for wood ash utilization
Parties involved, location
Collective research project funded by the Austrian Research Funding Organisation (FFG) *Parties involved:* Trade association of the Austria Wood Industry, University of Natural Resources and Life Sciences, Vienna, BIOS BIOENERGIESYSTEME GmbH, Graz, Bioenergy 2020+ GmbH, Graz, Chamber of Agriculture for Styria, partner companies from the energy, wood processing, paper and construction industry; scientific head: Ingwald Obernberger (BIOS BIOENERGIESYSTEME GmbH, Inffeldgasse 21b, A-8010 Graz, Austria, Tel.: +43 316 481300 12, e-mail: obernberger@bios-bioenergy.at)
Description (goal, methods, results)
Goal/duration: Development of innovative and practical utilization technologies for wood ash in order to significantly decrease the amount of wood ashes in Austria that needs to be disposed of. The project started in December 2009 and will last until November 2013 *Methods:* Chemical and physical characterization of different wood ashes, calculation of ash balances for different biomass combustion plants. Theoretical (simulation of the composting process) and practical investigation (performance of lab-scale and field tests accompanied with comprehensive analyses) of different utilization technologies: • Utilisation of wood ashes on short rotation coppice sites • Utilisation of wood ashes as an additive to the composting process • Utilisation of wood ashes as a binding material in road construction • Utilisation of wood ashes as a building material in forest road construction Comprehensive technical, ecological and economical investigation of the complete process chain from the biomass plant to the point of utilization under special consideration of the intermediate storage of ashes. *Results:* The investigation of the utilization of wood ashes as an additive to the composting process has already been completed. The results show that the amount of wood ash as an additive to the composting process can be increased significantly compared to the current limits in the Austrian Compost Ordinance (from the current maximum of 2% (w/w, w.b.) to 8%(w/w, w.b.)), if certain limiting values of heavy metals in the ash applied can be met (OBERNBERGER, 2010).

First results of the investigations regarding forest road construction indicate that wood ashes are suitable as a building material for forest roads. Field tests with different ashes and different admixing ratios for the ashes are currently ongoing.

First results of the lab tests performed and ongoing field test regarding road construction show that wood ashes are suitable as a substitute for lime as a binding material for soil stabilization in road construction (SUPANCIC, 2011).

Further investigations are necessary and underway in order to analyze the long-term ecological impacts of these utilization technologies.
In addition, field tests investigating the impact of wood ash as a fertilizing and liming agent on the yield and heavy metal content of short rotation coppice are underway. The plants will be harvested in 2013, accompanied by comprehensive investigations and analyses regarding plant growth and yield, heavy metal uptake of the plants as well as chemical composition of soils and plants.

Based on the results of the lab-scale and field tests performed the technical, economical and ecological feasibility of the individual utilization technologies will be investigated.

Name of project 2
BIOTREAT-Wood ash
Parties involved, location
University of Innsbruck, partner companies from the energy and wood processing industry
Description (goal, methods, results)
Goal: Recycling of biomass ashes to the natural mineral cycle in order to substitute mineral fertilizers. *Methods:* Performance of lab-scale and field tests with biomass ash as an additive to the composting process as well as a fertilizing agent in combination with anaerobic sludge. Performance of field tests with wood ash amended composts on different acid soils in order to investigate the ameliorating potential of these composts. *Results:* Composts with wood ashes as an additive show, compared to compost without biomass ash, positive results on the yield of grass lands. Tests with wood ash amended composts in greenhouses with acid soil show that these composts can be used to ameliorate acid tropical soils. Further investigations are currently underway.

Denmark

Name of project 1
Electrodialytic upgrading of fly ash
Anticipated time schedule
2000 to 2013
Parties involved, location
DTU Civil Engineering, Lisbeth Ottosen
Description (goal, methods, results)
On-going R&D work on an electrodialytical method to separate trace elements in various types of ash.

Name of project 2
Chemical upgrading of biomass ashes
Anticipated time schedule
2011 (commercial)
Parties involved, location
Kommunekemi, Nyborg
Description (goal, methods, results).
Chemical treatment of ashes in order to separate nutrients from trace elements. Commercially available technology offered by Kommunekemi A/S, www.kommunekemi.dk, however at a relatively high cost pr. tonne.

Finland

Name of project 1
Recycling of Keljonlahti power plant ashes in Central Finland (ERDF-project)
Anticipated time schedule
1.6.2009 – 30.9.2011
Parties involved, location
Jyväskylä Energy Ltd, Vapo Ltd, HB Betoniteollisuus Ltd., FA Forest Ltd., Andament Ltd., Ultranat Ltd. and VTT Technical Research Centre of Finland
Description (goal, methods, results)
The goal of the project is to utilise peat-wood ashes of Keljonlahti power plant instead of land filling. Keljonlahti is a new, large (465 MW_{th}) CHP-plant and has CFB-boiler. About 40 000 tons of peat-wood fly ash and 10 000 tons of bottom ash are produced yearly.

Main research subjects are utilisation of ashes in concrete production, in civil engineering applications or as fertiliser products. Refining experiments are also performed to improve the suitability of ashes for recycling and to find new options for ash recycling.

Name of project 2
Granulation of ash in Northern Ostrobothnia (ERDF-project)
Anticipated time schedule
1.1.2011 – 31.8.2012
Parties involved, location
Finnish Forest Research Institute (METLA), Oulun autokuljetus, Laanilan voima, Oulun Energia, ProAgria
Description (goal, methods, results)
Aim of the project is to determine operational conditions for regional ash granulation plant.

Germany

Name of project 1
“Verwendung und Beseitigung von Holzaschen“
Anticipated time schedule
Ended 2009
Parties involved, location
Bayrisches Landesamt für Umwelt (LfU), Augsburg Bayerische Landesanstalt für Landwirtschaft (LfL), Freising Bayerische Landesanstalt für Wald- und Forstwirtschaft (LWF), Freising
Description (goal, methods, results)
Summary of the state of the art of the legislations/regulations in Bavaria. Contains also estimates about the amount of produced ashes.

Name of project 2
“Schwermetallbelastung erschwert Aschenutzung”
Anticipated time schedule
Published 01.10.2010

Parties involved, location
Dr. Rainer Schrägle
Description (goal, methods, results)
Contains the possible way of using bed ash as fertiliser

Name of project 3
"Organo-Asche-Presslinge als zukunftsorientiertes Düngemittel - Produktionsoptimierung, ernährungs-kundliches Potential und Machbarkeitsstudie"
Anticipated time schedule
01.02.2007 bis 30.06.2010
Parties involved, location
Dettendorfer Wertstoff GmbH & Co. KG, TUM Fachgebiet für Waldernährung und Wasserhaushalt
Description (goal, methods, results)
http://www.nachwachsenderohstoffe.de http://www.forst.tu-muenchen.de/EXT/LST/WAERN/Forschungsprojekte.html http://www.patent-de.com/20071108/DE102006019939A1.html

Ireland

Name of project 1
An investigation of the ecotoxicological and growth-promoting properties of clean non contaminated wood ash: from trees to energy to fertiliser?
Anticipated time schedule
Three Years Duration:
Parties involved, location
University College Cork (Professor John O Halloran)
Description (goal, methods, results)
The central aim of project is to examine the physical, chemical and ecotoxicological properties of wood ash and to investigate the potential sustainable use of the end product as a forestry fertiliser

The Netherlands

Name of project 1
EOS-LT Co-firing of biomass
Anticipated time schedule
2006-2011
Parties involved, location
KEMA, ECN, TU Delft. Financial support by Dutch government
Description (goal, methods, results)
Study on technical aspects of co-firing high shares of biomass with coal. Ash management issues, including application requirements and list of potential utilization options. Two cases studied in detail: synthetic aggregates and use of ash from cacao shells.

Norway

Name of project 1
CenBio (SP 1 WP1.4) – Bioenergy Innovation Centre
Anticipated time schedule
2009-2013/2016
Parties involved, location
Mainly Bioforsk Soil and Environment (Trond Haraldsen)
Description (goal, methods, results)
<u>Development of soil mixtures for indoor plants and green house</u> Aim: develop soil mixtures based on waste products which are better for plant growth and environmentally sustainable than products in the market. ► Compost replaces parts of the peat content ► **Bottom wood ash** is used for liming instead of lime from bedrock ► Used Filtralite instead of sand ► Poultry manure instead of mineral NPK-fertlizer Method: pot tests, experiments of various mixtures. <u>Raw materials for organic NPK fertilizer</u> ► **Bottom wood ash**: Ca, K, Mg, P and trace elements ► Meat and bone meal (MBM): N, P, Ca and minor amount of S, Mg and K Method: experiments with various mixtures. <u>Development of soil mixtures for urban greening with bottom ash</u> Experiments in 2011.

Name of project 2
NextGenBioWaste (EU project) SP3
Anticipated time schedule
2006-2010 (finished)
Parties involved, location
SINTEF (Norway), AVR (The Netherlands), VRD (Sweden), KEMA (the Netherlands)
Description (goal, methods, results)
- **MSWI ash** upgrading, stabilization and utilization (granular construction materials and shaped building products) - Ash composition and quality Sadly, this project target and most of the related activities were cancelled in 2007 due to regulatory changes in the Netherlands. However, several ash-related tasks did not stop and valuable results pertaining to ash treatment/stabilization methods and parameters controlling ash quality were obtained, especially concerning extended ageing, wet separation technology and relation between combustion conditions and leachability.

Sweden

Name of project 1
Environmentally friendly use of non-coal ashes More than 100 different projects. More information can be found on http://www.varmeforsk.se/files/english/
Anticipated time schedule
Research program running from 2002-2011
Parties involved, location
More than 30 different companies involved and several authorities; for example Swedish EPA, Swedish Energy Agency
Description (goal, methods, results)
The aim of Värmeforsk's Ash programme is to find the most environmentally friendly way of using all sorts of different non-coal ashes from fuel for heating and electricity boilers.