E.ON’s Experiences of Methods for Measuring Biomass Purity of Mixed Fuels

Patrick Cook – 15th September 2009

Introduction

E.ON Engineering – specialist science and engineering consultancy

- Operational Support
- New Build
- Research Development and Innovation

Combustion and fuel technologies

- Coal, Oil, Gas
- Biomass, Wastes, Biogas, Syngas, Hydrogen

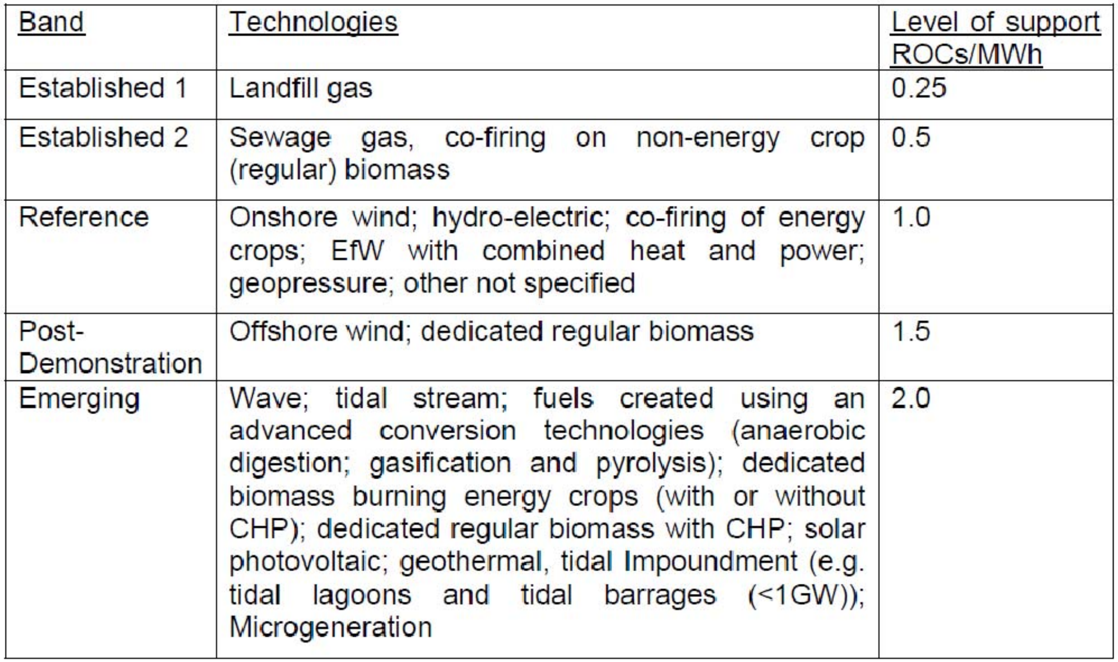
Summary

1. Renewables obligation
2. Biomass fuel sources
3. Biomass purity – Why is it important?
4. Experience of methods for purity measurement
    - Nitrogen marker
    - Carbon 14
    - Selective dissolution
5. Conclusions

The Renewables Obligation

Obligation to supply an increasing proportion of electricity from renewable sources

- 2008/2009 - 9.1%
- 2015/2016 - 15.4%
- ROC
- Buy out



Band	Technologies	Level of support ROCs/MWh
Established 1	Landfill gas	0.25
Established 2	Sewage gas, co-firing on non-energy crop (regular) biomass	0.5
Reference	Onshore wind; hydro-electric; co-firing of energy crops; EfW with combined heat and power; geopressure; other not specified	1.0
Post-Demonstration	Offshore wind; dedicated regular biomass	1.5
Emerging	Wave; tidal stream; fuels created using an advanced conversion technologies (anaerobic digestion; gasification and pyrolysis); dedicated biomass burning energy crops (with or without CHP); dedicated regular biomass with CHP; solar photovoltaic; geothermal, tidal Impoundment (e.g. tidal lagoons and tidal barrages (<1GW)); Microgeneration	2.0

Biomass Fuels

“Fresh Biomass”

- Wood chips
- Energy crops
- Agricultural/food processing residues

Pros

- 100% pure

Cons

- High costs
- Sustainability - food Vs fuel debate

Biomass Fuels

“Recovered Biomass”

- Waste wood
- Solid Recovered Fuel (SRF)
- Waste paper

Pros

- Low cost
- Sustainability?

Cons

- Fossil and metals contamination
- Perception

Biomass Purity

For the purpose of the Renewables Obligation, fuel will be considered “Biomass” if >90% of its energy content is derived from plant or animal matter.

The generator must develop a fuel measurement and sampling procedure which is able to prove this to the satisfaction of Ofgem.

For recovered biomass fuels there are two main challenges:

- Obtaining a representative sample
- Measurement of the fossil and biomass energy content

Nitrogen Marker – Stevens Croft

Stephens Croft Plant, Lockerbie

44MWe Bubbling Fluidised Bed commissioned in 2008

Fuels

- Forestry residues
- Short Rotation Coppice (Willow)
- Waste wood

FMS Procedure

- Hand Picking (plastics , paint, varnish)
- Nitrogen measurement

Nitrogen Marker – Stevens Croft

Waste wood contaminants

- Inerts
- Discreet fossil contaminants (plastics, paint, varnish) hand picked
- Resin binder for chipboard and MDF

Nitrogen Contents:

Clean wood - 0.17% (ar)

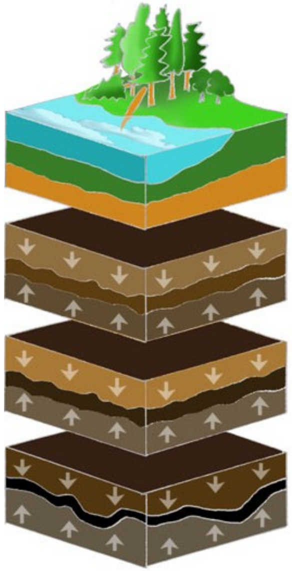
Urea formaldehyde resin – 39% (ar)

$$W_{resin} = 100(N_{total} - N_{wood})/(N_{resin} - N_{wood})$$

Carbon 14

Radio carbon dating of CO_2 produced during combustion

- Measures the ratio of C14 to C12 in the sample
- Known proportion of atmospheric carbon is C14, fossil carbon is all C12
- Comparison of C14 to atmospheric baseline determines fossil/biomass ratio
- ASTM-D 6866 +/- 3%



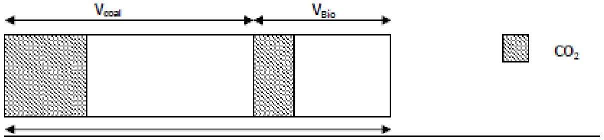
Advantages

- Can theoretically sample flue gas

Drawbacks

- Complex and expensive technique
- Sampling logistics
- Provides a ratio of biomass to fossil carbon only

Carbon 14



V_{sample} - Sample flue gas volume

V_{Total} – Total flue gas volume

V_{Coal} – Coal derived flue gas volume

V_{Bio} – Biomass derived flue gas volume

F_{Coal} – Flue gas volume per tonne coal burned

F_{Bio} – Flue gas volume per tonne biomass burned

K_{Coal} – Coal flue gas carbon dioxide content factor

K_{Bio} – Biomass flue gas carbon dioxide content factor

VC_{Coal} – Volume of coal derived CO_2 within sample

VC_{Bio} – Volume of biomass derived CO_2 within sample

β – Ratio of biomass to fossil carbon

$$V_{Sample} = V_{Coal} + V_{Bio} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.$$

$$\beta = \frac{VC_{Coal}}{VC_{Bio}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.$$

Since $V_{coal} = VC_{coal}K_{coal}$ and $V_{bio} = VC_{Bio}K_{Bio}$

Hence from equation 1, we have $V_{Sample} = VC_{coal}K_{coal} + VC_{Bio}K_{Bio}$ ……… 3.

Using equation 2, $VC_{coal} = \beta VC_{Bio}$ which substituted into equation 3 leads to the result

$$\beta VC_{Bio}K_{coal} + VC_{Bio}K_{Bio} = V_{Sample}$$

$$VC_{Bio}(\beta K_{coal} + K_{Bio}) = V_{Sample}$$

$$VC_{Bio} = \frac{V_{Sample}}{(\beta K_{Coal} + K_{Bio})}$$ From as $V_{bio} = VC_{Bio}K_{Bio}$ therefore $VC_{Bio} = \frac{V_{Bio}}{K_{Bio}}$

Hence, $V_{Bio} = \frac{K_{Bio}V_{Sample}}{(\beta K_{Coal} + K_{Bio})}$

$$Mass_{Bio} = \frac{V_{Bio}}{F_{Bio}}$$

$$= \frac{K_{Bio}V_{Sample}}{(\beta K_{Coal} + K_{Bio})F_{Bio}}$$

$$\text{Biomass heat input} = \frac{K_{Bio}V_{Sample}CV_{Bio}}{(\beta K_{Coal} + K_{Bio})F_{Bio}}$$

From equation 1,

$$V_{Coal} = V_{Sample} - \left(\frac{K_{Bio}V_{Sample}}{(\beta K_{Coal} + K_{Bio})}\right) = V_{Sample}\left(1 - \frac{K_{Bio}}{(\beta K_{Coal} + K_{Bio})}\right)$$

$$\text{Coal heat input} = V_{Sample}\left(1 - \frac{K_{Bio}}{(\beta K_{Coal} + K_{Bio})}\right) \times \frac{CV_{Coal}}{F_{coal}}$$

$$\text{Biomass generation} = \frac{\text{Biomass Heat Input}}{\text{Coal Heat Input} + \text{Biomass Heat input}} \times \text{Total generation}$$

$$= \frac{\frac{K_{Bio}V_{Sample}CV_{Bio}}{(\beta K_{Coal} + K_{Bio})F_{Bio}}}{V_{Sample}\left(1 - \frac{K_{Bio}}{(\beta K_{Coal} + K_{Bio})}\right) \times \frac{CV_{Coal}}{F_{coal}} + \frac{K_{Bio}V_{Sample}CV_{Bio}}{(\beta K_{Coal} + K_{Bio})F_{Bio}}} \times \text{Total generation}$$

Carbon 14

Selective Dissolution

Dissolution and oxidation of biomass using concentrated sulphuric acid and hydrogen peroxide

- Chemically removes biomass from the mixed fuel
- Calorific value of the fossil residue is measured
- Calorific value of the bulk fuel is measured
- Biomass content by CV can be calculated

Advantages

- Suitable for mixed fuels with small particle size

Drawbacks

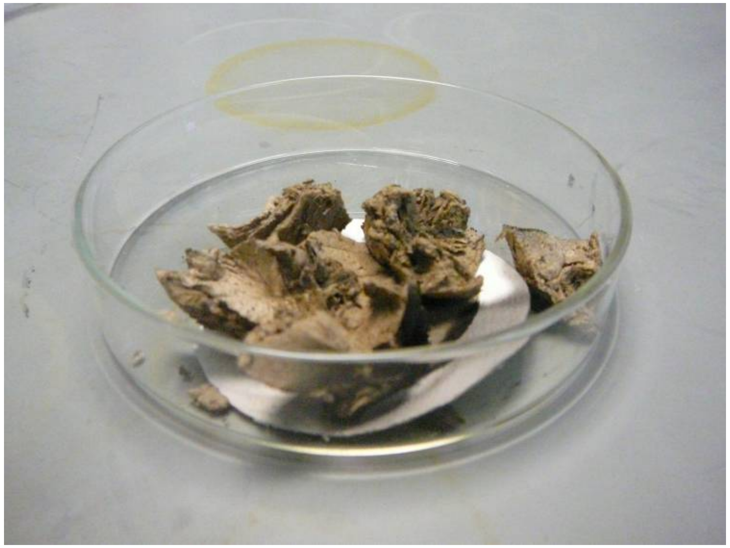
- Some fossil materials are also dissolved

Selective Dissolution

CEN TS/15440 – Sets out the analytical procedure

In house testing produced inconclusive results

- Acid strength? w/w v/v
- Volume of acid?
- Volume of peroxide?
- Mistake in the draft standard
  - Inconsistent notation
  - Double counting of ash



Conclusions

- Being able to accurately measure biomass purity is fundamental to the viability of biomass power projects
- Biomass purity is easiest to measure for carefully controlled and well defined feedstock mixes
- Waste derived fuels present much more of a challenge
- Selective dissolution appears to be most promising but requires validation by hand picking
- Carbon 14 is not believed viable for highly mixed fuels of uncertain composition BUT – if subsidies ever moved to MWh_{gen}/Tonne fossil carbon basis C14 would be ideal