ANAEROBIC DIGESTION & CLIMATE CHANGE
Sustainable recycling of organic resources with renewable energy production

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Introduction

Anaerobic biological technologies have been used by mankind for many centuries, initially for food and beverage production and more recently in the water industry for treating sewage sludge and generating renewable energy. Our need to tackle climate change will demand widespread adoption of sustainable solutions and this will favour biological anaerobic technologies. These processes offer high energy yield, high treatment rates and low residuals production; important benefits increasing popularity of digestion in the future.

The treatment of organic materials involves the breakdown of large composite structures, initially into complex molecules of proteins, fats and carbohydrates and eventually to smaller molecules to allow the reuse of essential carbon, phosphorus and nitrogen for the growth of new plant and animal life. The biological pathways which facilitate this can be aerobic or anaerobic. Both occur naturally but aerobic pathways are rate limited by the transfer of oxygen to the organic material, and whilst man in his ingenuity has been successful in overcoming this by using energy intensive aeration processes, these contribute further to climate change.

In nature, concentrated organic materials resulting from decomposition of plant and animal life undergo recycling by the anaerobic route and it is this pathway which is used and intensified in anaerobic processes such as Anaerobic Digestion (AD). This is the preferred technology used by the water industry for stabilising sewage sludge and providing beneficial safe sustainable recycling of biosolids (i.e. treated sewage sludge) to the environment.

There are many other strong putrescible organic wastes and these have traditionally been buried in landfills or spread on land, generally without prior treatment. The Landfill Directive, and EU diversion targets mean that by 2015 some 65% of putrescibles wastes must be diverted from landfill and treated. AD offers an environmentally friendly, energy producing, fully proven and resilient alternative to landfilling of putrescible organics.

In the UK the total amount of “waste” organics is about 40 million dry tonnes p.a.[1,2,3,4] (see Table below) and if all of this was treated using AD it could in theory provide about 10% of the total UK electrical energy requirements. Diversion of organics from landfill has a further significant beneficial impact on global warming by eliminating uncontrolled emissions of methane from the decomposition of the waste and converting them to renewable energy as heat and electricity.

Organic Waste Energy Sources	Production Dry tonnes p.a (million)	Tonnes oil equiv. (million)
Sewage Sludge	1.4	0.2
Livestock Manure	15	2.2
Commercial Food	16	4.5
Domestic Food	7.5	2.1
TOTAL	40	9

In the UK over the last decade, there has been significant technical advancement and financial investment in advanced anaerobic digestion to increase utilisation of existing assets and safeguard the beneficial recycling route for sewage sludge to land.

Advanced digestion involves pre-treatment before digestion to increase hydrolysis and acidification of the waste. This provides a substantial efficiency gain in conversion of organics to gas and renewable energy along with increased throughput, a higher quality, pathogen free, “compost” like end-product and reduced operating costs. Much of the AD expertise derives from this experience in the water industry sector and despite differences in the input “waste”, is transferable to other “waste” sectors. Thus existing knowledge allows fast-tracking of process application to other “wastes” such as municipal household (organic fraction), domestic and commercial food waste, and livestock manures.

Anaerobic Digestion Biochemistry

Anaerobic digestion involves the breaking down of complex organic materials, typically consisting of carbohydrates, proteins and fats, into simpler compounds, in the absence of oxygen.

Hydrolysis reactions bring about the solubilisation of solid particles and these are then broken down into smaller molecules of simple sugars, amino acids and fatty acids. The process continues until all degradable material is converted to acetic acid or hydrogen and ultimately to biogas (a mixture of methane and carbon dioxide). Other essential nutrient elements such as nitrogen and phosphate are liberated from the original complex material largely as simple inorganic salts.

The process can take place at ambient temperatures and in a single reactor, however, optimisation is achieved by using higher temperatures (35 -55^{o}C) and multiple reactors.

The residue from digestion is known as the digestate. This is a stable, nutrient rich humus which is used sustainably to improve soil quality and fertility with the addition of valuable stable organic matter and nutrients.

Food waste

Each year in the UK about 7 million dry tonnes of food waste is produced as part of the manufacturing processes and there is a further 9 million tonnes of "out of date" or damaged food waste from supermarkets. Currently most of this is disposed of in landfill sites. This waste has a significantly higher energy value than the organic residues currently treated by AD (i.e. sewage sludge and livestock manure) and is generally available uncontaminated in large amounts, providing an ideal feedstock for AD treatment and recycling to farmland.

Municipal waste

About one third of Municipal household waste is organics which includes kitchen waste, garden waste and disposables such as nappies as well as paper and cardboard. Not all of these are biodegradable but kitchen waste is and it rapidly becomes putrid and smells. It is ideal for anaerobic digestion whereas garden waste is best composted, and paper can be more directly recovered. Current collection practice focuses on source sorting of clean waste (paper, bottles, cans, garden waste) whilst food waste is mixed in with the non-recyclables. In modern high density housing this can cause odour nuisance and health concerns amongst residents. The unsorted non-recyclables are then collected by the municipality and the organic fraction can then be separated out and treated. This process is generally known as Mechanical Biological Treatment (MBT) and the Biological stage is typically AD or composting.

Perhaps a better method is to separate the kitchen waste at source. When coupled with frequent collection of these organics using biodegradable plastic bags, odour and health worries are no longer a concern and this waste provides an ideal feed for AD. There are a small but increasing number of kitchen "waste" sorting schemes across the UK serving both composting and AD technologies.

Agriculture

Agriculture is responsible for 6.5% of the UK's GHG's (Greenhouse Gas) emissions[6]. The emissions of interest for AD, are those resulting from the decomposition of oganic matter in livestock manure. The methane emitted from liquid manure management systems can be captured and used as a renewable energy source. In the UK this is about 700,000 tonnes p.a. of carbon equivalent.

AD is used in the European Union particularly in Germany, Austria and Denmark, to allow capture of this methane from livestock manures and by recycling the nutrients in the digestate back to the land, the use of inorganic fertilisers can be substantially reduced.

In Germany the plan is for 10,000 AD plants by 2010 with an installed electrical capacity of 3,000 MW capable of supplying about 5% of Germany's electrical requirements. These agricultural based plants in Germany have benefited from the stable "Feed-in Tariff" arrangements (equivalent to 4 renewable obligation credits - ROCs) and a flexible feed approach allowing manure, energy crops and food waste all to be used.

There is much interest in the UK farming industry in AD. However, uncertainty about long term ROC values, increases the risk for any investor. More secure payback of capital can be achieved by co-digesting commercial food waste (which arrives with a gate fee) along with the manure. A number of such schemes are now operating in the UK.

Energy crops

There is much interest currently in using sustainable energy crops for production of bio-ethanol and bio-diesel. Whilst AD provides an excellent solution for treating putrescible organics, it is also possible to directly digest energy crops such as sugar beet, wheat grain and maize (before they become food and waste) for energy production.

AD should generally provide a more efficient conversion from crop to usable fuel than other technologies[5]. For example in producing bio-ethanol from sugar beet, the energy required for running the process is equivalent to 46% of the energy produced. By comparison such "parasitic" energy use is only 18% in producing biogas energy by AD from sugar beet.

AD produces biogas which is a premium fuel, ideal for electrical power generation and for heating using combined heat and power plants (CHP). The CO_2 present in biogas can also be removed and the methane fed into the gas grid or compressed and used as a vehicle fuel. The latter is being trialled in Sweden, and despite the parasitic energy use increasing it is still a very competitive 22%.

In comparing efficiencies of various processes for renewable energy production, clearly capital as well as running costs must be optimised. Whilst it is difficult at present to obtain reliable data for the above new applications, what is clear is the simplicity and resilience of the biological AD process using low temperature and simple robust tanks. This should ensure that over the long term, the total cost for an AD renewable energy installation, remains highly competitive.

Barriers to AD Growth in the UK

All sustainable energy and waste technologies are inevitably more expensive than present practices. Without incentives, market economics will not provide the investments needed to deal with climate change.

There are two main drivers for AD; gate fees for accepting the waste and enhanced prices (ROCs) for the renewable energy generated. In the longer term, viability will depend upon how investors view the risk-reward profile with a crucial factor in the analysis being investor confidence in the value and long term stability of ROCs.

The present ROCs regime has worked well and provided an incentive for AD particularly where existing digestion assets exist. The UK water industry is a good example and output of renewable energy from AD has increased threefold between 2002 and 2006.

Current generating capacity in the water sector is $40MW_e$ and sector data shows plans to expand this to 115MWe by 2010 with an ultimate potential of $186MW_{e.}$ The discussion proposal to reduce the ROC incentive to 25% of its current value will curtail energy based investment in this sector. This will also have a knock-on effect to other sectors since the water sector is the cradle of innovation in AD technologies in the UK and supports a world class UK based supply chain. Growth and knowledge transfer to new applications in the UK will be best achieved by building on a stable base in the water sector.

The current definition of a waste within the Waste Framework Directive is also a barrier in that it limits recycling of prime quality organics material, e.g. "food waste" and this also limits the co-digestion of different wastes. The EA and WRAP have adopted an innovative approach to overcoming this, namely the development of treated product quality protocols along the lines of BS PAS100 for compost. This approach should greatly assist the application of AD technology in other sectors.

The scale of any sustainable AD development is ultimately constrained by the balance between nutrients supplied and the crop needs on the surrounding land to utilise the recycled nutrients, especially nitrogen in the digestate. This is overcome by dewatering the digestate and treating the liquors.

Forward View

Anaerobic Digestion (AD) is the ideal process for treating "waste" generated from all stages of the food chain including the farm, abattoir, manufacturer, distributor, commercial and home food preparation to the resultant sewage sludge. Food "waste" has a high energy value and in capturing this, AD contributes to UK electricity needs whilst simultaneously facilitating recycling of essential nutrients and humus to the soil.
AD can also use crops as well as "wastes" to generate renewable energy, especially electricity,

and in a more efficient process, with lower parasitic energy requirement, than that used for bio-ethanol and bio-diesel production.

In practice there will be a variety of AD plants and whilst some will be dedicated to particular applications such as sewage sludge and household waste others will take a variety of feedstocks including livestock manures, food waste and energy crops. The new WRAP/EA quality protocols planned for the UK should revise the legislation and provide a level playing field for recovery of all biodegradable organics including those currently classed as wastes.

In the longer term AD's great strength as a natural biological process, able to convert putrescible organics into renewable energy and control odour, will become increasingly valued.

Endnotes

1. Sewage sludge data from e-digest of environmental statistics, published February 2006.
2. Livestock manure data from Biomass task force report, 2006.
3. Commercial food waste data from Encycle News, November 2006.
4. Domestic food waste from DEFRA annual waste arisings survey 2003 and OU Household waste survey 2004.
5. Energy crop conversion data from Dr Andrew Salter, Southampton University, personal conversation.
6. Agriculture emission from NFU and Methane to Markets Partnership.

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