Anaerobic Digestion at the University of Leeds: System Optimisation

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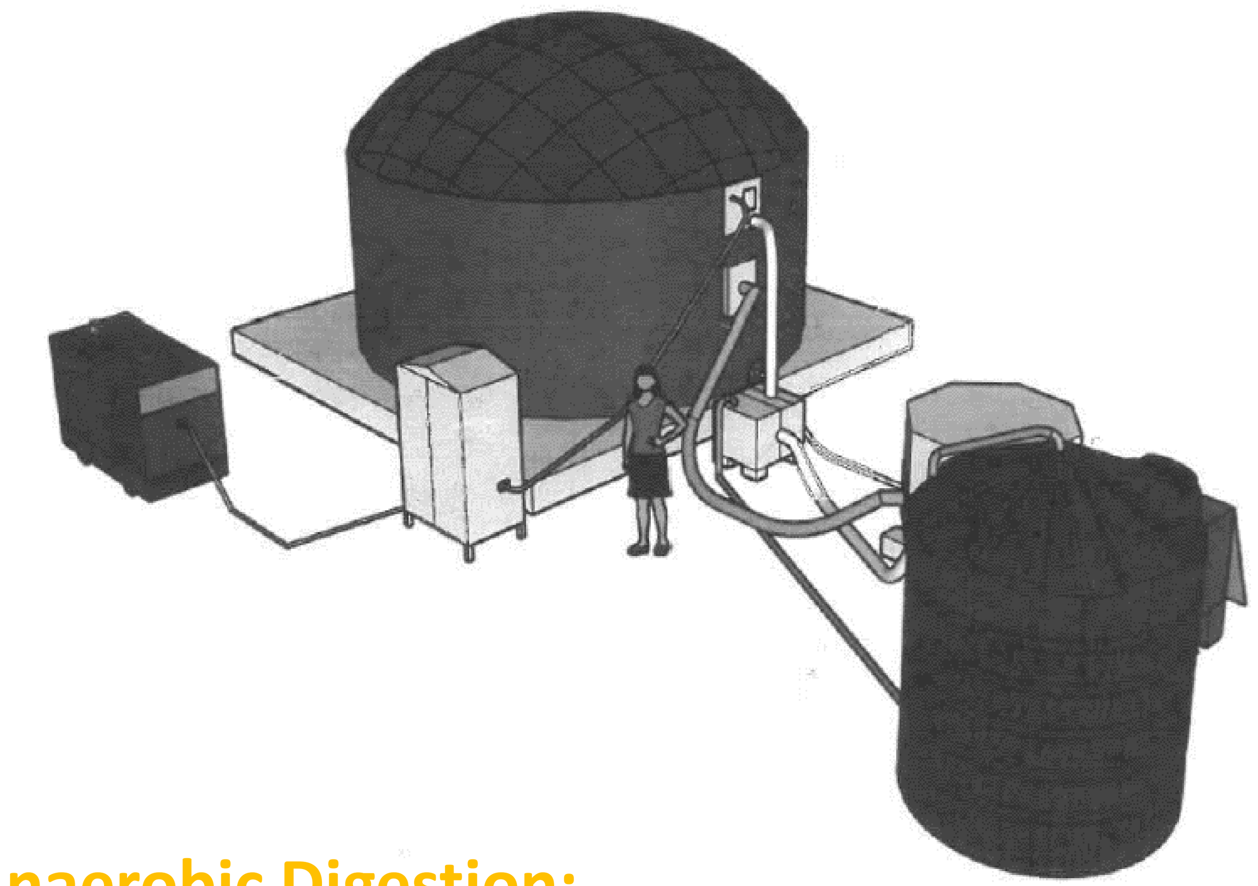
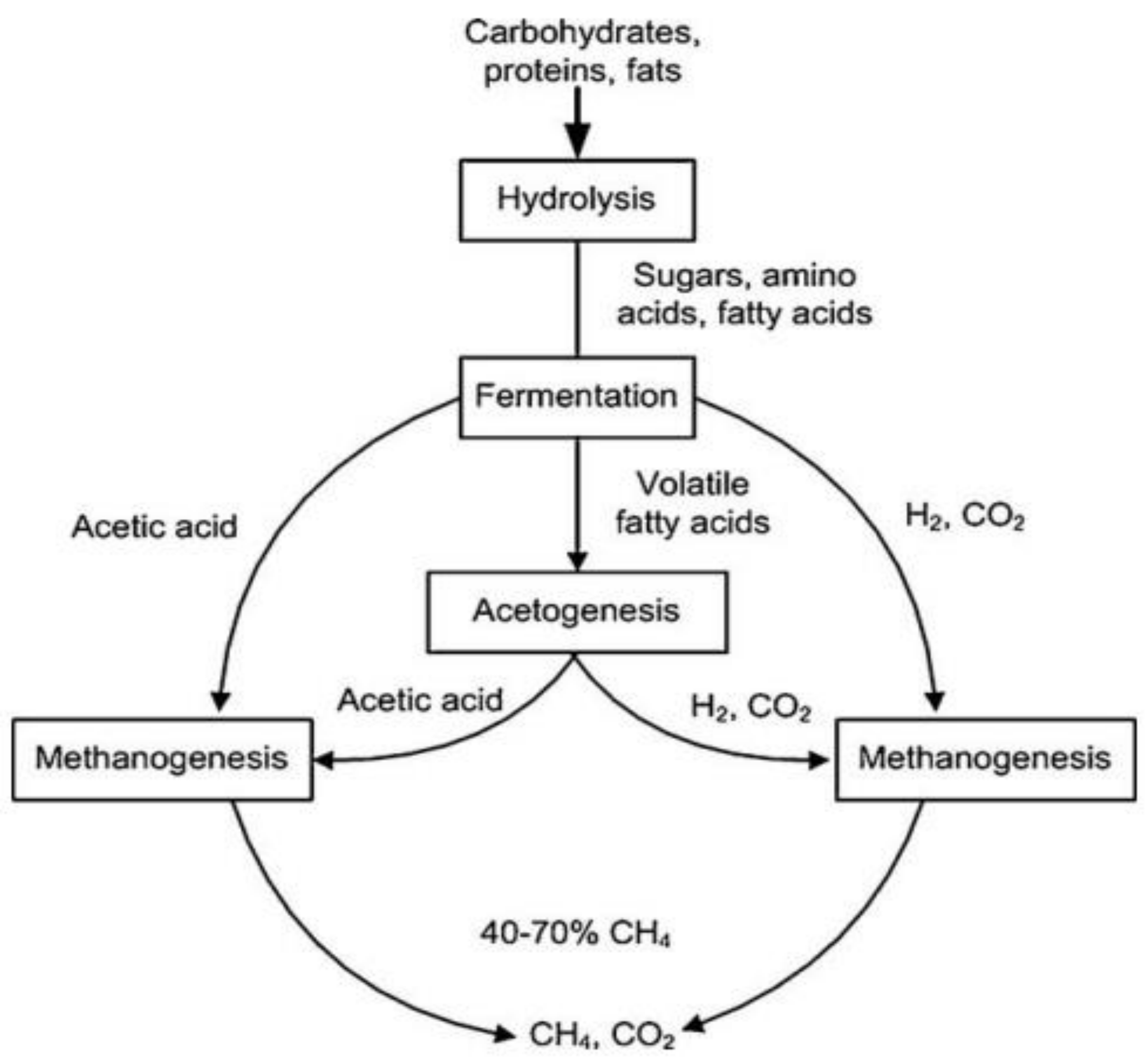
Introduction:

With rising energy demands and increasing landfill taxes, anaerobic digestion (AD) is becoming a popular technology to manage biodegradable waste and create renewable energy. Optimisation of the AD process is crucial to the income generated by an anaerobic digester. With the University of Leeds planning to install a pilot-scale anaerobic digester on campus, this research will examine the optimisation options available for such a digester through monitoring systems, vehicle fuel end use and precipitation of struvite. Cost-benefit analysis will be used to assess these optimisation options.



Anaerobic Digestion:

Anaerobic Digestion (AD) is the decomposition of organic material into methane, carbon dioxide and bio-fertiliser. As the name suggests, 'anaerobic' digestion occurs without the presence of oxygen. There are 4 main stages of anaerobic digestion; Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. These stages are illustrated in the figure below *(Li et al., 2011)*:



Aim:

Investigate the potential for economic and environmental optimisation of the proposed University of Leeds Anaerobic Digestion Facility through monitoring systems, vehicle fuel end use and precipitation of struvite.

Objectives:

1. Carry out cost-benefit analysis of the monitoring systems
2. Perform economic assessment of biogas-transport fuel system
3. Perform economic feasibility analysis of a struvite precipitation process
4. Make recommendations to the University as to potential approaches that could economically or environmentally optimise the facility.

Monitoring:

Proposed AD Facility	£/year
Total Benefits	£10,481.00
Total Costs	-£1,053.00
1ST Year NPV:	£9,428.00
Installation (one-off £180,000.00 payment)	-£9,000.00
Opportunity cost	-£12,327.00
Annual NPV (including opportunity cost)	-£11,899

Monitoring options	Approximate cost (£)
Enzyme biosensor - VFA	~£500/year
Electrochemical ammonia sensor	£80/year
Diaphragm Gas Meter	£180
NDIR sensor	£150

The cost-benefit analysis revealed that spending more than £5,500 on sensors would not be economically sensible. With that in mind, an NDIR sensor for both methane and carbon dioxide would be affordable, combined with a diaphragm gas meter to measure gas volume.

Struvite:

With a projected annual yield of 196 kg, it is estimated the annual NPV would equate to only £20-98 a year. Despite being unable to determine and verify capital expenditure for such a system, this income would certainly not be enough to break even over the facility's lifetime.

Biogas-Transport Fuel:

For biogas to be used as a transport fuel it must be first scrubbed of CO_2 and H_2S in order to contain high methane concentrations (~95%) . The capital cost figures have been calculated using a small-scale water scrubbing system from Metener equating to £47,000 (WRAP, 2012)

	CHP	Transport Fuel
Capital Cost (£)	180,000	221,500
1st year NPV (£)	9,600	14,200
Payback (yrs)	15.3	13.2
GHG savings (kgCO_2e yr^{-1})	13,000	19,600

The table above shows the far superior nature of a transport fuel based facility, both environmentally and economically. The only drawback of using the biogas as transport fuel is the higher capital costs. The transport fuel receives much of its income from RTFOc and the abatement of petrol which equate to almost £10,500 annually.

Conclusion:

The results reveal that monitoring systems costing under £5,500 could be cost-effective and worth implementing if a 5% boost to biogas yields is seen. Recommendations have been made for the sensor options that are considered financially beneficial. It is also recommended that that the biogas generated from the AD facility should be utilised as a transport fuel for university vehicles in replacement of CHP if the University can afford the £41,500 higher capital expenditure. The payback time would reduce by over two years and generate £77,000 more profit over the facility's lifetime. Whereas the incorporation of struvite precipitation from digestate is considered economically nonsensical.

References:

Li, Y., Park, S. Y., & Zhu, J. (2011). Solid-state anaerobic digestion for methane production from organic waste. Renewable and Sustainable Energy Reviews, 15(1), 821–826. doi:10.1016/j.rser.2010.07.042

WRAP 2012a. Small-scale biogas upgrade for vehicle fuel.

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