Memo

To	Jennifer Bailey
From	JBL
Date	30 May 2010
Project	Proposed Kildare Biomass CHP Plant
Project no.	OP16

Subject: Project Design Specifications and Emissions to Air Projections

Plant Data

The steam boiler plant at the Biomass CHP Plant shall be designed for the following performance data at 100 % load i.e. nominal load:

- Live steam temp ..... 540 C
- Live steam press ..... 90 bara
- Live steam flow ..... 18.6 kg/s
- Feed water temp ..... 230 C
- Net heat ..... 46.3 MW

During day-to-day operation and presumed solely straw firing at 15% moisture, the fuel consumption of the steam boiler plant at nominal load is expected to be:

- Calculated boiler efficiency ..... 92.6 %
- Fuel heat ..... 50 MW
- Lower heating value, average ..... 14.5 MJ/kg
- Fuel consumption, average..... 12.4 t/h

Minor variations in fuel consumption may be found and will mainly be due to variations in fuel quality and long-term degradation of the plant.

During day to day operation and presumed solely straw firing at 15% moisture, the electricity and heat outputs are expected for an above-average quality steam turbine, subject to heat balance calculations for the water/steam cycle, to be as follows:

- Gross power electricity output ……..... 18.0 MW
- Power for sale (Non CHP Mode) ……. 16.2 MW
- Power for sale (CHP Mode) ……. 13.8MW
- Heat produced (Non CHP Mode) ……. 27.6 MW
- Heat for sale (CHP Mode) …… 30.3 MW

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Fuel Types

Predominantly straw of the wheat type shall be utilised at the Biomass CHP Plant. However, straw from linseed rape as well as other straw types may be utilised.

If commercially viable, supplementary firing of clean wood or other bulk type fuels may be made. Operational experience shows that supplementary firing has a positive effect (less emissions) on the emissions from the plant, and may consequently be excluded from this analysis.

Flue Gas Data at Stack Outlet

At an excess air ratio at 1.30, the calculated flue gas data at the stack outlet are:

Load	**100 %**	**Dim.**
• Flue gas flow	24.1	kg/s
• Flue gas flow	67,100	Nm^3/h
• Flue gas temperature, approx.	135	C
• Density, wet	1.292	kg/Nm^3
• Density, dry	1.377	kg/Nm^3
• Dew point, water	53.6	C
• CO_2, wet	13.3	%-vol
• N_2, wet	67.2	%-vol
• H_2O, wet	14.5	%-vol
• O_2, wet	4.2	%-vol
• Ar, wet	0.8	%-vol
• CO_2, wet	20.2	%-mass
• N_2, wet	64.9	%-mass
• H_2O, wet	9.2	%-mass
• O_2, wet	4.6	%-mass
• Ar, wet	1.1	%-mass
• O_2, dry	4.88	%-vol

At reference conditions, 0 ^oC and 1,013 mbar, flue gas flow is:

• Flue gas flow, 6 % oxygen, dry	61,475	Nm^3/h
• Flue gas flow, 10 % oxygen, dry	83,830	Nm^3/h

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Emissions to Air

Compared to most other fuels types, straw fuel has a high content of alkali metals such as potassium and sodium, which capture some of the sulphur and chlorine in the ashes from the plant. Consequently, Danish CHP plants fuelled with biomass such as wood and straw are only provided with a fabric filter or electrostatic precipitator for removal of particulate matter.

At Danish CHP plants firing normal straw qualities i.e. containing 0.05-0.2 % (dry basis) sulphur and 0.2-0.7 % (dry basis) chlorine, the following emissions have been measured as 1-hour average values:

- Emission of SO_2, 10 % oxygen, dry..... 10-200 mg/Nm^3
- Emission of HCl, 10 % oxygen, dry ..... 10-130 mg/Nm^3

Converted to 6 % oxygen:

- Emission of SO_2, 6 % oxygen, dry..... 14-275 mg/Nm^3
- Emission of HCl, 6 % oxygen, dry ..... 14-180 mg/Nm^3

Peak values may be found- especially for HCl.

Emission of nitrogen oxide and carbon monoxide is strongly related to the quality of the combustion process. At Danish CHP plants firing normal straw qualities, the following emissions have been measured as 1-hour average values:

- Emission of NO_x, 10 % oxygen, dry..... 200-300 mg/Nm^3
- Emission of CO, 10 % oxygen, dry ..... 15-175 mg/Nm^3
- Emission of dust, 10 % oxygen, dry ..... <5 mg/Nm^3

Converted to 6 % oxygen:

- Emission of NO_x, 6 % oxygen, dry..... 270-410 mg/Nm^3
- Emission of CO, 6 % oxygen, dry ..... 20-240 mg/Nm^3
- Emission of dust, 6 % oxygen, dry ..... <7 mg/Nm^3

Estimated average monthly mass flows at sustained 100 % load are:

Substance	Emission [mg/Nm^3]	Flue gas flow [Nm^3/h]	Hours [h]	Amount [kg]
SO_2	200	61,475	720	8,852
HCl	150	61,475	720	6,640
NO_x	340	61,475	720	15,050
CO	100	61,475	720	4,426
Dust	2	61,475	720	89

These substances will be emitted to the atmosphere through a high stack.

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Notes:

1) NOx level to be guaranteed by the steam boiler supplier to comply with the EU Directive for large combustion plants and would be 400mg/Nm^3 at 6% oxygen, dry.

2) The emission of HCl originates from the content of Cl in the fuel. In Denmark, where the ground is old sea bottom, the Cl content in the soil is high and consequently in the straw too. This may be quite different in continental areas. Some of the Cl in the fuel will be transformed into salts by the content of potassium (Na and K) and end up in the fly ash. The content of potassium in the straw is also differing by origin. Hence, the capture of Cl (and S) in the fly ash is depending on the origin of the straw. In some reference plants in Denmark, low emissions of HCl have been observed despite the fact that the Cl content in the fuel is high.

Ash Produced By the Plant

The data below shows the estimates for the production of bottom ash and fly ash at 100 % load and firing 100 % straw of nominal quality. It is estimated that approx. 75 % of the total ash is transferred into bottom ash. This may, as well as the anticipated data, vary due to the actual straw quality and type fired.

Total ash

Fuel type	Nom.	-
Fuel flow at 100 % load, approx	12.4	t/h
Ash content, dry	6.6	%
Ash content, wet at 15 % moisture	5.6	%

Bottom ash

Bottom ash portion	75	%
Unburned	10	%
Water content	50	%
Water consumption, incl. 10 % for evaporation	0.64	t/h
Bottom ash flow, wet	1.22	t/h
Density, wet	1,000	kg/m^3
Bottom ash flow, wet	1.22	m^3/h

Intermediate storage:

Number of 14/10 (gross/net) m^3 containers per 24 h	2.9	pcs.
or		
Number of 37/26 (gross/net) m3 containers per 24 h	1.9	pcs.

Fly ash (excluding by-product from lime injection)

Fly ash portion	25	%
Unburned	10	%
Fly ash flow, dry	0.19	t/h
By-product from flue gas cleaning (estimated)	(to follow)	t/h
Density, dry	200	kg/m^3
Fly ash flow, dry	0.96	m^3/h

Intermediate storage:

Number of 2/1.6 (gross/net) m^3 bigbags per 24 h	15	pcs.

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Recommendations

First of all, it is recommended to select a proven firing technology for the Biomass CHP Plant for which good combustion quality shall be expected.

It is recommended, initially to provide the steam boiler plant with a fabric filter for removal of particulate matter i.e. dust.

Should the content of critical substances in the straw and other fuels exceed the expected, it is recommended to make provisions for a future retrofit of the following additional abatement technology:

- Provision for a SNCR system and 30-40 % reduction of NO_x may be expected.
- Provisions for dry injection of hydrated lime upstream the fabric filter and a reduction of SO_2 and HCl of 60-70 % may be expected.
- Provisions for dry injection of activated carbon upstream the fabric filter.

These provisions will not include large initial capital cost, but duly provisions are made for reducing emission levels and meeting future demands from the authorities.

However, it is recommended to await the operational experience with the Biomass CHP Plant, say for 1-1½ year after commissioning to see whether any of the mentioned additional initiatives for flue gas abatement is necessary. The reason for this suggestion is that by introducing hydrated lime, activated carbon and ammonia to the flue gas system, the fly ash may be regarded as a hazardous waste product for which no practical uses are found other than landfill or storage in long-term depots. By not introducing hydrated lime, activated carbon and ammonia to the flue gas system, the fly ash may potentially be returned to farmlands as a fertiliser.

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