360ECO

Opportunities for waste management

Martin Kay

PITA/CPI BAT Workshop 29th Jan 2015

Content

- *BREF – Pressures and drivers for reducing solid waste and improving waste management*
- *Sources of waste and waste profiles*
- *Emerging technologies*
- *Conclusions*




360ECO - Areas of expertise

- Effluent treatment plant optimisation studies (aeration efficiency, chemical fate, microbiological status and toxicity assessment, evaluation of new monitoring techniques)
- Technology scouting – clean technologies, emerging effluent treatment and recycling technologies, monitoring and control, new packaging concepts (barrier, shelf life extension, light weighting, recycled content, thermoforming, bioplastics etc)
- Assessment of UK magazine recycling rates
- EU Ecolabel – tissue, printed paper and copying and graphic paper
- Training – sustainable packaging, new technologies, BAT
- 20 years experience in industrial microbiology, recycling research, and supply chain investigations (eg damage, shelf life extension)
- Collaborative research with universities including gasification and pyrolysis, advanced light weight materials, food shelf-life extending anti-microbials
- Strategic WRAP projects to reduce food waste; recover food grade PP
- Carbon foot-printing, Environmental Product Declarations

360ECO

Environmental solutions for paper, packaging and print

- Filamentous bulking control in the P&B industry 2002 to 2005
- Advanced process control for liner and flute- 2004 to 2006
- MBR treatments of P&B waste waters 2005 to 2007
- Environmental solutions - benchmarking ETP performance and water quality, 2000 to 2009
- Bioplastics roadmap – 2008 to 2010
- Print and packaging strategy –T&T - 2010
- Sustainable food packaging training programme, DARD NI, 2009 to 2011
- Shelf life extension-meeting the unmet needs of the food industry -2011
- UK magazine recycling rate survey – 2006 to *present*
- EU Ecolabel tissue, printed paper and copier and graphic grades -2008 to *present*
- Sustainable energy from P&B residues-2010 to 2012 (PhD Case award)
- AD of papermill sludge - 2012 to *present*
- Paper ash for advanced building materials – 2012 to 2015 (PhD Case award)
- Global packaging waste scenarios - 2013
- Machine readable inks for food grade PP recycling -2014
- Optimising aeration energy for ASP's- *present*
- Thermochromic inks for food waste reduction - *present*
- Developing commercial routes for a novel anti-microbial within paperboard packaging-*present*

PEER-REVIEWED | **BIOENERGY**

Waste to power

MILOUD OUADI, JOHN BRAMMER, ANDREAS HORNUNG, AND MARTIN KAY

ABSTRACT: There has been a growing trend towards the use of biomass as a primary energy source, which now contributes over 54% of the European pulp and paper industry energy needs [1]. The remaining part comes from natural gas, which to a large extent serves as the major source of energy for numerous recovered fiber paper mills located in regions with limited available forest resources. The cost of producing electricity to drive paper machinery and generate heat for steam is increasing as world demand for fossil fuels increases. Additionally, recovered fiber paper mills are also significant producers of fibrous sludge and reject waste material that can contain high amounts of useful energy.

Currently, a majority of these waste fractions is disposed of by landspreading, incineration, or landfill. Paper mills must also pay a gate fee to process their waste streams in this way and the result of this is a further increase in operating costs. This work has developed methods to utilize the waste fractions produced at recovered fiber paper mills for the onsite production of combined heat and power (CHP) using advanced thermal conversion methods (pyrolysis and gasification) that are well suited to relatively small scales of throughput. The electrical power created would either be used onsite to power the paper making process or alternatively exported to the national grid, and the surplus heat created could also be used onsite or exported to a local customer. The focus of this paper is to give a general overview of the project progress so far and will present the experimental results of the most successful thermal conversion trials carried out by this work to date.

Application: The research provides both paper mills and energy providers with methodologies to condition their waste materials for conversion into useful energy. The research also opens up new markets for gasifier and pyrolysis equipment manufacturers and suppliers.

Every day, the world consumes vast quantities of energy from fossil fuels. This is now placing immense pressure on our planet's natural resources, and the CO_2 produced from the combustion of fossil fuels is widely believed to be the principal cause of climate change. Furthermore, there are increasing concerns over the price and security of supply of petroleum and natural gas. Therefore, any attempt to decrease the demand for fossil fuel reserves is considered to be beneficial.

The paper industry is a significant user of energy in the form of electricity and heat to power machinery and to dry paper sheets. According to the UK Department of Energy and Climate Change [2], in 2008 the pulp and paper industry within the UK was ranked 19th out of the 93 highest fuel consuming industrial sectors, and consumed a crude oil equivalent of 1.8 million metric tons. Furthermore, the total energy input at UK-based paper mills accounts for approximately 13% of operational costs [3]. As the cost for producing this energy increases year upon year, many UK-based paper mills are finding it increasingly difficult to remain profitable, and this has led to the closure of lower tonnage operations that manufacture commodity grade paper and board products. It is extremely difficult to reduce the high energy demand from this industry without compromising the rate of production and quality of the papermaking process itself. There is therefore increasing interest in alternative lower cost methods of providing the energy.

In recent years, there have been significant efforts by paper manufacturers to make their process more sustainable by increasing the use of recycled paper and board (recovered fiber) as a feedstock. The amount of recovered paper used by UK paper mills as a proportion of their total output stands at approximately 72%, which is a figure believed to be close to the maximum achievable [3]. However, the use of recovered fiber feedstocks results in large volumes of wastes such as rejected plastics, fibers and other coarse materials, "stickies" (adhesive residues), and, in the case of newsprint and tissue mills, deinking sludge (mainly fibers, minerals, and ink). Up until now, these have been disposed of by landspreading or incineration (combustion) [4].

Landfilling of biogenic waste in the UK is fast becoming an unacceptable method of disposal and in some countries, such as Germany and the Netherlands, the disposal of certain types of paper mill wastes in this way has already been banned [5]. Furthermore, landfilling costs are increasing year over year, making this disposal method less feasible economically. Some paper mills have tried to reduce this cost by landspreading a proportion of their sludge [5-7], or by supplying deinking sludge for further processing to become cattle bedding.

A small number of the larger mills (>400000 tpy) incinerate and therefore reduce the volume of their waste. However, due to the low calorific value of some waste fractions, such as deinking sludge (typically 4-7 MJ/kg), autonomous combustion systems cannot be sustained on this fuel alone; therefore,

Materials Letters 142 (2015) 80–83

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/matlet

A simple method for preparing super-hydrophobic powder from paper sludge ash

Charikleia Spathi [a], Neale Young [a], Jerry Y.Y. Heng [b], Luc J.M. Vandeperre [c], Chris R. Cheeseman [a,*]

[a] Department of Civil and Environmental Engineering, Imperial College London, Skempton Building, South Kensington Campus, SW72AZ, London, UK
[b] Department of Chemical Engineering, Imperial College London, Skempton Building, South Kensington Campus, SW72AZ, London, UK
[c] Department of Materials, Imperial College London, South Kensington Campus, London SW72AZ, UK

ARTICLE INFO

Article history:
Received 20 August 2014
Accepted 22 November 2014
Available online 29 November 2014

Keywords:
Biomimetic
Functional
Powder technology
Surfaces
Hydrophobic

ABSTRACT

Paper sludge ash (PSA) is a readily available waste material generated by the paper recycling industry. This work reports on the production of hydrophobic powders by dry milling PSA in the presence of a fatty acid surface functionalising agent. Optimum laboratory processing involves dry milling for 8 h with a 4 wt.% addition of stearic acid and this produced a super-hydrophobic powder with a water contact angle of 153°. Different chain length fatty acids were investigated but stearic acid produced the highest hydrophobicity. The super-hydrophobicity of PSA results from the micro-particulate texture induced by dry milling with simultaneous formation of calcium stearate self-assembling surface monolayers chemically bonded to fracture surfaces.

1. Introduction

The European pulp and paper industry generates ~7.7 million tonnes per year of paper sludge [1]. Dewatered paper sludge is often combusted to reduce the amount of material requiring disposal and this produces paper sludge ash (PSA). Currently ~125 ktonnes of PSA are produced each year in the UK and this is a fine, highly alkaline (pH > 12) powder with moisture content less than 0.1% w/w [2,3]. Approximately 70% of UK PSA is used in low-value applications such as land spreading where it neutralises acid soils [4]. Other uses include as a cattle bedding material and as an additive in waste effluent neutralisation processes. PSA has also been investigated as a potential hydraulic concrete admixture, although the porous PSA particles increase water demand and excess free lime causes durability problems [3,5,6]. There are increasing legislative, economic and social drivers for the development of higher value reuse applications for PSA [2,7].

Hydrophobicity is widely exploited in biological systems as in the self-cleaning mechanism used by super-hydrophobic leaves [8,9]. Water droplets remove particles and pathogens from the leaf, resulting in greater resilience to chemical and biological damage. This effect could provide considerable advantages in many engineering applications. For example, low cost hydrophobic coatings that produce self-cleaning building facades resistant to bio-deterioration, algal growth and general soiling would have significant advantages [10]. Other important uses for hydrophobic coatings include bio-fouling-resistant ship hulls and marine infrastructure, anti-icing surfaces and corrosion-resistance applications.

PSA has been dry milled in the presence of stearic acid in experiments designed to investigate the use of PSA as a bloating agent in sintered glass products [11]. This produced a hydrophobic powder that could not be formed into pellets when subsequently mixed with water. The optimisation of this effect is reported, with hydrophobicity assessed by measuring the water contact angle (WCA) and the interaction between PSA and stearic acid studied using Fourier transform infrared spectroscopy (FTIR).

2. Experimental

Paper sludge ash was obtained from a major newsprint recycling company operating in Southern England (Aylesford Newsprint Ltd). This facility produces 400,000 t per year of recycled newsprint from 500,000 t of waste paper fibre and produces ~70 ktonnes of PSA. The chemical composition of PSA was determined by X-ray fluorescence spectroscopy (XRF, Spectro 2000 Analyser) and the mineralogical composition of PSA was determined by X-ray diffraction (XRD, Philips PW 1830 diffractometer system) using 40 mA and 40 kV, Cu radiation.

The surface functionalising agents (SFAs) used to produce hydrophobicity were the saturated fatty acids capric acid ($CH_3(CH_2)_8COOH$), myristic acid ($CH_3(CH_2)_{12}COOH$), stearic acid ($CH_3(CH_2)_{16}COOH$) and behenic acid ($CH_3(CH_2)_{20}COOH$). Laboratory production of hydrophobic powders involved dry ball milling 500 g batches of PSA in the

* Corresponding author. Tel.: +44 20 75945971.
E-mail address: c.cheeseman@imperial.ac.uk (C.R. Cheeseman).

Fibre quality and sources of rejects

Fibre quality is changing:

- Growth of co-mingled collection ~ 96% of UK households now have kerbside collection (single source or co-mingled)
- Growth in use of mixed paper grades (hard and soft mix)
- MRF's unable to remove contaminants
- Rejects carried forward to mills
- Papers may comprise ~45% fillers, coatings and non fibrous substances

Contamination is not unique to the paper sector

Where is the food grade PP?

Sources of paper mill residues

	Recovered paper grade	Total losses %	Course heavy	Fine/light	Deinking	Primary settlement	Secondary (wasted) sludge
Graphic grades	Newspaper, magazine	15 to 20	1 to 2	3 to 5	8 to 13	2 to 5	~1
Test Liner and flute	OCC/mixed papers	4 to 9	1 to 2	3 to 6	NA	0 to 1	~1
Tissue	Mixed office waste	28 to 40	1 to 2	3 to 5	8 to 13	15 to 25	~1

	Example Production (t/y)	Total losses (t/y)	Course heavy (t/y)	Fine/light (t/y)	Deinking (t/y)	Primary settlement (t/y)	Secondary (wasted) sludge (t/y)
Graphic grades	400,000	60,000-80,000	4,000-8,000	12,000-20,000	32,000-52,000	8,000	4,000
Test Liner and flute	500,000	20,000-45,000	5,000-10,000	15,000-30,000	NA	0-5,000	5,000
Tissue	40,000	11,200-16,000	400-800	1,200-2,000	3,200-5,200	6,000-10,000	400

Composition of 'typical' sludge and rejects

	Dry solids %	Organic matter %	Inorganic %	Content	Energy MJ/t(wet)	Energy MJ/t (dry)
Primary sludge	50	40	60	Fibres, filler, coating clay, calcium carbonate	2,690	
Secondary sludge	40-50	50	50	Calcium carbonate, microorganisms, fibres	4,000-5,000	
Deinking sludge	56	50	50	Fibres, calcium carbonate, ink, kaolin	3,000	7,000[1]
Coarse rejects	55	92	8	Fibres, wet strength paper, plastics	12,000	22,900[1] /23,800[2]
Screen rejects	55	90	10	Fibres, plastics, stickies	8,000	

1 Waste to power – Quadi *et al* 2012. Tappi Journal, Feb, Vol 11, No2
2 BREF 2014

BAT Conclusion 12 – waste management

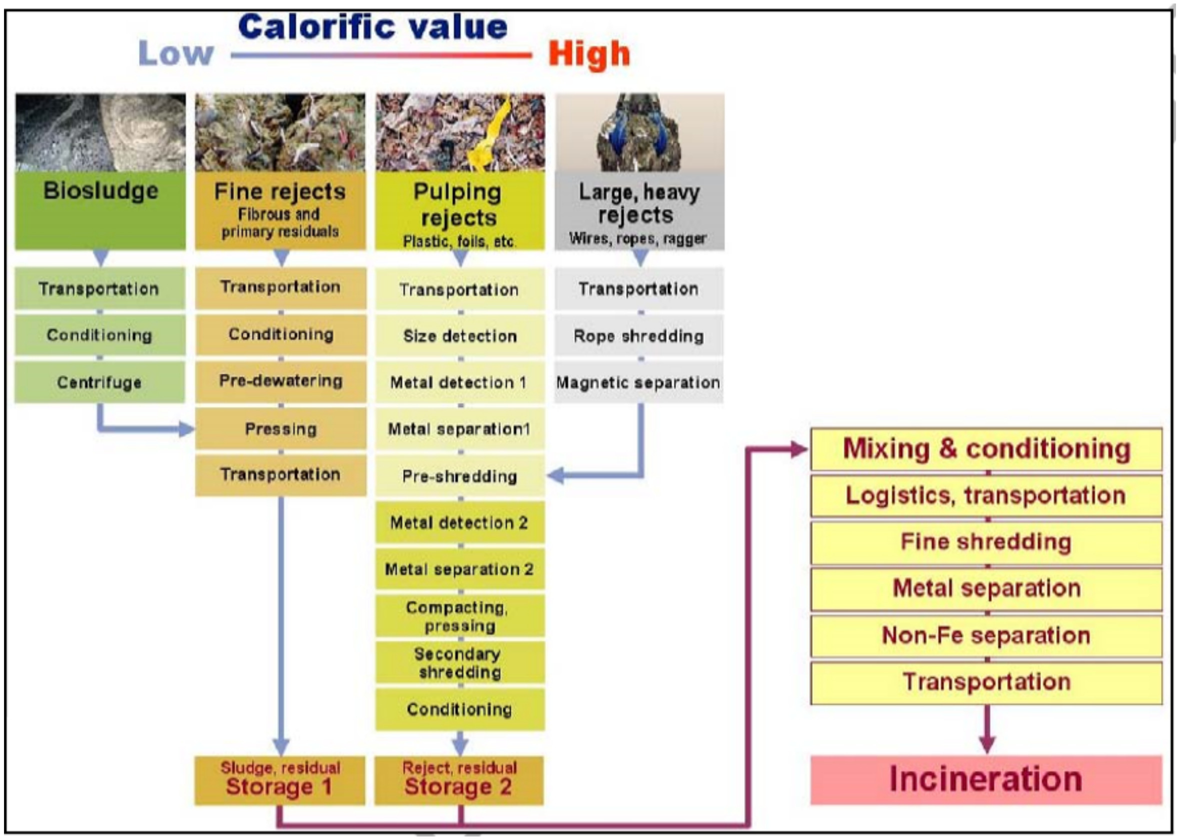
*'**In order to reduce the quantities of wastes sent to landfill**, BAT is to implement a waste assessment (including waste inventories) and management system so as to facilitate: **waste reuse** (or failing that), **waste recycling** (or failing that), **other recovery**, including a combination techniques given below'*

	Technique	Applicability
A	Separate collection of different waste fractions (including separation and classification of hazardous waste	Generally applicable
B	Merging suitable fractions of residues to obtain mixtures that can be better utilised	Generally applicable
C	Pre-treatment of process residues before reuse or recycling	Generally applicable
D	Material recovery and recycling of process residues on site	Generally applicable
E	Energy recovery on – or – off site from wastes with high organic content	For off site utilisation the applicability depends on the availability of a third party
F	External material utilisation	Depending on the availability of a third party
G	Pre-treatment of waste before disposal	Generally application

FEEDSTOCK STRATEGY (A–C)

END USE (D–F)

BAT Conclusion 12 is a feedstock strategy to meet end use (r) needs



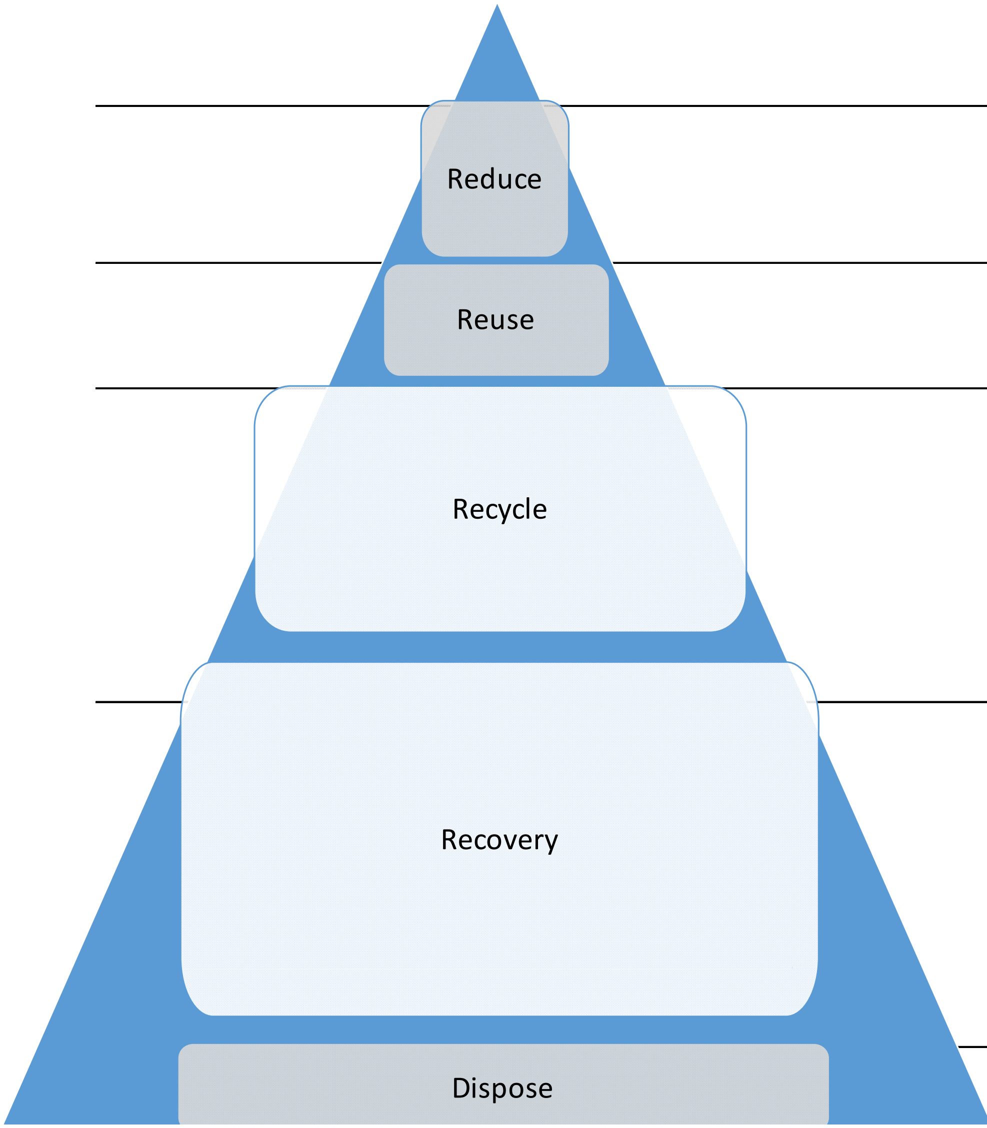
Example shown is from RCF-based test liner and fluting mill

‘Wet Fuel Feedstock’ – Mayr-Melnhof Cartonboard – Austria[1]

Parameter	Rejects	Wood	Effluent sludge	Mixture
Fuel ratio	7,500	5,000	2,500	15,000
CV (kJ/kg)	5,898	15,700	340	8,239
Dry Solids %	45	85	15	53

Economics:
- Investment = €5-6 million
- Operating costs = €0.5-0.6million/y
- Savings estimated at €1.3 million/y

1 BREF 2014

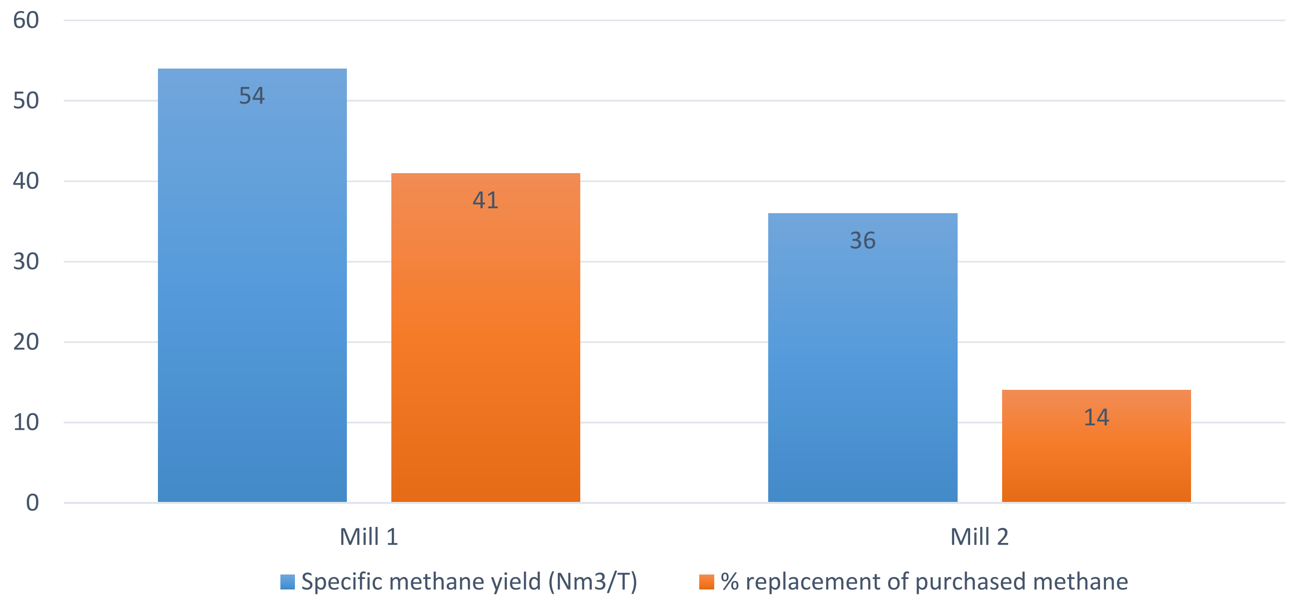


Technologies	Feedstock	Products
		Not applicable
		Not applicable
		No commercial technologies identified
Near closed loop	Rejects	
Near closed loop	Paper sludge	Calcitech
Open closed loop	Rejects	Mixed plastics compounding (pipes, rainwater goods, pallets, planks)
Open closed loop	Papermill ash	New materials/building products
Gasification	Rejects/paper sludge	Syngas for new chemical products/ash
Gasification	Rejects/paper sludge	Syngas for energy recovery/ash
Pyrolysis	Rejects/paper sludge	Pyrolysis oil for energy recovery/ash
Incineration	Rejects/paper sludge	Heat and power/alkaline ash
Anaerobic digestion	Paper sludge	Methane for energy recovery/digestate
RDF/SDF	Rejects	Fuel (solid)
Composting	Paper sludge	Soil improver/organic cover
Landspread	Paper sludge	Soil improver/organic cover
Landfill	Rejects/paper sludge	None (GHG emissions)
Incineration without energy recovery	Rejects/paper sludge	Alkaline ash

8

Emerging techniques for treatment of mill residues

1 Paper sludge AD and potential for gas displacement



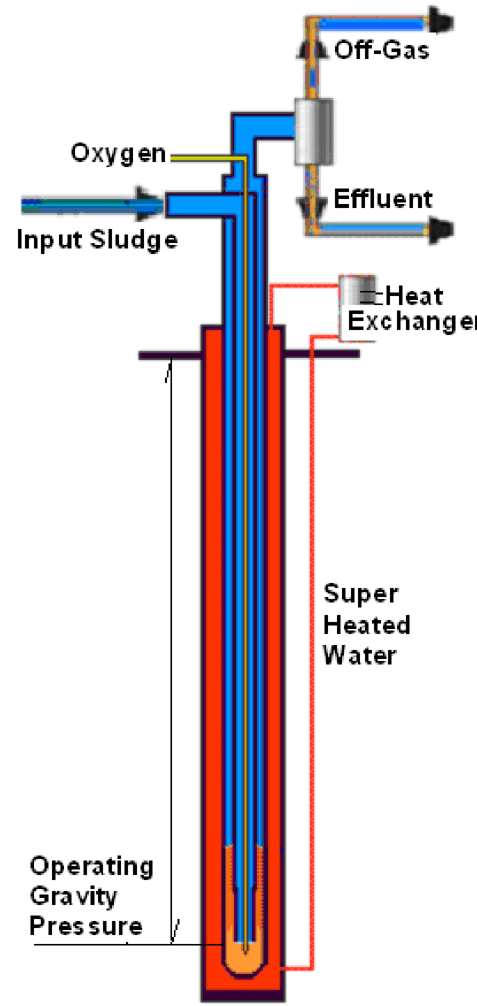
NB: 1 tonne ‘green waste’ generates 115Nm^3 biogas containing 75 Nm^3 methane

Constraints to scale up ?

1. Behaviour of paper sludge in larger volumes (concretion?)
2. Gas evolution (biogas and methane content) at larger volumes
3. Behaviour of other paper sludges?
4. Process robustness with time (mill shuts/start ups)
5. Digestate ‘quality’ and recovery of inorganic fraction for further use
6. Installation cost/ROI– incentives?

2 Wet oxidation - Genesyst

- *Gravity Pressure Vessel* – a 700m deep shaft into which are inserted a 'feed-in pipe' allowing cellulose feedstock to be delivered to a reaction chamber
- Conversion of cellulose to sugars takes place in a weak acid environment at high temperature and pressure
- 'collection pipe' returns 'converted sugars' for fermentation to ethanol or methane
- Target - 425,000 wet tonnes of biomass annually and generate 88,000 m^3/y of ethanol by 2016



'Outline planning' permission for first UK facility at The Maltings Organic Treatment Plant, N Yorkshire

Rejects – what can you do?

- Landfill ~£80 per tonne
- Centralised 'fuel carrier' ~100,000 tpa
- Rofire ~ 35,000 tpa of rejects pelletised (production 530,000 tpa)
- Incineration with energy recovery – largest manufacturers only
- **What can I do if I make 40,000 to 200,000 tpa and generate 2,500 to 12,000 tpa rejects?**

Consider:

- Conversion to value add products
  - Pallets, rainwater goods, fruit boxes
- Advanced thermal technologies
  - Gasification
  - Pyrolysis
- Refuse derived fuel ?

3 Recycling 'conditioned' mixed plastic rejects into value-add products?

Conditioned rejects may still qualify as a waste rather than 'feedstock'

4 Gasification - INTERVATE

RENEWABLE ENERGY FROM BIOMASS

Cradley Heath 3.6MWe Biomass Facility
Gasification facility processing waste wood

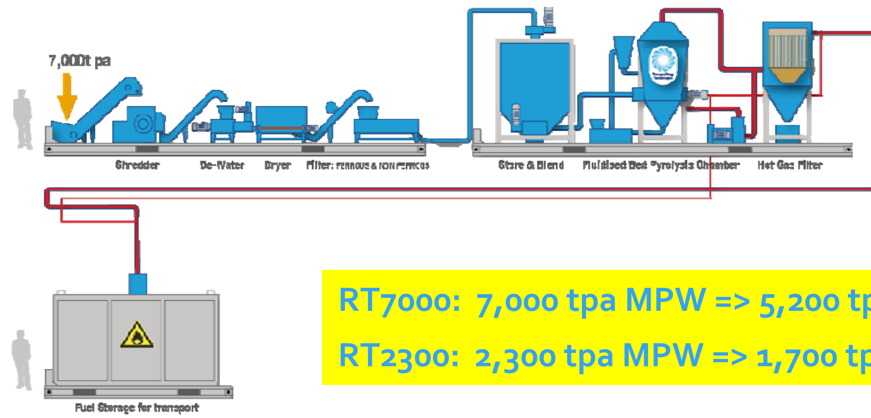
'Gasification requires disciplined processing of feedstock for successful operations'

- Intervate's experience in waste management and deployment of pellet production technology should widen the feedstock envelope
  - EA Permit allows wide range of waste-sewage sludge, paper rejects

- Co-location with waste wood companies, process sites and ability to process lower grade materials are key goals

5 Pyrolysis - Recycling Technologies

RT has developed an innovative modular solution which converts Mixed Plastic Waste into PlaxOil™.



RT7000: 7,000 tpa MPW => 5,200 tpa PlaxOil

RT2300: 2,300 tpa MPW => 1,700 tpa PlaxOil

MODULE 1 Unsorted Mixed Plastic Waste (MPW) is shredded and dried .

MODULE 2 The MPW undergoes Advanced Thermal Treatment, producing a hot hydrocarbon gas from which all contamination is removed.

MODULE 3 The clean gas is condensed to form a clean low sulphur hydrocarbon we call Plaxx™. This commodity can be used as slack wax, industrial heating oil, diesel engine for marine transport or CHP.

6 Off-site fuel carrier for incineration - Qlyte

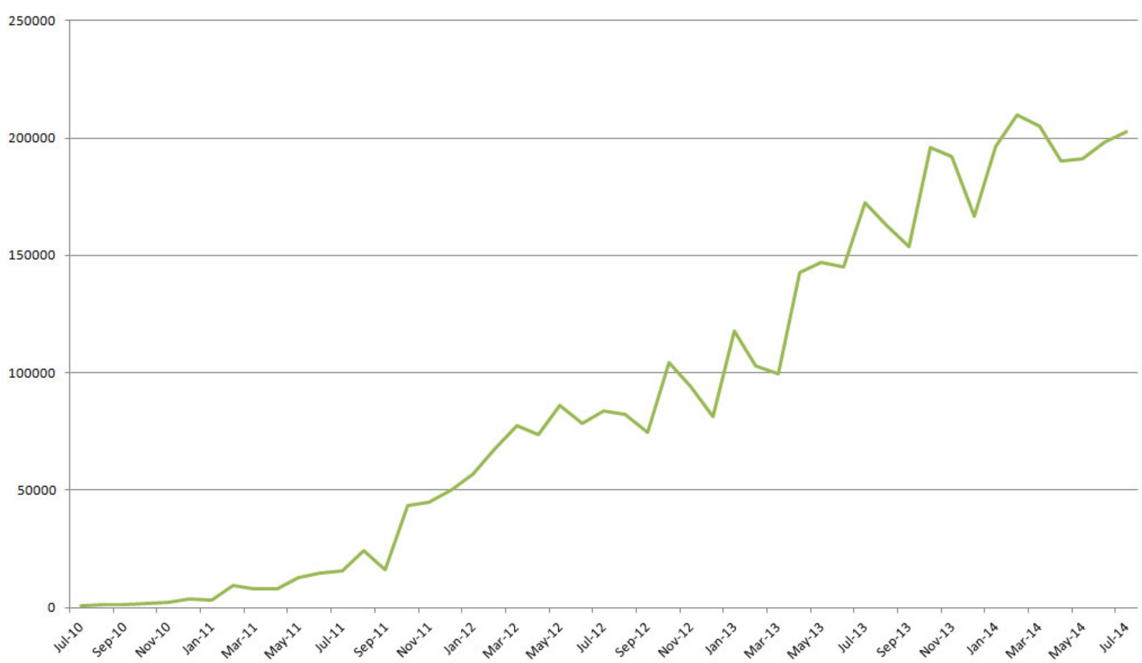
- Large scale facility fully owned and operated by Qlyte in Delfzijl (NL)
- Input 100,000 tpa of paper-plastic waste fractions from NL, Belgium, Germany and UK
- Output approximately 75,000 ton per annum of Subcoal® pellets
- Fuel pellets marketed in Netherlands, Scandinavia and Germany for co-combustion in:
  - Lime kilns
  - Cement kilns
  - Power stations

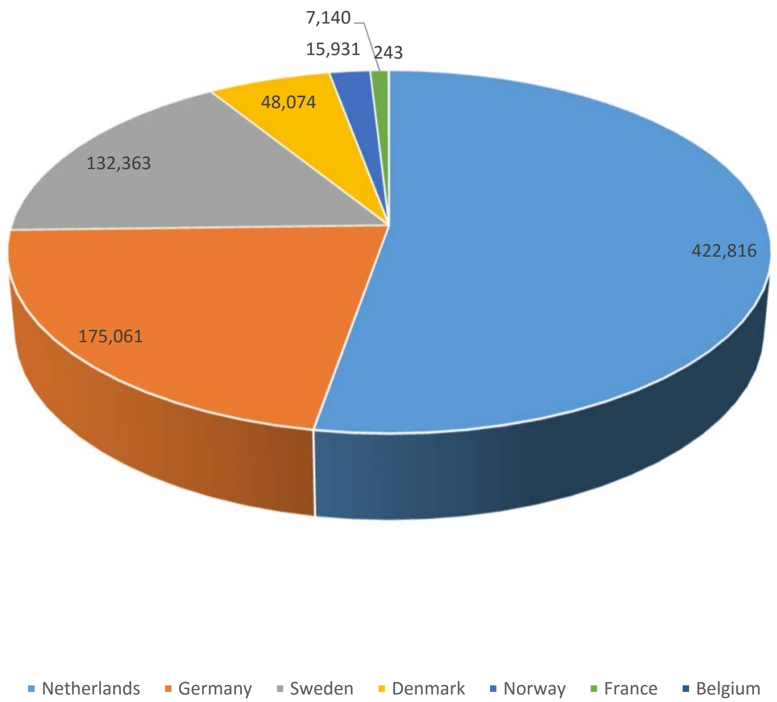
7 Off site fuel carrier for incineration - Fibre Fuel Ltd

- Feed stocks: non recyclable packaging, poly-coated board, adhesive labels, photographic paper, waxed paper, short fibre paper sludge etc

- 6 X Warren Baerg Model 250 'cubers'
  - 1-8 tonnes/hour/'cuber'
  - Each cuber delivers 24 to 192 tonnes of 'Cubed Energy' per day~7,000 to 56,000 tpa

Around 2.4 million tonnes of RDF was exported to Europe in 2014 – a short term solution?





RDF – abundant and production expected to reach 9 million tonnes by 2020

8 Sustainable solutions for PSA

- EPSRC Industrial Case PhD Award at Imperial College London
- Industry demand for low density, lightweight filler (LWFs) particles
- Manufactured from PSA (20%) and waste glass (80%)
- LWFs produced with diameters from 1 to 7mm with densities <1g cm^{-3}
- Novel high-value, re-use application

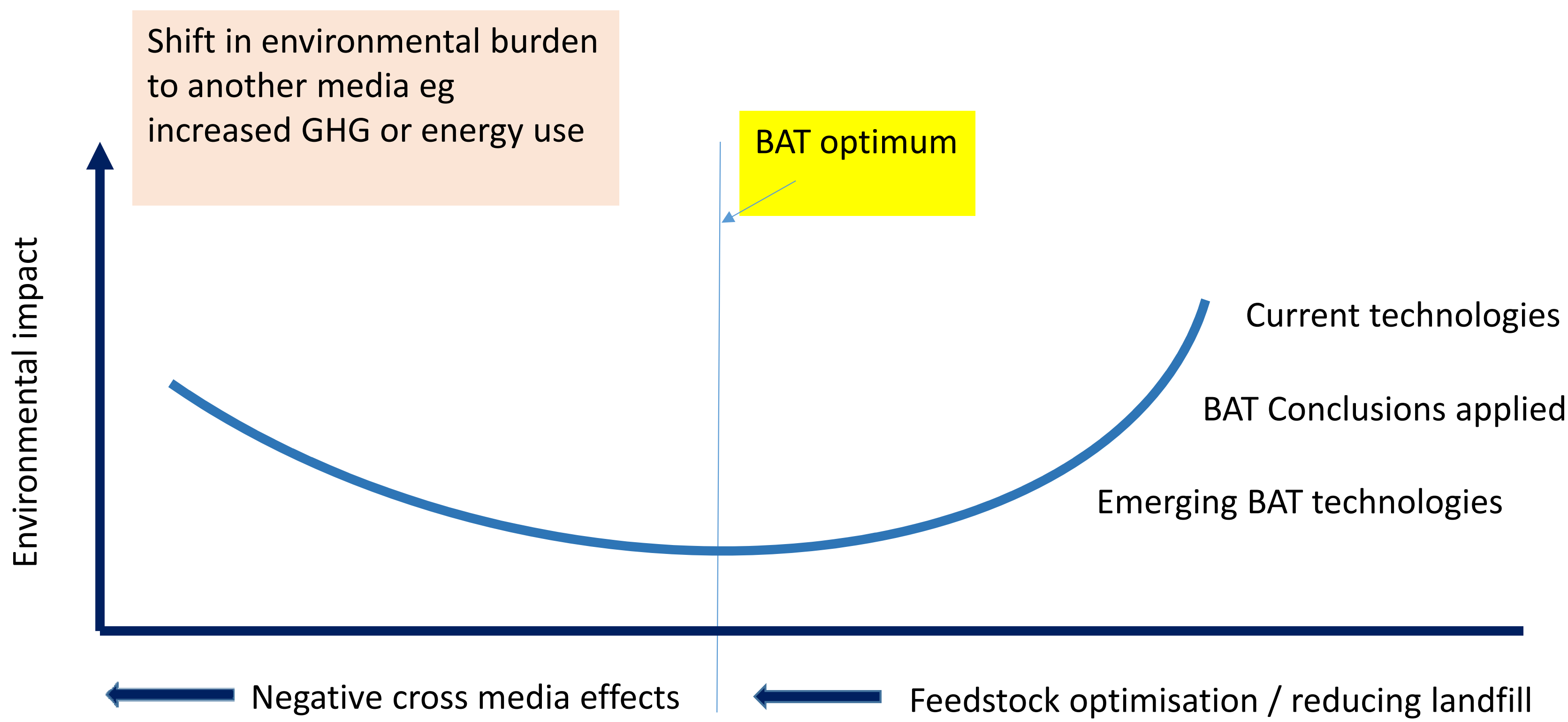
Imperial College London

Aylesford Newsprint

UPM

EPSRC

BAT Conclusion 12 ‘Feedstock strategy meeting end use(r) need’



Thank you

Martinkay@360eco.co.uk