

Adding Value to Ash and Digestate (AVAnD).

Developing a Suite of Novel Land Conditioners and Plant Fertilisers
from the Waste Streams of Biomass Energy Generation

Dr. Ben Herbert, Dr. Alfonso Lag-Brotons, Dr. Rachel Marshall and Prof. Kirk Semple

Resource Recovery from Waste Event Resource Recovery from Waste projects
showcase

Leeds - 1 December 2016

Aims of project

This project aims to radically change the way in which biomass energy producers can support a circular economy.

This will be achieved through utilising bio-energy waste streams to develop soil conditioners and plant fertilisers, facilitating new ways to mesh commercial ideas with positive environmental benefits.

- 1) Assess the environmental impacts of applying a waste derived product to land
- 2) Optimize a novel soil conditioning material derived from mixtures of bio-energy waste (ash and digestate)
- 3) Close the nutrient cycle and ensure food security

Overall rationale

- Increase in anaerobic digestion (AD) and thermal conversion bio-energy generation
- Waste streams from these technologies (digestate and ash) typically have limited monetary value
- Potential for increased amounts to be applied to land
- Digestate and ash are rich in complementary nutrients, but currently of limited use
- Finite primary reserves of mineral fertilisers (phosphorus)
- Drivers:-
 - rising pressures on environmental resources
 - landfill taxes
 - waste-minimisation legislation
- Alternative options for waste reuse are increasingly being sought.

The Team

- Lancaster University
 - Prof Kirk T Semple
 - Dr Alfonso Luis Lag Brotons
 - Dr Rachel Marshall
 - Prof Nick Ostle
 - Prof John Quinton
 - Dr Ian Dodd
 - Dr Ben Surridge
 - Dr Farid Aiouache
- Stopford Energy and Environment
 - Dr Ben Herbert
 - Lois Hurst
- The James Hutton Institute
 - Dr Marc Stutter
 - Samia Richards
 - Lysa Avery
- Aqua Enviro
 - Dr David Thompkins
 - Andy Burgess

Partners & Steering committee

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Centre



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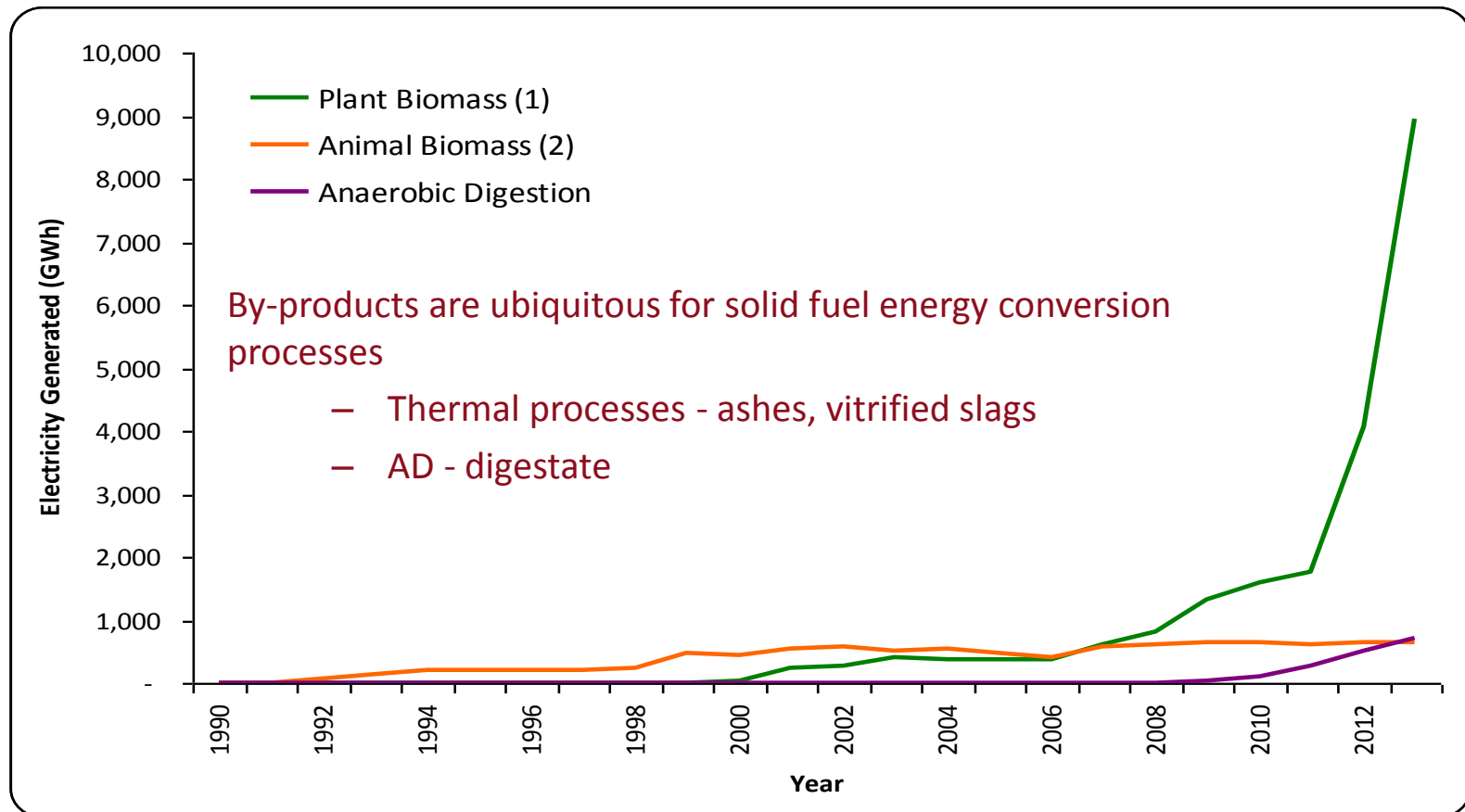


NERC RRfW funding – Catalyst Phase

- Stopford Energy & Environment – 2012 Proof of Concept
- Catalyst Phase 2013 - £77,496.
- Database of those working in sector
- Two workshops to the sector on the background and development of the project
 - identification of key issues/areas requiring research
 - a consortium to take project forward
- Position paper published in *Environment International*
 - Matthew J. Riding, Ben M.J. Herbert, Lois Ricketts, Ian Dodd, Nick Ostle, Kirk T. Semple. 2015. Harmonising conflicts between science, regulation, perception and environmental impact: The case of soil conditioners from bioenergy. *Environment International* 75, 52–67
- Writing and submission of full grant proposal to NERC
 - Funded £856,484 (2015-18)

Project overview

An energy-industry problem



Source: *Digest of UK energy statistics (DUKES) 2014*

(1) Includes the use of straw combustion and short rotation coppice energy crops.

(2) Includes the use of poultry litter and meat & bone.

Why Ash?

- Ash contains inorganic minerals; potassium, phosphorus, calcium and magnesium are particularly abundant
- Plants require these minerals for nutrition
- Ash is a cost to most operators; £80/T to landfill
 - Estimated £50M annually

Why Digestate?

- Digestate provides nitrogen, organic matter, trace nutrients etc
- Known difficulties
 - Quality and consistency
 - Dewatering
- Closing the Loop

Masses of ash...

- 50 operating dedicated biomass plants in 2013⁽¹⁾
 - Total electrical output 1849MW
- 620,000 TPA ash
- 174 Olympic swimming pools worth of ash...

- A further 300MW under construction
- 3,600MW awaiting construction
 - Potential for 2,000,000 TPA

(1) Renewable Energy Planning Database (REPD), excluding small-scale domestic installations

...and digestate

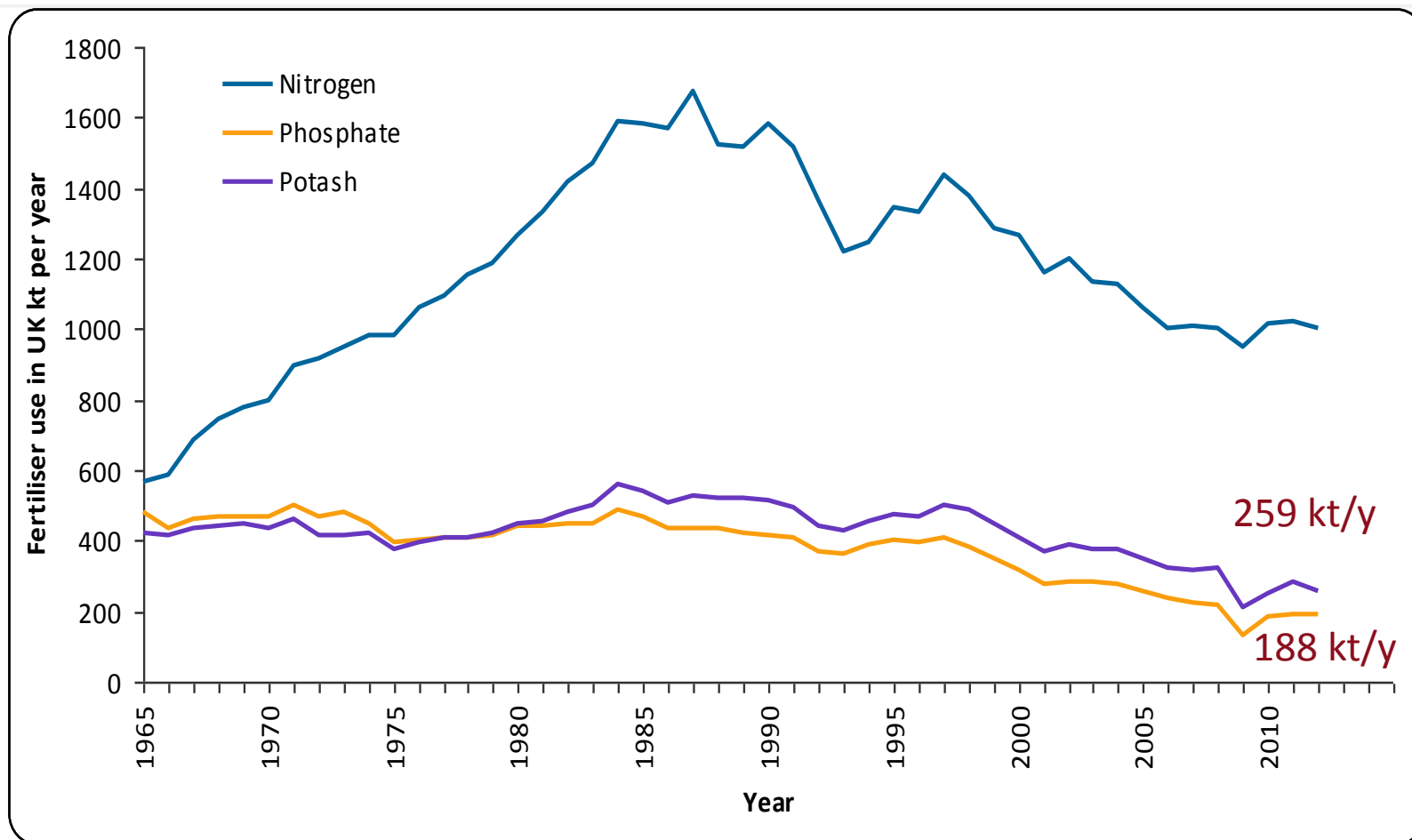
- Currently 152 operating AD units in the UK
- 88 of which are “waste-fed”
 - Operational capacity of 6.3M TPA
 - Estimated mass of digestate ~6.3M TPA
 - 2,500 Olympic sized swimming pools
- So how do we turn these wastes into an economic benefit?

Conventional fertilisers

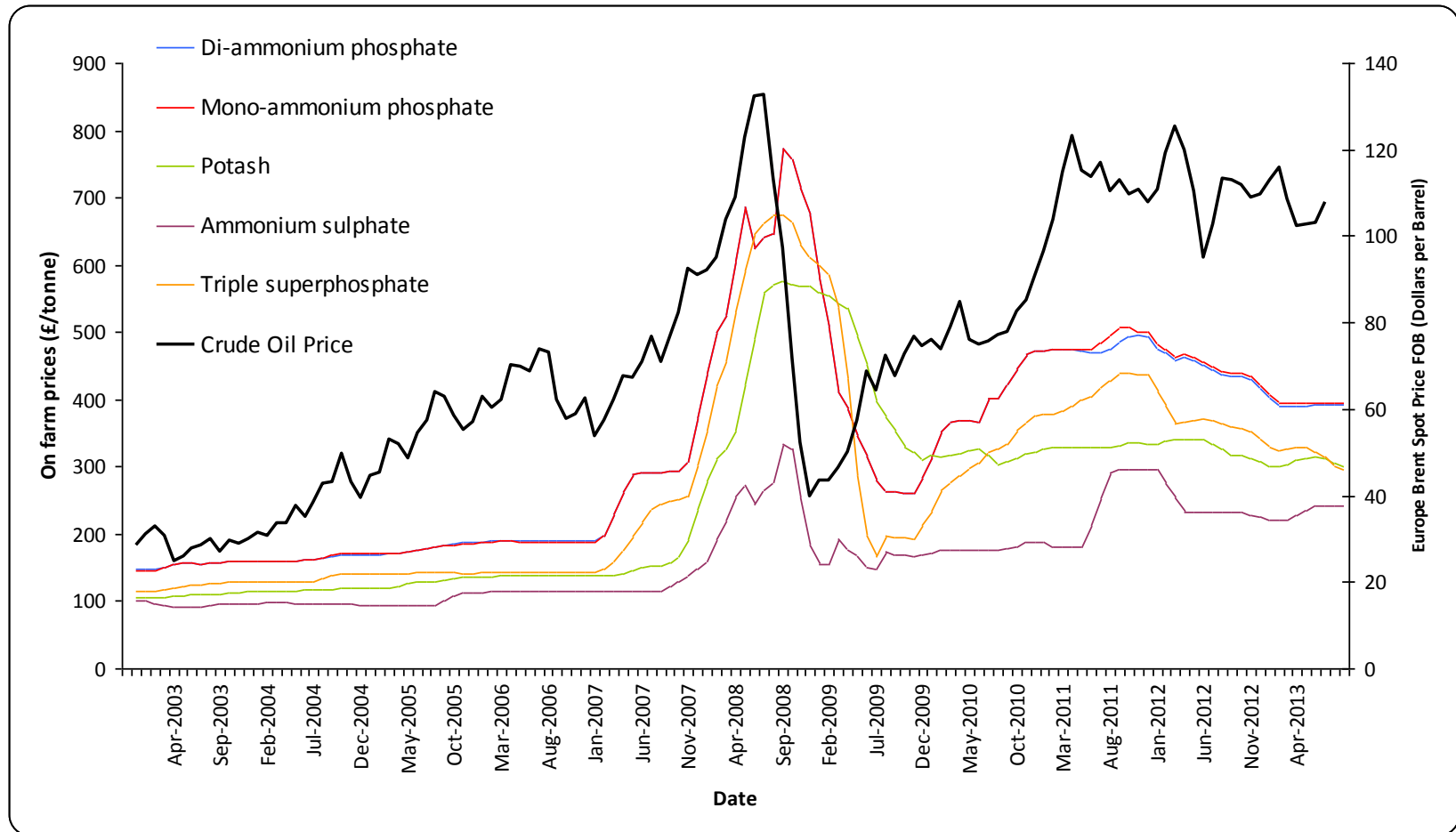
- Highly formulated, consistent product
- Supply N, P, K
- 100% phosphate, 30% of potash and almost 90% of sulphur is imported to the UK.



UK Fertiliser Use



Fertiliser prices



Our project

- NERC funded Resource Recovery from Waste project
- Develop soil conditioners and fertilisers from ash and digestate
- Assess the environmental impact and any detrimental effects of using the products

Challenges?

Ashes and digestates	Conventional fertilisers
Highly variable composition	Consistent and reliable
Problematic form for use and storage	Concentrated, stable forms
Restrictive (but necessary) regulations	Well established regulatory framework
Scepticism among users	Trusted
Readily available	Energy intensive to product Diminishing availability
Low cost	Expensive to buy

Project start

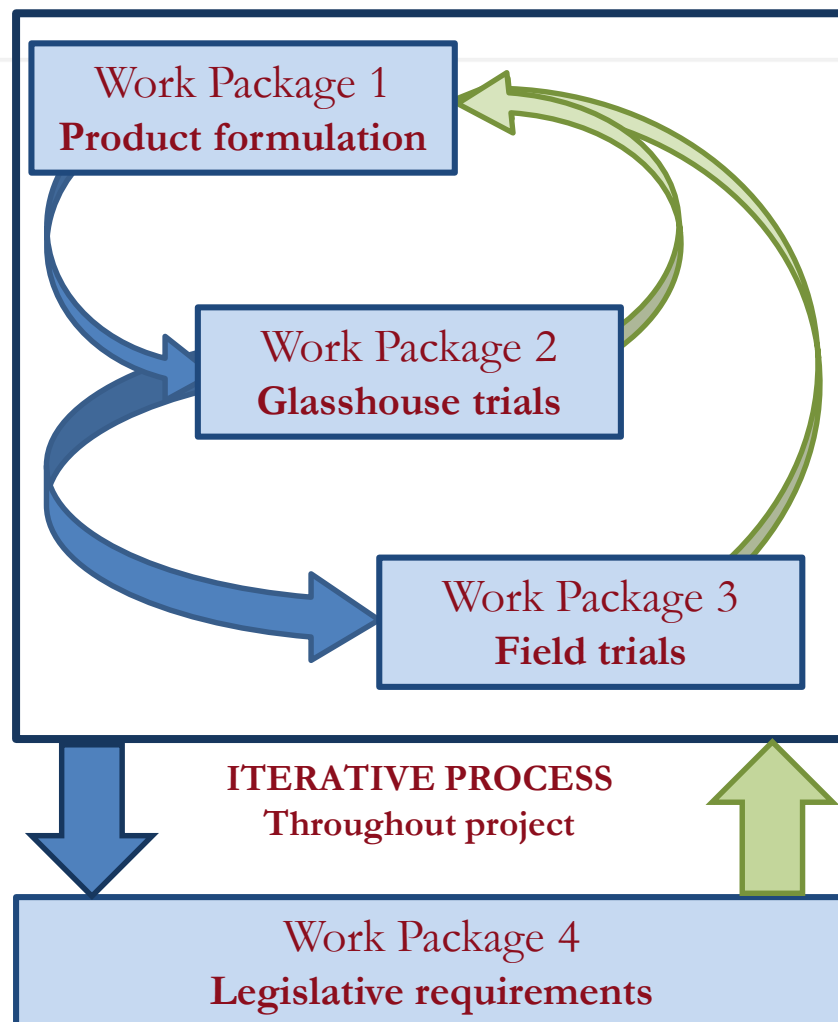
Jan. 2015

Oct. 2015

Oct. 2016

Project end

Jan. 2018



Characterisation of selected ash/digestate and selection of blends for WP2

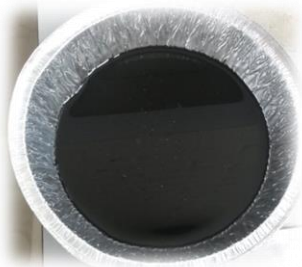
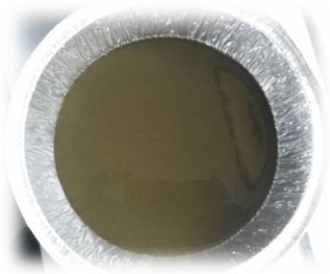
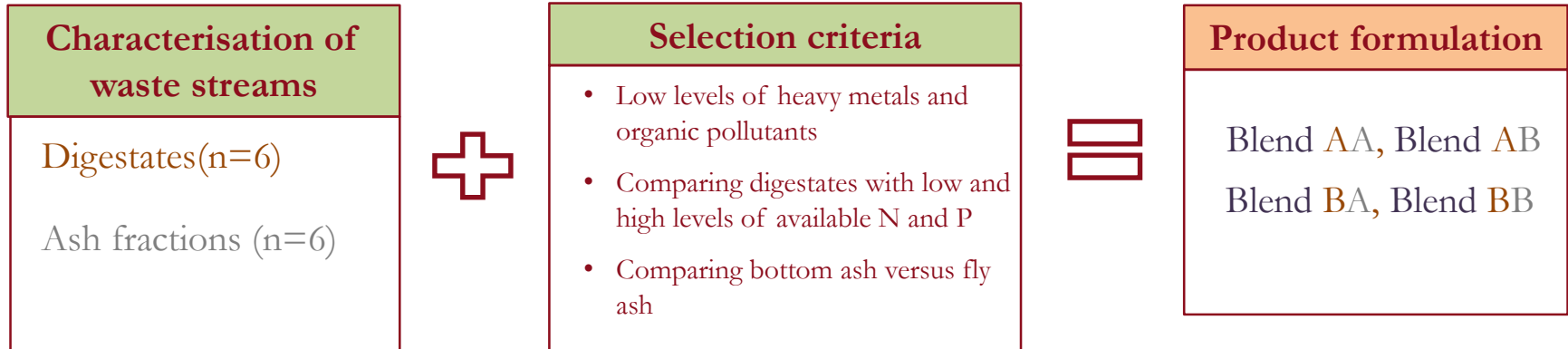
Assessment of ash, digestate & blend impact on soil quality and crop growth

As for WP2, but with most promising blends. Additionally, further ecosystems impacts considered (i.e. GHG emissions).

Gathering of evidences to permit application to land (“End of Waste”)

Workpackage 1 Update:

Feedstock characterisation and Blend formulation



• WP1: Interactions between the wastes

Laboratory Trials to test unknown potential for:

- *NH₃ loss (Completed at Lancaster Univeristy)*
- *Changes in P-speciation (Ongoing at Lancaster University and JHI)*
- *Dewatering and blend stability (Ongoing at Aqua Enviro)*
- *Pathogen reduction (Ongoing at JHI)*

WP2 - Greenhouse trials – Design and results so far

Potential fertilisation Treatment	Code	Levels (n)
Control	C	1
Organic Nitrogen control (Urea)	C _{ON}	1
N (Urea)-P-K	C _{NPK}	1
Ash	A	2
Nitrogen (Urea) ash control	A _N	2
Digestate	D	2
Blends	D+A	4
Total		13

Overarching Factors

- Planted/Unplanted (n=2)
- Soil type (n=2) [Neutral Loam and Acidic Sandy]
- Plant type (n=1) [winter wheat]

**Experiment split in two
experiments on soil type
(2x2)**

WP2 - Greenhouse trials – Design and results so far

DURATION

Six weeks

(From 29/10/15 to 17/12/15)

During growth

Plant growth measurements including
germination, water use efficiency

At the end

Shoot fresh and dry weight
Tissue mineral composition
Tiller number (branching) in wheat

pH, EC

Water holding capacity

Total C, N, P and K (before)

Plant available N, P and K

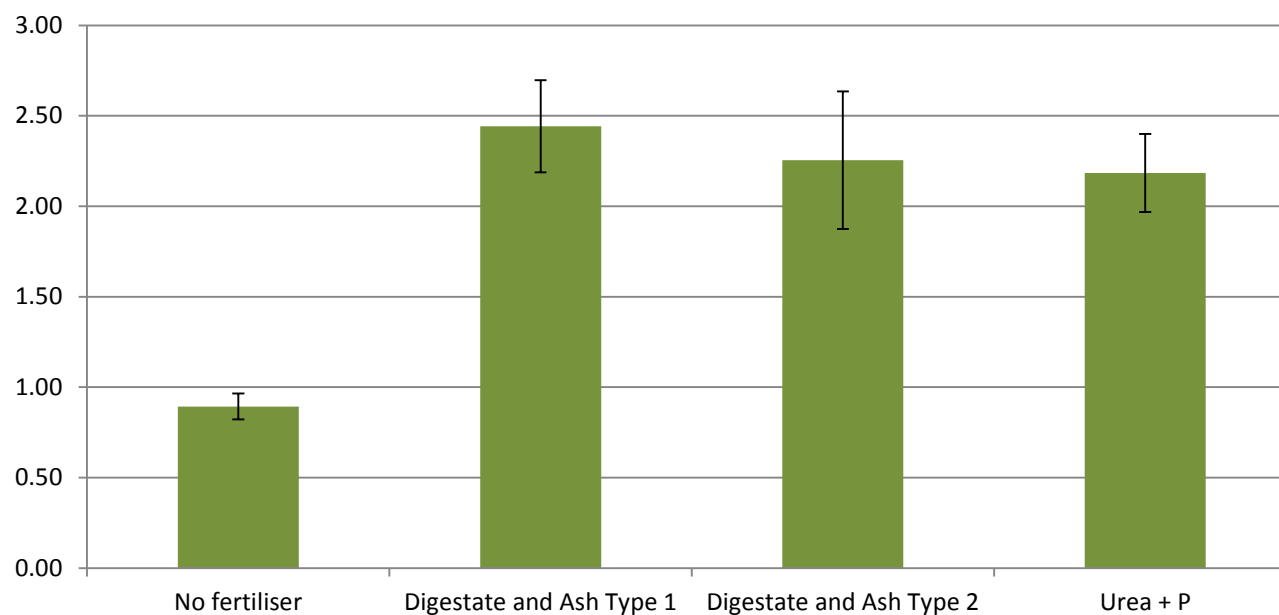
Total & available elements

VARIABLES

Assessed at the start ($t=0$) and the
end of the experiment ($t=6$ weeks)

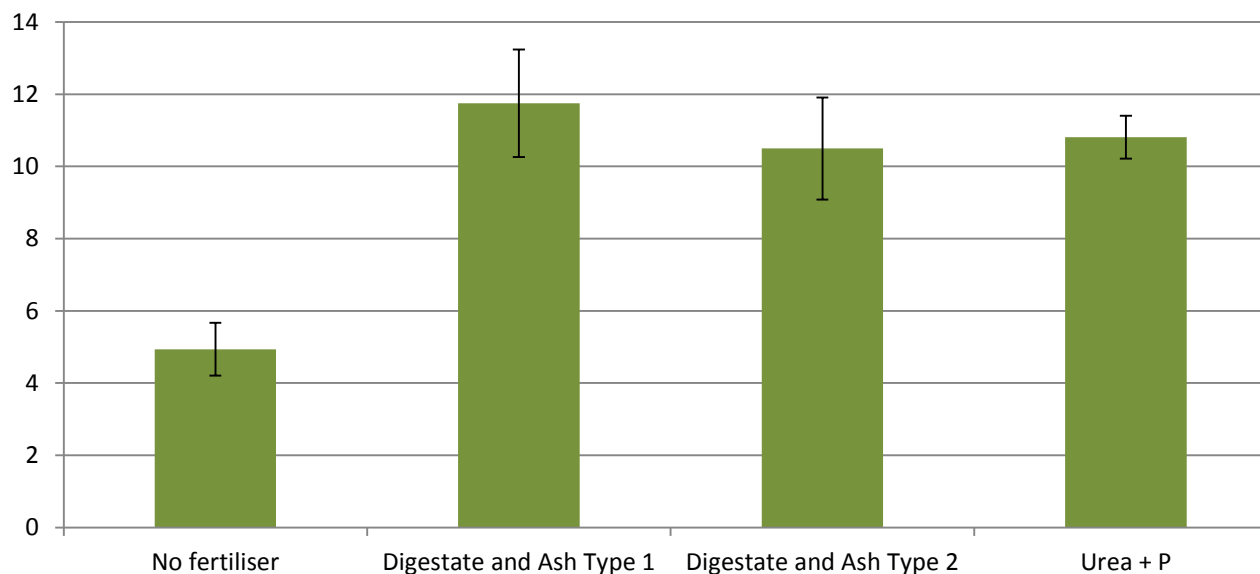
WP2 - Greenhouse trials – Design and results so far

Mean aboveground biomass (Dry Basis (g))



WP2 - Greenhouse trials – Design and results so far

Mean number of tillers (per pot)



WP3 – Experimental design

Overarching Factors

Planted species (n=2) Winter wheat + spring wheat
Fert. Treatments (n=7) 120/60 kg/ha (N-P₂O₅) for whole cycle.
60/63 kg/ha (N-P₂O₅) as basal dressing initially.
Remaining N (57 kg/ha) – *Inorganic top up (Urea-fertirrigation)*



Fertilisation treatment	Code	Levels (n)	Replicates (n)
Control	C	1	7
Conventional/Inorganic fertiliser (fixed target)	U+P	1	7
Ash with Urea	U + A1	1	7
Digestate	D1, D2	2	7
Blends	D1A1/D2A1	2	7
Total		7	49

Exp. description:

Location: Myerscough Agricultural College; Lee farm (polytunnel)
Crop: Wheat (winter)
Management: Conventional (fertilization and crop).
Irrigation: Well watered ($\approx 80\%$ pot WHC). Drip irrigation based on crop requirements
Soil type (n=1): Myerscough field

3. WP3 – Experimental design

Randomised blocked design (7x7)

49 mesocosms.

Nov16 – July17

Moisture sensors (ML2X Thetaprobes)

28 sensors (7 treatments x 4 replicates)
Monitor well water conditions (Check)
Probes buried 10 cm into the soil (rods till 16-18 cm)

Rhizon-samplers

Pore Water sampling

Cost to be determined.

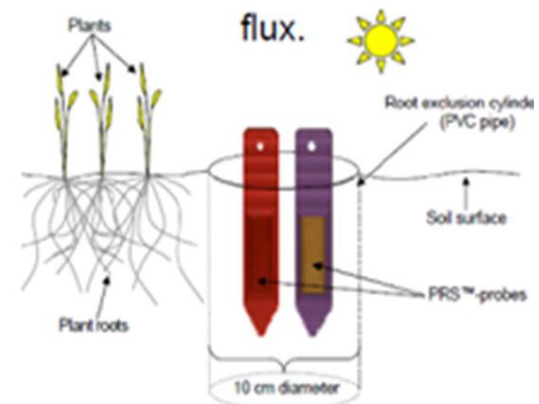
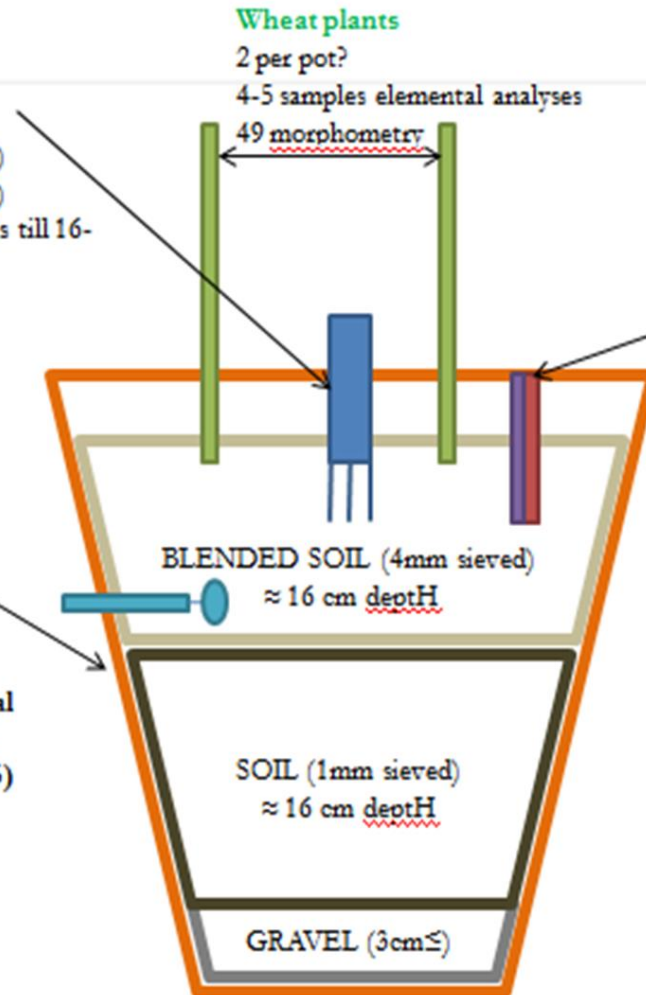
Matching GHG samplings and total number of experimental units (4-5 replicates per treatment, total 28-35)

Wheat plants

2 per pot?
4-5 samples elemental analyses
49 morphometry

PRS probes

Grant application (30 ud)
Passive sampling
3 treatments monitored (4 replicates)



Nutrient Flux = f(Temp, Moisture, Time, Other Competing Sinks)

4. Case studies – AVAnD project



IMPACTS

Impact Highlights

- **Government Chief Scientist's Annual Report – Case Study**
- **Publications**
- **Nuffield Foundation**
- **Undergraduate Teaching**
- **Farmers Forum**
- **IP Protection**
- **Licensing and Assignment Options**
- **Market Testing**
- **Business Planning**

Intellectual Property

- Patent application
- Licensing
- Spin-out
- Assignment

climate news network

Waste could fertilise food cost cuts

White rot, not just a marine anaerobic digester on a farm in the UK

Image: Air Marshall Clark Energy Ltd via Wikimedia Commons

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Developing sustainable fertilisers

Fertilisers from renewable energy could boost food security

Lancaster University scientists are leading research looking at formulating sustainable fertilisers from renewable energy waste.

This new area of research aims to produce a sustainable, environmentally-friendlier source of soil conditioner and crop fertilizer that could also reduce costs to farmers and potentially, with wide-spread take-up, help to slow down rising food prices.

The collaborative project, which also includes Stoford Energy and Environment Limited, the James Hutton Institute and Aqua Enviro Limited, builds upon research originally conducted by Stoford looking at using a mixture of digestates, derived from anaerobic digestion, and ash, from burnt biomass, as an alternative to existing crop fertilisers.

Almost all existing fertilisers, such as phosphorus and nitrate-based products, are produced using energy-intensive methods involving the use of oil and gas. In addition phosphate-based fertiliser relies on the mining of phosphate, a finite and unsustainable resource, and a production process using various toxic chemicals.

The project represents excellent collaboration between academia and industry to address the major challenge of food and energy. Although the project is based here in the UK, it has the potential to provide a sustainable alternative to existing fertilisers.

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ScienceDaily

at the University of Lancaster, says their fertiliser would also cut fossil fuel use and save natural resources.

Source: Lancaster University

Sustainable green alternatives to fertilizers could boost food, energy security

Date: August 14, 2014

Source: Lancaster University

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Sustainable green alternatives to fertilizers could boost food, energy security

Date: August 14, 2014

Source: Lancaster University

Summary: Research is looking at formulating sustainable fertilisers from renewable energy waste. This new area of research aims to produce a sustainable, environmentally-friendlier source of soil conditioner and crop fertilizer that could also reduce costs to farmers and potentially, with wide-spread take-up, help to slow down rising food prices.

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Farmers Guardian

While there may be little to achieve in the way of a positive health outcome for sufferers of organophosphates, for most, recognition of their plight and the truth behind it would be hugely significant steps forward.

Emma Penny, Editor

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Researchers developing fertiliser from renewable energy waste

7 December 2014 | By Olivia Midgley

Researchers are developing a sustainable fertiliser from piggy waste which they claim could improve food security and potentially slow down rising food prices.

This could provide a sustainable alternative to existing fertilisers and reduce costs to farmers.

These forms of renewable energy more than make up for the costs, as ash is currently expensively dumped in landfill.

Working together with Lancaster University on a collaboration with Stoford Energy and Environment Limited, the James Hutton Institute and Aqua Enviro Limited, builds upon research originally conducted by Stoford looking at using a mixture of digestates, derived from anaerobic digestion, and ash, from burnt biomass, as an alternative to existing crop fertilisers.

The three-year project has received £866,494 funding from NERC, the Natural Environment Research Council, and will progress through laboratory trials to field trials.

Currently fertilisers which use phosphorus and nitrate based chemicals are produced using fossil fuel energy intensive methods involving the use of oil and gas which are limited resources. In addition, phosphate-based fertiliser production also relies on the mining of phosphate, a finite resource, which uses toxic chemicals during the production process.

Potential

It builds on research originally conducted by one of the partners, Stoford Energy and Environment Ltd consultancy, which investigated using a mixture of digestates – the waste left over after material has been through an anaerobic digester – and ash, from burnt biomass, as an alternative to existing fertilisers.

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Professor Kirk Semple, from the Lancaster Environment Centre, is leading the project. He said: "The aim of this research is to modify the by-products from anaerobic digestion and biomass energy plants to create a new, safe and sustainable source of nutrients for agriculture."

It could also help to improve food security by reducing the costs to farmers of producing food. The project would not be linked to the global price of oil and gas.

Chicken Litter Has a New Use

June 23, 2010 - Chicken manure is much more valuable as a fertilizer than previously thought, an agricultural study showing its nutrient advantages over conventional fertilizers.

Calculating Agriculture's Phosphorus

Researchers in the UK think they may have found a way to produce fertilizers that should cut farmers' costs and at the same time boost some types of renewable energy.

Their scheme, which involves using waste material from anaerobic digesters and ash from burnt biomass, would also cut fossil fuel use and save natural resources.

at the University of Lancaster, says their fertiliser would also cut fossil fuel use and save natural resources.

Farmers Guardian Classified

Auctions (131)

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- CropTec 2014: New spraying innovations demonstrated 28 November 2014
- Project to develop intelligent application of nitrogen and PGRs 28 November 2014

Land conditioners and plant
fertilisers from biomass
generation by-product

Lois Ricketts

ADBA R&D Forum, Southampton

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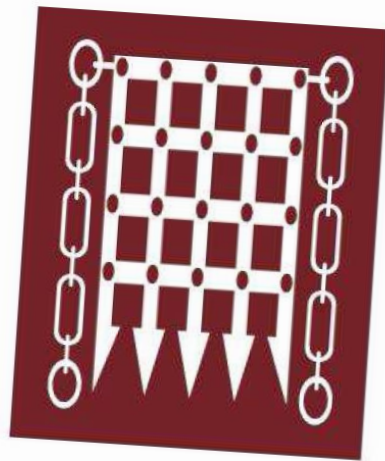
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Events

Growing The UK Nutrient Platform

AIM: To establish a cross-sector UK Nutrient Platform for all stakeholders with interests in sustainable nutrient use and recycling, nutrient management and security and environmental impact.

Royal Society of Chemistry | Burlington House | London

In November 2014, the concept of a UK Nutrient Platform was introduced at a successful event in Leeds.

This second event will be an opportunity to meet other stakeholders and participants and to define organisation, funding, objectives & actions.

Register your interest

To be on the mailing list for this and other UK Nutrient Platform events, please mail the event manager at:
info@link2energy.co.uk.

More details and full programme to follow.

Please note—if you did not attend the first event in Leeds, don't let that put you off participating in this or future events. You are welcome to attend.

Save the date:
29th April 2015
09:30 - 16:30

Renewable chemicals from waste – securing the molecular value from waste streams



Chemical Biology & Medicinal | Energy | Industry | Materials | Environmental | Biological | Nanoscience

Renewable chemicals from waste – securing the molecular value from waste streams

20 November 2015, London, United Kingdom



Students projects

Masters projects

Undergraduates projects

C-cycling
(priming effect)
Alexandra Wilkinson

C-cycling conditions
(priming effect)
Isabelle Jones

Plant productivity
Emma Pearce

Plant – Soil interactions
(Dif. digestates)
Cynthia Ibeto

Blends processing
Alejandro Abelenda

Soil biota
(earthworms)
Bathélémy Louvain

Soil biota
(micro fauna)
Abiola Ogunyomi

Pollutants degradation
(Bioremediation)
Ojo Adesola

Adding Value to Ash and digestate (AVAnD)

PhD student

Research visitor

The vision

- Widespread adoption of this technology
- A sustainable substitute for conventional chemical fertilizers
- Reduction in the carbon footprint of the agrochemical industry
- Underpin the long-term commercial viability of the biomass to energy sector by monetising sector derived waste streams
- Utilisation of growing waste streams of biomass by-products to promote the growth of crops
- Close the production loop for biomass to energy generation enabling a cradle to grave approach

Outcomes

- A sustainable substitute for conventional chemical fertilizers
- Significant reductions in the carbon footprint of the agrochemical industry.
- Closing of the production loop for biomass to energy generation enabling a cradle to cradle approach.

Thanks for listening

