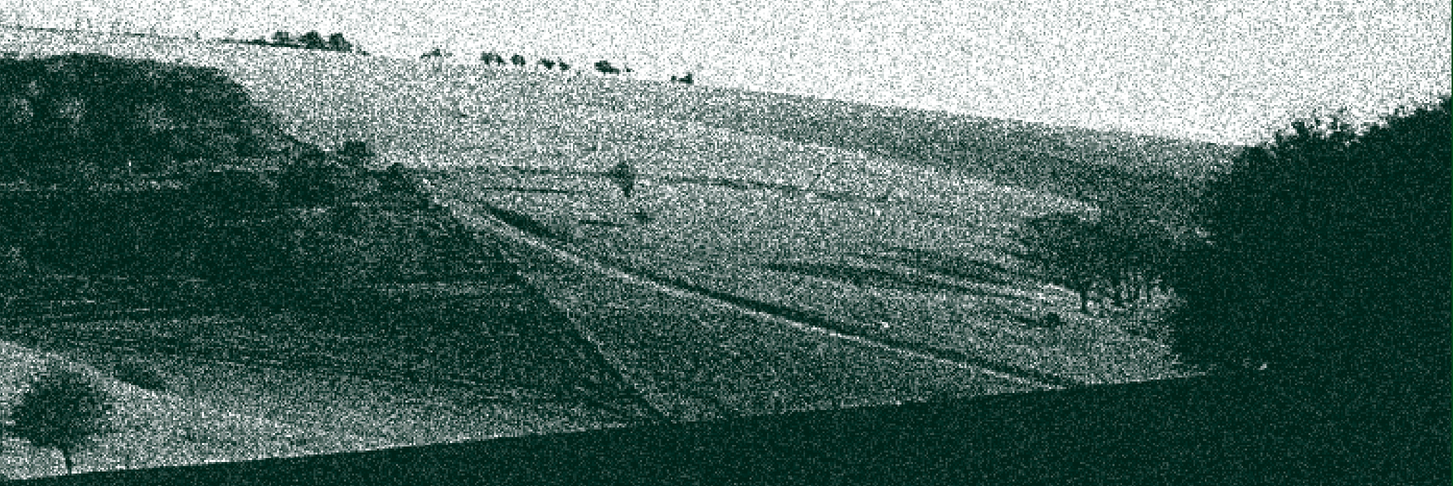
Anaerobic Digestion

of farm and food processing residues

Good Practice Guidelines



integrated waste management

energy production

soil conditioner

liquid fertiliser

The development of a sustainable industry

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AD technology
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Maltin Pollution Control Systems
MEB Midlands Electricity plc
NFU
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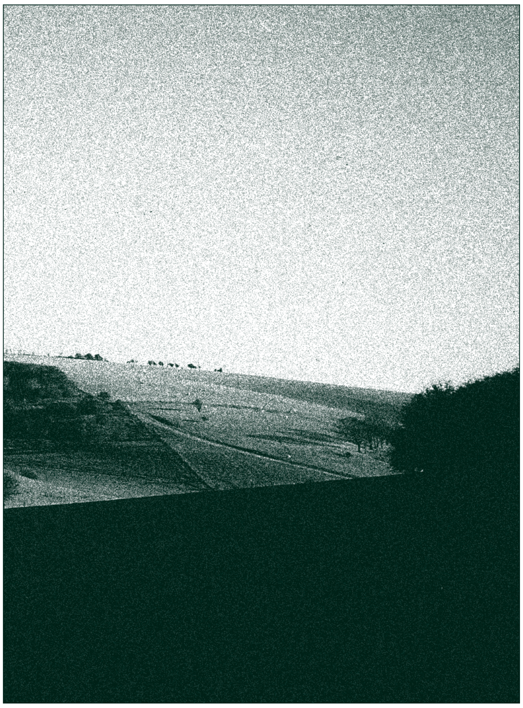

Anaerobic Digestion of farm and food processing residues

The development of a sustainable industry

Good Practice Guidelines

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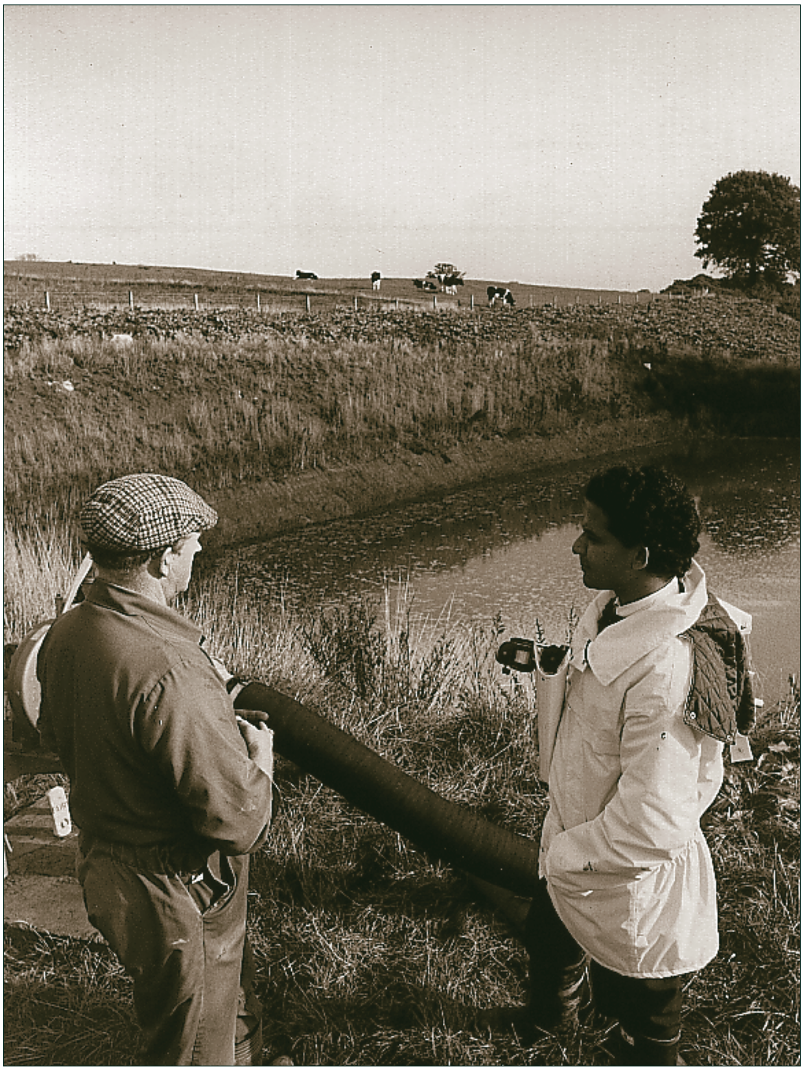


Photo: ETSU

AD is a process which manages farm and food processing residues

What is Anaerobic Digestion?

Anaerobic digesters produce conditions that encourage the natural breakdown of organic matter by bacteria in the absence of air. Anaerobic digestion (AD) provides an effective method for turning residues from livestock farming and food processing industries into:

- **Biogas** (rich in methane) which can be used to generate heat and/or electricity
- **Fibre** which can be used as a nutrient-rich soil conditioner, and
- **Liquor** which can be used as liquid fertiliser.

The AD process is already used for treating agricultural, household and industrial residues and sewage sludge. It has been used in the UK agricultural sector in the form of small on-farm digesters producing biogas to heat farmhouses, dairies and other farm buildings. Experience has shown that an AD project is most likely to be financially viable if it is treated as part of an integrated farm waste management system in which the feedstocks and the products from AD all play a part. Larger scale centralised anaerobic digesters (CADs) are also now being developed, using feedstock imported from a number of sources.

This document avoids the term 'waste' in the context of the residues from livestock farming and food processing industries because 'waste' implies that the material is a problem rather than a resource. These guidelines therefore use the term 'residues' wherever possible to reinforce the importance of seeing these materials as a renewable resource.

These residues offer positive opportunities to contribute to AD as a new and sustainable industry. Feedstock is the term used to describe the material introduced into the digester; in these guidelines it refers specifically to residues from livestock farming (such as dairy, beef and pig slurry, or poultry litter) and the food processing industries (including vegetable preparation and dairy food processing).

At present, any waste from premises used for agriculture is not controlled waste, including food processing waste. However, food processing waste from other premises is controlled waste and is subject to waste management licensing controls.

How does AD work?

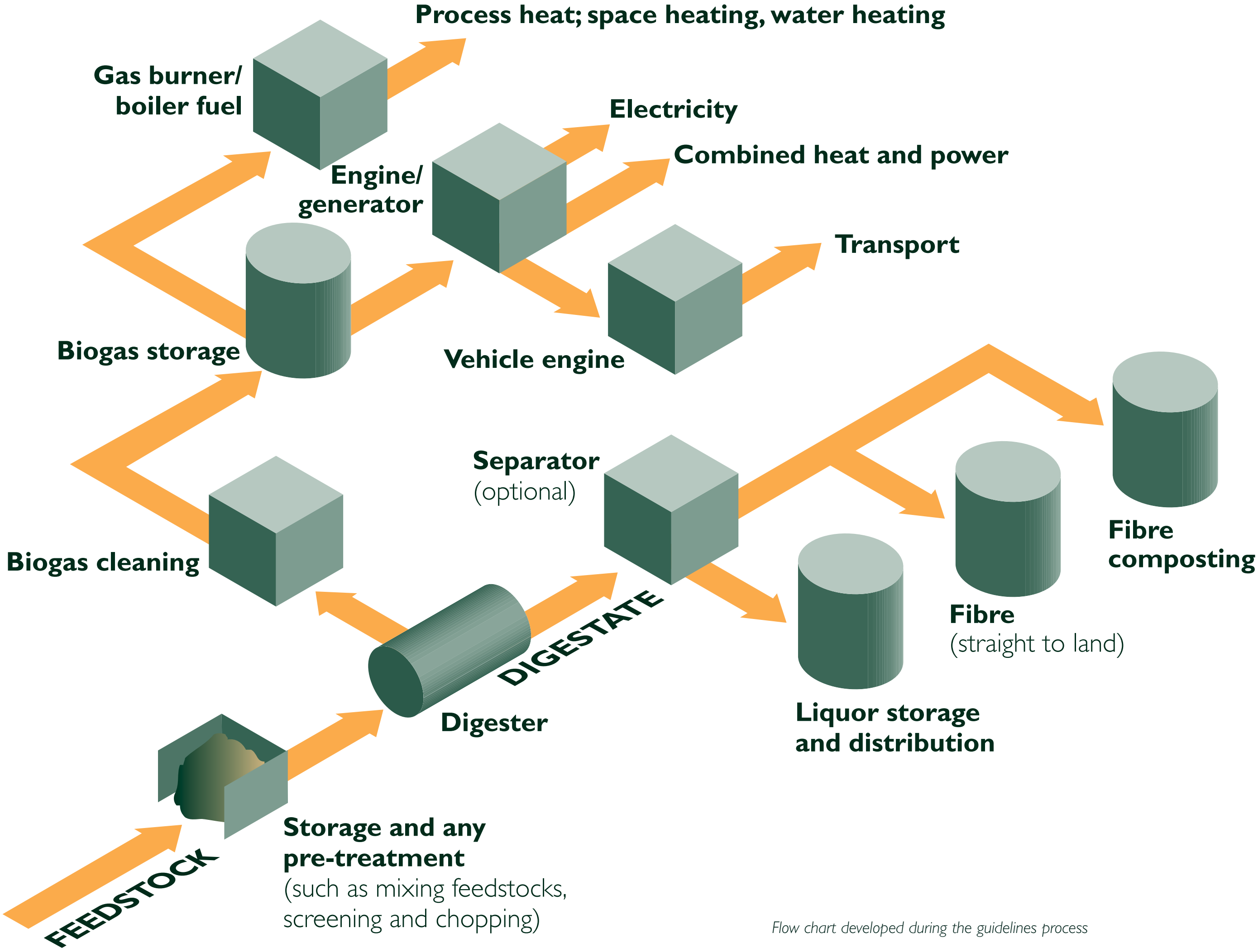
The digestion process takes place in a warmed, sealed airless container (the digester) which creates the ideal conditions for the bacteria to ferment the organic material in oxygen-free conditions. The digestion tank needs to be warmed and mixed thoroughly to create the ideal conditions for the bacteria to convert organic matter into biogas (a mixture of carbon dioxide, methane and small amounts of other gases).

There are two types of AD process.

- **Mesophilic digestion.** The digester is heated to 30 - 35°C and the feedstock remains in the digester typically for 15 - 30 days. Mesophilic digestion tends to be more robust and tolerant than the thermophilic process, but gas production is less, larger digestion tanks are required and sanitisation, if required, is a separate process stage.
- **Thermophilic digestion.** The digester is heated to 55°C and the residence time is typically 12 - 14 days. Thermophilic digestion systems offer higher methane production, faster throughput, better pathogen and virus 'kill', but require more expensive technology, greater energy input and a higher degree of operation and monitoring.

Figure 1.

Overview of the AD process



Flow chart developed during the guidelines process

During this process 30 - 60% of the digestible solids are converted into biogas. This gas must be burned, and can be used to generate heat or electricity or both. It can be burned in a conventional gas boiler and used as heat for nearby buildings including farmhouses, and to heat the digester. It can be used to power associated machinery or vehicles. Alternatively, it can be burned in a gas engine to generate electricity. If generating electricity, it is usual to use a more efficient combined heat and power (CHP) system, where heat can be removed in the first instance to maintain the digester temperature, and any surplus energy can be used for other purposes. A larger scale CHP plant can supply larger housing or industrial developments, or supply electricity to the grid.

As fresh feedstock is added to the system, digestate is pumped from the digester to a storage tank. Biogas continues to be produced in the storage tank; collection and combustion may be an economic and safety requirement. The residual digestate can be stored and then applied to the land at an appropriate time without further treatment, or it can be separated to produce fibre and liquor. The fibre can be used as a soil conditioner or composted prior to use or sale. The liquor contains a range of nutrients and can be used as a liquid fertiliser which can be sold or used on-site as part of a crop nutrient management plan.

AD products can, therefore, help farmers reduce their requirement for non-renewable forms of energy such as fossil fuels, and the digestate, if correctly used, can reduce demand for synthetic fertilisers and other soil conditioners which may be manufactured using less sustainable methods.

Using these guidelines

These guidelines cover good practice for existing and potential AD plants using residues from livestock farming and food processing: they do not cover all possible feedstocks for AD. They specifically do not cover wastes such as sewage sludge, municipal solid waste or specified bovine material or other abattoir residue, all of which are covered by other guidelines and regulations.

Whether an on-farm digester, or a larger scale centralised anaerobic digester (CAD), is being considered, the principles remain the same. These good practice guidelines aim to help new projects to proceed in an appropriate and sensitive manner so that the industry as a whole can continue to expand with a responsible reputation. The guidelines will also be useful for local authority officers and councillors, who may be considering applications for planning permission for a digester, or establishing waste management or renewable energy projects themselves or in partnership with others, and for local communities and neighbours. They have been developed by a whole range of organisations and individuals with extensive experience of AD development as developers, farmers, users, environmental bodies and planners.

The guidelines cover reducing the risks of environmental pollution, ways of maximising economic viability, and consultation with local communities. They show how AD can reduce the risk of farm pollution through integrated waste management, reduce greenhouse gases, generate energy from a renewable, relatively non-polluting source, and provide soil conditioner and fertiliser, reducing input costs. The guidelines stress that, although AD is a proven and relatively simply technology, the importance of health and safety should not be underestimated and management must always consider safety as well as effective production and environmental impact.

All new developments have some negative environmental impacts. It is the responsibility of the developer of any AD scheme, whether a farmer, a co-operative or a commercial CAD developer, to consider its environmental and health and safety impacts and its acceptability to local communities, as well as its economic viability - minimising any negative impacts through appropriate developments for local circumstances and good practice in establishment and management. All these issues are considered throughout these guidelines.

Renewable energy

Renewable energy is the process of producing energy without using finite resources. By replacing fossil fuels (such as coal and oil), it can avoid the pollution that causes climate change and acid rain. Any development producing energy from renewable sources is generally considered to be environmentally beneficial.

All renewable energy developments must be seen in the context of UK and EU policy on sustainable development: that is, development which meets the needs of the present without compromising the ability of future generations to meet their own needs. Energy production is a vital element of such a future. Problems of pollution, current rates of consumption of finite fossil fuels, and dependence on imported fuels associated with conventional methods of energy production are generally seen as unsustainable.

Energy from AD offers great potential for using a renewable resource for electricity, heat, and combined heat and power generation. It is also carbon neutral (ie does not generate extra carbon dioxide), and can therefore reduce overall quantities of carbon dioxide in the atmosphere, reducing dangers of climate change, when it is used to replace energy from fossil fuels. Adoption of the AD process can lead to improvements in the management of farm and food processing residues, and there may be significant further environmental and ecological benefits alongside the development of a fully sustainable energy resource.

Why establish an AD project?

AD projects may be initiated from several perspectives:

- Commercial interests such as electricity companies, fertiliser and compost manufacturers
- Residue (waste) producers (farmers, land owners and food processors)
- Local community initiatives such as partnerships between local authorities and farmers.

The full environmental and practical impacts of AD are given in detail on pages 8 – 10. Different interests will have different priorities in wanting to establish an AD project. Some of the main reasons for developing an AD project are summarised below.

Reduction of pollution through integrated waste management

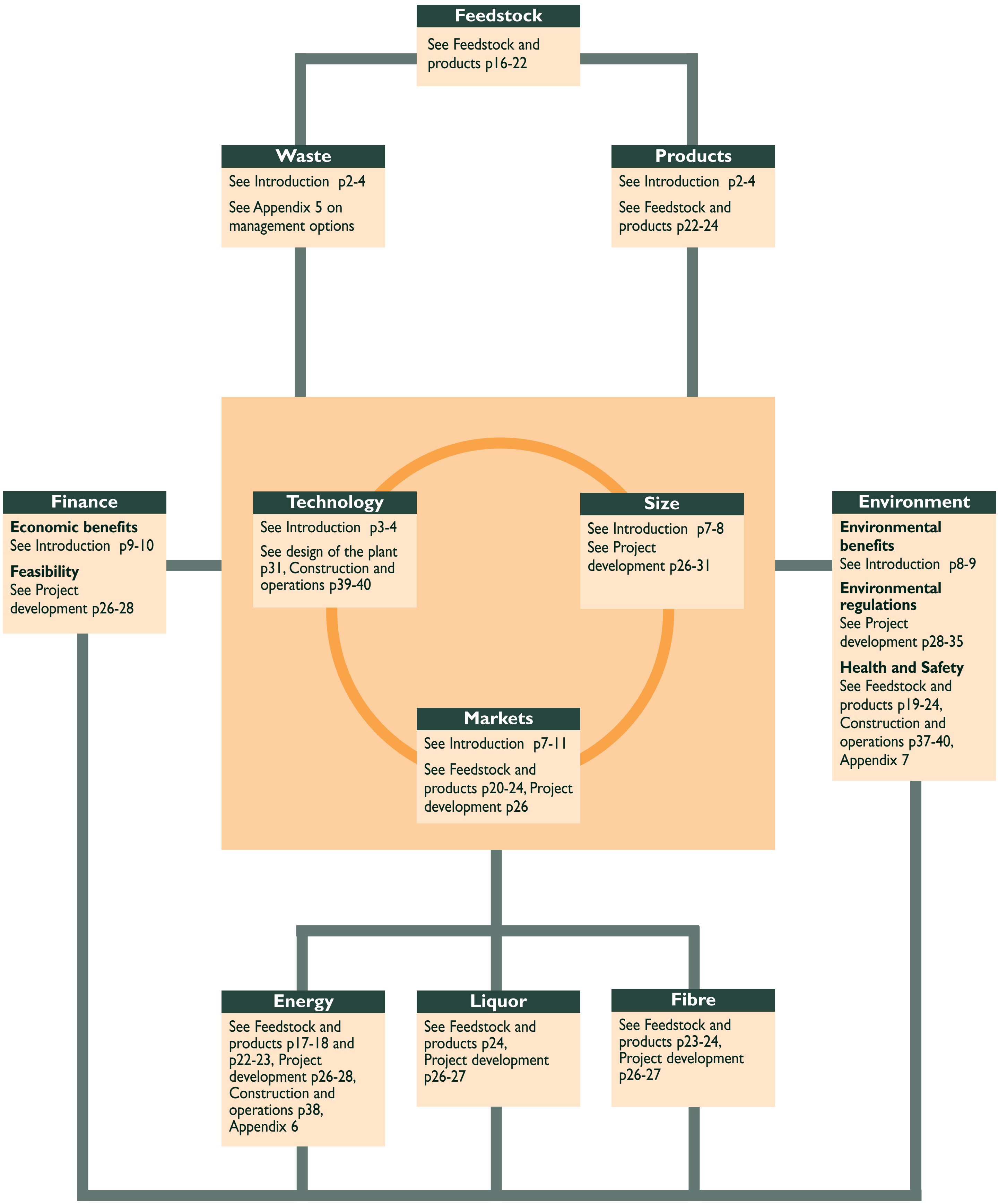
- AD offers an opportunity to reduce odour.
- AD can reduce nitrate pollution of water courses because run-off is reduced through more effective control of nutrient application to land.
- If applied correctly, AD may reduce the risks of the spread of disease and weed seeds.
- Well-managed AD can control methane emissions more effectively than some other waste management methods.
- AD therefore helps farmers and others to respond to new regulations and public pressure to increase the effectiveness of farm residue management.

Increased income and savings

- AD can generate income from sale of biogas (as electricity), liquor and fibre products.
- AD can offer financial savings through the use of the products on-site avoiding the costs of synthetic fertilisers, other soil conditioners and energy from other sources.

Figure 2.

Factors affecting the development of an AD project



Changing legal and political context

- Public perceptions are changing, and consumers are increasingly demanding farming practices that are environmentally sensitive.
- There are increasing legislative and regulatory pressures on farmers in relation to local waste management and wider environmental concerns about farming practices.

Growing demand and market for renewable energy

- Heightened concern about global warming and climate change have influenced UK Government and EU action plans. Prior to the election the Labour Party's manifesto made a commitment to reduce UK carbon dioxide emissions by 20% of 1990 levels by 2010.
- Government and EU policy is to increase the proportion of energy from renewable sources. The UK is considering what would be necessary and practicable to achieve 10% of the UK's electricity needs from renewable sources by 2010.
- The energy industry is being opened up to full competition, offering new and expanding markets for energy from alternative sources such as AD.

Community issues

- AD projects can directly boost the local rural economy through creating jobs in AD developments, and indirectly through increasing disposable incomes in rural areas.
- AD can provide a waste management option with positive environmental and economic benefits.
- AD can offer an opportunity to realise potential in local communities through stimulating associated new developments.

Scale

AD can be done on a variety of scales:

- On-site, using residues produced only on that farm or food processing unit
- As a co-operative enterprise between several farmers
- By developing a centralised anaerobic digester (CAD) project supplied with feedstock from several sources including industrial sources.

Photo: WRI Services

Large on-farm digester

Photo: ETSU

Small on-farm digester

Potential resource

Livestock slurry and food processing residues currently exist in large quantities and should be seen as resources which, among other things, provide an opportunity to develop the AD industry. For example:

- Every year in the UK about 150 million wet tonnes of livestock slurry (pig and cattle) and about 3.4 million wet tonnes of used poultry litter and excreta (1.8 million dry tonnes) are produced.
- It is estimated that, every year, in excess of one million tonnes of food production residues (such as vegetable or dairy processing residues) could be suitable for AD.

Some of these residues are already used in other ways, such as being spread on the land, or disposed to landfill. Although AD will never be able to deal with all these residues, there is clearly potential for AD to reduce the negative impacts of other approaches to managing residues from these industries.

These resources offer enormous potential for electricity generation. If all the farm residues that can be collected are used for AD, the potential for electricity generation is a total of 9.4 TW_e hours per year (see Table 1). The total UK energy use in 1995 was 315 TWh, of which 4 TWh were in the agricultural sector, and 101 TWh were in the domestic sector. To put this into perspective, there is the potential to produce twice the amount of energy per year from AD as was used in 1995 in the agricultural sector.

Table 1.

Livestock populations and farm residues in the UK and their potential for methane generation and electricity output

Resource	Population	Potential methane yield (m^3/day)	Potential annual electricity output (TWh_e/year)
Cattle	12,200,000	5,700,000	6.2
Pigs	7,900,000	800,000	0.9
Poultry	124,000,000	1,000,000	1.1
TOTAL	**–**	**8,600,000**	**9.4**

Adapted from table in 'UK Strategy for Centralised Anaerobic Digestion', by S. Dagnall, ETSU, in Bioresource Technology *52 (1995), 275-280.*

Benefits and problems of AD

Environmental benefits

Energy balance

A properly designed and operated AD plant can achieve a better energy balance (taking emissions from transport operations into account) than many other forms of energy production. The energy balance relates to the amount of energy consumed in order to produce energy.

Reducing greenhouse gases

- Methane is a major greenhouse gas if it escapes to the atmosphere. Current disposal practices for slurry and food residues cause methane to be released through natural processes. AD exploits this process so that the gas can be used as a fuel. A well-managed AD scheme will aim to maximise methane generation, but not release any gas to the atmosphere, thereby reducing overall emissions.
- AD provides an energy source with no net increase in atmospheric carbon. Using fossil fuels for energy production creates carbon dioxide which causes climate change, resulting in a warming of the planet. By replacing energy from fossil fuels,

AD can help reduce overall quantities of carbon dioxide in the atmosphere and reduce dangers of climate change and its potential impacts including sea level rise, storms, drought and flooding.

Displacing use of finite fossil fuels

The feedstock for AD is a renewable resource, and does not deplete finite fossil fuels. Energy generated through this process can help reduce the demand for fossil fuels (if used to replace energy from fossil fuels). The use of the fibre and liquor as a contribution to fertiliser regimes can in turn reduce fossil fuel consumption in the production of synthetic fertilisers.

Recycling nutrients

AD products (liquid fertiliser and fibre), if correctly applied, can reduce the need for synthetic fertilisers within an overall fertiliser programme.

Reducing land and water pollution

Poor disposal of animal slurries can cause land and ground water pollution. AD creates an integrated management system which reduces the likelihood of this happening, and reduces the likelihood of fines being imposed for such pollution.

Reducing demand for peat

The fibre produced by the AD process can be used as a soil conditioner, in some instances as an alternative to peat (although they are not strictly comparable as peat is nutrient-free). Peat extraction is a major environmental problem, destroying the fragile ecosystems of the peatlands.

Supporting Organic Farming

AD has the potential to support Organic Farming if used as part of a closed loop (see Box on AD and Organic Farming).

Reducing odour

AD can reduce the odour from farm slurries and food residues by up to 80%.

Efficient electricity distribution

Local power generation reduces transmission losses and can strengthen the grid.

AD and Organic Farming

Anaerobic digestion is the bacterial fermentation of organic material in oxygen free conditions. In this context, organic means any plant or animal material that contains carbon and so can be broken down in this way.

This should not be confused with Organic Farming. Although AD could be used within the context of an Organic Farming system, it is not necessarily the case.

Organic Farming is a production system which is recognised throughout the world as one in which the use of fertilisers, in the form of soluble mineral salts, and pesticides is avoided. As far as possible, Organic Farming systems rely on crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. In addition, animal husbandry must meet the animal's physiological, behavioural and health needs.

Although the fibre and liquor produced as a result of AD are not regarded as artificial fertilisers, they would contain residues (such as artificial pesticides) if the plant and animal wastes being digested had come from a conventional farming system.

AD can be used to provide Organic Farmers with soil conditioners and liquid fertilisers if developed within a closed loop Organic Farming system. However, the great majority of the feedstock for AD will come from conventionally farmed sources and in this case, use of the fibre and liquor can be used as part of an integrated farm management system to reduce the amount of inorganic fertilisers used on the land, but is unlikely to replace them altogether.

Economic and practical benefits

Many of the environmental benefits outlined above will translate into economic benefits, and vice versa. AD will have further economic and practical benefits as outlined below.

Improving farm waste management

- Establishing an AD project does not eliminate wastes, but it can make them easier to manage. Although there are costs, with careful planning and management, AD can be a cost effective, efficient and environmentally sound method of integrated waste management on farms or food processing plants. However, in any particular circumstances all options will need to be considered to find the most appropriate method. The options for farm waste management include composting, aeration systems, mechanical separation, weeping walls, storage and spreading residues directly on to land. The merits and problems associated with the different options are described in Appendix 5.

- The AD process stabilises slurries (so they do not putrefy or create odour), which allows them to be stored more easily and for longer.
- Slurry handling costs are reduced because the digestate liquor is easier to pump than slurry: conventionally, slurry has to be tankered on to the land which can incur contracting costs.
- Costs can be saved by not having to use alternative forms of residue disposal: spreading raw animal manures requires heavy plant and machinery and will often be contracted out, whereas liquor can be spread with existing lightweight farm equipment.
- Farmers supplying feedstock to CAD projects may find the treatment burden of residues removed completely, which is especially useful to farmers with little land.

Reducing spread of weeds and disease

AD destroys virtually all weed seeds, so digested slurry can be spread with minimal risk of weed spread, reducing the need for costly herbicide and other weed control measures.

Contribution to nutrient regimes

The quality of unprocessed slurries which are spread on the land can be difficult to manage. After AD the nutrient content of the liquor and the fibre is more constant, allowing it to be more precisely used within a fertiliser management system, reducing wastage. AD can therefore reduce fertiliser costs while making a major contribution to nutrient regimes, provided that applications of inorganic fertiliser are adjusted to take account of the nutrient content of the organic fertiliser.

Financial incentives

There are two aspects to the financial incentives for developing an AD project: firstly in saving costs (see above), and, secondly, by converting residues into potentially saleable products: biogas, soil conditioner, liquid fertiliser. It can also contribute to the economic viability of farms, by keeping costs and benefits within the farm if the products are used on site. In addition, some funding may be available to support infrastructure investments (such as grid connections) for larger CAD developments under European Structural Funds, although this is only likely to be relevant where significant social benefits to the region can be demonstrated.

Biogas and energy

- AD can provide an on-site energy source for the farmer or food processor, displacing their existing bought-in electricity.
- Due to Government policy promoting energy from renewable sources, and the opening up of the electricity market in the UK, the market for electricity from renewable sources such as AD is likely to grow significantly, and opportunities for AD operators to sell their energy will therefore be increased.

Local economic development

- AD can contribute to rural regeneration by creating or maintaining jobs; for example, in local support businesses, transport and operating staff for CAD plants.
- A 1MW plant can create 2 to 5 jobs on the plant, depending on the process used.
- AD can stimulate new industries, creating structural changes in the local economy and generating further new jobs: for example, fish farms or local greenhouses may be able to use local heat produced by AD projects.

Meeting new regulatory pressures

There are increasing regulatory and public pressures on farmers and others to ensure that residues are dealt with in new ways which are more environmentally sound, and carry less risk to human and animal health than traditional methods. UK and EU legislation and regulations are likely to be increasingly stringent on these issues. Properly managed AD schemes will help farmers meet these pressures.

Reducing pathogens

It is possible that, in future, another significant benefit of AD could be the reduction of pathogens in residues; further research is needed in this area. It should be noted that heat treatment to 70°C is needed to kill all pathogens.

Potential problems of AD

Anaerobic digestion projects, as with any development, will create some risks and have some potential negative environmental impacts. These need to be removed wherever possible, or at least minimised. The specific potential problems with AD projects are outlined below.

With good design and proper management of digesters, and the appropriate technology in the right place in the right circumstances, all the potentially negative environmental and economic implications of AD can be minimised or removed completely. More detail on reducing all these risks and impacts is given later in these guidelines.

Costs

AD has significant capital and operating costs (see the Project Development section for details). Given these, it is unlikely that AD will be financially viable as a source of renewable energy alone and therefore must always be seen as an integrated system. However, it is likely to be cost effective for those who can use (or have or can develop a market for) the other products of AD: better waste management, liquid fertiliser and fibre.

Potential emissions

AD produces certain emissions and effluents, to air, ground and water, which need treatment to avoid damage to human health and the environment. Proper management should ensure that all these risks are controlled, and the best available technology should be used in all cases. See the Construction and Operations section for more details on the risks of emissions and mitigation.

Traffic movements

All waste management systems create traffic movements (lorries already collect food residues) but, although overall quantities of vehicle movements may not be a major issue, the traffic may be more concentrated in a small area, especially where a CAD project is established. All AD developments should aim to minimise traffic movements to reduce potential pollution and nuisance, and alternative methods of transport should be investigated. The energy balance of the AD project overall will be crucial to its success, not least in terms of cost, obtaining planning permission and meeting other regulations. See the Feedstock and products section for details on minimising transport impacts.

Noise

AD projects can generate noise. Consideration needs to be given to potential noise from deliveries, pumps, compressors, the power plant and the overall scheme should be designed to minimise noise. See the Project development section for details on design, and the Construction and operations section for details on minimising noise from plant operations.

Health and safety

There may be some risk to human health from the pathogenic content of the feedstock and digestate. There may also be some risk of fire and explosion, although no greater than with systems using natural gas. See the Construction and operations section for details on minimising these risks.

Animal health

There may be some risk of animal disease transmission between farms in CAD schemes through cross contamination from vehicle movements and centralised collection of feedstock. Strict quality control measures are likely to be needed. See the Feedstock and products section for details on minimising the risks from parasite and pathogen transfer, and Appendix 7.

Visual impact

Larger CADs may have some visual impact, although the digester can be partially sunk into the ground to reduce visual impact and make it easier to load. Screening with trees can also reduce the visual impact of AD plants. See the Project development section for details of site design.

Animal welfare

A potential public concern is likely to be animal welfare issues. AD does not influence the ways in which animals are housed or kept; it simply uses the by-products of livestock farming by any methods, from intensively reared to free range animals. AD is never going to be the determining factor for any husbandry method; it will always only be part of an integrated waste management strategy. It would never be economically feasible for farmers to change farming practices to maximise the production of feedstock for AD and worsen conditions for animals as a result.

Deciding to develop an AD project

Any decision to establish an AD project will be based on an assessment by the farmer or developer of the marginal increased costs (if any) set against the additional benefits and opportunities created. AD will generally be a more expensive capital option for farmers (or food producers) seeking solutions to their residue and/or pollution problems than alternative waste management solutions. Financial and other costs are covered in detail in the Project development section but, in summary, include:

- Capital costs in establishing a digester
- On-going maintenance and replacement costs
- Obtaining planning permission and adhering to other regulatory frameworks
- Training for operators.

The decision to establish an AD project dealing with farm residues is likely to be based on answering the questions:

- Do the extra benefits from the process and the opportunities for possible increased income streams warrant spending the extra (marginal) investment costs for an AD plant compared with other options?
- Do I have the time, inclination and necessary skills to consider it as a viable option?

More specifically, the decision process for a farmer or food processor on whether a 'stand-alone' AD plant will be viable for their business, or whether they should consider other options (including participating in a CAD project), is likely to include the following questions:

- What capacity plant would I require to process my feedstock?
- What are the marginal costs for me to consider an AD plant?
- What return would I want to consider this extra investment?
- Can I adequately utilise the liquor produced? How much land do I have access to?
- Can I utilise the energy produced within my farm business? What is the value of this to me?
- What price can I get for the energy if I sell it?
- Is there a shortfall between the value of the energy produced and the return I require?
- Can I make up this shortfall from reduced operating costs, increased yields, sales of compost, income from handling other farm or food processing residues?

If a farmer or food processor cannot show a surplus from this process, a stand-alone plant would not be appropriate and they could then consider the benefits of co-operating on a CAD plant, or other options for waste management. All these issues are considered in the Project Development section of these guidelines. A case study of Walford College AD project, including detailed costings, is given in Appendix 8.

Consultation

As with any new development, establishing an AD plant will require consultation with statutory and non-statutory bodies, local communities and near neighbours to discuss concerns, share information and adapt proposals to take into account particular worries. The extent to which formal consultation is required will depend on the scale of the proposed development: a small on-farm digester is likely to be affected by fewer regulations and generate fewer anxieties than a CAD plant.

Photo: ETSU

Visitors to a farm AD plant

Statutory and non-statutory consultees

The bodies which are consulted will depend on the scale, location and nature of the proposal. However, it would be good practice to consider which of the following bodies are likely to have an interest in, or be affected by, the digester and its operations and consult them at an early stage. This is by no means an exhaustive list, and may be extended to include specific local organisations, or additional organisations relevant to particular local circumstances.

Within local government

Different departments within the local authority may require consultation. Some of these may require consultation across the boundaries of the responsibilities of county and district authorities, or may be within a unitary authority:

- Planning (Policy, Economic Development)

  Under the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988, the local planning authority is required to consult the following bodies when an environmental statement is produced:

  a) any body which the local planning authority would be required by article 15 of the General Development Order (amended by SI 1986/435), or any direction under that article, to consult

  b) the following bodies if not included in paragraph (a):

  i) any principal council for the area where the land is situated, if not the local planning authority (including consultation of the county council by the district council)

  ii) the Countryside Commission (or Countryside Council for Wales, or Scottish Natural Heritage)

  iii) English Nature (formerly the Nature Conservancy Council)

  iv) the Environment Agency (formerly HMIP, NRA and waste regulation authorities).
- Environmental Health
- Engineer/Technical Services/Building Regulations
- Highways
- Waste Disposal
- Minerals
- Archaeology
- Environment/Countryside Management/Wildlife Conservation
- County Fire Officer

Other consultees

It will be appropriate, depending on the size and nature of the scheme, to consult with a range of other consultees. The following sample list is not exhaustive:

- Government Office (generally, when a major scheme is proposed; Department of Transport/Highways Agency if a trunk road is affected)
- Town and Parish councils
- Regional/local water company
- English Heritage
- Local amenity groups (eg preservation group, wildlife/naturalist trust, town society)
- Local environmental groups (eg Friends of the Earth local groups)
- Local community and residents groups
- Ramblers Association, for proposals which affect a public right of way
- British Gas, British Telecom or other telecom company or Railtrack if near one of their installations, land or equipment
- Civil Aviation Authority or Ministry of Defence, for major proposals in close proximity to a civil airport or military installation
- The Royal Society for the Protection of Birds (RSPB) regional office
- The county wildlife trust

Almost all digesters are likely to need planning permission, which will involve formal public consultation as well as discussions with the planning authority. Planning permission is covered in detail in the Project development section. Consultations with the Environment Agency, as the agency responsible for waste management and control of pollution, are also likely to be needed. Advice on health and safety issues is available from the Health and Safety Executive (HSE).

Issues that may arise, for all plants, include concerns about visual impact, odour, transport implications, environmental impact and health; many of these issues are dealt with in these guidelines. Page 53 gives a summary of the key facts about AD and has been designed to be copied and distributed to interested parties.

The remainder of this section provides general guidelines on consultation which should be useful in projects of all sizes, although the extent to which they will all need to be used will vary.

Timing

Early consultation is particularly important in AD projects as they are relatively new in the UK. Most people will know little about the visual appearance of a plant or the potential impact it may have on local people and the environment. Early information to local people on all aspects of AD, as well as quick responses to particular concerns, will help people feel confident about this new industry in their area. Local people will welcome the opportunity to comment at an early stage.

Early consultation with statutory conservation agencies over locations for digesters may also be helpful. These statutory agencies are used to dealing with informal consultations in confidence.

Consultation should continue throughout the development stages of a scheme, and will need to cover all aspects including the design and management, construction and operation of the digester, and transportation of the feedstock. To some extent, consultation can be structured alongside the process of obtaining formal planning permission for the digester, but may need to be extended.

Who to consult?

People who live and work in the immediate vicinity of the proposed scheme, the parish or community council, specific local interest groups and statutory agencies are all likely to have an interest in the development of an AD scheme. The project leaders for the development will need to identify all the likely areas of concern and involve interested groups at the most appropriate stages. Different stakeholders will have concerns about different aspects of the project. A sample list of statutory and non-statutory consultees is given opposite.

Whose responsibility?

For large CAD schemes, the developer will usually have overall responsibility for managing the consultation process. However, the farmer setting up a small on-farm digester, or farmers supplying feedstock to a CAD will also want to manage their activities in a manner which is sensitive to the environment, health and safety and other local concerns, and may become involved in consultation processes. Even where the digester is a co-operative community project, run by local people, there will still be a need for wide consultation and involvement.

Preparing for consultation

Consultation needs to be planned and integrated into the overall development process. The following steps may help to maximise the effectiveness of consultation and enable the developer or farmer to address any concerns that arise:

- Developers should analyse the community, or communities, that might have an interest (stakeholder analysis). Information will also be needed on local issues that may be relevant. This will enable developers to prepare their consultation and communications strategy.
- AD is a relatively new industry and it may be appropriate to produce information for local people about the nature of the industry and the specific local development, what it will look like and the impact and benefits it will have (see page 53).
- Consultation needs to start as early as possible in the planning and design stage. It needs to be planned, but also be flexible enough to meet the needs of changing circumstances.
- Honesty, openness and commitment to consultation are essential. Although developers would not be expected to resolve all concerns expressed, they should always respond to concerns. If something cannot be altered, a clear explanation of the reasons should be provided.

Consultation methods

A number of consultation methods may be used, depending on local circumstances such as the particular needs of the community and other interested organisations and the scale of the project. These might include:

- Leaflets outlining proposals and inviting comments
- Exhibitions
- Open days, and visits to similar sites already in existence
- Public meetings
- Questionnaires
- Special meetings for key local organisations (such as parish councils)
- Workshops for mixed groups of stakeholders to consider particular issues.

Any printed materials produced should always include a contact name, address and telephone number so that local people can ask questions and comment on proposed developments. Consultation is a two-way process and channels must be kept open.

Liaison should continue after plant construction is completed. For example:

- Visitors to the farm, digester or CAD: local groups and others may be interested in visits.
- Links may be made to the environmental programmes of local schools.
- A liaison forum could be established between the developer, the local authority and local communities, building on contacts made during the development stages. This could be linked to formal and informal monitoring, which may be required in any case under the conditions of the planning permission.


Photo: ETSU

Feedstock comes from cattle slurry, chicken litter, pig waste and food processing residues.

Feedstock and products

This section covers the main issues relating to feedstock for, and products from, anaerobic digestion, including choice of feedstock, maintaining quantity and quality control, storage and transport. The nature and potential uses of products are also covered.

Which feedstocks?

The focus of these guidelines is anaerobic digestion using farm residues and food processing residues. These include residues from:

- Cattle and pigs (manure and slurry)
- Poultry manure (with or without litter)
- Vegetable processing residues (eg from potatoes, sugar beet)
- Silage effluent
- Dairy processing residues (eg cheese and yoghurt processing).

CAD schemes may use additional feedstocks to supplement the above residues. The content of any imported feedstock will require careful assessment as it will affect the nature of emissions and outputs. Feedstocks for CAD schemes may also include:

- Brewery residues
- Fish oil and fish processing residues
- Bleaching clay (from the paper-making and textile industries)
- Milk processing residues (eg whey and bioplant sludges)
- Crushed oil waste (eg rape and sunflower seed).

An environmental assessment should identify the impact of the use of different feedstocks. Materials in addition to those listed above may be used as feedstock for AD but are not covered by these guidelines because they are covered by different licensing arrangements and regulations; these include sewage sludge and municipal solid waste.

It is essential that toxic substances are minimised in feedstock, and certain materials should never be fed to digesters because they will arrest or kill the process. These include:

- Toxic materials that inhibit digestion (eg high ammonia levels, pesticide residues, sheep dip, heavy metals, oil)
- Bioagents (aflatoxins, antibiotics)
- Disinfectants (eg creosol, phenol, arsenic).

Long straw and non-biodegradable materials should be avoided as they can cause blockages in the system.

Quantity and quality of feedstock

The main aim of managing the quantity and quality of feedstock for the digester is to maximise the quality and quantity of the outputs, and therefore the economic and environmental benefits from the feedstock. Different priorities for outputs will affect the quality criteria for the feedstock.

For example:

- To maximise gas yields, the key factors will be organic matter content and the percentage of dry matter (5-12.5% maximum of feedstock should be dry/solid waste). Different feedstocks produce different amounts of gas: 1 tonne of cattle manure will not produce the same as 1 tonne of chicken manure. The gas production performance of different feedstocks will vary, as shown in Table 2.
- If the main objective of the project is waste management, the main criterion will be to avoid anything which may arrest or kill the process.

The amount of different feedstocks which are needed at different times depends on which products are a priority. There are two key principles related to the quantity of feedstock required for digesters:

- Whichever product is chosen as the priority (biogas, liquor or fibre), the others will be affected. A balance will always need to be sought because it is only through producing all three products that the digester is likely to be viable: one product alone will not generate sufficient income.
- Summer top-ups may be needed for when stock are outside, and mixtures might have to change. Alternatively, an on-farm digester can be allowed to become dormant.

If there is a problem with the digester, caused by quality failures or a break in the continuity of the feedstock supply, it can be rested. For example, a dairy farmer may be able to keep the digester going at full capacity during winter months while cows are in sheds, and ticking over in summer with slurry collected from the yard when the cows are outside.

Table 2.

Biogas production and energy output potential from 1 tonne of various fresh feedstocks

Feedstock	No of animals to produce 1 tonne/day	Dry matter content (%)	Biogas yield (m^3/tonne feedstock)	Energy value (MJ/m^3 biogas)
Cattle slurry	20 - 40	12	25	23 - 25
Pig slurry	250 - 300	9	26	21 - 25
Laying hen litter	8,000 - 9,000	30	90 - 150	23 - 27
Broiler manure	10,000 - 15,000	60	50 - 100	21 - 23
Food processing waste	–	15	46	21 - 25

Table adapted from information from ETSU.

Notes.

1 Figures should be taken as indicative values

2 Cattle slurry covers both dairy and beef cattle

3 Poultry manures are highly susceptible to ageing and should be used as fresh as possible

4 1 m^3 of biogas (at an assumed 20MJ/m^3) would typically give the following:

- electricity only: 1.7 kWh of electricity (assumed conversion efficiency 30%)
- heat only: 2.5 kWh of heat (assumed conversion efficiency 70%)
- combined heat and power: 1.7 kWh of electricity and 2 kWh heat

Alternatively, if the digester is not fed it will simply slow down. To ensure the regularity of supply of products, it is cost-effective to have the digester working all year, but if the demand for products is also seasonal, the digester can be allowed to become dormant.

Different feedstocks will require different loading systems, depending on the consistency of the feedstock (ie how solid or liquid it is). Examples of pre-treatments include:

- Screening for foreign matter (eg bricks, sand, grit and long straw).
- Adding water, or taking water out. In general, it is not advisable to add water as the more water there is in the feedstock, the more energy is needed for the process; however, some water may need to be added to ensure the feedstock is the right consistency.
- Conditioning the waste (eg chopping straw), although the equipment for this can be expensive.
- Stirring the feedstocks.

The quality of the feedstock in terms of its gas yield will partly depend on its freshness: the fresher it is the higher the gas yield will be and the less danger there is of it becoming acidic. An acidic feedstock may inhibit or even kill the bacteria in the digester. Ideally, the pH range in the digester should be 6.8 - 8.

Even though AD is by and large a robust process which can adjust to slow changes, drastic changes of feedstock should be avoided and the operator must be diligent in monitoring the input and mix it according to the products required. Every digester is unique in terms of the feedstock used, and it will change over time; during the life of a plant it is likely that the feedstock will change several times.

An on-farm scheme will have less problem managing the quality of the feedstock because the operator will control the farm's own wastes. Some screening can be done by farmers using natural techniques of settlement and drainage. A co-operative would need to appoint a member with the appropriate knowledge and experience to take responsibility for monitoring quality control.

A CAD scheme will require a formal quality control and assurance system, as there will be a risk of cross-contamination which could affect operations. Therefore, CAD plants are likely to provide farmers and other suppliers with detailed contracts and specifications of the appropriate content for feedstock, and any feedstock which fails to meet the specification is likely to be rejected. Certainly, if one of the supplying farms has a notifiable disease in its livestock, it could both contaminate the plant and be passed on to other supplying farms: obviously, suppliers in these circumstances must never take feedstock to the CAD.

It is good practice to test feedstock before processing, as well as the resulting products. Larger CAD plants are likely to need on-site laboratory facilities to test feedstock before processing for elements which may contaminate or arrest the digestion process. It may also be necessary to check for moisture loads and for health and safety reasons. After processing, such facilities are likely to be needed to check the quality and safety of products. Holding facilities may be needed to store feedstock, check it and then pass it on for processing or distribution.

Planning permission may be given to a scheme specifying a certain feedstock and in these circumstances the feedstock will not be able to be changed without the further prior approval of the planning authority. A CAD plant will need to be licensed under the Waste Management Licensing Regulations 1994 if it imports industrial waste (ie food processing residues). The subsequent disposal of liquor by spreading on agricultural land becomes an activity that requires pre-notification to the local Environment Agency office. Neither of these controls applies to AD plants treating or spreading digestate sourced from their own animals and returned to their own land.

Parasites and pathogens in feedstock

Feedstock for AD inevitably contains plant or animal pathogens (such as *Salmonella*) and parasites (such as *Cryptosporidium*) to different degrees in different materials, which can be a danger to human and animal health. Precautions are therefore needed in AD projects, especially in CAD projects which involve transporting residues from various sources to a central point, which could lead to cross-contamination unless appropriate preventative measures are taken.

Mesophilic anaerobic digestion will reduce pathogenic organisms and bacteria, but will not eliminate them from the waste. Thermophilic digestion will further reduce the levels, but again cannot guarantee total removal. Pasteurisation (holding the waste at 70°C for 30 minutes, or for longer at a lower temperature eg 55°C for four hours) is the only method which will ensure the complete elimination of pathogens. It should be noted that pasteurisation may affect the energy balance: the hotter and quicker the pasteurisation, the more energy is used.

As neither mesophilic or thermophilic digestion is likely to totally eliminate the pathogens in the feedstock, considerable care is needed. In some cases, depending on the initial quantity of pathogens in the feedstock, levels of pathogens after AD will still be high enough to cause ill health for those working with the feedstock before and after treatment, and for those who may come into contact with the treated feedstock. For those occupationally exposed, the employer's COSHH assessment should indicate the level of risk and the measures that will be put into place to control it. This is a complex area in which research is continuing. Further details are given in Appendix 7 about the effects of different AD processes on parasites and pathogens. Advice is available from the Health and Safety Executive (HSE).

Storage of feedstock

CAD plants will require access to up to several hundred tonnes of feedstock at any time, so extensive storage facilities are likely to be needed to ensure continuity of supply over weekends (when traffic movements may be controlled) and holidays. Ten days is likely to be the maximum storage period for a CAD plant as, in general, feedstock should be used as soon as possible. Feedstock providers may be required to take the liquor back, which will also have storage implications.

The storage of farm slurry is covered by the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991, which specify minimum standards relating to the design, construction and operation of any farm slurry storage system. The regulations require the store to be big enough to hold at least four months slurry production unless a safe year-round disposal system is 'approved' by the Environment Agency. The production of a Farm Waste Management Plan which includes details on feedstock storage, digester operation and liquor spreading (including locations, rates and times of year) would normally be considered an acceptable alternative to the four month rule. Further information is available from the local Environment Agency office.

Feedstock may be stored near the digester or elsewhere, although the need to minimise transport movements will affect the decision on siting storage. Feedstock needs appropriate storage facilities which must be planned in accordance with environmental, health and safety issues and regulations. It may be necessary to balance the planning requirements (such as for feedstock to be stored in a totally enclosed space with tank covers to reduce the escape of odour), with health and safety regulations (that substances are controlled so that there is no exposure to substances hazardous to health).

Methane continues to be produced from the digestate in storage. Up to 15% of usable gas, from the total that can be obtained from the feedstock, can be recovered from slurry storage tanks. It is possible to extract the gas given off the stored feedstock, and then flare it or draw it into the combustion chambers of an engine.

Transport of feedstock

Transport movements at on-farm digesters are not likely to have greater impact than normal farm activities. However, CAD plants will draw traffic to their central location as feedstock is delivered and products are distributed. The impact of these transport movements needs to be minimised through logistics and use of alternative methods of transport (such as rail), as well as careful design of the location of storage tanks so that distances travelled are minimised between the production of the feedstock, the storage tanks and the digester. The potential for pumping (suitable for pig slurry) should be investigated for cost and environmental reasons, including reducing emissions and reducing the need for transport.

Where vehicles are moving onto and around a site, it will be important to have a system to control risks, with turning areas, one-way systems, pedestrian walkways, barriers and so on.

Other issues in transporting feedstock are likely to include those outlined below.

Planning restrictions

The conditions of any planning permission may restrict deliveries to a CAD plant. These restrictions may result in some farmers having to store the feedstock on their farms. There may also be other planning conditions or obligations (agreements):

- Data and monitoring on the frequency of lorry movements may be required.
- An assessment of the suitability of certain roads for this traffic is likely to be needed. CAD developers should be encouraged to site plants in areas already served by appropriate infrastructure such as industrial estates, which may also have the benefit of being away from residential areas, in order to avoid the need to upgrade roads, with all the cost and environmental impacts that would create. Where roads are not considered suitable, the developer of the CAD plant may be expected to contribute to the costs of upgrading them.

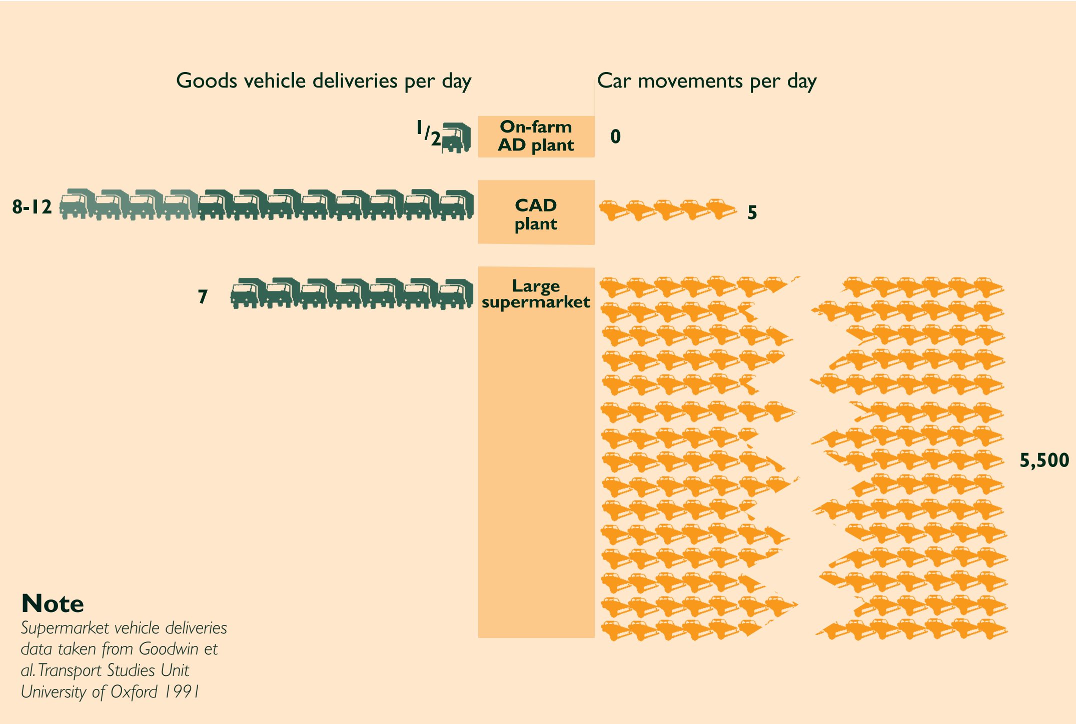


Figure 3.
Transport movements

- Specification of routes may be required, for example avoiding villages.
- There may be a requirement that open-topped vehicles are sheeted. Chicken wastes are normally moved in sheeted open-topped lorries. Pig and cattle slurry is usually moved in enclosed tankers.
- There are likely to be restrictions on timing of deliveries to reduce noise nuisance to neighbours. For example, deliveries may only be allowed Monday to Friday (7am to 7pm) and Saturday morning (7am to 1pm).

Emissions

Delivery vehicles using conventional fossil fuels will produce carbon dioxide and other emissions, and deplete non-renewable resources. Fuel efficient vehicles should be used. The energy required to transport feedstock and products needs to be balanced against the energy yielded from the AD process. This element of the energy balance requires further investigation. The negative nature of the consumption of fossil fuels can be partly avoided by using vehicles which run on the biogas produced by AD (once it has been cleaned), although this technology is still in the early stages of development.

Catchment area

Generally speaking, it is financially viable to transport chicken and broiler waste transported up to 40km, thick cattle slurry 15 - 20km, and pig slurry only 5 - 10km because it is more liquid. A number of plants pump pig slurry to avoid the need for transport and reduce the risk of spreading disease: a maximum of 6km has been achieved.

Cost

The unpleasantness of the load may increase the cost of transport and handling. Specialist contractors, who may need to use dedicated vehicles, will be able to provide an appropriate transport service and will be aware of the nature of the loads.

Business considerations

The whole project can become uneconomic unless transport movements (and therefore transport costs) are minimised. Transport costs can make the difference between the success of one scheme and the failure of another.

Handling feedstock

Farmers are likely to be aware of the dangers of disease from farm residues, although lorry drivers and other workers may need special training to avoid health risks to themselves as well as the risk of spreading infection to other sites. The main health and safety risks are:

- Pathogenic micro-organisms
- Parasites
- Fumes and inhalation of slurry gases.

These dangers can be reduced by taking precautions including:

- Using known and reliable sources of feedstock.
- Analysing feedstock and careful quality control.
- Monitoring and screening for disease in the animals creating the feedstock.
- Personal hygiene ie washing people, clothes and vehicles; it is also recommended that work clothing is left at the CAD site.

All material going in or out of a CAD scheme will need strict controls to avoid pathogen transfer including:

- Being able to isolate the site.
- Vehicle wheel washing is likely to be compulsory at CAD plants and desirable for farms, to avoid cross-infection. Disposal of contaminated wash water needs to be considered.
- Liquid leaving the site needs to be carefully contained; fibre must be exported in covered lorries.

Products of AD

The AD process creates biogas, fibre and liquor. In order for a scheme is to be financially viable overall, markets and/or uses for all AD products need to be developed and balanced. Consistency of supply, and of quality, as well as increasing public knowledge of the environmental advantages of AD products, will influence the growth and development of markets.

The balance of the different products from AD is shown in Figure 4.

Biogas

The biogas produced in the digester is primarily composed of methane (approximately 60%) and carbon dioxide (approximately 40%), with traces of hydrogen sulphide and ammonia. The quality of the feedstock used in the digester will determine how much gas is produced and its constituents.

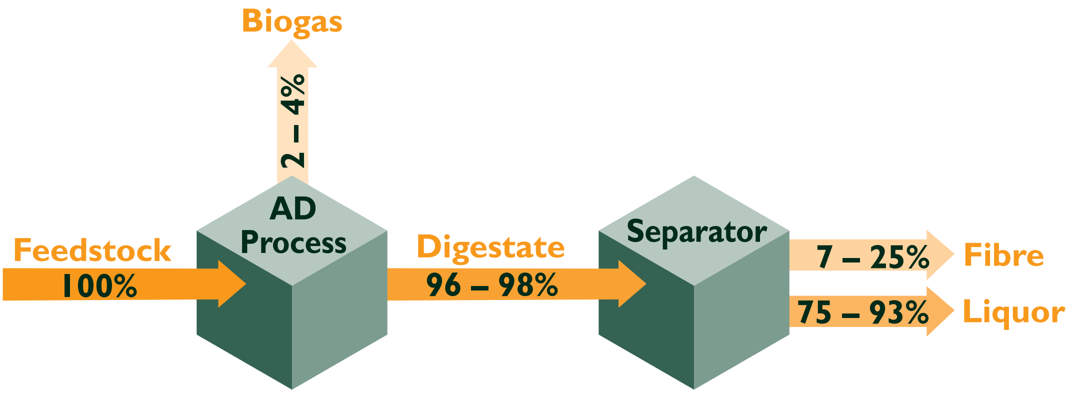
Cleaning the gas

The biogas produced through the AD process usually needs to be cleaned to varying degrees as soon as possible after generation for two main reasons:

- The gas is corrosive and may damage engines.
- For health and safety reasons (see Construction and operations section for the health and safety implications of biogas); a risk assessment may be needed.

Figure 4.

Anaerobic digestion mass balance



Ref. ETSU

Alternatively, zoning can be used to exclude people from areas which may have health and safety risks. In general, it would be unwise to burn 'as produced' gas anywhere other than in an engine to produce electricity or in a boiler to produce heat.

There are many different ways of cleaning the gas. The best advice is to choose the appropriate equipment, consult the manufacturer as to the best methods for specific plant requirements, and ensure that anyone using it is fully trained to operate it efficiently.

Using the biogas

Up to one third of the biogas energy will be needed to sustain the heat in the digester; the remaining two-thirds will be surplus and can be put to various uses:

- The gas can be burned to generate heat, either on site or piped elsewhere. Small AD units are likely to produce heat only. The gas can be used for cooking (using safe equipment), to heat the farmhouse, dairy or other nearby buildings, without any need to convert it to electricity. However, contaminants in the gas may restrict its use for any purpose other than electricity generation unless it is cleaned.
- The gas can be used as fuel for an engine connected to a generator to produce electricity which can then be used on site, marketed to the grid and to other networks. Details on the planning permissions needed, and on electricity connection, are given in the Project Development section of these guidelines.
- If a combined heat and power (CHP) plant is used, all gas will be consumed to provide both electricity and heat. This is a more efficient use of the available energy; the whole digester heat requirement is normally provided from the heat recovered from the engine and exhaust gas.
- The biogas is of a lower calorific value than natural gas and it would generally not be cost effective to store large volumes on site. However, the value of electricity produced may be enhanced if small volumes of gas are stored overnight (4 - 8 hours) and used for generation at peak demand times during the day.
- It is also possible to use the gas (if carbon dioxide is removed through the use of water towers, and the gas is compressed), to run motor vehicle engines, which would need to be converted to use the gas. The processes to clean and compress the gas for this purpose, and the conversion of the vehicles, are expensive, but may become more viable in future.

Electricity from renewable resources will continue to be a growth market. Currently, the Non-Fossil Fuel Obligation (NFFO) requires regional electricity companies to purchase a certain amount of energy from renewable sources, and NFFO contracts of up to 15 years, offering premium rates, may be awarded to suppliers. There are currently (1997) seven NFFO contracts for energy from AD which, if all are built, will provide a total of 7MW capacity. There are also increasing opportunities outside NFFO to sell energy from renewable resources to a growing niche market as energy markets are liberalised.

Digestate

The digestate which remains after the gas has been removed is pumped to a storage tank, after which it can be spread directly on to the land. However, this digestate can only be considered partially treated at this stage, and should be stored ready for applying to the farm land at the appropriate rate (see MAFF *Code of Good Agricultural Practice for the Protection of Water*, as well as specific guidelines in Nitrate Sensitive Areas and Nitrate Vulnerable Zones). It may be necessary to consult the Environment Agency. Alternatively, the digestate can be separated into fibre and liquor.

Fibre

The fibre produced from AD is bulky and contains a low level of plant nutrients. It can be used as a soil conditioner, and the most efficient use for the fibre is to return it directly to the land locally. This is much easier to do after processing than conventional land-spreading as spreading the fibre requires much less power and can be done using a small tractor rather than specialised equipment. It is also much less offensive to neighbours, having no odour after digestion.

AD fibre can be used to condition the soil, and as a low grade fertiliser. In some cases the fibre from AD can be used as an alternative to peat, although it does not have exactly the same purpose as peat (which is nutrient-free). A possible strategy for increasing the value of the fibre is to further compost it aerobically after processing to produce a potting compost/growing medium. This process can be speeded up through careful management and control such as adding heat or insulating the composting bins. However, market development is required to make the commercial sale of fibre viable on any large scale. For any sale of fibre, access to local markets is crucial as it would not be economically viable or environmentally sound to transport it long distances.

Storage facilities will be needed for the processed fibre. The market is seasonal, so storage could be needed for up to six months output. Stored fibre will continue to compost aerobically, so it will need to be carefully managed and controlled, using methods such as stabilising through further composting. Fibre needs to be stored under cover to prevent rainwater getting in. Flies may also be a problem around stored fibre, so siting the storage facilities will need to take that into account.

Liquor

The liquid from the AD process has a low level but diverse range of nutrients. It can be used as a liquid fertiliser in a planned fertiliser regime. As it has a high water content, the liquor also has irrigation benefits, so it can be used for 'fertigation' on agricultural land. However, as it contains particles, it should not be used for fertigation in greenhouses because it can block feeder pipes if not separated effectively.

The liquor is generally used on the farms on which it was produced. A potentially wider market has yet to be fully developed, although some AD schemes have successfully bottled and sold the liquor as a liquid fertiliser.

Spreading and application methods for the liquor depend on the type of crop being grown. As with any fertiliser containing nitrogen, the liquor should only be used on actively growing crops, in certain locations and on certain types of soil. Liquor from the AD process should be used or disposed of in a way which prevents excess run-off to underground or surface waters. Production of a Farm Waste Management Plan will assess and devise pollution prevention measures, in accordance with MAFF Codes of Good Agricultural Practice for the Protection of Water and Soil.

The liquor should be applied as part of an integrated fertiliser programme to ensure that the optimum nutrient requirements for the crop are supplied. It is good practice for the farmer or operator to regularly analyse the soil, and the AD liquor, to assess the appropriate application rate, and to quantify the amount of chemical fertiliser to be applied to crops and grassland. Over application causes vegetation scorching.

Liquor can be stored on the farm, or at the CAD plant. Once cooled, it can be stored in lagoons or large tanks. If possible, these should be located adjacent to the areas where the liquid will be applied. These containers will need to be constructed to meet HSE and planning regulations. Some liquid storage facilities may need bunding around storage silos; bunding will certainly be required on CAD sites. While it is still warm, the liquor will continue to produce small amounts of methane.

Once stored, the sediment in the liquor will settle, so it will need to be stirred or agitated to ensure uniformity throughout before application or transporting. If bulk transport is needed from CAD plants, it is possible to use the same tankers which have delivered feedstock to export the liquor, although they would need to be thoroughly cleaned in between to avoid cross-contamination (this would have energy implications, and care would need to be taken over the disposal of any wash water). As the liquor is pumpable, where appropriate it should be pumped away from the process plant to long term storage sites.

Table 3.

Nutrient analysis of the fibre and liquor from the AD of farm slurry/manure

	Liquor (gms/100 litres)	Fibre (% of dry matter)
Nitrogen	800	3
Phosphate	500	4
Potash	500	2

Notes:

1 Figures are not for elemental mass but mass of compounds of nitrogen, phosphate and potash.

2 The fibre and liquor also contain trace elements including magnesium, manganese, sulphur, calcium, zinc, copper, boron and sodium.

3 There is considerable scope for increasing nitrogen levels in final liquor or changing the balance of final effluent nitrogen, phosphate and potash rations by manipulating feedstock sources in larger digesters.

Photo: WRI Services

Digester under construction.

Project development

This section covers all the main issues for developing an AD project from assessing feasibility to designing the facility. Site and location, environmental assessment and obtaining planning permission are also covered. The principles of this section will apply to all schemes, although the extent to which all the guidelines need to be applied will depend on the scale of the project. For smaller scale projects, many of the impacts will be less and the issues more easily dealt with.

Feasibility

The development of an AD project, either on-farm or as a CAD scheme, is not a simple process, and the starting point depends on the motivation of the developer. For example, it may be a farmer or a food processing company needing a solution to the problem of waste disposal, or to take up an opportunity to supply a CAD scheme, or a local authority energy team wanting to develop a community CAD scheme as a local source of renewable energy. The first stage is therefore likely to be a mixture of decisions about scale, products and markets, feedstock availability and technology (see Figure 2).

A technical feasibility study will be needed, although the complexity and cost of this will depend on the scale of the scheme. Even a small on-farm AD project, with all feedstock being supplied by the farm itself and all the products used on the farm, will need some calculations as to the continuous availability of feedstock, the quantities of the products and the opportunity to use them. A large scale scheme is likely to need a detailed formal plan covering all key issues which can be used to raise finance.

There are six factors which will typically determine the economic feasibility of any scheme:

- Type and quantity of feedstock available, and security of supply.
- A sustainable outlet for the liquor: the potential for the land application of the liquor is likely to be the main constraint on the size of the plant, in order to meet local standards (especially in a Nitrate Vulnerable Zone or similarly controlled area).
- There are outlets, or uses, for the fibre; all products must be used if the scheme is to be viable.
- There are outlets, or uses, for the biogas as heat and/or electricity.
- The size and location of the plant, if using the biogas for electricity production, will need to be considered as this will affect planning and grid connection restrictions and costs.
- Transport costs and logistics.

All schemes should seek expert advice, on costs and potential income, from local energy teams, agricultural business advisers, suppliers of equipment, electricity supply companies who might buy the electricity generated, British Biogen and others with experience of establishing and running AD projects.

A case study of Walford College's AD project is in Appendix 8, including detailed costings.

Economics

Costs

The main financial costs of establishing an AD project are likely to include capital costs, project development costs and training costs.

Capital costs

The equipment has to be manufactured to a high standard to prevent corrosion, and the resulting high capital costs may only be justified if the equipment has a long active life. In this respect, a digester may be regarded more as a mortgageable infrastructural project like a house than a piece of equipment like a tractor. Construction of the plant and associated site works, including any landscaping required under planning permission, will also incur costs.

The capital costs for an AD plant will vary between £3,000 to £7,000 per kW_e of electricity generating capacity. For example:

- A small digester of $10kW_e$ capacity, using residues from 100 head of cattle or 1000 pigs (requiring a digester with a capacity of 150 m^3), is likely to cost £60,000 to £70,000.
- A CAD plant of $1MW_e$ capacity (requiring a digester with a capacity of 10,000 m^3) is likely to cost £3 million to £4 million.

Project development costs

These can be very significant and may include:

- Technical, legal and planning consultants' fees, and the farmer or developer's own time, in negotiations with legal and statutory bodies (for example in obtaining planning permission and consulting the Environment Agency)
- Financing and legal costs, including the costs of arranging finance
- Electrical connection costs
- Costs of licences (for example, if imported food processing residues are used, a Waste Management Licence will be required, which will involve an initial charge and an annual fee)

Running costs

The running costs vary enormously depending on variations in design and operating circumstances. They are likely to be in the order of £7,000 - £10,000 per year for an on-farm project, or up to £100,000 per year for a CAD project. Running costs will include:

- Staff costs: management of an on-farm digester with power generating equipment is likely to require two staff days per week
- Insurance
- Transport costs
- Annual fees for licenses and pollution control measures
- Other maintenance and operating costs.

Training costs

The people who run AD projects, of whatever size, need to be fully trained in the safety, financial and environmental implications of the project. These skills will need to be updated as technology and knowledge develop.

Income

The largest revenue streams from AD are likely to be from electricity (including avoided cost and sales) and fibre sales. Markets for all the products will need to be developed and balanced for the project to be economically viable. The way the project develops depends on the priority product for the developer (that is, energy, fibre or liquor), which will have implications for the technology which should be chosen.

In summary, income streams are likely to include:

- Electricity sales (or displaced purchases); energy from renewable sources is likely to continue to command premium rates
- Heat sales (or displaced purchases)
- Fibre sales (or displaced fertiliser costs)
- Liquor sales (or displaced fertiliser costs)
- Gate fees: charges made for processing wastes (this mainly applies to CAD projects using food processing wastes; gate fees are increasing as charges for alternative waste management methods, such as landfill taxes, also increase)
- Savings on slurry handling and other waste management costs.

It is important for all those involved in the industry to be in touch with the relevant networks so they are aware of the latest market developments. British Biogen is a good first point of contact.

Financing the project

An AD scheme, whether single farm or CAD, will require a large amount of capital investment and, in most cases, developers will require finance from an external source.

There are two types of loan: those secured against the developer's existing assets (on-balance sheet financing), and those secured against future cash flows (limited recourse project financing). Most farmers and commercial developers will be familiar with these and be able to make an informed decision about which is the best route to follow, although the decision may be made for them by the lending bank. It is unlikely that a lender will finance 100% of a project's costs. Between 20% - 40% may have to be funded by the developer.

The maximum amount of money that a local clearing bank might be expected to lend is about £200,000. This level of loan would be sufficient for a single farm AD or very small CAD. Investment banks usually have a minimum level of investment of about £2 million, and a minimum loan arrangement fee which can be as high as £100,000. There is therefore a financing gap into which many projects may fall, and these developers may find great difficulty in raising finance.

Traditional investors do not recognise the environmental benefits and sustainability of AD and view it in the same way as any other high-risk commercial project, demanding high security and high returns on invested capital, leaving less for other investors and shareholders. Ethical or 'green' banks and funds are beginning to appear. They take a more sympathetic view of renewable energy in general and seem willing to invest on less onerous terms. These should be sought by AD project developers, particularly those whose projects fall into the financing gap described earlier. Certain Regional Electricity Companies (RECs) may be interested in supporting (through investment) alternative renewable energy sources in some areas.

Grant aid may be available for large AD projects from European Union funding programmes, administered by MAFF, for rural development. More information can be found in *Financing Renewable Energy Projects-A guide for developers*, published by ETSU for the DTI. MAFF's Farm Waste Grant Scheme provides help to farmers in Nitrate Vulnerable Zones who are installing or improving farm waste facilities. Grants are not available for anaerobic digesters but funds may be available for storage which could be used for part of an AD scheme. More information can be found in the MAFF leaflet *Farm Waste Grant Scheme: Nitrate Vulnerable Zones*.

Site and location

Planning permission is likely to be required for most AD projects, so the proposed development will need to be acceptable in terms of site, layout, the appearance of the buildings, any impact on local amenity or landscape and any environmental risks such as water contamination. On-farm digesters are likely to be sited near other farm buildings so there may be little new impact. However, decisions on the location of all new plants, especially CAD developments, will need to take the following into account when considering sites for the digester:

Feedstock and transport

- A local supply of feedstock needs to be available so that transport costs and environmental impacts are kept to a level which would provide a positive energy balance.
- Accessibility to road links for the import of feedstock and export of products is essential.

Markets for products

- Secure uses, outlets and markets are needed for liquor and fibre products (both can be stored relatively easily but at a cost).
- Access to potential uses or markets for excess heat, or reaching a niche electricity market, will be important.
- Distribution networks. The right location can save thousands of pounds on grid connection costs, and the value of the electricity is enhanced by minimising transmission losses; the closer it can be connected to its end users when sold off site the better.

Planning and environmental restrictions

- Impacts on neighbours. CAD plants may be best sited in areas designated for industrial development in the development plan of the local planning authority. All plants need to consider noise, smell and traffic impacts on local residents.
- Sufficient land available. It would be good practice for a farm to produce a Farm Waste Management Plan to demonstrate to the Environment Agency that there is sufficient land available for the storage and spreading of digestate on the farm.

- Landscape designations. Additional care needs to be taken with landscaping and building design in designated areas such as Areas of Outstanding Natural Beauty (AONBs) and National Parks, and it is possible that planning permission will not be forthcoming in these areas.
- Ecological impacts. Consult the statutory conservation agencies (English Nature, Countryside Commission, Countryside Council for Wales and Scottish Natural Heritage) informally before considering a site in or near to a designated area such as a Site of Special Scientific Interest (SSSI), Special Protection Area (SPA), Special Area for Conservation (SAC), RAMSAR sites (sites of international importance listed under the Convention of Wetlands in the UK; sites are designated as SSSIs) and county wildlife sites, as there are likely to be objections to developments in these areas. Any international, national or local nature conservation designation is a clear indicator of the sensitivity of the intrinsic ecological value of the site and these areas should be avoided.
- Water courses. Consult the Environment Agency at an early stage to ensure compliance with any regulations to prevent pollution.

Visual impact of digester and other buildings

A digester, storage buildings (for feedstock and products) and reception tanks will all be required; the size and number of the buildings will depend on the scale of the project. The buildings may need to be up to 6 or 7 metres high to allow for lorry tipping in some cases - about the same height as normal farm buildings. This should be taken into consideration when choosing the site.

Technology

The size of the digester tank will influence the choice of site and location. The size of the digester depends on the length of time required for the conversion cycle; this depends on the priorities of the developer in terms of products (eg biogas) and other objectives (eg odour reduction).

Water pollution

Construction sites should be selected so as to minimise water pollution. This can be done by avoiding sites liable to flood, sites with a high water table, sites where underdraining has been installed, sites where differential settlement is likely to occur, and steeply sloping sites. Alternatively, expensive ground preparation may be needed to prevent subsidence on some types of land.

Design and planning issues

An AD project will require detailed design and planning to ensure the development is not only economically viable, as discussed above, but also that all environmental impacts will be minimised. It is good practice for the developer of an AD plant to make contact with the planning authority at an early stage to seek advice on the making of a planning application and to enlist their help in structuring the project development and designing the site. It is good practice to consult with local people on design and planning issues (see Consultation section for details).

Planning permission is likely to be needed in almost all developments of AD projects, even for small on-farm installations, because the planning definition of agriculture does not include AD which is an industrial/waste treatment process. In a minority of small on-farm projects, where the feedstock originates and the products are used entirely on their own land, planning permission may not be required because the proposed development may be held to be ancillary to agriculture carried out on the farm and be 'permitted development' (under Part 6 of Schedule 2 of the Town and Country Planning (General Permitted Development) Order 1995) providing all the relevant conditions set out in the Order can be complied with. In cases where small on-farm projects are accepted as 'permitted development', an application to the local planning authority is needed for a determination as to whether their prior approval will be required in respect of the siting, design and external appearance of the development.

Design of the site

The main issues which need to be taken into account in designing the site and obtaining planning permission are outlined below.

Traffic

Any planning application will require information on the suitability of access roads for increased volumes of traffic, and any improvements that may be required

Photo: WRI Services

Digester landscaped into a site

both during construction and operation of the plant. Measurement of the existing traffic levels will be important as this will form the context in which additional traffic movements will be judged. See the Feedstock and products section for details on traffic impacts.

Emissions to air

Planning authorities will also consider any potential emissions to the atmosphere from the construction and operation of the plant, and the vehicles transporting feedstock and the products. There are regulations for controlling emissions and statutory nuisances under the Environmental Protection Act 1990.

Emissions to ground and water

The Environment Agency require that all tanks and digesters are surrounded by containment bunding of either concrete or clay. The relevant standards will also be required for any lagoons built for storing liquor.

Noise

The conditions of the planning permission are likely to specify noise limits which must not be exceeded at specific identified points. Expert advice is required in each case to identify and negotiate acoustic measures (if these are required) and noise conditions. Although not always essential, the developer and/or the local authority may wish to carry out a background noise survey to establish the ambient level of noise in the environment prior to the development.

Sources of potential noise need to be identified, such as engines and pumps, and plans can then be made to mitigate these through appropriate design of the site and buildings by using acoustic enclosures, creating hedge or tree barriers around the plant, and appropriate technology.

Noise is regulated by the planning and environmental health departments of local authorities, and by the Health and Safety Executive in relation to noise at work regulations.

Visual impact

The visual impact of the digester and associated buildings can be minimised in on-farm schemes if new buildings are grouped with existing farm buildings. Bunding, planting around the site and partial burial of the digester and storage or reception tanks will help to reduce the visual impact of the new development. However, these measures will increase the costs of the plant and may only be viable in sensitive locations. There is also potential for dividing the plant up; for example, the digester could be located separately from liquor and fibre storage to reduce visual impact, although the transport implications of this would need to be considered.

New electricity connections will have a visual impact both on-site and off-site (ie lines or cables to make the connection to the grid). The visual effect of overhead lines can usually be mitigated to an acceptable level by careful route selection. Developers will plan for the likely route of a grid connection at the same time as they are planning the power generating plant. Where a grid connection already exists, there will still be an impact on-site (ie simple fixing to existing grid system). Underground connection reduces the visual impact and may in certain cases be economic in comparison with overhead lines. In this case, the visual intrusion is only short term whilst the work is carried out.

Control of odour levels

A properly managed AD plant will reduce odour overall. However, odour from the feedstock will be released as it is stored, and especially whenever it is moved or mixed, and this odour needs to be carefully managed. In a properly designed and operated facility, the compounds which cause odour should be effectively contained and/or destroyed. Odour from AD is regulated by the local authority under the Environmental Protection Act 1990. Potential problems need to be addressed through the design of the site, and expert advice is required in each individual case to consider what is likely to be discharged, what are the potential risks and how they can be avoided or at least minimised. To meet planning requirements, it is likely that all manures and feedstocks for CAD plants will have to be contained in buildings or tanks with negative ventilation systems fitted with bio-filters to control and contain odours.

Design of the plant

Decisions about the equipment and technical design of the plant also need to be considered. The main requirements for good design for AD plants include:

- Minimising mechanical and electrical equipment
- Effective insulation properties, and corrosion resistant materials
- Simple design and automatic operation
- Equipment fail safe devices throughout
- Environmental controls.

Although the main process stage is the anaerobic digestion tank, there are a range of preliminary and post-digester units necessary for an integrated plant. For a farm-scale digester, feedstock conditioning may be limited to minimising the water content of the material and preventing large lumps reaching the digestion tank, whereas a CAD plant will require special feedstock handling and storage units. Overall, there will be a range of structures, depending on scale including:

- Appropriate waste reception and loading facilities
- Digester; the size depends on projected volume and nature of waste to be dealt with, and on the temperature and retention time in the digester
- Mixing devices
- Gas holder
- Gas handling equipment including pipework, valves, flare stack/heat dump
- Electricity generating equipment, powered by ignition engines converted to run on methane, gas turbines and electricity generators
- Boilers to provide heat for the digester
- Pipework to remove the water which condenses out from the saturated gas which is produced by AD
- Appropriate storage for liquor and fibre
- Control and monitoring equipment
- Odour control equipment.

CAD operations are also likely to require equipment for volume recording and analysis facilities for quality assurance and contractual requirements, as well as monitoring equipment for safety and operational purposes.

The crucial factor is to identify the appropriate plant design to meet the user's requirements for the whole project. The plant, to be successful, should have both a quality guarantee from the feedstock suppliers and a performance guarantee from the plant installers and designer. The performance guarantee should include factors such as:

- Heating performance, eg keep digester contents at 35°C with an ambient temperature of -10°C provided adequate feedstock is being added
- Digester contents mixing, which can be defined as the total contents being mixed within 30 minutes
- Temperature differential does not exceed 2°C across the digester vessel
- The digester loading system will handle the feedstock
- The unloading system will handle the digestate at the designed rate, including separation (when appropriate)
- The generator should, when supplied with the correct amount of biogas, produce the specified electrical and heat loads, for a minimum of the stated number of hours per year
- The developer should choose the best available technology to minimise environmental impact; the performance guarantee should cover operation to required environmental standards.

Figure 5.
Planning process

Consultations — **Planning application prepared** — **Consultations**

Registration and administration
- Checks to ensure that all forms, plans and fees are correct; if the application is valid then an acknowledgement letter is sent
- Application entered onto the statutory planning register and plotted on Ordnance Survey maps
- Technical background information prepared for Case Officer

Publicity and consultation
- Application details appear on a weekly list of applications appearing in the local press and a notice posted on or near the site OR either a site notice or a neighbour notification letter(s); minimum publicity period is 21 days
- Statutory and technical consultations undertaken; minimum consultation period is 14 days

Publicity and consultation carried out in parallel.

Case Officer
- Inspects site and its surroundings
- Assesses proposal against planning policies, DTER Planning Policy Guidance, previous planning history on the site and normal development control criteria
- Takes into account any letters of representation received and the results of consultations; may negotiate changes to proposal
- Prepares either report and recommendation to the planning committee OR draft decision for the Chief Planning Officer

Committee agenda
Public release of Chief Planning Officer report and recommendation

Delegated decision
Taken by Chief Planning Officer, for usually minor development or where the application is unopposed.

Committee decision
- Some aspects may be delegated
- Committee site visit: usually where proposal is controversial, or raises unusual issues.

Section 106 Planning Obligation
(If necessary) prepared and negotiated

Permission
Notice, usually with conditions, issued

Refusal
Notice, with reasons, issued

Appeal
The applicant can APPEAL to the Secretary of State if:

(i) Permission is refused

(ii) Applicant is unhappy with conditions imposed on a permission

OR where no decision has been made on the expiry of the statutory determination period

Note
This is a general guide to the processing of a planning application only. The extent of powers delegated to the Chief Planning Officer and the committee procedures of each local planning authority will vary.

Chart devised by Chris Preece, Torridge District Council.

Planning permission

The process of applying for and obtaining planning permission is a crucial element of the overall development of an AD project regardless of scale. This process is outlined in Figure 5 and the detailed summary below.

This summary of the planning process is not a step-by-step guide, since the actual procedure will vary according to the size and type of plant and to the requirements of different planning authorities. Also, all assessments will be done in parallel, rather than one at a time. Moreover, this procedure does not cover all the actions required of the developer: others are necessary before and after planning permission is applied for and granted.

Some digesters may require an Environmental Assessment (EA) (see Box 1 overleaf), as well as regulation and monitoring by the Environment Agency. Whether a statutory Environmental Assessment and environmental statement are required will depend on the location, scale and nature of the scheme (see Box 2 for when an EA is required; see Box 3 for what an environmental statement should cover). Some local planning authorities may request an EA at their discretion. Even if a formal EA is not required, it would be good practice to produce simple environmental information for the public on any potentially adverse environmental effects of the proposed development and how they will be mitigated. As well as showing that the risks of any impacts have been considered, information produced and distributed at an early stage can reduce problems created by misunderstandings later in the project development process, and therefore save time and money in the long term.

The way the planning procedure will work in normal circumstances is shown in Figure 5 and detailed below.

1 The developer will make contact with the planning authority at an early stage. The planning authority with jurisdiction for the development will be either the district or county council, or unitary authority, depending on the local government structure in the area and the nature of the project. In areas covered by both county and district councils, the county council is the authority which deals with matters relating to waste management or treatment. Early discussions with the local authority's building control and Environmental Health Officers are also important.

The initial contact should be with the Chief Planning Officer or with one of his senior officers, who will decide who should deal with the matter (it may be delegated). There may also be contact with the economic development officer about larger schemes. At this stage, the project may not reach the public domain, although early provision of information to local communities is always recommended.

2 Between initial contact and a formal application for planning permission, most of the preparatory work for the development will be carried out. This will include regular contact with the planning authorities, especially relating to initial work on any EA required (or alternative provision of environmental information). The scope of the EA can be developed informally in discussion, or more formally in correspondence. The latter approach would mean that the project will become more widely known because the planning authority will consult statutory consultees. The need for a statutory EA will depend in part on how far, in negotiations, the developer agrees with the planning authority to address environmental issues which will be covered in detail as part of the application procedure.

While planning applications and EAs require a high degree of technical input, it is important to recognise that these are public documents, and developers should ensure that results are presented in as accessible a form as possible, with the minimum of technical or scientific jargon. In addition, the developer will be required to produce a non-technical summary planning statement for public information, and a formal summary will be required if there is an EA. There will also be detailed consultation with the local community and with statutory and non-statutory consultees, at a sufficiently early stage for plans to be adapted in response to local concerns. Only when all this is completed, and all issues of concern have been addressed, should a formal application for permission be made.

3 If a CAD plant is planned, a more intensive dialogue between the developer and the planning authority, prior to the submission of the planning application, is recommended. It is good practice to submit the environmental statement (or informal environmental information) at the same time as the planning application. It is good practice to state 'no significant impacts anticipated' where this is the case, although if this statement is used, and subsequently found to be inaccurate, there is likely to be serious questioning of the entire project.

Box 1

What are Environmental Assessments and statements?

Environmental Assessment (EA):

'A technique and a process by which information about the environmental effects of a project is collected, both by the developer and from other sources, and taken into account by the planning authority in forming their judgement on whether the development should go ahead ... the whole process whereby information about the environmental effects of a project is collected, assessed and taken into account in reaching a decision on whether the project should go ahead or not. The term 'environmental impact assessment' (EIA) is also in common use and for practical purposes is synonymous with EA' .

Environmental Statement:

'A document setting out the developer's own assessment of his project's likely environmental effects, which he prepares and submits in conjunction with his application for consent'.

Taken from Environmental Assessment-A guide to the procedures, *HMSO/Welsh Office 1989.*

Box 2

When is an EA required?

Statutory EA is only mandatory for a thermal power station with a heat output of 300 MW or more referred to as a Schedule 1 development under the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988, and no AD projects are likely to reach anything like this size.

However, smaller plants will require an EA if they are likely to have significant effects on the environment because of their nature, size or location (referred to as Schedule 2 developments under the 1988 regulations).

'Significant effects' have no general definition, but Government guidance lists three main criteria of significance:

- Whether the project is of more than local importance, principally in terms of physical scale
- Whether the project is intended for a particularly sensitive location, for example, a National Park or Site of Special Scientific Interest (SSSI), and for that reason may have significant effects on the area's environment even though the project is not on a major scale
- Whether the project is thought likely to give rise to particularly complex or adverse effects, for example, in terms of the discharge of pollutants.

Taken from Environmental Assessment-A guide to the procedures, *HMSO/Welsh Office 1989*.

Exactly what supplementary environmental information may be required in any application for planning permission would need to be negotiated in each individual case with the planning authority concerned. The regulations governing this procedure are the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988 (as amended) implementing EU Directive 85/337. These regulations include details of the matters to be addressed by an EA, and provide useful guidelines for any supplementary environmental information produced by developers (see Box 3).

4 The formal process begins with the submission of the planning application, which will lead to some form of statutory consultation. The planning authority is obliged to publicise the planning application as soon as it is formally received, at which point anyone can make comments on the proposals. The planning authority will take into account any representations received when making a decision on the application. The decision could be made by either a planning committee or the chief planning officer using delegated powers.

If the development does require a formal EA, the local authority has 16 weeks to deal with the application. If no formal EA is required, the local authority has up to 8 weeks. The developer has the right to appeal against the failure of the local authority to decide the application at the end of 8 or 16 weeks. Such an appeal must be made no later than 6 months from the statutory determination date.

5 Where an adopted or approved development plan contains relevant policies, Section 54 (a) of the Town and Country Planning Act 1990 requires that a planning application or an appeal shall be determined in accordance with the plan unless material considerations indicate otherwise. Regard should also be had to DOE Planning Policy Guidance Notes (PPGs), and particularly PPG22 on Renewable Energy.

6 The Secretary of State has the ability to call in planning applications, at which point they are taken out of the hands of the local authority. This may happen if there is considered to be a breach of the development plan policy or if the Government Regional Office (in England only) considers that the proposed development raises issues of more than local concern. If the developer is working effectively with the local authority and local community, any such issues and potential problems will have been identified at an early stage.

7 If planning permission is granted, developers will be aware of the need to comply with any agreed voluntary planning obligations and planning conditions which could be imposed, which will normally have been negotiated prior to granting any permission. Discussions will have been held with planning authorities to agree methods of complying with those conditions, which may involve some form of monitoring. Some elements could be dealt with through a liaison forum set up from the links the developer has already established with the local community. There may also need to be agreement to off-site highway improvements, which would involve discussions with the highway authority and local landowners.

Box 3

What should an environmental statement cover?

It is not possible to offer a definitive list of topics for an environmental statement, and developers will need to look at both wider and more local issues which cannot be identified in general guidelines. Also, circumstances and technologies change over time. Developers are advised to discuss it with the local authority and the Environment Agency to clarify specific local issues. However, the 1988 Regulations (Schedule 3, paras 2, 3 and 4) state that an environmental statement should provide certain specified information including:

(a) a description of the development proposed, comprising information about the site and the design and size or scale of the development

(b) the data necessary to identify and assess the main effects which that development is likely to have on the environment

(c) a description of the likely significant effects, direct and indirect, on the environment of the development, explained by reference to its possible impact on:

- human beings
- flora
- fauna
- soil
- water
- air
- climate
- the landscape
- the interaction between any of the above
- material assets
- the cultural heritage

(d) where significant adverse effects are identified with respect to any of the foregoing, a description of the measures envisaged in order to avoid, reduce or remedy these effects

(e) a summary in non-technical language of the information specified above.

An environmental statement may include, by way of explanation or amplification of any specified information, further information on any of the following matters:

(a) the physical characteristics of the proposed development, and the land-use requirements during the construction and operational phases

(b) the main characteristics of the production processes proposed, including the nature and quality of the materials to be used

(c) the estimated type and quantity of expected residues and emissions (including pollutants of water, air or soil, noise, vibration, light, heat and radiation) resulting from the proposed development when in operation

(d) (in outline) the main alternatives (if any) studied by the applicant, appellant or authority and an indication of the main reasons for choosing the development proposed, taking into account the environmental effects

(e) the likely significant direct and indirect effects on the environment of the development proposed which may result from:

(i) the use of natural resources

(ii) the emission of pollutants, the creation of nuisances, and the elimination of waste

This includes secondary, cumulative, short, medium and long term, permanent, temporary, positive and negative effects

(f) the forecasting methods used to assess any effects on the environment about which information is given under subparagraph (e), and

(g) any difficulties, such as technical deficiencies or lack of know-how, encountered in compiling specified information

Where further information is included in an environmental statement in this way, a non-technical summary of that information shall also be provided.

Taken from Town and Country Planning (Assessment of Environmental Effects) Regulations 1988.

8 If planning permission is refused, or conditions made with which there is disagreement, developers have a right to appeal within six months.

Overall, if a site is suitable, and a well-considered planning application is made which seeks to take into account the concerns or likely concerns of local communities and statutory consultees, it is much more likely to receive a positive response.

Construction and operations

Constructing and operating an AD project, and managing a digester, is an art as much as a science: operators must learn about and understand their digester and feedstock. This section covers all the main issues relevant to constructing and operating an AD project, including planning and managing construction, electricity connection, training, monitoring, minimising operational risks and optimising performance.

Photo: ETSU

Digester control panel

Construction

The level of the impacts of construction work will depend on the scale of the plant being constructed. An on-farm heat generating plant is likely to have minimal impacts during construction. In larger energy generating schemes, in which electricity is exported via the distribution network, a purpose-built power generating plant will be constructed, which is likely to entail new building, creating greater impacts which need to be mitigated. As with any new development, there are specific issues arising from the construction of the power generating plant which are more related (for neighbours) to living near to a building site than to a power plant. These include construction noise and dust, impact on the access road, transport noise, light pollution, oil spillages, soil erosion, establishing a construction compound which may be larger than the final site, and negotiations for wayleaves.

A developer can apply to the local authority for a prior consent over times of working, noise levels, and similar issues (under the provisions of Section 61 of the Control of Pollution Act 1974). This may help provide reassurance to local residents: difficulties at this stage can damage the reputation of a plant before it even starts operation. It would also be good practice to consult with the local authority's Environmental Health Officers, as they would deal with any complaints and could defuse any local antagonism more quickly if they can give answers directly.

The Construction (Design and Maintenance) Regulations 1994 place new duties upon clients, clients' agents (where appointed), designers and contractors to take health and safety into account, and co-ordinate and manage it effectively throughout all stages of a construction project from conception, design and planning through to the execution of works on site and subsequent maintenance and repair. A health and safety plan (to bring together all relevant information from those responsible, starting in pre-construction) and a health and safety file (an enlarged maintenance manual to inform future decisions) will be required.

The degree of the detail required of all duty holders to comply with the Regulations should be adapted to the scale and complexity of the project. Projects involving minimal high risk work will call for simple health and safety plans and few, if any, specialist skills. Large projects or those involving high risk work will call for correspondingly more detailed assessment and specialist skills.

Method statement

The method statement should spell out specific measures which developers plan to take to minimise disruption and mitigate any undesirable impacts during construction. It will have been negotiated as part of the planning permission and should be built into the contract with the contractors for the building. The method statement will need to provide detailed guidance for the construction contractors, but it would be good practice to produce an additional summary in plain English for local communities and the local planning authority.
It is likely to include:

Noise
Reducing noise nuisance as much as possible by working only during the normal working day. It would be good practice to consult the local authority's Environmental Health Officer who can advise on acceptable construction site noise levels. Developers will wish to consult and have regard to British Standard (BS) 5228 on Noise Control on Construction and Demolition.

Timing
Timing construction carefully, to avoid damage if the area or surroundings are environmentally sensitive (eg at certain times of year): there should also be consultation with the local planning and highway authorities regarding proposed traffic movements.

Dust
Water can be used to suppress dust. Care is needed, however, to avoid excessive application of water so that suspended silt is not washed into a drain or watercourse.

Lighting
Consultation is recommended with the local authority's Environmental Health Officer for advice on guidelines on light pollution (details on light pollution are given on page 40).

Size of construction compound
The site will need to be sufficiently large to allow space for mitigation of any construction impacts, as well as simply meeting the physical needs of construction. Attention should be given to returning the surrounding area to its original status after construction.

Spillages
Measures to reduce or contain spillages, such as bunding, would probably be a condition of planning permission.

Duration of construction
An estimated construction timetable should be included in the method statement; construction of an AD plant would normally take from 3-12 months.

Transport and traffic
The construction process might require consideration of:

- Off-site highway changes such as setting back hedges, hedge-trimming
- Bridges: need to consider loading and height
- Road developments eg road widening.

Such works should be the subject of early discussions with the planning authority and highway authority as they will need to be identified in the planning application. Road widening and other highway alteration works are likely to be covered by legal agreements under the Town and Country Planning Act 1990 and the Highways Act 1980.

Method statement

Most larger AD projects will be subject to the Construction (Design and Maintenance) (CDM) regulations, except projects which take less than 30 days for construction, or less than 500 person work days.

A method statement may also be required as part of the planning permission. This should be drafted by the developer, and discussed with the planning officers, the building control officers and the environmental health department of the relevant local authority and with community representatives and local people. This will help to demonstrate that the developer has thought about the possible problems and their mitigation, as well as about residual impacts and how to address them. The issues the method statement should address are outlined in the Box above.

Electricity connection

If an AD plant is constructed on a new site it will generally require an electricity connection to the local electricity distribution network to provide energy to operate ancillary equipment and other site loads during maintenance and shut-down periods, unless stand-by generation equipment is also installed.

An electricity connection and appropriate import/export metering will be required if the gas produced by an AD plant is to be used to generate electricity which cannot be consumed within the curtilage of the plant and associated businesses. The operator will then have to decide on a number of trading options depending upon the size and location of the generator and to whom the electricity is sold or consumed, and address various technical, regulatory, commercial and contractual issues.

The risks and benefits with each option will need to be appraised and understood by the prospective developer to maximise the value of the energy generated and to ensure that the appropriate agreements, contracts and licenses are entered into by the developer.

The Regional Electricity Company (REC) has statutory obligations under the Electricity Act 1989 in respect of the safety and quality of electricity supply to its customers and will determine the method and the point at which connection can be made to the distribution network, depending upon the export capacity of the AD plant and the relative parameters of the immediate distribution network.

The cost of connection could vary considerably depending on where the AD plant is located within the REC's distribution network. The cost of connection will in part reflect the distances involved. However, because the REC for operational and economic reasons needs to use standard component sizes for its own assets, the connection cost will not tend to rise smoothly with increasing plant capacities, but will tend to increase in steps as the thresholds for requiring particular assets and voltage levels are crossed. If the developer has some flexibility as to where the plant can be located within a particular area, they should discuss with the REC the respective connection costs for different sizes of generator and, if practicable, size and locate the installation accordingly.

In some cases, some benefits may also accrue to the local REC and/or the licensed second tier supplier who contracts to sell the electricity and it may be possible to negotiate agreements to optimise the costs to the developer and maximise the value of the energy generated. A summary of the options, benefits and the associated agreements, contracts and licence requirements is given in Appendix 6.

Training

Good practice requires that all operators of AD plants are trained to the highest possible standards in the engineering aspects of the running of the equipment, be trained in and fully understand the health and safety aspects, and be trained to recognise problems and how to respond to them. Farmers and developers may obtain training on the use of equipment from manufacturers and equipment suppliers. A number of consultants can also offer training on health and safety and operating procedures.

Monitoring

An AD project should be regularly monitored in order to:

- Optimise economic and environmental performance
- Assess quality control of feedstock and products regularly
- Check records of what is produced and what has gone through the system
- Monitor and control emissions, and ensure emissions on site are within set limits (this may be a planning condition)
- Check comments made by members of the public and neighbours of the plant
- Ensure planned actions are carried out effectively.

Minimising operational risks

Good practice requires careful planning and management to ensure that the benefits of the products of AD, including sustainable energy production, are matched by sensitively and effectively managed systems for operations. As with any agricultural or small industrial development, the operation of the scheme will have some risk of negative environmental impacts. All of these will need to be addressed in order to obtain planning permission and may be governed by planning conditions. Some of these impacts, and therefore any mitigating activities, may be negligible in smaller schemes. However, even the largest AD plant can be compared more easily with other agricultural developments than with any conventional industrial facilities. Nevertheless, and especially in larger schemes, attention needs to be given to the following, all of which are covered in more detail below:

- Emissions to air
- Emissions to ground and water courses
- Light
- Transport and traffic (see Feedstock and Products section)
- Feedstock and product storage (see Feedstock and Products section).

The regulations which will be in force depend on the scale of the development, as will the identity of the regulatory authority: it is likely to be the local authority and the Environment Agency.

Emissions to air

Environmental impacts

There is the potential for emissions of methane (a greenhouse gas) to the atmosphere from leaks from the plant. It is also important to ensure efficient combustion as carbon monoxide (human health risk), nitrogen oxide (precursor to acid rain) and volatile organic compounds (VOCs - toxic air pollutants) are released at unacceptable levels if the biogas is combusted inadequately. Proper management should ensure that all these risks are controlled, and the best available technology should be used in all cases.

The Environment Agency will apply Integrated Pollution Control regulations to larger plants which will control emissions to all media (not just air); this will apply to larger on-farm schemes as well as CAD plants.

Health and safety risks

Biogas is primarily composed of methane and carbon dioxide, with traces of ammonia and hydrogen sulphide. Ammonia and hydrogen sulphide may arise during fuel gas production, from stored feedstock and in the mixing pits or conveying plant. Exposure to any of these gases may result in ill-health or death, and levels in the biogas may vary widely and cyclically. Carbon dioxide, ammonia and hydrogen sulphide are all toxic gases, and are subject to the COSHH regulations as substances hazardous to health.

Employers of people working in biogas plants must assess the risk from exposure to the gases (and other hazardous substances such as pathogens in the feedstock), and take steps to control that risk. For new plants, the risk of operators or others being exposed to toxic gases should be considered at the design stage under the Construction (Design and Management) Regulations 1994.

Identifying the hazards in the plant design, whether in the construction stage, under normal running or during maintenance and repair, will enable many risks to be designed out and thus subsequent operation of the plant will be easier.

The COSHH assessment will identify hazards from operating the plant, and the extent of risk to be controlled. The assessment will lead the operator of the plant to institute the necessary procedures to control exposure down to or below the legal limits, known as Occupational Exposure Standards (OES), which must not normally be exceeded. The main hazards of these gases are outlined below.

- Methane is an asphyxiant (its presence at high concentrations in air reduces the oxygen content to such an extent that life cannot be supported) but is not subject to COSHH.
- Carbon dioxide is colourless, odourless and heavier than air. As well as being mildly toxic, it is an asphyxiant and has an Occupational Exposure Standard (OES) of 5000ppm.
- Hydrogen sulphide is a colourless gas which smells of rotten eggs at low concentrations. At higher and more dangerous concentrations it has no smell. It is heavier than air. Due to its toxicity, it has an OES of 10ppm.
- Ammonia is a pungent and lachrymatory gas which is lighter than air. The OES is 25ppm, to protect the eyes and mucous membranes from irritation.

Good practice entails using reasonably practicable means to control risks. Controls may include removing the toxic elements of the gas, establishing totally enclosed systems, systems which minimise or contain the hazardous substance, local exhaust ventilation, general ventilation or, as a last resort, personal protective equipment. The controls instituted should not rely on venting (which may create risks elsewhere due to the heavier than air nature of hydrogen sulphide and carbon dioxide) or on unforced general ventilation. Health and safety issues will be regulated by the Health and Safety Executive.

Emissions to ground and water courses

- **Water.** Water courses could possibly be affected by discharges resulting from poor storage of feedstock, inappropriate storage of liquor, spillage or spreading of liquor. Site containment will be required. If there are accidental spillages or leakages into water courses, the Environment Agency should be notified immediately. The Environment Agency is responsible for controlling emissions to rivers and land. Water companies regulate any discharge into public sewers.
- **Soil.** Pollution prevention measures will be dealt with at the planning stage in consultation with the local authority environmental health department and the Environment Agency. Any accidental contamination should be reported to the Environment Agency immediately.

Light

CAD plants are likely to operate 24 hours a day so there may be a problem with light spillage. There are no statutory criteria for light pollution although measures can be taken to reduce unnecessary obtrusive light: light pollution can cause serious physiological and ecological problems, and wastes energy and money. The Institution of Lighting Engineers' *Guidance Notes for the Reduction of Light Pollution* suggests a number of measures, including:

- Lights should be directed at and not above their target; if aimed at observers, the main beam angle should be no more than 70°.
- In certain environmental zones, such as National Parks, Areas of Outstanding Natural Beauty (AONBs) or other 'dark landscapes', only light from public roads should be deemed acceptable for all night lighting. Similar guidelines apply to other special areas.
- Curfews should be introduced, for example between 11pm and dawn, when lights not required for security are shut off.
- Further advice can be obtained from the local authority Environmental Health Officer, or the Institution of Lighting Engineers.

Optimising performance

It is possible to automate AD plants, but they will always need daily management and monitoring for quality, performance and health and safety. Anaerobic digestion is a robust process, but to ensure optimum performance the following aspects of management and monitoring should be considered:

- Choice of appropriate technology for the specific circumstances
- Security of supply and disposal routes
- Achieving the desired dry solid content of feedstock: the more dry solids, the more gas per kg of feedstock that will be produced
- Ensuring efficient mixing
- Maintaining the correct temperature in the digester and ensuring sufficient heat transfer and capacity
- Regular process monitoring
- Efficient management, including operator training and the establishment of environmental management systems
- Regular maintenance of moving parts and heat transfer surfaces
- Maintenance of pH in the digester.

Maintenance

General points to be considered include:

- Maintenance contracts for digesters and generators
- The potential for letting an operations contract (to run the digester and generator)
- Pressure systems, as defined by the Pressure Systems and Transportable Gas Containers Regulations 1984, require a formal written scheme of examination drawn up by a competent person; this would specify the intervals between examinations
- Operation and/or maintenance contracts need to take the timespan of specific contracts into account (eg NFFO contracts may run for 15 years).

Start up and shut down

Starting up and shutting down the digester can be one of the most risky procedures in running an AD plant. Training must be provided for all operators to ensure they understand and comply with procedures and advice sought from specialists.

If the heat is turned off, a typical digester will lose at least 0.5°C to 1°C a day if loading of feedstock ceases. Once the temperature has dropped to 28°C, the gas production will reduce significantly. To start the digester up again, the contents should be mixed continuously, so there is no mat on the top, and then slowly warmed up again. This process can be used if the operator is in any doubt about contaminated feedstock: if feeding is stopped the digester will recover.

As a matter of good practice, any developer of a scheme of any size will also need to take into account what will be done when the digester reaches the end of its useful life. It is likely that any planning consent will require decommissioning to be addressed, and advice should be taken from the Environment Agency and the Health and Safety Executive on any plans for decommissioning the digester and plant.

Appendix I

Glossary

The following terms are used in these guidelines, and the definitions given below refer to their meaning in the context of this document: other sources may use the terms differently.

AD: Anaerobic digestion; the process by which bacteria that act only in airless (anaerobic) conditions decompose organic matter with the concurrent production of biogas

Bacteria: Microscopic single celled organisms which break down the organic matter of the feedstock

Bio-filters: Remove unwanted substances using biological processes

Biofuel: Liquid fuels produced from biomass sources; biomass is any mass of biological material

Biogas: Gas evolved from the anaerobic digestion process which is typically 60% methane, 40% carbon dioxide, with other trace compounds

Bleaching clay: Porous clay filter media used for clarifying edible oils

BOD: Biological Oxygen Demand

Bunding: A barrier constructed around the site to prevent discharge entering water courses in the event of an accident

CAD: Centralised Anaerobic Digester; digester which imports feedstocks from a variety of sources

CHP: Combined Heat and Power: In normal mode of a generator, the major sources of heat, engine cooling water and exhaust system, are normally discharged to atmosphere; CHP recovers this heat via heat exchangers, increasing the efficiency of utilising fuel

COSHH: Control of Substances Hazardous to Health, Regulations 1994

Decommissioning: Closing and removing the facility after its useful life

Digestate: The digested output from the AD process

Digester: The closed container in which anaerobic digestion takes place

Dioxins: A group of harmful chlorinated organic compounds

DOE: Department of the Environment; Government department; now called Department of Environment, Transport and the Regions

Dry solids: The residue remaining when water is evaporated away from the residue and dried under heat

EA: Environmental Assessment; see box in Project Development section for details

Energy balance: Comparison of energy going into a process (inputs), to energy coming out of the process (outputs)

ETSU: Energy Technology Support Unit; manager of the Department of Trade and Industry's New and Renewable Energy Programme

EU: European Union

Feedstock: The material fed to the digester

Fertigation: Irrigation with water containing nutrients

Fibre: The coarse solids which have been mechanically separated from the liquid portion of the digestate

Fossil fuel: Any energy source derived from finite fossil sources eg coal and oil

Fossil Fuel Levy: Levy on electricity generated from fossil fuel sources used to fund NFFO

Heavy metals: Potentially toxic metals such as nickel, cadmium, etc present through natural or other causes

HMIP: Her Majesty's Inspectorate of Pollution; duties now undertaken by the Environment Agency

HSE: Health and Safety Executive

Leachate: Water which flows through the soil or ground and ends up in the water course and can cause pollution

Liquor: The liquid fertiliser which has been mechanically separated from the coarse fibre portion of the digestate

Mesophilic digestion: Digestion involving micro-organisms with a growth optimum around 20-45^{o}C

MAFF: Ministry of Agriculture, Fisheries and Food; Government department

NFFO: Non-Fossil Fuel Obligation, obligation requiring Regional Electricity Companies to purchase a certain amount of electricity from non-fossil fuel sources

NFPA: Responsible for purchase of electricity under NFFO

Nitrate Vulnerable Zone: Catchment areas where water quality standards for nitrates at risk of being exceeded

NRA: National Rivers Authority; duties now undertaken by the Environment Agency

OES: Occupational Exposure Standard

Organic Farming: see box in Introduction section for details

Pathogens: Organisms that can cause disease

pH value: A numerical scale for expressing the acidity or alkalinity of a liquid, ranging from 0 for strong acids to 14 for strong alkalis, with 7 representing the neutrality point. The ideal pH range in an anaerobic digester should be 6.8 - 8.

Planning conditions: Conditions relating to the construction and operation of a development imposed as part of the granting of planning permission

Pool (Electricity): Mechanism for centrally controlled trade of electricity

REC: Regional Electricity Company; holds franchise to operate and maintain the local electricity distribution network

Reception tank: Storage tank for feedstock prior to digestion

Second tier supplier: Licensed supplier (other than the local REC) contracting to supply electricity to customers connected via the electricity distribution networks

Separator: Machine used to separate digestate into fibre and liquor

Siltation: Settlement of solid particles in the digester causing blockage and reducing digester volume

Soil conditioner: A material which improves the friability of a soil (eg peat, garden compost or fibre from AD); soil conditioners may or may not contain nutrients

Sustainable development: Development which meets the needs of the present without compromising the ability of future generations to meet their own needs

Thermophilic digestion: Digestion involving micro-organisms that grow above 40^{o}C, typically kept at about 55^{o}C

Tilth: The condition of soil (ie fine, water retentive etc) which has been prepared for planting

Transmission losses: The decline in energy when it is moved from the point of generation to the point of use

Triad: Three half hours of system peak during which power take off by a REC is used as the basis for the use of transmission system charge

Volatile solids: Those solids in the feedstocks which are volatile (ie will convert into gases when heated) and which are therefore digestible

Wayleaves: Rights of way for the provision of services

Weeping Wall: Slurry contained by a wall with horizontal or vertical gaps, through which liquid passes leaving a relatively dry manure; the liquid requires collection and treatment

UNITS OF POWER

Kilowatt (kW) = 1000 watts

Megawatt (MW) = 1000 kW

Gigawatt (GW) = 1 million kW

Terawatt (TW) = 1 thousand million kW

When 'e' added (eg kW_e) = electrical power, so kW_e = kilowatt of electrical power

When 't' added (eg kW_t) = thermal power (heat), so kW_t = kilowatt of thermal power

Appendix 2

Contacts

AD Technology
Windover Farm, Longstock, Stockbridge,
Hampshire SO20 6DJ
Tel: 01264 810569

The Association of Electricity Producers
First Floor, 41 Whitehall, London SW1A 2BX
Tel: 0171-930 9390

Barton Willmore Planning Partnership
Intercell House, 1 Coldhams Lane, Cambridge CB1 3EP
Tel: 01223 322 444

Bow Maurice
Barton Farmhouse, Dartington Hall, Totnes, Devon TQ9 6ED
Tel: 01803 867 891

British Biogen
7th Floor, 63-66 Hatton garden, london EC1N 8LE
Tel: 0171-831 7222

Council for the Protection of Rural England (CPRE)
Warwick House, 25 Buckingham Palace Road,
London SW1W 0PP
Tel: 0171-976 6433

Countryside Commission
John Dower House, Crescent Place, Cheltenham
Glos GL50 3RA
Tel: 01242 521 381

Enertech
Engineering Consultants
1a Barnsley Road, Ackworth, Nr Pontefract
West Yorkshire WF7 7BS
Tel: 01977 612 391

Environment Agency
Hafren House, Welshpool Road, Shrewsbury,
Shropshire SY3 8BB
Tel: 01743 272 828

Environmental Energy Ltd
PO Box 3, Knighton, Powys LD8 2WD
Tel: 01544 267 880

ETSU
Harwell, Didcot, Oxfordshire OX11 0RA
Tel: 01235 433 302

Farm Energy Centre
National Agricultural Centre, Stoneleigh Park,
Kenilworth, Warwickshire CV8 2LS
Tel: 01203 696 512

Farming and Rural Conservation Agency
Brooklands Avenue, Cambridge CB2 2BL
Tel: 01223 462 762

Farming and Wildlife Advisory Group
National Agricultural Centre, Stoneleigh,
Kenilworth, Warwickshire CV8 2RX
Tel: 01203 696 699

Friends of the Earth
26-28 Underwood Street, London N1 7JQ
Tel: 0171-490 1555

Greenfinch Ltd
Burford House, Tenbury Wells,
Worcs WR15 8HQ
Tel: 01584 810 777

Health and Safety Executive
(Agricultural Sector), The Pearson Buildings
55 Upper Parliament Street, Nottingham NG1 6AU
Tel: 0115-971 2800

Hydro Agri (UK) Ltd
Immingham Dock, Immingham, NE Lincolnshire DN40 2NS
Tel: 01469 554 784

Linking Environment and Farming (LEAF)
National Agricultural Centre, Stoneleigh Park, Kenilworth
Warwickshire CV8 2LZ
Tel: 01203 413 911

Livestock Systems
The Long Barn, Clevedon Road, Tickenham
Nr Bristol BS21 6RY
Tel: 01275 857 799

MAFF
Nobel House, 17 Smith Square, London SW1P 3HX
Tel: 0171-238 6000

Maltin Pollution Control Systems (1967) Ltd
Gould's House, Horsington, Somerset BA8 0EW
Tel: 01963 370100

National Farmers Union (NFU)
Agriculture House, 164 Shaftesbury Avenue, London WC2H 8HL
Tel: 0171-331 7200

National Farmers Union Scotland
Agriculture House, Rural Centre, West Mains, Ingleston,
Newbridge
Midlothian EH28 8LT
Tel: 0131-472 4000

National Trust
36 Queen Anne's Gate, London SW1H 9AS
Tel: 0171-222 9251

Northern Chicken Growers
The Elms, Ottringham, East Yorkshire HU12 0DX
Tel: 01964 622 278

Nigel Parker
MAFF/EU Objective 5b Facilitator, Chessels,
Daws House, Launceston, Cornwall PL15 7JF
Tel: 01566 777 422

Practically Green Environment Services
Solar House, Magherafelt, Northern Ireland BT45 6HW
Tel: 01648 32615

Shropshire Energy Team
Shropshire County Council Environment Department,
The Shirehall, Abbey Foregate, Shrewsbury SY2 6ND
Tel: 01743 252 565

Soil Association
Organic Food and Farming Centre
86-88 Colston Street, Bristol BS1 5BB
Tel: 0117-929 0661

Walford College,
Walford, Baschurch, Shrewsbury SY4 2HL
Tel: 01939 262 100

WRI Services
Donnington, Wroxeter, Shrewsbury SY5 6PU
Tel: 01952 740 414

Appendix 3

Publications and regulations

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Appendix 4

Development of the guidelines

The process

These guidelines were produced using consensus building techniques. Environmental Resolve, an undertaking of The Environment Council, designed and managed the process, which brought together the industry, environmentalists, planners and government agencies in order to address potential stakeholder concerns and support the development of the industry in a sensitive manner. The process was guided by a steering group led by Environmental Resolve and made up of British Biogen, Friends of the Earth, National Farmers Union and ETSU.

This approach involved a series of workshops and small sub-group meetings, during the first half of 1997. Participants used their experience to develop and agree detailed guidelines on what constitutes good practice in developing an economic, efficient, environmentally sound and publicly acceptable AD industry. Draft material was written up by the editor, circulated and amended by agreement at a final workshop, and then collated by the editor. A full list of all those involved is given below.

The following attended one or both of the main workshops:

Ewan Bent, Shropshire Energy Team
Peter Billins, British Biogen (Steering Group member)
Chris Bow, Bow Maurice
Fergal Callaghan, Chemical Engineering Department, University of Birmingham (provided special help on dealing with pathogens and parasites, including (Appendix 7)
Henry Chesshire, WRI Services (provided special help with Appendix 5)
Michael Chesshire, Greenfinch Ltd
Ken Dann, Walford College
Les Gornall, Practically Green Environment Services
John Harrison, Shropshire County Council
Bob Harvey, Environment Agency
Ian Higham, ETSU (Steering Group member)
Joanne Hirst, National Farmers Union (Steering Group member)
Graham Hurd, Shropshire Energy Team (provided special help with section on electricity connection, including Appendix 6, in consultation with Midlands Electricity plc personnel)
George Macpherson, Home Grown Energy Ltd
Chris Maltin, Maltin Pollution Control Systems (1967) Ltd
Robin Maynard, Friends of the Earth
James Murcott, Woodhouse Farm
Matthew O'Brien, Farming and Wildlife Advisory Group
Dan O'Connell, ETSU
Tamzin Phillips, National Trust
Chris Preece, Torridge District Council (provided special help with section on planning processes)
Chris Reynell, AD Technology
Michael Sebastian, Health and Safety Executive
Ralph Simms, ETSU
Anna Stanford, Friends of the Earth (Steering Group member)
Gerald Tetchner, Enertech
Gregg Tillotson, Barton Willmore Planning Partnership
Peter Tipping, W.S. Atkins
Penny Troop, Hydro Agri (UK) Ltd (provided special help with Appendix 5)
John Wase, Chemical Engineering Department, University of Birmingham
Roger C. White, Glenfield Farm
Diana Wilkins, Ministry of Agriculture, Fisheries and Food
Robert Wilson, Chatwall Farm
James Wyllie, National Farmers Union, Scotland.

The following individuals also participated in drafting group meetings:

Peter Billins, British Biogen
Fergal Callaghan, Chemical Engineering Department, University of Birmingham
Henry Chesshire, WRI Services
Bob Harvey, Environment Agency
Ian Higham, ETSU
Joanne Hirst, National Farmers Union
Graham Hurd, Shropshire Energy Team
Chris Preece, Torridge District Council
Ralph Simms, ETSU
Gerald Tetchner, Enertech
Peter Tipping, W.S. Atkins
Penny Troop, Hydro Agri (UK) Ltd.

The following commented on written drafts only:
Michael Browne, University of Westminster, Transport Studies Group
Nigel Parker, MAFF/EU Objective 5b Facilitator.

Editor

Diane Warburton drafted text on behalf of the participants and acted as overall editor.

Design

Chris Lord Information Design

Environmental Resolve team

Pippa Hyam (project manager)
Schia Mitchell (project co-ordinator)

Environmental Resolve,
The Environment Council,
21 Elizabeth Street,
London SW1W 9RP

Appendix 5

Summary of management options for farm residues

Storage, treatment, then disposal			
Option	**Merits**	**Problems**	**Conclusions**
Anaerobic Digestion	● Good odour control. ● Energy production. ● Valuable digestate: fibre (soil conditioner), and liquor (liquid fertiliser). ● Continuous flow process. ● Improves storability. ● Ease of handling. ● Reduces spreading costs. ● Reduces methane emissions.	● High capital costs for full system ● Operational costs. ● Needs to be integrated into the whole business. ● Requires daily management.	● Comprehensive. Management-driven. ● May entail a separate business. ● Suitable for producers that have a specific waste management problem, and are prepared to give extra commitment to overcome problems.
Aeration Systems	● Mixes at same time as it aerates to maintain consistency. ● Various types and techniques of aeration. ● Reduced BOD and odour.	● Management important. ● Medium capital cost ● Some operational costs. ● Not applicable to high dry matter slurries › 4%.	● An option for thin slurry odour control.
Composting of Manures and for Fibrous Solids	● Alleviates nuisance odours if properly managed. ● Markets already in existence. ● Many organic wastes can be composted.	● If badly managed, can cause odour problems and emissions. ● High marketing costs. ● Medium/high capital costs associated with requirement for covered yards and concreted areas ● Management and operational costs.	● May entail a separate business. ● Suitable for producers that are prepared to give extra commitment to waste management problems. ● Requires marketing.
Mechanical Separation	● Reduces the size of the storage tanks required. ● Reduces capping over the top of the store. ● Slurry easier to pump. ● Produces a saleable fibre. ● Enhanced utilisation of the liquid on crops.	● Requires a pit with a chopper, pump and mixer. ● Some power requirement. ● Requires management. ● Medium/high capital costs.	● Increasingly popular addition to new stores.

Continued overleaf

Storage, then disposal			
Option	**Merits**	**Problems**	**Conclusions**
Weeping Wall	● Convenient: all manure or slurry conveyed to one store. ● Passive separation of solid from liquid fraction. ● Liquid fraction used as liquid fertiliser.	● Medium/high capital cost ● Requires storage for the separated liquid. ● Two types of spreading equipment required. ● Potential odour problems.	● Practical option for dairy and pig farms.
Manure/solid residue storage	● Allows for better timing of applications to land as the residues are stored and spread when required. ● Convenient at cleaning out times. ● Low capital cost.	● Rainfall causes effluent run-off and loss of nutrients. ● Potential risk of pollution.	● Commonly practised. ● Siting of manure/solid residues subject to MAFF *Code of Good Agricultural Practice for Protection of Water.*
Liquid residue storage	● Allows for better timing of applications to land, as the residues are stored and spread when required. ● Convenient at cleaning out time.	● Problems can occur with the capping of stores. ● Requires a powerful mixing system. ● Energy costs associated with mixing. ● Medium capital cost. ● Potential odour problems.	● Appropriate option in many cases, ● Application to land subject to MAFF *Code of Good Agricultural Practice for Protection of Water.*
Direct disposal			
Option	**Merits**	**Problems**	**Conclusions**
Spread residues directly to land	● Routine process. ● Saves storage and treatment costs. ● Avoids peak in work load associated with cleaning out stores, yards etc.	● Access to land may be restricted at certain times of year. ● Potential risk of pollution due to run off, particularly in high rainfall areas. ● Poor utilisation of nutrients. ● Potential damage to soil structure by application machinery.	● Still an option in limited cases, subject to MAFF *Code of Good Agricultural Practice for Protection of Water.*
Export			
Option	**Merits**	**Problems**	**Conclusions**
Export Manure from Farm via Contractors	● Limited farm handling facilities required. ● Low management input.	● High charges on a continual basis. ● Loss of nutrients from the farm.	● Appropriate where the farm has no land for spreading.
Dry Manure as Fuel (Poultry)	● Income from sales. ● Continual off-take from the farm. ● Reduces the requirement for storage.	● Applies only to dry poultry manures eg broiler litter. ● Low price paid to the farmer. ● Nutrients lost from the farm ie not recycled back to the land.	● Appropriate where there is no land on the farm to spread the manure.

Derived from Department of Trade and Industry, Agriculture and Forestry Fact Sheet 2. November 1993.

Appendix 6

Electricity connection

The majority of schemes will require an electricity connection to the local electricity distribution network to provide energy to operate ancillary equipment and other site loads during maintenance and shut-down periods, unless stand-by generation equipment is also installed.

If the gas produced by the AD plant is to be used to generate electricity then the operator will have a number of trading options depending on the size and location of the generator and who consumes or buys the electricity. These include:

- Consumption by the operator for own on-site business
- Sale as an on-site generator, that is, sale to a single customer or a qualifying group of customers related through common ownership on the same site
- Sale to the local Regional Electricity Company (REC)
- Sale via the Non-Fossil Fuel Obligation
- Sale through the electricity supply pool
- Sale to a second tier supplier through the Non-Pooled Generation Scheme
- Sale direct to own customer(s)
- New outlets which may emerge following deregulation of the energy market.

Each of these options will raise technical, planning, regulatory, commercial and contractual issues; some of the options involve mandatory licensing arrangements with cost implications and some will involve commercial risks. The risks and benefits need to be appraised and understood by the prospective developer to improve the negotiating position and to maximise the value of the energy generated. This appendix provides an introduction to the issues; more detailed information is available in *Electricity Production Connected to the Local Network - A Guide*, published by the Association of Electricity Producers.

The final option(s) chosen will determine the nature of the agreements and contracts and licences entered into by the developer and the equipment that will form part of the installation. These may include:

- A connection agreement with the local REC determining the connection cost, import and export capacity, and any operational restrictions which may be applicable.
- An agreement with the local REC or other second tier supplier (post 1998) to supply electricity for standby and top-up purposes, either for on-site use or by contracted customers.
- A meter connection agreement with a licensed meter operator to measure and record the half-hourly import and export of electricity by the generator and/or contracted customers.
- Purchase contract(s) with the local REC, second tier suppliers, NFPA (for NFFO contracts) or contracted customers for electricity supplied and/or for spill export when surplus to agreed declared generation capacity.
- Interlocks on stand-by generators and contractual agreements to restrict the use of fossil fuels if the electricity is sold via a NFFO purchase contract.
- Arrangements with the local REC or other second tier supplier for the benefits accruing from reduction in triad peak capacity charges and other embedded generation benefits.
- A generator's licence if exporting more than 50MW to anyone other than a single on-site customer (or exporting more than 10MW from a plant with an overall capacity greater than 100MW).
- A DUoS agreement with the local REC to pay the tariff charges for use of their distribution system where the generator is also operating as a second tier supplier and selling the electricity generated to contracted customers (DUoS refers to charges to be paid to the local REC for use of their distribution system to export electricity to other users or suppliers).
- A second tier suppliers licence if exporting more than 500kW to anyone other than the pool or a licensed supplier.
- If gas leaves the plant, an OFGAS license will be required because the operator is then classified as a gas producer.
- Electricity Pool membership to cover fees applicable to generator registration, data collection and settlement reconciliation for electricity generated and consumed by contracted parties.

Even if a generator is not required to have a licence, they may still apply for Pool membership on a voluntary basis, although this would not normally be beneficial to a generator with output capacity lower than 30MW.

An electricity connection to the local electricity distribution network will be required for any electricity exported, even if this is only during periods of spill when the output of the generator is greater than demand on-site or by its own contracted customers.

It is therefore advisable to establish a dialogue with the local REC at the earliest opportunity to appraise the various options, and to determine the relative terms and conditions for connection.

The REC will determine the method and the point at which connection can be made to the distribution network, dependent on the export capacity of the AD plant, the relative parameters of the immediate distribution network and the pre-existing requirements of other electricity users in the vicinity. The scope for connection to the local network in rural areas with few industrial and commercial electricity users may be limited and it may be necessary for connection to be made at a higher voltage level on the primary distribution networks.

The REC has statutory obligations under the Electricity Act 1989 in respect of the safety and quality of electricity supply to its customers and they need to ensure that generators connected to the distribution network do not impose risks that will affect their ability to fulfil this duty. However, connection of generators to the distribution network can in some cases be beneficial to the REC. In some cases it may

- Reduce the level of transmission and distribution losses (nationally it is calculated that 7% of electricity generated is lost annually due to heating in cables and transformer iron losses)
- Reduce the cost of purchase of electricity from the pool (particularly at times of peak demand when prices can be high)
- Reduce triad peak capacity charges
- Defray the need to reinforce the local network
- Avoid Fossil Fuel Levy surcharges if generated from renewable energy resources outside NFFO
- Be a valued source of reactive power to assist in voltage control.

The cost of connection could vary considerably depending on where the AD plant is located within the REC's distribution network. The cost of connection will in part reflect the distances involved; but the connection cost will tend to increase in steps (rather than smoothly) as the thresholds for requiring particular assets and voltage levels are crossed.

If the developer has some flexibility as to where it can locate within a particular area, they should discuss with the REC the respective connection costs for different sizes of generator and the potential benefits that may accrue to the REC in order to optimise the costs to the developer and maximise the value of the energy generated.

The REC is required by its licence obligation to offer terms for connection to the distribution network within three months of receipt of all the technical information in relation to the size, location and operation of the generating plant, but this will generally be qualified subject to planning permission approvals and wayleave consents. To provide the terms for connection, the REC will need to appraise the impact on several voltage levels of their distribution networks and ensure that safety and statutory obligations to all connected customers (including the generator to be connected) are not compromised. However, they will generally provide an initial estimate based upon the perceived least constrained supply route (usually by underground cable connection along the path of public highways) to give a ceiling price for the guidance of the developer, with an undertaking to provide a detailed quotation on examination of alternative routes involving securing landowner wayleave consent and planning permissions if overhead line construction and/or transformer substation construction would be required. The REC may charge a fee to appraise the connection implications but this would generally be set against the final connection charge if the project proceeds.

The connection point would usually be at the curtilage of the generation plant and if the connection charges quoted are accepted by the developer, then the REC would take on the responsibility to complete the statutory procedures required for excavation on public highways and to secure any wayleave consents and planning permissions required. All the plant and equipment, cables etc would remain in the ownership of the REC and they would accept all future liability for maintenance and replacement if subsequently damaged. The benefit to the REC would be that the additional network installed could be utilised for future connection of other customers and/or generators.

All the installation work required would generally be carried out by staff or contractors employed by the REC, although the developer can opt to use an approved contractor to carry out some of this work which is 'contestable' if they feel they can secure a more competitive quotation (the elements that are 'contestable' generally relate to the supply and installation of the new equipment, providing it meets the technical specifications set by the REC); the final connections, energisation and moving of existing connected assets, however, for safety reasons are 'non-contestable' and have to be carried out by the REC.

In some cases, where the developer is able to secure his own wayleave consents, he can opt to nominate the point of connection to the distribution at the point where it is coupled into the existing network. The developer may derive some benefit from cost reductions in equipment specification (particularly if capacity of the connection determined with standardised plan specifications by the REC cannot be fully utilised by increasing generator capacity) but the developer will then be fully responsible for the ongoing maintenance and replacement costs and will need to include the works involved in the application for planning permission for the AD plant.

Good practice would suggest that the local planning authority should be consulted on the route of the line, as they have an opportunity to make representations or requests for amendments, or indicate that they have no objection. Developers may also feel it would be appropriate to consult local residents over the potential route of the line at this stage. County councils and district councils (or unitary authorities) are consultees on the application for consent, and objection by either council means that there is likely to be a public enquiry.

Appendix 7

Effects of AD on parasites and pathogens

The following paragraphs outline the effects of the anearobic digestion (AD) process on different pathogens.

Parasites

Anaerobic digestion at 35°C (known as mesophilic digestion, used by the vast majority of farm digesters), has been shown to reduce the numbers of viable larvae and eggs of some parasitic worms to undetectable levels after one week, although there is generally poor control of *Ascaris*, *Tacnia* and *Cryptosporidium*. However, the oocysts (a type of egg) of these worms, which can infect any animal ingesting them, remain viable after 50 days at 35°C. Digestion at 55°C significantly reduces the numbers of oocysts, but many viable units still persist, even after digestion for extended periods of time. Mesophilic anaerobic digestion will not significantly reduce the infectivity of slurry contaminated with parasites.

Pathogenic bacteria

Experiments with pig slurry have shown that mesophilic digestion for four days will destroy 90% of a population of *Salmonella* bacteria, although low levels of the bacteria persisted even after 70 days digestion. This persistence may be due to poor mixing within the digester, allowing pockets of bacteria to survive in a crust on the surface. Properly managed, thermophilic digestion can reduce bacterial levels by an even greater factor, but again low levels may persist due to poor mixing. Mesophilic anaerobic digestion will significantly reduce the levels of pathogenic bacteria, but will not eliminate them completely from the waste and so the COSHH assessment will determine the measures required to control the potential damage to human health.

Viruses

Research findings have shown that mesophilic anaerobic digestion reduces virus numbers in sewage samples, but viable virus units may still be found to be present, even after extended periods of digestion.

Appendix 8

Walford College: case study

Location

Walford College Farm, Baschurch, Shrewsbury, Shropshire is owned and operated by Walford College, a county-based further education establishment for agricultural and land-based industries.

Concept

The 260-hectare mixed farm attached to Walford College includes a 130 dairy cow herd, 160 sows and progeny, plus beef cattle and dairy young stock. These produce some 3000 tonnes of organic manure per annum. Environmentally acceptable disposal of this waste presented a problem. In 1990, the college decided to introduce an integrated farm slurry management system based on anaerobic digestion (AD) to assess its advantages over the previous method of spreading raw manure directly to land. AD involves the breakdown of organic waste by bacteria in the absence of oxygen; products include a methane-rich gas which can be used as a fuel.

As part of a three year demonstration project, an AD system incorporating an Enviropower combined heat and power (CHP) facility was installed in 1994, rated at 35 kW_e (kilowatts of electricity) and $58kW_t$ (kilowatts of heat) output. Actual output has averaged $18.22kW_e$ for 19.5 hours per day. Approximately $30kW_t$ is harnessed to maintain the digester at the requisite temperature of 35-37°C. The system also produces $15m^3$ per day of treated liquid slurry or 'liquor' and 3 tonnes per day of separated fibre. The liquor, which is odourless and easier to handle than raw manure, has an average analysis of 2.32kg nitrogen, 1.32kg phosphate and 5.3kg potash per 1000 litres and is spread on grazing land. The fibre is made into compost for the college's own use and for sale to garden centres and other customers.

Technology

Slurry is fed from the pig and dairy units via flow channels to a reception pit. A chopper pump then pumps the slurry into a $335m^3$ above-ground digester. Digestion takes 16-20 days. Digestion produces $450m^3$ per day of biogas which fuels the CHP unit driving an electricity generator; heat is recovered from the engine's coolants and exhaust system. A stand-by boiler is used to heat the digester in the event of failure of the CHP unit. After digestion, the treated slurry is passed over a sieve separator; the fibre is removed to a composting shed and liquor is fed to a 950,000 litre storage tank. It is planned to use the farm's existing irrigation main to irrigate the liquor onto the grass fields.

Legal and planning requirements

The planning application was submitted in December 1993. Specific proposals for the erection of buildings or other works relating to AD are normally determined by the county council in shire areas. At Walford College chicken litter is imported as a supplementary feedstock for the digester when the farm's dairy herd is in the fields. The application was dealt with by Shropshire County Council. Planning permission was granted in February 1994.

Construction

Construction work began in February 1994. A single contractor was engaged to supply, install and commission the digester, CHP unit and composting shed. The contractor went into receivership before completion and Walford College engaged other companies to provide the CHP unit and composting shed. The system was commissioned in October 1994. Seed material was imported from a working digester to start the AD process.

Operating experience

The system requires no more than one hour per day from the cowman, who is very enthusiastic about the installation. Actual repair costs are likely to stabilise as the system settles down and teething problems are overcome. The lack of slurry smells around the unit is noticeable. The area around the digester is cleaner than might be expected from a slurry disposal system.

Costs and financing

The project is jointly funded by Walford College and the European Community's LIFE programme.

Capital cost	**£**
Digester	89,349
CHP unit	34,700
Composting unit (including site infrastructure and connections)	9,600
	£ 133,649

Benefits	**actual (£) in first 6 months**	**potential (£)**
Value of electricity generated annum 18.22kW x 19.5hrs x 365 days x £.08	10,374	(30kW) 17,082
Avoided contractors' spreading costs	2,500	2,500
Value of fertiliser saving to grassland (summer 6 months), nitrogen only 34.8kg/day x 180 days x £.32kg	2,004	2,004
Compost sales	400	(1460m³ x £10/ m³) 14,600
Waste hot water 20kW x 20hrs x 365 days x £0.18/kWh	2,628	
Annual income generated	£15,278	£38,814
Running costs: repairs and callouts	(2,100)	(2,100)
Net annual income	£13,178	£36,714
Labour: 1hr/day @ £8/hr	£(2,920)	£(2,920)

The need to allow for addition of labour charge will depend on individual farm case, whether worked in overtime or absorbed in working day etc.

For further information contact Ken Dann, Walford College, Baschurch, Shrewsbury, Shropshire SY4 2HL, tel: 01939 260461, fax: 01939 261112.

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Copies of these guidelines are available from:
British BioGen
7th Floor
63-66 Hatton Garden
London
EC1N 8LE

or on:
telephone +44 (0)171 831 7222
fax +44 (0)171 831 7223
info@britishbiogen.co.uk

These guidelines may be viewed on-line and downloaded at:
www.britishbiogen.co.uk

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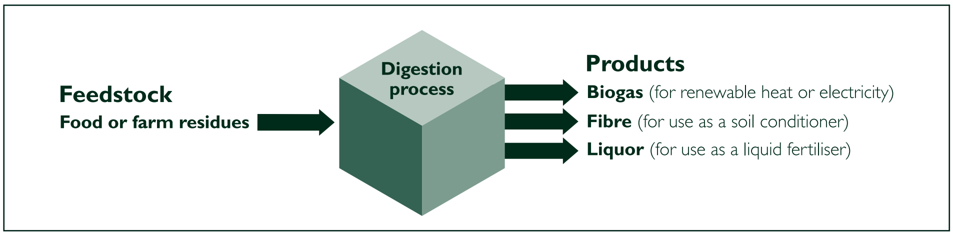
Summary

Anaerobic digestion for public information



What is Anaerobic Digestion?

Anaerobic digesters produce conditions that encourage the natural breakdown of organic matter by bacteria in the absence of air. Anaerobic digestion (AD) provides an efficient and effective method for converting residues from livestock farming and food processing into useful products.

Feedstocks include animal slurry (from cattle, pigs and chickens) and residues from food processing industries. Other organic materials can also be digested.

The initial reasons for developing an AD plant will vary but are likely to include one or more of the following:

- A wish to manage food processing residues and farm slurries more effectively, including control of odour
- A wish to utilise biogas to offset farm or factory energy costs
- A wish to sell electricity off-site (through the grid or other local user)
- A wish to utilise or sell fibre and liquor as soil conditioner and liquid fertiliser.

Whatever the initial reasons, for a scheme to be successful it must utilise all the products of AD.

What does the process involve?

The feedstocks are placed into a digester (a warmed sealed airless container). The materials ferment and are converted into a gas and a solid called the digestate, which in turn can be separated out into fibre and liquor.

The AD plant could be a small on-farm facility run by a farmer using only the slurry produced on the farm and using all the resulting products on the farm. Alternatively, it could be a larger scale development known as a Centralised Anaerobic Digester (CAD), taking feedstock from local farmers and food processors and marketing the products on a larger scale. The process is the same whatever the scale but the safe running of the digester and marketing of products is more complex for a CAD scheme.

What are the benefits of AD?

AD has a number of potential and actual benefits.

Reducing emission of greenhouse gases

- Methane is the main constituent of the biogas and is a major greenhouse gas. By burning the gas as a source of heat and/or electricity, the amount of methane lost to the atmosphere is likely to be reduced. Equally, by using this renewable source of energy it could displace the need to use energy from fossil fuels such as coal and oil.

Reducing odour

- AD can reduce the odour from farm slurries and food residues by up to 80%.

Reducing land and water pollution

- Land and water pollution can be reduced through efficient waste management.
- Badly managed disposal of animal slurries can lead to land and ground water pollution. AD can reduce the risk of pollution by stabilising and allowing more control of residues.

Nutrient recycling

- The nutrients available in the liquor and fibre can be used as part of an overall fertiliser programme and reduces the need for inorganic fertilisers.

Effective waste management

- AD can be regarded as part of an integrated waste management plan. The process stabilises slurries, making them easier to handle and reducing odour. New legislation is placing increased pressures on the safe handling of waste. Properly managed AD schemes will help farmers meet these pressures.

What are the problems of AD?

Costs

- AD has significant operating and capital costs. It is likely to be most viable for those people who can utilise all the products effectively.

Control of dangerous emissions

- Some of the trace gases found in the biogas are toxic and dangerous to human health (hydrogen sulphide and ammonia). This means the gas must be cleaned and only dealt with by trained operators.

Traffic

- If a CAD plant is being developed it will involve transporting feedstock to and from the site. Consideration needs to be given to the impact on local communities and the overall distance it will be viable to transport residues.

Animal health

- There may be some risk of animal disease transmission between farms in CAD schemes, through cross contamination from vehicle movements between farms and the centralised site. Strict quality control measures are needed.

Careful planning, design and operating will reduce the problems and maximise the benefits of AD. Good Practice Guidelines have been produced in partnership by a wide range of organisations which have an interest in AD including the AD industry, farmers, planners, electricity companies and environmental groups. They explain in detail all the issues that must be considered in any AD scheme.

For more information contact British Biogen,
7th Floor, 63-66 Hatton Garden, London EC1N 8LE, or on:
telephone +44 (0) 171-831 7222, fax +44 (0) 171-831 7223.
info@britishbiogen.co.uk.