SOLID EMISSIONS FROM PROPOSED 18MWe STRAW AND WOOD-CHIP FIRED BIOMASS COMBINED HEAT AND POWER PLANT AT LEWISTOWN, NEWBRIDGE, COUNTY KILDARE

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1 INTRODUCTION

Organic Power Limited have developed a proposal for an 18MW electric straw – fuelled steam boiler with supplementary wood chip firing capacity for the production of electricity and heat at Lewistown, Newbridge, County Kildare. The ambition of this project is to produce carbon neutral energy which is not dependent on imported fuels, and in addition, can sequester carbon through the addition of char to agricultural soils.

The plant will combust the fuel to produce 50MW thermal energy in a high efficiency boiler (92.6%) to raise a head of steam of 46.3MW to produce 18MW electricity via a high-efficiency turbine and generator . Waste heat will be made available for industrial use in adjacent and nearby industrial sites.

The biomass fuel required to produce this energy will fall within the range of approximately 100,000 to 115,000 tonnes of straw per year assuming 15-30% moisture content. Straw may be supplemented by wood chip, to the combined fuel input levels of 90,000 tonnes of straw and 30,000 tonnes of woodchip assuming 15% and 50% moisture contents respectively.
The boiler is capable of taking only biomass fuels. Fuel is fed on to the firing grate in the boiler in 2 forms:

- Compressed bales of 1.2 x 1.2 x 2.4m dimensions, suitable for straw, and energy crop grasses such as switchgrass and miscanthus. These are fed into the boiler by conveyors and scarifiers.
- Chipped, suitable for forestry residues, fruit and nut husks, which are fed into the boiler by screw conveyors.

For the proposed plant, it is intended to use straw and wood chip as the fuels.

When combusted, biomass releases thermal energy, combustion flue gases, ash entrained in the flue gas i.e. fly ash, and bottom ash which falls from the grate. The purpose of this report is to identify, quantify, and describe the management of the solid emissions outputs of the plant which are classified as waste. Regulation covering the licensing of this management is presented, along with an outline of a waste management plan which would be included in the preparation of an IPPC application and waste license if required. Air emissions are dealt with in a separate report.

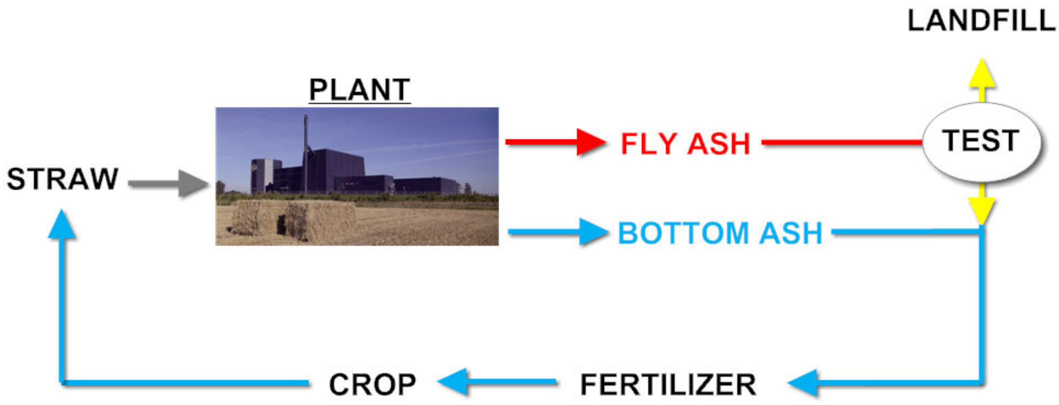
2 THE FUEL CYCLE

The proposed plant will be fuelled by straw, with potential for supplementary addition of wood chips. This fuel is a by-product of cereal production. Straw as a fuel is sourced from cereal producers on the basis of the following mutually beneficial relationship with the plant:

- Sale of straw to the energy plant provides an additional stable income stream based on contracts in advance based on a rolling 5 year average price, which contrasts positively with the highly variable commodity price which is paid for the primary cereal product.
- The solid emissions from the plant are separated into high carbon bottom ash, and high potassium fly ash, both of which can be used to improve the fertility of lands used for cereal production.
- The export of straw from the field has advantages to the farmer, by obviating the expense of chopping straw on the field without the nutrient losses associated if the farmer accepts straw ash from the plant to spread as fertiliser on the land.
- The addition of char in the ash to the soil improves soil texture and microflora.
- The supply of straw grown on lands fertilised with the fly ash results in lower chlorine content in the straw which reduces corrosion on the superheater pipes inside the plant.
- The cycle of straw purchase, fuel combustion, ash spreading and new straw production builds a strong relationship between the cereal producer and the plant.

Fly ash is only provided for land-spreading once tested to ensure acceptable levels of heavy metals. Thus there is no risk of land degradation from the use of ash by the cereal grower.

THE FUEL CYCLE FOR STRAW PLANTS

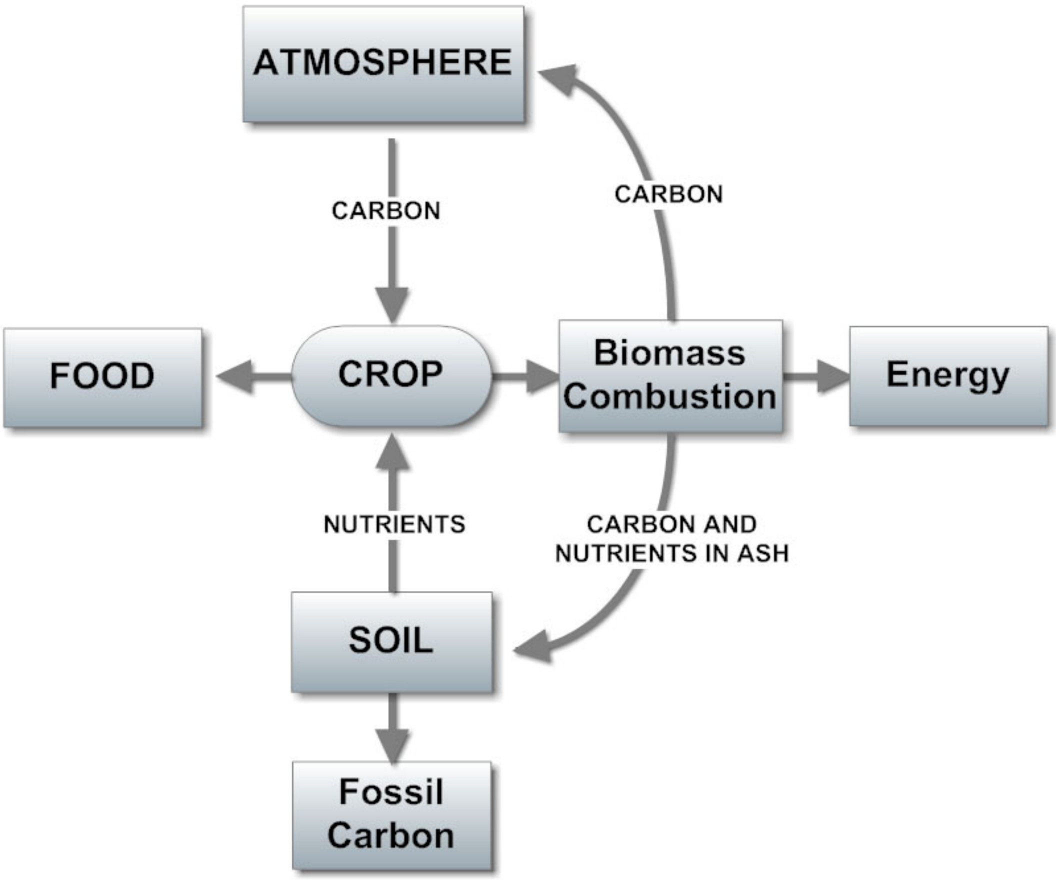


3 THE CARBON CYCLE

Energy production from thermal processes involving fuels is inextricably linked with the planetary Carbon Cycle. Simplistically put, fuels are generally complex hydrocarbons which are combusted or sintered into their elemental constituents to release thermal energy. As carbon is a major elemental constituent this process affects the Carbon Cycle. The energy contained in hydrocarbons employed as fuels is stored solar energy transformed by photosynthesis into biomass, which is further concentrated by geological metamorphosis over long periods into fossil fuels.

The premise of biomass fuelled plants is that they use biomass which contains fixed carbon which is actively part of the gaseous sequestration of atmospheric carbon rather than buried carbon which is removed from the cycle under natural conditions. This means that the release of energy from combustion of biomass rather than fossil hydrocarbons provides no net addition of atmospheric carbon, and thus it is neutral as a contributor to climate change. In addition, the burial of inert carbon char provided as soil additive to agricultural lands adds to the balance of fossil carbon, thus actively reducing the net balance of carbon in the atmosphere.

SCHEMATIC FIGURE SHOWING CARBON AND NUTRIENT FLOWS IN THE PRODUCTION OF FOOD AND STRAW BY-PRODUCT FROM CEREALS



4 CHARACTERISATION OF SOLID ASH EMISSIONS

4.1 Solid ash emissions type from the plant

There are 2 types of separate solid emissions from the plant i.e. bottom ash and fly ash. The classification of hazardous waste is regulated by the European Hazardous Waste Directive 91/689/EEC[1]. As a result of the directive, the European Waste Catalogue was produced, listing all wastes grouped according to industry, process, or waste type[1]. Ash from thermal processes is listed in the catalogue[1]. Ash from biofuels for use on forest or farmland belongs to the waste category "**EWC 10 01 01 Bottom ash, slag, and boiler dust"**, or "**EWC 10 01 03 Fly Ash from peat and untreated wood"** and is not listed as hazardous[1].

Many boilers need to be co-fired with oil at startup, at production peaks and sometimes due to insufficient biofuel quality[1]. Nordic GuidelineS (NT TECHN REPORT 613, 2008) suggest that the directive should be interpreted as ash containing less than 1% of oil fly ash and boiler dust should still be considered as 10 01 01 and 10 01 03 due to the relatively small amount of oil in the total fuel mix as well as the negligible impact of the oil ash on the properties of the biofuel ash[1]. However, the ash shall still be classified as hazardous wastes if it contains dangerous substances[1]. For the proposed plant, the co-firing fuel proposed is biomass derived biodiesel, thus obviating any confusion on the ash classification.

This means that the bottom ash and fly ash generated at the proposed plant shall only be regarded as hazardous, if the content of heavy metals is larger than stated in the permissions for the plant, assumed to be the IPPC license.

4.2 Description of solid emissions

Typical ash elemental data (major elements) for some industrial biomass materials are described in Table 1. These figures represent total ash, including both fly and bottom ashes. For the fuels potentially in question for the plant, see those highlighted in blue. Main biomass constituents are projected as either cereal straw entirely, or cereal straw supplemented with coniferous forestry residues.

Cereal straw typically has high levels of potassium, chlorine, and silica with moderate levels of phosphorous. The potassium and chlorine come mainly from chemical fertilizers containing KCl. Silica comes from the soil and is important for biomechanical properties of the straw. Phosphorous comes mainly from fertilizer also.

Table 1

Typical ash elemental data (major elements) for some industrial biomass materials[2]

Biomass Type (%, w/w, dry)	Coniferous forestry residue	SRC Willow	Cereal Straw	Oil seed rape straw	Miscanthus	Reed canary grass	Olive residue	Palm kernel	Poultry litter
Sulphur content	0.04	0.05	0.1	0.3	0.2	0.2	0.2	0.2	0.5
Chlorine content	0.01	0.03	0.4	0.5	0.2	0.6	0.2	0.1	-
Ash Content	2	2	5	5	4	6	7	4	13
Elemental analysis (mg/kg, dry basis)									
Al	-	-	50	50	-	-	1,500	750	600
Ca	5,000	5,000	4,000	15,000	2,000	3,500	6,000	3,000	20,000
Fe	-	100	100	100	100	-	900	2,500	900
K	2,000	3,000	10,000	10,000	7,000	12,000	23,000	3,000	21,000
Mg	800	500	700	700	600	1,300	2,000	3,000	5,000
Na	200	-	500	500	-	200	100	200	3,000
P	500	800	1,000	1,000	700	1,700	1,500	7,000	14,000
Si	3,000	-	10,000	1,000		12,000	5,000	3,000	9,000

4.2.1 Specification of solid emissions that will be produced by the plant

As set out by the Nordic Innovation Centre the specification of Ash, and recommended sampling analyses are as follows:

Fuels used for combustion/conversion	Cereal straw
	Coniferous forestry residue
Combustion conversion unit	Grate combustion
Type of Ash	EWC 10 01 01 bottom ash and slag
	EWC 10 01 03 fly ash
Ash properties (Content %, dry)	Sulphur, chlorine
Sampling procedures:	
Elemental analysis (Annually for bottom ash, and by batch for fly ash)	Al,Ca, Fe, K, Mg, Na, P, Si
Minor element analysis (By batch for fly ash)	Arsenic (As) Boron (B) Cadmium (Cd) Chromium (Cr) Copper (Cu) Mercury (Hg) Nickel (Ni) Lead (Pb) Vanadium (V) Zinc (Zn) Cesium Cs_{137}
Projected annual volumes bottom ash and slag, wet	9,760 m^3/year*
Projected weight bottom ash and slag (Dry weight basis)	9,760 tonnes/year*
Projected annual volumes fly ash	7,600 m^3/year*
Projected weight fly ash (Dry weight basis)	1,520 tonnes/year*

*Assuming 8,000 hours operation per year

4.2.2 Description of solid emissions that will be produced by the plant

According to Bioenergy Consultants ApS, who have designed the plant process, the plant will annually produce:

- 9,760 tonnes of wet bottom ash and slag per year[3]
- 1,520 tonnes dry fly ash per year[3]
- 11,280 tonnes total ash per year[3]

The 50 year lifetime tonnage of the plant solid emissions are projected as

- 488,000 tonnes of wet bottom ash and slag[3]
- 76,000 tonnes dry fly ash[3]
- 564,000 tonnes ash total [3]

The bottom ash is wet because it is deposited in the wet well of the boiler below the firing grate. The fly ash is dry because it is collected by deposition in fabric bag filters directly from the flue gasses.

Both ashes are destined for recovery and re-use as fertilizer, pending certification of fly ash suitable by batch analysis prior to consignment. This use is consistent with EU Waste Framework Directive (98/2008) as defined as follows:

"Recovery' in relation to waste, means any activity carried on for the purposes of reclaiming, recycling or re-using, in whole or in part, the waste and any activities related to such reclamation, recycling or re-use, including any of the activities specified in the Fourth Schedule of the Waste Management Acts, 1996 to 2008."

Further, in the context of the Waste Management Acts, the proposed activity relates to land improvement

"i.e. the deposition of waste for improvement or development of land, e.g. farmland reclamation, quarry restoration, construction foundations."

More particularly the purpose and reason for the deposition of ashes is the provision of nutrients and inert carbon to enhance the productivity of arable soils. The fly ash in particular will provide Low chlorine non-fossil fuel derived Potassium fertilizer.

The waste will be suitable as soil additive material, where certified as such under an IPPC license including a waste license carried out to specific standards. Such standards do not exist in Ireland, and should be defined in the IPPC process.

5 REGULATION ON THE USE OF ASH

National legislation exists in several European countries governing ash utilisation in forestry and agriculture. Relevant legislation is detailed below, by country, as extracted from *"Guideline for classification of ash from solid biofuels and peat utilised for recycling and fertilising in forestry and agriculture"*. 2008. Nordic Innovation Centre, Oslo, Norway

Country	Denmark	Finland	Finland	Sweden
Status	Legislation 2006	Legislation 2007	Legislation 2007	Recomendations draft 2007
Application	Agriculture/Forestry	Agriculture	Forestry	Forestry
Nutrients (minimum)	g/kg	g/kg	g/kg	g/kg
Calcium (Ca)		80	60	125
Potassium (K)		K+P 20	K+P 20	30
Magnesium (Mg)				15
Phosphorous (P)		K+P 20	K+P 20	7
Zinc (Zn)				0,5
Minor elements (maximum)	mg/kg	mg/kg	mg/kg	mg/kg
Arsenic (As)		25	30	30
Boron (B)				800
Cadmium (Cd)	5/15[a]	1,5	17,5	30
Chromium (Cr)	100	300	300	100
Copper (Cu)		600	700	400
Mercury (Hg)	0,8	1,0	1,0	3
Nickel (Ni)	30/60[b]	100	150	70
Lead (Pb)	120	100	150	300
Vanadium (V)				70
Zinc (Zn)		1500	4500	7000
Cesium Cs_{137}				0.5[c]

[a] Straw ash/Wood ash, [b] The limit is 30mg/kg. For values between 30-60 mg/kg there is a dosage limit. [c]Measured as kBq/kg ash applicable to agriculture land)

5.1 Denmark

Legislation for ash usage in forestry and agriculture is defined in BEK 1636 of 22 December 2006. Review in progress.

Only ashes from wood and straw are allowed to be utilised. Wood ash is only to be utilised in forestry and straw ash only in agriculture. Mixtures can be used on both types of land.

Maximum ash dose in agriculture is 5 tonne/ha per 5 year period. The ash dose in agriculture is also limited by cadmium content. Maximum cadmium load is 0.4-0.8g Cd/ha and year (0.8-1g/ha and year in the proposed update). The total dose of phosphorous shall not exceed 30kg/ha, year.

5.2 Finland

Legislation for ash usage in agriculture and forestry is defined in the following:

Fertiliser Product Act 539/2006

Ministry of Agriculture and Forestry Decree on fertiliser products 12/07

Ministry of Agriculture and Forestry Decree on the operations concerning fertiliser products and their supervision 13/07

Only wood, peat or agrobiomass ash is allowed as raw material for agroash and forest ash. Air pollution control (APC) residues are not allowed to be used as fertiliser products. Agroash regulation :

- Ash to be used as such as a fertiliser product
- To be used in agriculture, horticulture, landscaping, and forestry
- Minimum content of P&K 1% and at least 6% of Ca.
- Maximum content of Cl 2%.
- The maximum load of cadmium due to the use of fertiliser products must not exceed 1.5 grammes of cadmium per hectare per year.
- The maximum load of cadmium due to the use of fertiliser products as used in batches and periodic cycles of application may not exceed 6 grammes per hectare at an interval of four years.

5.3 IRELAND

No specific legislation regulates non-hazardous ash disposal in Ireland. On-site disposal of fly ash to landfill is encompassed by the Integrated Pollution Control Licensing process[4]. It is assumed that all emissions will be covered by this process.

5.3.1 Registration Requirement.

It is unclear whether the ashes qualify under Class 13 of wastes requiring registration with the local authority, regardless of threshold, as defined as

"Recovery of organic waste, other than manure and sludge when used in agriculture for the purposes of benefit to agriculture (including energy crops), silviculture or ecological improvement, where the total quantity of organic waste recovered at the facility shall not exceed 1,000 tonnes per annum".

in the third schedule, Part II of the

CONSOLIDATED WASTE MANAGEMENT (FACILITY AND REGISTRATION) REGULATIONS S.I 821 OF 2007 AND WASTE MANAGEMENT (FACILITY PERMIT AND REGISTRATION (AMENDMENT) REGULATIONS S.I 86 OF 2008

5.3.2 Article 11 classification

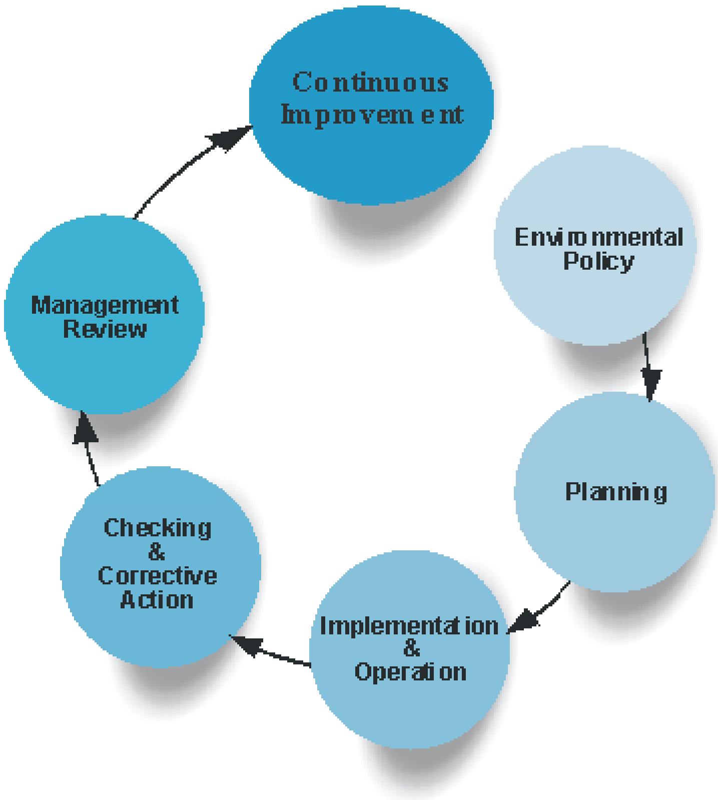
An article 11 application form for classification enquiry has been completed and sent to the EPA. It is argued by the promoters in this form that the ashes are non-hazardous wastes destined for recovery as fill for land improvement. No response has been received from the EPA as of writing. It is assumed that the classification will be non-hazardous waste and that its management will be subject to an application for an IPPC licence.

In summary with regard to Ireland's waste legislation and the proposed plant, and with particular regard to the regulation of the on-site storage, testing, certification for transport, certification for land spreading, transport, off-site storage, and land spreading as fertiliser and soil enhancer, it is expected that all of these will be licensed as part of the Integrated Pollution Prevention and Control process as monitored, inspected, and enforced by the Irish Environmental Protection Agency.

6 Waste Management (Ashes)

6.1 Environmental Management System

The management of the solid emissions output from the plant will be governed by a Waste Management Plan (WMP) which will be incorporated into the Environmental Management System (EMS), which will ensure compliance with licenses. It is assumed that this will be regulated as part of the IPPC process by the EPA. The basis of the EMS will be as outlined below:



6.2 Ash Management

6.2.1 Ash characteristics

Subject to the actual fuel quality fired, the operation of the biomass boiler will produce bottom ash and fly ash from the combustion of straw and wood chip, which are classified as waste by the EWC. The plant will generate 11,280 tonnes of ash per year approximately. This ash is elementally composed in declining fractions of carbon, potassium, silica, calcium, and phosphorous. The potassium is concentrated in the fly ash.

6.2.2 Waste recovery

The ash will be used as a means of inert carbon burial, and a non-fossil fuel derived fertilizer to provide nutrients to the soils where the fuel straw has been grown, thus returning some of the nutrients extracted by the crop to the soil. This has an added benefit in that the ash contains lower levels of chlorine than chemical fertilizer, which results in lower chlorine levels in the straw when combusted reducing corrosion potential in the boiler. Thus it is mutually beneficial for the plant operator, and the crop producer to use ash as fertilizer.

6.2.3 The waste recovery plan

The WMP shall include plans for recovery of ashes, and shall contain the following elements:

- Ashes will be transported off-site using trucks suitable for the purpose i.e. in such a manner that spillage of ashes or water is avoided.

- Wetted bottom ash is removed weekly from the site storage compound and transported in closed containers to 10 separate straw storage areas within 10km radius of straw producing lands for provision to farmers for land spreading, in the appropriate season. Bottom ash containers will be stored on a clause 804 covered hardcore base in sealed containers to avoid dust emissions, and container deterioration.

- Dry fly ash as produced during the combustion of a straw batch (straw from a single straw storage site), is stored at the plant in 1 tonne bags suitable for purpose until the batch cycle is completed. The bags are protected from rainfalls and surface waters. The fly ash is then tested for heavy metal content, and if levels are acceptable, it is transported (accompanied by a material Safety Data Sheet) to straw storage area in the 1 tonne bags where it will be stored covered by tarpaulin until provided for land spreading in the appropriate season on a concrete slab. If levels of heavy metal content are unacceptable the fly ash produced from the batch combustion will be land-filled in its entirety.

- The ash is land spread during the appropriate season in accordance with the applicable laws or ministerial guidelines by the farmers, who collect it from the straw storage areas. This results in the burial of char in the soil, which is an excellent substrate for microflora and encourages humus formation. Potassium, calcium, and phosphorous nutrients are also made available to the soil, while undesirable chlorine addition is reduced.

7 BENEFITS OF RECOVERY USE OF ASH FOR LAND SPREADING ON ARABLE LAND USED TO GROW CEREALS

7.1 Avoidance of use of landfill

If the 11,280 tonnes of ash are used as soil additive, this amount of land-fill will be avoided. In Denmark in particular, the benefits of use of ash to farmers is well accepted[6].

7.2 Carbon sequestration and burial of fossil carbon

The Lewistown CHP Biomass Plant will burn 84,320 tonnes/year of dry straw equivalent. Dry straw is 42% carbon. The carbon contained in the ash represents 20% of the carbon in the straw. This carbon is in an inert form and when applied to land as char will end up buried as fossil carbon.

0.2 x 0.42 x 84,320 = 7,083 tonnes carbon contained in ash,

C+O+O = 14+16+16 (Atomic weights)

so CO_2 = 46/14 x 7,083= 93,089 tonnes CO_2/yr

corresponding to carbon sequestration of 22,273 tonnes CO_2 per year.

7.3 Avoidance of use of mineral fertiliser

Mineral fertiliser is used to increase yields in cereal farming. The use of fertiliser can increase yields approximately fourfold, and the optimum application rate is 195kg/Ha[5]. Typical NPK ratios for cereal application are 42% : 18% :40%. The main active constituent in mineral fertiliser for cereal growth is nitrogen, with lesser contents of phosphorous and potassium. The ash from the plant will contain valuable levels of both P (1%) & K (10%). Approximately 30kg K/Ha is removed annually from the land in the straw[7].If used in conjunction with high nitrogen organic fertiliser, the combination of ash and organic slurry can effectively replace the use of mineral fertiliser in the production of cereals.

An example

If all the 1520 tonnes/year fly ash from the plant is used as soil additive, and K is used as the limiting nutrient for calculation purposes, and the ash contains 30kgK/tonne of ash, and a desired K application of 60kg K/HA is used, then approximately 760 hectares of wheat could be fertilised entirely for potassium with plant fly-ash. The required application rate of ash would be 2 tonnes/ha. Thus assuming 5 tonnes straw per hectare of wheat[7], 3800 tonnes of straw can be produced without the use of chemical K per year, or just under 4% of the plant's straw requirement.

7.5 In-cycle benefits in reducing chlorine content in boiler input fuel

Reducing the chlorine content of feedstocks grown for fuel purposes is important to improve combustion efficiencies[8].The use of fly ash as potassium fertiliser reduces the addition of chlorine to soils, and consequently reduces the chlorine in the crop. This has a benefit to the plant operation, in that low chlorine fuel is less corrosive in the firing chamber. Therefore there is a strong incentive for the plant operator to encourage the use of ash as fertiliser with the express intention of burning the low chlorine straw produced from the use of that fertiliser.

7.6 Savings in fuel consumption by avoiding the need to chop straw.

If straw is not baled for export as either fodder or fuel, it is chopped during harvest for return directly to the soil. Up to 50% of the straw in Ireland is chopped. Chopping has a cost of fuel associated. Up to 30% less fuel is used at harvest when straw in left in the swath, representing 25l/hr fuel consumption from chopping[7]. No chopping will free up extra combine capacity of about 20-25%, equivalent to 10Ha per day[7]. Chopper blades need to be replaced annually also at a cost of over €1,000 each[7].

8 CONCLUSION

With good planning, design and management of the entire bioelectricity production chain, it is usually possible to limit any negative environmental impacts to satisfactory levels [9].

Use of ash for land spreading is widely practised in Denmark which provides a comparator for best practice.

Although direct regulation of the spreading of straw plant ash is absent in Ireland, the IPPC licensing procedure can cover this activity, and it is recommended that reference to best practice in other countries is considered in the preparation of a management plan.

Solid emissions from straw burning power plants are non-hazardous waste that can be used advantageously as recycled nutrients and soil conditioner, diminishing the use of mineral fertiliser in cereal production.

Solid emissions from the plant can be used as carbon sequestration vehicle, fossilising 22,000 tonnes of CO_2 equivalent per year.

Efficiencies of cereal production can be increased by use of ash from the plant, through reduced mineral fertiliser use, reduced fuel use by avoiding chopping, and greater efficiency in the use of harvesting equipment through the avoidance of chopping time for machinery.

The use of ash as part of the bioelectricity supply chain, removes the need for landfill.

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