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Anaerobic Digestion

Overview

- AD can process food waste, manures, sewage sludge and purpose-grown crops.
- It can reduce methane emissions from agriculture and landfills and could produce up to 1% of the energy delivered to UK consumers by 2020.
- A range of financial incentives for biogas production are now in place.
- Regulations can be complex, notably for injection of biomethane into the gas grid.
- Other barriers to the development of AD include a lack of guaranteed material supply and difficulties in accessing finance.
- The use of digestate as a fertiliser may be limited by a lack of market acceptance.

Anaerobic digestion (AD) can divert waste from landfill and produce biogas, a source of renewable energy, and "digestate", a fertiliser. This POSTnote examines the potential for AD in the UK, and the main challenges connected with its development.

Background

Anaerobic digestion (AD) is the breakdown of biodegradable organic material by microorganisms in the absence of air. It occurs extensively, for instance in landfills and the stomachs of cows. By controlling the process two useful products are obtained: biogas and residual digestate (a nutrient-rich fertiliser). AD technologies are well-proven and have been used in the UK for over 100 years to treat sewage sludge. However, there is growing interest in processing a wider range of materials including food waste, manure and crops.

The biogas produced by AD can be combusted directly to produce electricity and heat, or purified for injection into the gas network or for use as a transport fuel. In the UK, the main focus has been electricity generation. In August 2011:

- 147 plants were treating 18.3 million tonnes (Mt) a year of wet sewage sludge;[1]
- 66 plants were treating approximately 1 Mt a year of wet food and agricultural waste.[2]

Together these plants represent 151 MW_e of generation capacity,[1, 2] which could provide the electricity for around 300,000 homes annually.[3] AD is used more widely across Europe. Germany has about 6800 plants mainly producing electricity, while Sweden has 173 plants chiefly supplying heat and transport fuel.[4]

The government has committed to an increase in energy from waste through AD, with the "AD Strategy and Action Plan" for England published in June 2011.[5] AD can help to meet several UK targets (Box 1) by:

- **producing a flexible source of renewable energy.** It could provide 0.2–0.7% of the energy delivered to UK consumers by 2020, as part of the 15% target (Box 1).[5, 6]
- **recycling waste and avoiding the emission of methane**, a powerful greenhouse gas. This is released when biodegradable waste breaks down in landfills and when manures and slurries are stored.
- **recycling nutrients,** especially nitrogen and phosphorus, by using the digestate as a fertiliser, thus displacing manufactured or mined fertiliser.

This note examines some of the challenges related to maximising each of these benefits using AD.

Box 1. Legislative Drivers for Anaerobic Digestion

Energy and Climate Change

The EU Renewable Energy Directive requires that 15% of the energy delivered to UK consumers comes from renewable sources by 2020. The UK's Climate Change Act (2008) requires greenhouse gas emission reductions of 80% by 2050, compared with 1990 levels.

Waste

The EU revised Waste Framework Directive requires 50% of household waste to be recycled by 2020. This is expected to include biodegradable waste treated by AD, as long as the digestate meets "End of Waste" criteria (Box 3). The EU Landfill Directive requires the amount of biodegradable municipal waste going to landfill to be reduced to 35% of 1995 levels by 2020. The diversion of waste from landfills is encouraged through the Landfill Tax, currently set at £56 a tonne and rising to £80 in 2014. As waste management is a devolved issue, other regulations and incentives vary across the UK.

Renewable Energy

Biogas is a mixture of methane (50-70%), carbon dioxide (25-45%) and minor impurities. The aims for energy production are to:

- **maximise the amount of methane produced,** which partly depends on the raw material used (Table 1).
- **efficiently convert this methane** into electricity, heat or transport fuels.

The method of biogas use affects the level of carbon savings and the total amount of renewable energy produced. The Carbon Trust found that, if the electricity system is decarbonised, the greatest carbon savings from AD would be gained by upgrading the biogas to nearly pure methane ("biomethane"), equivalent to natural gas, and using this as a transport fuel or injecting it into the gas grid.[7] Electricity-only generation gave the lowest carbon savings. Nevertheless, most AD plants in the UK currently burn the biogas to produce electricity as this has had the fewest technical and regulatory barriers and the most financial support. Incentives are now in place for all biogas uses (Box 2), although barriers still remain.

Box 2: Financial Incentives

The financial incentives available for AD plants depend on their size and the use of the energy produced. Under EU State Aid rules these incentives cannot be obtained if a project has received any other public funding, such as a grant.

- **the Renewables Obligation (RO),** introduced in 2002, supports renewable electricity generation (>50 kW_e) by requiring suppliers to source an increasing proportion from generators, through the purchase of tradable Renewable Obligation Certificates (ROCs). The RO was banded in 2009 to vary support for different technologies. AD using sewage sludge currently receives 0.5 ROCs per MWh and other AD receives 2 ROCs.
- **Feed-in Tariffs (FiTs),** introduced in 2010, provide a guaranteed payment for renewable electricity producers (<5 MW_e). Smaller generators, with higher capital costs per MW, receive a higher price. From 1 August 2011, support was increased for the smallest AD plants (up to 500 kW_e) as a result of a fast-track review.
- **the Renewable Heat Incentive (RHI),** introduced this year, will provide a guaranteed payment for heat used from biogas combustion (<200 kW_{th}) and all biomethane injected into the grid.
- **the Renewable Transport Fuels Obligation (RTFO),** introduced in 2008, places an obligation on suppliers to source 5% of their transport fuels from renewable sources by 2014. Biomethane is eligible for Renewable Transport Fuel Certificates (RTFC), which can be bought by fuel suppliers to meet the RTFO. The DfT has recently consulted on the introduction of double RTFCs for transport fuels made from waste.

Biomethane Injection into the Gas Grid

Biomethane can be injected into the gas grid, and is one of the few renewable alternatives to natural gas. The AD industry has welcomed the level of financial support within the Renewable Heat Incentive (RHI; Box 2). However, biomethane injection is hindered by the gas specifications in the Gas Safety (Management) Regulations 1996. These are based on the composition and production volumes of North Sea gas, and require extremely low oxygen contents and expensive monitoring equipment. Although enforced by the Health & Safety Executive, any changes require the agreement of the Department of Energy and Climate Change (DECC). There are also issues around who should pay for and maintain gas connection equipment:

Table 1. Feedstocks: Availability, Methane Yield and Waste Status

Feedstock	Methane yield[a] (m^3/wet t)	Max availability in the UK (wet weight) in million tonnes[b]	Waste Status
Food and drink waste	30 - 145[8, 9]	**8.3 Mt** from homes.[10] Approx. **3.6-5.8 Mt** from commerce.[11, 12]	**Waste**
Sewage sludge	9 - 16[13]	**24-34 Mt**. 71% recycled in 2010.[14]	**Waste**, exempt from Environmental Permitting Regulations (Box 3)
Animal slurry and manure	12 – 23[8]	Approx. **76 Mt**[15]	**Waste if used in AD.** Digestate is not a waste.
Purpose-grown crops	50 – 220[8]	**10–29 Mt** could be grown for all energy uses by 2020.[16,17]	**Not waste.**

[a] Higher water contents reduce the total methane yield. Approx. water content: 70-85% for food waste; 90-95% sewage sludge, manures and slurry; 60-85% crops.
[b] This is the maximum available and does not indicate the feasible quantity for AD.

biomethane producers or the gas grid owners. Regulators, gas grid networks and the AD industry are working to solve these issues. Even where there is a gas pipeline near an AD plant, it may not be able to receive the biomethane output all year round, due to lower demand for gas in the summer months. To overcome this, gas could be moved around the gas grid. Two AD plants in the UK are currently able to inject biomethane via exemptions from the gas regulations.

Transport Fuels

Biomethane can be used in vehicles designed to run on compressed natural gas. These are widely used throughout the world, although they are currently very limited in the UK. As well as decreasing carbon dioxide emissions, use of compressed biomethane can improve air quality by reducing particulate and nitrogen dioxide emissions. However, in the UK only 0.01% of renewable transport fuels are supplied by biomethane, partly due to the low price of the Renewable Transport Fuel Certificates in comparison with other financial incentives for biogas use. As an alternative, the European Natural Gas Vehicle Association advocates injection into the gas grid, to obtain the RHI, with removal at existing distribution depots. Currently no vehicles in the UK use biomethane from AD, although there are trials using landfill gas.

Combined Heat and Power (CHP)

By-product heat is produced when biogas is burnt to create electricity. If this heat is used, the overall energy efficiency and carbon savings of electricity production from biogas are greatly improved. However, there is a lack of infrastructure to distribute the heat, the value of heat is low and optimum use requires a site with constant heat demand throughout the year. Increasingly, some heat is used to maintain the temperature of the digester but most AD plants do not use all of their heat. The industry is waiting for information about RHI support from 2012 for larger CHP plants (>200 kW_{th}).

Purpose-Grown Crops

Non-woody crops, such as grasses and maize, can be used in AD as the sole feedstock, or mixed with others. They have high methane yields (Table 1) and their production could be increased, unlike limited sources of waste. However, it remains uncertain how much can be produced in the UK for energy uses. The government recognises that crops for AD can be grown as part of a normal agricultural rotation or on land which is not suitable for food crops, and that some crops may need to be added to slurry-based AD to ensure efficient operation (see later). However, it has stressed that it does not want to encourage the sole use of these materials, due to concerns about the displacement of food and feed or increased greenhouse gas emissions from land-use change. Operators compare this with support for other bioenergy technologies, with the planting of woody perennial crops for combustion assisted by grants worth £47 million.[18] Defra and the industry are now working to study the "sustainability and role of purpose-grown crops in AD". Knowledge of the optimum use of the UK's biomass resource for energy purposes should also be improved by DECC's Bioenergy Strategy and the Committee on Climate Change's Bioenergy Review, both due in late 2011.

Access to Finance

Access to finance is currently challenging for many AD plants. The rate of return provided by the "Feed-in Tariffs" (FiTs) or the RHI (Box 2) may not be sufficient to overcome the technological and feedstock supply risks that are greater than for other renewable technologies. There are also fears about the long-term security of financial incentives following the recent unplanned adjustment of the FiTs. Specifically, the incentives may be too low to stimulate small farm-based AD. The AD industry has suggested that the Green Investment Bank could help to provide loans.

Recycling Waste

The main sources of waste feedstocks for AD are food and drink, sewage sludge, animal slurries and solid manures (Table 1). Different environmental regulations (Box 3) and barriers apply to the supply and treatment of each material.

Box 3. Environmental Regulations

Environmental Permitting Regulations (EPR)

Digestion of wastes is regulated by the Environment Agency (EA). Permits are required for the digester, biogas combustion and digestate storage, transport and use. Although the regulations can be complex and are developing, the industry has praised the Environment Agency for responding to its needs. They have also welcomed the introduction of exemptions for small-scale facilities and standard permits for on-farm and food waste digestion. If any feedstock is a waste, the biogas and digestate (except digestate derived from manures and slurries) are classified as wastes until they meet End of Waste (EoW) criteria.

End of Waste Criteria (EoW)

EoW criteria are being developed to enable materials that will not harm human health or the environment to be used as a product. Once these criteria have been met, the material is no longer classed as a waste and can be used without obtaining environmental permits.

- once combusted, **biogas** is no longer a waste
- EoW criteria are being developed by the EA for **biomethane**
- existing EoW criteria for **digestate** (The Quality Protocol for anaerobic digestate) require that the feedstock must be source-segregated (and cannot include sewage sludge), be recycled to land and meet an approved specification (PAS110).

Animal By-product Regulations (ABPR)

These control the use of materials of animal origin that are not intended for human consumption, such as blood, feathers and uneaten eggs, meat or fish. AD plants can treat low-risk forms of this waste (e.g. catering waste, cooking oil, fish) and manures. Food waste (and imported manure) must be batch pasteurised at 70°C for 1hr to reduce the content of possible disease-causing microorganisms.

Food and Drink Waste

Several studies indicate that it is more environmentally beneficial to treat food waste by AD than by centralised composting or incineration.[19] Although careful control of the process is required for all inputs (Box 4), plants using food waste are the most complex due to the variable and protein-rich feedstock and the need for batch pasteurisation (Box 3).

Box 4. Factors to Control During Anaerobic Digestion

- **homogeneity**, by adding a consistent feedstock continuously
- **feed rate**, to ensure that the bacteria are not overloaded
- **nutrients**, at the correct levels for the bacteria. For example, the high levels of nitrogen found in meat can inhibit AD.
- **toxic compounds**, which could kill the bacteria
- **temperature**, to ensure the bacteria work optimally
- **safety management**, to reduce the risks associated with biogas including explosions and hydrogen sulfide poisoning.

AD plants can currently charge a price (gate fee) to take food waste, providing an important source of revenue. However, over the past year, gate fees have decreased. In the light of potential future reductions, waste producers are unwilling to lock themselves into supply contracts, creating a lack of feedstock supply security and inhibiting access to finance. Local authorities offer longer term contracts, but these may be tied into other waste treatment technologies, and the food waste may not be "source-segregated".

Separate collection and storage ("source-segregation") of food waste is necessary to ensure that the digestate will meet "End of Waste" (EoW) criteria (Box 3). If these are not met, environmental permits are required to use the digestate as a fertiliser. In England an estimated 13% of households receive a separate weekly food waste collection,[5] rising to 82% in Wales.[12] Evidence indicates that more food waste is captured when this is provided in conjunction with a fortnightly, rather than weekly, residual waste collection.[20] It has been suggested that food waste disposers (Box 5) could reduce the need for separate kerbside collections.[21]

Box 5. Food Waste Disposers (FWDs)

These units dispose of food waste down kitchen sinks, by macerating and transporting it within the sewers. Although only 6% of UK homes have FWDs, in total households annually throw away 1.8Mt of food and drink down the sink.[10] Water UK has raised concerns about the additional load on sewerage systems if FWDs are promoted,[22] though some other countries have not encountered this problem.[20] Concerns remain that the "out-of-sight, out-of-mind" mentality that FWDs uphold may reduce waste prevention. FWDs may be most suitable for situations where separate food waste collections are challenging, such as flats. A Defra-funded project comparing the sustainability of various food waste collection and treatment options is due to report shortly.

The Welsh Government has introduced a statutory recycling target for local authorities (LAs) of 70% by 2025. Where LAs recycle source-segregated food waste using AD, it will fund up to 25% of the LAs' food waste treatment costs under 15 year guaranteed contracts. Scotland is consulting on the Zero Waste Regulations 2011, which could require the source-segregation of all food waste from 2013, with a landfill ban from 2015. In England, some in the industry have argued for a similar landfill ban to increase feedstock supply and access to finance. However, the Local Government Group is adamant that LAs need to determine locally the best method for the collection and disposal of waste. The government will review the case for a landfill ban on biodegradable waste during the current Parliament.

Sewage Sludge

The water industry is interested in co-digesting sewage sludge with other organic materials to use the small amount of spare capacity in their AD plants. However, because sewage sludge is excluded from the feedstocks allowed for a digestate to meet EoW criteria (Box 3), if it is co-treated with another material the digestate will always be a waste. The tests that apply to the use of treated sewage sludge (under the Sludge Use in Agriculture Regulations 1989) and EoW digestate as fertilisers are similar. However, there appears to be little desire in the EU or from retailers to include sewage sludge as an allowable material for co-digestion. If the water industry were able to accept a variety of organic materials, smaller AD companies are concerned about whether there will be a level playing field for competition over feedstocks. To address this, Ofwat, the independent regulator of the water industry, has asked the Office of Fair Trading to carry out a market study of organic waste. This should be published in September 2011.

Animal Slurries and Solid Manures

Solid manures and slurries are already spread on to land, but passing them through an AD plant first can produce a less odorous, more uniform fertiliser, as well as reducing methane emissions and pathogen and weed seed levels. Because manures are already partially digested, biogas yields and economic returns can be greatly improved when they are co-digested with other organic materials, such as purpose-grown crops or food waste.[23] The amount required will vary during the year as manure and slurry will be collected only when animals are housed. As purpose-grown crops are a non-waste feedstock, their use for co-treatment adds fewer regulatory burdens than other materials. The Environment Agency is looking into whether low-risk agricultural wastes, such as vegetable peelings, could be controlled in the same way as manure, (i.e. the digestate is not a waste). An alternative model could involve the central pasteurisation of source-segregated food waste, with distribution to farms to combine with manures.[24]

Recycling Nutrients

The digestate contains all of the non-degradable elements of the feedstock including any pollutants, water and a high proportion of the vital plant nutrients nitrogen, potassium and phosphate. The last are usually applied to fields via manufactured fertilisers. However, prices have increased dramatically and there are concerns about a future phosphate shortage and the impact of large-scale fertiliser manufacture on the nitrogen cycle. Initial data indicate that using one tonne of food waste digestate as a fertiliser could provide 4-6 kg of nitrogen, saving 20-40 kg of CO_2 equivalent emissions.[25] Digestate from sewage sludge has been used as a fertiliser for many years. However, several factors can affect the use from other sources including:

- **a lack of knowledge** about the impacts on crop growth, soil quality and the environment. A government-funded study on "Digestate and Compost Use in Agriculture" should be completed by March 2014.
- **a lack of market understanding and acceptance** in the farming, retail and farm assurance sectors. EoW criteria (Box 3) are expected to improve confidence.
- **the cost to AD operators** of spreading digestate onto land, though future increases in fertiliser prices may improve the digestate value.
- **storage requirements** during periods when digestate cannot be spread in Nitrate Vulnerable Zones (Box 6).
- **odour levels,** (can be reduced by controlling application)
- uncertainty about whether digestate from non-household food sources can be **used on certified organic land**.

Box 6. Nitrate Vulnerable Zones (NVZ)

These apply to agricultural land where waters are polluted by nitrate leaching. In autumn and winter, when rainfall is highest and plants are not taking up nitrogen, farmers must not apply nitrogen- containing fertilisers. Application limits apply for the rest of the year. AD can increase the availability of nitrogen in the digestate, so knowledge of its nitrogen content and control of its use is vital.

Future Challenges

Several overarching issues may ultimately influence the scale of the AD industry and its environmental impacts:

- **efficiency of biogas use.** The total amount of renewable energy supplied will depend on how the biogas is used. Electricity-only production is the least efficient use.
- **competition with other technologies for a continuous feedstock supply.** High energy materials such as crops and fatty foods are useful for several technologies other than AD, including combustion and biofuel production.
- **food waste prevention versus use for AD.** 64% of household food and drink waste is estimated to be avoidable.[10] If prevented this could save 2.4% of the UK's annual greenhouse gas emissions but would also reduce the potential feedstock for AD.[10]
- **the impacts of digestate use on soil and water quality**. The effects of heavy metals, persistent organic compounds, nitrates or phosphates, should be monitored.

Endnotes

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More information is available from the AD Portal at www.biogas-info.co.uk

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