Future challenges for AD to deliver economically and environmentally sustainable fuel and bioenergy

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Contribution of biogas technology

- Renewable energy
- Greenhouse gas emissions
- Waste management
- Environmental
Renewable energy

Grid injection — more than 150 schemes currently operational across EU

CHP - Germany >7000 plants producing 2.7GW of power supplying 4.5M homes

Vehicle fuel — can be coupled to CNG vehicle growth, about 25% worldwide

Heating and cooling — local application or for DCH or community projects
GHG - Savings in tonnes CO₂ per tonne ww processed

• cattle slurry:
  0.24 t fossil fuel displacement by using biogas as fuel
  0.024 t prevention of fugitive emissions from tank storage

• Food waste:
  0.74t CO₂eq assuming half of the methane potential from landfill is prevented
  0.17t from electricity generated (at 35% efficiency)
  0.057 t from savings over fertiliser produced using fossil fuels

• Energy crops
  0.2t from electricity generated
Waste management

• Landfill Directive
  – Municipal solid waste generation 400 kg person\(^{-1}\) y\(^{-1}\)
  – 60% organic
  – Reduce biodegradable waste going to landfill to 35% of 1995 levels by 2014
  – Many of these wastes have a high moisture content, making anaerobic digestion a good choice for energy recovery (e.g. UK 50kg person\(^{-1}\) y\(^{-1}\) food waste)
Environmental contribution

- Recycling of nutrients
- Returns organic matter to land
- Helps in resource recovery
- Improves biosecurity

Drivers

• Biogas can deliver many benefits, but not necessarily all of them simultaneously!

• Direction and future development will depend on the drivers in place and include:
  – Subsidies
  – Penalties
  – Regulations

• These drivers are not uniform across different countries, and biogas will develop in different ways
Research needs

- Capturing more feedstock
- Ensuring sustainability and minimising environmental impact
- Improving biodegradability
- Optimising conversion
- Engineering design and process integration
Capturing more feedstock

• Exploiting the potential of manures and slurry through co-digestion
• Source segregation and improvement in biowaste quality
• Full integration of AD into biorefineries
• New substrates – micro and macro algae (freshwater and marine)
Ensuring sustainability and minimising environmental impact

• Sustainable management of energy crops
  – Crop rotations, catch crops, site adapted crops, EIA and biodiversity, life cycle assessment

• Ensuring the input quality of wastes so we do not compromise digestate use
  – Impact of digestate use on land, health risks to human and animal health and plants
  – Impacts or benefits in terms of GHG
Improving biodegradability

• How this can be achieved without cutting too deeply into the positive energy balance

• More research on methods to process difficult-to-degrade feedstocks
  – Heat treatments
  – Cavitation
  – Chemical treatments

• Development of new techniques
  – Enzymes?
  – Superbugs?
Optimising conversion

- Example

- Overcoming ammonia toxicity in food waste digestion in the UK

- Understanding the process, its biochemistry and requirements
Theory proposed

- Propionic acid accumulation is due to insufficient capacity of hydrogenotrophic methanogens to synthesis formate dehydrogenase enzyme
- Requirement for Se as part of this enzyme complex
- Ammonia toxic to acetoclastic methanogens less toxic to hydrogenotrophobic methanogens
Laboratory studies

- Control OLR=2
- Control OLR=3
- Se, Mo
- Se, Mo, Co, W
- Se, Mo, Co, W, Fe, Ni
- Se, Mo, Co, W, Fe, Ni, Zn, Cu, Mn, Al, B

Trace element supplementation stopped in Se, Mo, Co, W, Fe & Ni

Se supplemented accidentally
Evidence of ammonia toxicity to acetoclastic methanogens

**14C labelling experiments**

70% of the total $^{14}$C in labelled acetate went into CO$_2$ with $^{14}$CO$_2$:$^{14}$CH$_4$ ratios in the range of 1.94 to 3.07,
• After addition of micronutrients:
• VFA reduced from >30000 to <1000 mg l\(^{-1}\)
• SMP increased from 380 to 420 m\(^3\) tonne\(_{ODM}\)\(^{-1}\).
• OLR increased to 3.2 kg\(_{ODM}\) m\(^{-3}\) day\(^{-1}\)
Metabolic capacity

For source segregated domestic food waste
Interactions, inhibitions, and requirement

• We just don’t know enough about the anaerobic consortia
  – Sophisticated tools are available

But............

We need to understand cause and effects and relate these to long-term laboratory and pilot scale trials.
Engineering design

• Data capture and analysis on process energy efficiency
• Rationalisation of process design to meet feedstock characteristics
• Improving mass transfer - mixing
• Hybrid designs for new feedstocks such as algae where solids concentration may be low
• Gas upgrading- reducing energy requirements and slippage
• Solids liquid separation – digestates from many of the new feedstocks (food waste, sugar beet pulp, algae) are difficult to dewater
Process integration

• Already examples of how AD can be coupled to first generation biofuel production
• AD is a natural partner to most biorefinery concepts
• More novel integrations are being proposed e.g. pyrolysis / digestion
• Greater integration into process industries – not just a bolt-on ‘end of pipe’ process
Process modelling

• Develop process models with industry standard software e.g. ASPEN plus
• Adopt tools such as Pinch analysis to maximise energy efficiency in an integrated process
• Enhance and refine whole systems analysis to determine energy ratios for different schemes
• Continue to develop these models to include carbon and nutrient management
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