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Anaerobic Digestion (AD) – Farm Scale

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Summary

- **Incentive payments now favour installations using a higher proportion of wastes as feed stock.**
- **Plants can generate heat only, electricity and heat (CHP) or alternatively supply gas to the national gas grid.**
- **CHP systems should utilise all of the heat generated as well as the electricity for greatest viability.**
- **Digestate can displace artificial fertiliser and contains a high proportion of the nutrients in the feed stock.**

Introduction

AD is a natural process in which micro-organisms break down organic matter in the absence of oxygen into biogas and digestate. Typical feedstocks for farm scale systems are manures and slurries, vegetable waste, dedicated energy crops or imported materials such as draff or distillery waste. The biogas can be used as a fuel for boilers and gas engines or upgraded and fed into the local gas network or used as vehicle fuel. The remaining digestate can be spread back to land as a fertiliser.

AD technology

There is a wide variation in technology options for an AD installation. Choice of technology is based on the feedstock available, the scale of the plant and on the climate at the site. The parameters that need to be considered are covered in the following sections.

Moisture Content

Where the feedstock is relatively wet (i.e. between 5 and 15% dry matter) then following the initial loading of the digester,

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the substrate can be pumped and handled through pipes. This simplifies the automation of the process and is the more common system on UK farms. It is particularly suited to systems using livestock slurry as part of the feedstock but can also be used where no slurry is present. Wet AD systems generally run on a continuous basis. Bringing new feedstock up to digester temperature is more expensive with a wet system, however, due to the increased amount of water. No biogas will be released from the water content of the feedstock and therefore energy used to heat this water will be wasted. Where feed stock is 15% dry matter or above a dry system is more appropriate. Dry feedstock needs mechanical handling in the loading and unloading of the digester. This is normally operated on a batch process often with a number of cells operating on differing cycles to even out gas production.

More commonly on Scottish farms a wet system will be more appropriate although where crops form the major proportion of the feedstock it could be relatively dry and at the high end of dry matter content suitable for a wet system. Handling of both the feed stock and the digestate and automation of a continuous flow system will be more cost effective with a wet system. During initial commissioning, a greater proportion of slurry or digestate from an existing plant is often used along with drier feedstocks to seed the new plant which will help dilute the initial load and facilitate easier pumping. Once operational the dry matter content within the tanks will generally be sufficiently low for a wet system to operate effectively even where silage and FYM are added via a feed hopper.

Mesophilic or Thermophilic

This refers to the temperature at which the digester operates. A thermophilic digester operates at 50 to 60°C. Gas production is quicker at this temperature with shorter retention times and therefore throughput can be increased resulting in a similar gas output being achieved with a smaller digester tank. Thermophilic digesters more effectively kill pathogens in the feedstock where high risk feed stocks are used. They will however use a higher proportion of the energy produced to maintain the digester temperature, particularly in the Scottish climate.

Mesophilic digesters operate at 25 – 45°C. Retention time of the feedstock within the digester is higher for a similar gas yield and therefore a larger vessel is required. Where digestate is stored as it exits the digester for seasonal spreading and the store is enclosed, gas collection from the store can compensate for a reduced residence time.

Digester Layout

The digestion process takes place in four separate stages;

Hydrolysis – the process of breaking down the long chain carbohydrates and other feedstocks into simple soluble organic compounds. This process takes the longest and determines the retention time.

Acid Fermentation – Simple compounds are broken down into acetic acid by bacteria.

Acetogenesis – Simple compounds are broken down via propionic butyric and long chain volatile fatty acids to acetic acid. Hydrogen & carbon dioxide are also released.

Methanogenesis – Hydrogen then binds with carbon molecules released from the acid digestion to make methane.

In large scale installations these can be carried out in separate vessels which can maximise the efficiency of gas production. However the greater complexity comes at an increased capital and operational cost and is difficult to justify in farm scale systems. Single or double tank systems are more suitable at this scale. Digesters can operate either as batch flow or continuous. In order to provide a more even gas output and to simplify the automation of the process continuous flow systems are more common at farm scale in the UK.

The most common tank arrangement is a vertical tank with the feedstock being fed in displacing an equal amount of digestate from the top of the tank. The alternative is to have a horizontal flow tank where the feed stock is fed in at one end and effluent drawn off at the other. The more solid feedstock at the feed end acts as a plug to prevent backflow of material. This arrangement provides a better guarantee of achieving optimum output although is more expensive to construct.

For the feedstock and scale of farm based installations the most appropriate layout is likely to be a vertical single or double tanks operating on a continuous flow basis. Some manufacturers install concentric tanks with the primary digester in the outer ring and the secondary digester in the centre while others opt for two separate side by side tanks.

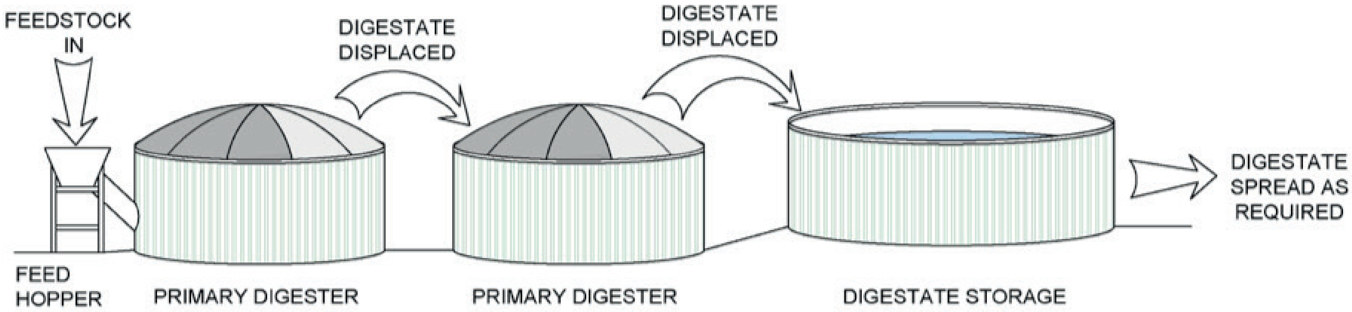

Figure 2: Schematic of AD plant with 2 vertical tanks and above ground circular digestate store

Short term biogas storage is often accommodated within the domed roof of the digesters in simple vertical digester layouts as shown in figure 2. Where a cylindrical above ground store is used for digestate, the addition of a roof can allow further gas to be collected, effectively increasing the residence time of the feedstock within the digester. In layouts using concentric tanks (Fig 4) short term biogas storage is usually accommodated in a separate building.

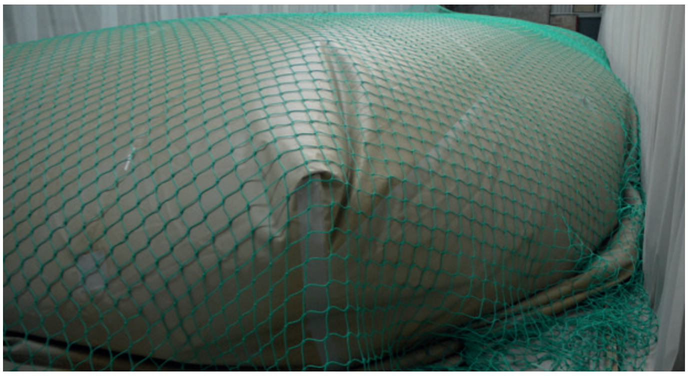

Figure 3: Biogas storage bag

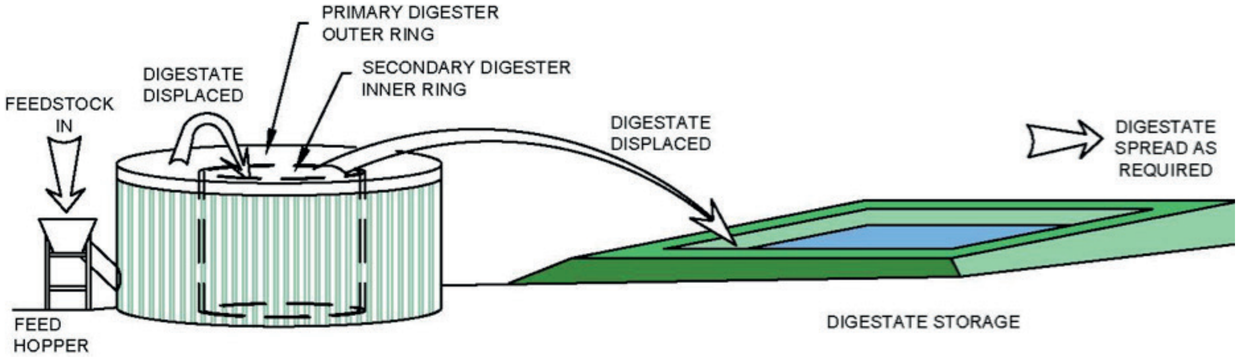

Figure 4: Schematic of AD plant with 2 concentric tanks and lagoon digestate store

A lagoon may be a more suitable option for digestate storage at some sites; particularly where seasonal restrictions apply to field spreading.

Retention time

The necessary retention time depends on the mix of feedstock used and the level of pre-processing. Some crops such as energy beet will break down quickly and produce methane relatively fast whereas rye will produce methane over a longer period. Basically, the higher the content of sugars (starch, fructose, glucose, sucrose, maltose) the quicker the digestion; complex carbohydrates, proteins and fats take longer to digest. Gas production will be greatest from new material soon after it enters the digester and will tail off in time. The majority of the gas will therefore be produced in the first tank of a two tank system. The longer the residence time the more gas that will be produced from the feedstock. There is however a law of diminishing returns where the benefit of a larger tank will be outweighed by the cost. AD equipment suppliers will make their own recommendations as to a suitable size of digester or digesters based on the proposed feedstock. However, in order to allow for some variation in feedstock mix, a total retention time of 60 to 90 days for a mesophilic system is considered appropriate. This includes for total retention time between primary and secondary digesters in a two tank system. Thermophilic systems can operate on a lower residence time of around 40 to 50 days.

Feedstocks

Feedstocks used in farm scale AD plants fall into a number of broad categories and the categories used in an individual plant will not only affect the energy yield but will also have a bearing on what renewable energy incentive payments may be available. The licencing requirements for a plant can also be dictated by the mix of feedstock and the potential uses for the resultant digestate can be limited where certain categories of waste are used.
Even for similar feedstock types the actual gas yields available can vary considerably and a large conservative margin should be allowed when planning feedstock requirements. Table 1 shows estimated gas yields for a range of feedstocks commonly used in Scottish on-farm anaerobic digesters. However, these figures should only be used at the early stages of planning a project; dry matter content will have a large influence on gas yield. Laboratory analysis of specific feedstocks will provide a more accurate figure.

Feedstock	Dry matter (%)	Typical Biogas Yield (m^3/fresh tonne)
Cattle slurry	10	20
Pig slurry	8	20
Grass silage	29	180
Hybrid Rye silage	34	200
Energy beet	22	180
Draff	23	40
Straw	80	280
Food waste	5	43

Table 1: Estimated biogas yields from a range of feedstocks

The methane content will vary though it will typically make up between 50% and 55% of the biogas produced and each cubic metre of methane will equate to 10.0 kWh (lower heating value) of energy. The amount of useable energy available will depend on the technology used to convert it to heat, electricity or a combination of the two. Table 2 shows the usable energy available from either a biomass boiler (assuming 80% efficiency) or a CHP plant (assuming 40% of the energy in the methane can be converted to electricity and a further 41% can be recovered as usable heat). The calculations assume a methane percentage of 52.5% in the biogas.

		m^3 biogas	m^3 methane	Efficiency of conversion (%)	Usable energy (kWh)
Boiler		1.0	0.525	80	4.70
CHP	Electricity	1.0	0.525	40	2.35
	Heat			41	2.41

Table 2: Estimated energy yields from biogas

The broad categories of feedstock commonly used are;
Farm derived feedstocks

- ***Agricultural wastes*** – Livestock manures and slurries
- ***Agricultural residues*** – Straw, husks, cobs etc.
- ***Energy crops*** – Grass silage, whole crop cereal silage (principally rye in Scotland), energy beet etc. grown specifically to feed an AD plant.

Manures and slurries

Treating manure or slurry from livestock in an AD plant provides benefits other than the value of the energy captured. Greenhouse gas emissions to atmosphere are reduced compared to conventional storage and field application of these wastes. Nutrients are more available immediately following spreading and the more homogenous material allows for greater precision in distribution and therefore closer control on the rate of application. A substantial reduction in artificial fertiliser requirement is achieved. Compared with energy crops as feedstocks, gas production from manures and slurries is much lower due to much of the energy being removed by the animals during digestion.

Figure 5: Feedstock intake hopper

Energy crops

Energy crops such as grass or rye silage will provide a much higher gas yield for each tonne of feedstock and therefore for each m^3 of digester capacity and will make it easier to justify the capital cost of a plant. From 2017 however incentive schemes are being revised for new plants to discourage use of energy crops in favour of wastes. Full payments will likely only be available to plants where 50% or more of the energy output is derived from wastes.

Table 3 shows typical biogas yields from a range of energy crops, although as stated earlier in this section yields can vary greatly and considerable variation has been found from crop to crop.

Feedstock	Dry matter (%)	Yield – fresh (t/ha)	Yield – dry matter (t/ha)	Typical Biogas Yield (m^3/ha)
Grass silage	29	36.0	10.44	6480
Hybrid Rye silage	34	40.0	13.60	8000
Energy beet	22	65.0	14.30	11700
Maize silage	30	38.0	11.40	7600

Table 3: Typical yields from a range of energy crops

The higher energy availability from energy crop feedstocks needs to be measured against the cost of production. Table 4 provides cost of production data (2015) for a range of energy crops.

Costs (£/ha)	Energy beet	Hybrid rye	Grass silage	Maize
Seeds	200	154	20	167
Fertiliser	145	207	241	176
Sprays	263	80	8	65
Contract cultivation	235	182	47	204
Contract harvesting	267	118	263	117
TOTAL COSTS (£/ha)	1110	741	579	728
TOTAL COSTS (£/t)	17	19	16	19
TOTAL COSTS (£/MWhr TH)	14	14	14	15

Table 4: Estimated cost of production(2016)

Most recent figures available from https://www.fas.scot/publications/farm-management-handbook-20162017/

Imported feedstocks

- Distillery by-products
- Catering and food processing waste
- Abattoir and animal waste

Distillery by-products such as draff or pot-ale make good feedstocks for farm digesters and are available in some areas although rising demand has raised the cost of these in recent years and demand has been tending to exceed supply. Food processing, catering or other imported wastes can also be added. This can not only boost the gas output but may also generate a gate fee, providing additional income although with increasing demand for AD feedstocks, gate fees are less available. However, use of food waste or animal by-products will increase the administrative complexity of the site and may add to the capital cost. It may also be difficult to obtain the long term supply contracts that are often required to satisfy project financers. An important consideration with imported waste products is the suitability of the resulting digestate for land spreading and the associated risks of contamination (or perceived contamination) of subsequent crops.

Sustainability

Any feedstocks used must comply with sustainability criteria to gain incentive payments such as RHI or FITs. Requirements vary depending on whether the feedstocks are classed as wastes, residues or products. This is more important where energy crops or certain residues are used. Slurry or manures are classed as wastes and are deemed to be sustainable.

Where energy crops are used, AD operators must provide evidence that the production of the feedstock complies with two separate criteria;

Carbon	**Minimum 60% GHG emission saving relative to EU fossil fuel heat average** **Target < 34.8g CO2eq/MJ of heat**
Land use	**Land use criteria (to prevent destruction of vulnerable habitats): UK Timber Standard for woody biomass; RED (Renewable Energy Directive) for other types**

Records of all feedstocks used and proof that they meet with these requirements have to be maintained and presented for inspection if requested.

Outputs

The primary outputs from an AD plant will be biogas and digestate. Biogas consists mainly of around 50% to 55% methane with the majority of the remainder being carbon dioxide. The biogas can be burned directly in a gas boiler to produce heat or burnt in a combined heat and power (CHP) unit to produce heat and electricity. Alternatively, the biogas can be cleaned to remove the carbon dioxide and other substances, to produce biomethane. This can be injected into the national gas grid to be used in the same way as natural gas, or used as a vehicle fuel.

Use of biogas

Biogas boiler

A boiler specifically set up to run on biogas can produce heat directly from the gas (c50 to 55% methane) produced from the digester without further processing. In a small system a proportion of this heat can be used to maintain the digester temperature and the remainder used to provide space heating, process heat or hot water. Biogas will have a net calorific value of around 20 to 22 MJ/m^3 (at 50% to 55% methane) compared with natural gas from the main at a net calorific value of 36.9 MJ/m_3 (estimated 2015 average). Typically one tonne of grass silage would offset around 74.6 m^3 of mains gas.

Figure 6: Biogas boiler

Combined heat and power (CHP)

Alternatively biogas can be used with minimal processing (desulfurisation and drying) to fuel an internal combustion engine which in turn drives a generator to produce electricity. Heat transferred to the cooling water of the engine and also recovered from the exhaust gases can also be used. Around 40% of the energy in the biogas will be delivered as electrical energy and a similar amount will be available as heat. Some of this energy will be required to run the plant; the amount will vary from plant to plant and depending on the time of year. On average parasitic electrical load will be around 6 kWh/tonne of feedstock to drive mixing paddles, pumps and other equipment. Heat will be required to maintain the digester temperature and this will depend on the ambient temperature, the type of feedstock and the operating temperature of the digester. The proportion of the generated heat required to maintain the digester temperature will depend on the feedstock used and on the specific system. Typically 20% of the heat will be required by a typical mesophilic digester fed on a mixture of energy crops and manure. Systems running on a high proportion of slurry will require a larger proportion of the heat.

The remainder of the electricity generated can be used to supply other on-site demands or exported to the local electricity network. Surplus heat can be used for space heating, water heating or process heat. AD plants normally operate continuously for 12 months of the year and maximum benefit from the heat produced is obtained where it is used to serve a continuous demand.

Many existing installations are used to heat drying floors which can be used to dry grain after harvest but are often used for the rest of the year to dry other products such as wood fuel. Some existing plants use heat to dry the solid fraction of separated digestate which can be used as a soil conditioner or in some cases as bedding for livestock buildings. However following changes proposed in 2017 digestate drying will no longer be considered an "eligible heat use" in respect of renewable heat incentive payments. To maximise the financial viability of an AD installation all sources of income need to be considered and for a CHP system this means taking full advantage of the heat as well as the electricity generation.

Figure 7: Combined heat and power (CHP) engine

Gas-to-grid

For larger scale plants the option of upgrading the gas produced to a quality suitable for direct injection to the natural gas network exists. The carbon dioxide, hydrogen sulphide, water and other contaminants present in biogas must be removed to leave biomethane. There are a number of different technologies used for this process including water washing and pressure swing adsorption. The calorific value of the biomethane must be matched to the standard set for the gas grid and this is normally done by blending with a small quantity of propane before the gas is injected into the grid. The equipment required for upgrading is costly and has to perform reliably to a consistently high standard, therefore due to economies of scale is easier to justify for larger scale plants. Viable gas-to-grid plants are likely to have a gas production capacity of equivalent to a 1.5 to 2.0 MW_e CHP plant or higher. Plants of this type running on agricultural waste or energy crops often rely on contracts with numerous businesses to ensure a sustainable supply of feedstock.

Digestate

Digestate is a useful fertiliser and can displace artificial fertilisers. The nutrient value of digestate is similar to raw manure and any limits on the application of raw manure will also apply to digestate. The availability of nitrogen in digestate is higher than that of raw manure and therefore utilisation can be improved if spread appropriately. A lower viscosity than raw slurry and a decrease in odour allows for more precise and targeted application with less likelihood of complaint from neighbours. The use of non-agricultural or imported feedstocks increases the risk of pathogens or contamination being dispersed with the digestate.

Digestates can be separated into liquid and solid fractions. The solid fraction is low in nutrients but can be used as a soil conditioner to increase organic matter. The liquid fraction contains a large proportion of the nutrients and if regular analysis is carried out can be easily spread at precise application rates. Where energy crops are used as feedstock, digestate is often returned to the land where the crops are grown. The financial benefit of using digestate over artificial fertiliser will reduce as the distance from the plant increases. Therefore in large scale operations it makes better sense to utilise the digestate as close to the plant as possible. Where digestate is returned across farm boundaries, care must be taken to reduce the risk of spreading pathogens or other contamination.

The regulation of digestate use in Scotland is dependent on a number of factors;

- Digestate will not be regulated as a waste where;
    - It is certified in accordance with PAS 110 (2014) – Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials, (available here; http://www.wrap.org.uk/content/bsi-pas-110-specification-digestate)

      and

      Meets the "additional scheme rules for Scotland" SEPA should be consulted in respect of these rules for which definitive detail was not available at the time of writing. These rules will include limits such as those on physical contaminants (including plastic) as set out in the Cattle & Sheep Standards published by QMS.

      or,
    - The only feedstocks are manures, slurries and non-wastes

Further information on the regulatory requirements of spreading digestate to land can be found here;

https://www.sepa.org.uk/media/219842/wst-ps-016-regulation-of-outputs-from-anaerobic-digestion-processes.pdf

General binding rule 18 (GBR18) regarding the storage and spreading of fertiliser also applies to digestate.

Licensing of AD plants

Depending on the feedstock used and on the capacity of the plant the requirements for licencing of an AD plant will be one of three differing options;

- Energy crops only – where only energy crops are used and no wastes of any kind are included in the feedstock mix, then provided the plant does not include a gas engine with a fuel input in excess of 20 MW, no permits/licensing is required.
- Pollution Prevention and Control (Scotland) Regulations 2012 – If any waste is included in the feedstock mix an AD plant will fall under these regulations where >100 tonnes (fresh weight) per day of total feedstock is used or if >10 tonnes of animal carcasses and food waste is used.
    - Must use best available techniques to control emissions to air, water and land
    - Emission limits for odour and combustion gases apply
    - Energy and resource efficiency conditions apply
- Waste Management Licensing (Scotland) Regulations 2011 – An AD plant will fall under these regulations where any waste is used as feedstock and <100 tonnes (fresh weight) per day of feedstock is used except where the only waste feedstocks used are exempted (see below).
    - Controls on emissions to air (e.g. odour) apply.
- Waste Management Licensing Exempt Activities – Where an AD plant uses feedstock including only the following feedstocks with or without non-wastes such as energy crops;
    - "Agricultural Waste" i.e. slurry, manure
    - "Distillery Waste"

  and the total feedstock <100 tonnes per day, then an exemption under paragraph 51 of the waste management licencing regulations will apply requiring registration with SEPA 21 days in advance of the facility being brought in to use.
- Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 2003 (SSAFO) – These regulations apply equally to the storage and treatment of digestate as they do to manures, slurries and silage effluent and AD facilities should be constructed and operated in compliance with these regulations.

Planning Issues

Like any other development in the countryside, planning for an AD plant can be contentious and as scale increases the detail in which relevant issues need to be addressed in a submission increases. Anyone considering the construction of a plant should consider local planning policies and consult the local authority at an early stage regarding siting. Once a basic layout and outline proposal for a plant has been established this can inform discussion with the planners and submission of a formal screening request under the environmental impact assessment (EIA) regulations can be made. Even where the response to this confirms that an EIA is not required it will provide detail on the scope considered appropriate by the planners for any subsequent planning submission. The list of issues that should be covered in a planning submission include the following;

- Transport, traffic and access – particularly important where feedstock is to be imported.
- Air quality/odour
- Ecology
- Landscape and visual impact
- Noise
- Hydrology
- Cultural heritage
- Sustainability

This list is not exhaustive and local issues will dictate the level of detail required in each section.

Grid Connection

For all generators of 3.68 kW per phase and above, permission must be obtained from the local distribution network operator (DNO) before a connection is made. Obtaining permission for connecting systems of up to 50 kW can be fairly straight forward in most areas provided a 3 phase supply is available although any requirement to upgrade existing transformers should be checked in advance of committing to a project. Most electricity generating AD installations are likely to be well in excess of this and as size increases potential connection problems will become greater. Many areas of Scotland have constrained networks already operating at their design capacity and access to the network may require extensive upgrading to the local distribution network or the national transmission network. This can not only add huge costs to a potential project it can also result in substantial time delays (often of several years) before a new generator can be connected. Liaison with the DNO at an early stage is advised. In order to be completely sure that a connection will be available when required it is necessary to have received an offer of connection including a connection date and have paid a deposit to secure the grid capacity.

Local Demand

Where a local demand exists for energy the income gained from an AD plant can often be enhanced by offsetting purchased carbon fuels. Energy production from AD is relatively constant and much more predictable than many other forms of renewable energy. Where a suitable local electricity demand exists with a third party there is a possibility of meeting this demand by providing a connection by private wire to the benefit of both the generator who can receive a premium over the export value and the customer who can receive a discount over grid electricity rates and/or a marketing benefit from improving their carbon footprint. CHP plants also have the option of selling heat to a neighbouring enterprise where a suitably located demand exists. This will be more cost effective where the demand is constant throughout the year and less attractive for seasonal demands such as space heating.

There is also an option to export biogas over a private supply pipe for use at other nearby locations where it could be used in a boiler or a separate CHP system.

Revenue

Income from an AD plant can be derived from the following sources;

- Sale of exported electricity from CHP installations – either from a power purchase agreement or from export tariffs payable under the feed-in tariff (FIT) scheme.
- Savings on imported electricity – energy used on site to offset imported energy will normally provide a greater saving than the export rate available.
- Payment of generation tariff – under the FIT scheme generation payments are made for energy produced whether it is used on site or exported.

  FIT rates change depending on the date a new generator enters the support scheme and on the scale of the installation. Details of current tariff rates can be found here;

  https://www.ofgem.gov.uk/environmental-programmes/fit/fit-tariff-rates
- Savings on imported heating fuel – will apply where gas is burned directly in a biogas boiler or where heat is recovered from a CHP installation
- Sale of exported heat to third parties from biomass boiler or CHP installations
- Payment of renewable heat incentive (RHI) from eligible heat use.

RHI payment rates change depending on the date a new generator enters the support scheme and on the scale of installation. Details of current tariff rates can be found here;

https://www.ofgem.gov.uk/environmental-programmes/non-domestic-rhi/contacts-guidance-and-resources/tariffs-and-payments-non-domestic-rhi

- Payment of renewable heat incentive (RHI) for biomethane exported to the gas grid.

Budget capital costs

Overall project costs for AD installations will depend on the infrastructure costs and ancillary structures required. In addition to the core AD equipment and tanks, additional storage is likely to be required for feedstock and also for digestate. The type of feedstock used, existing facilities on-site and the means of digestate disposal will all have a bearing on individual site costs. The cost of a grid connection can be large for CHP systems, and for gas-to-grid plants further costs associated with upgrading and injection will be incurred. A means of distributing heat from a CHP plant to an eligible demand will also require investment and will vary greatly from site to site. For early stage budgeting purposes plant costs ranging from £0.75/m^3 to £1.50/m^3 of biogas produced can be used depending on the scale and complexity of the proposed plant.

Business rates

Business rates in Scotland have been revaluated in 2017 resulting in changes to the rateable value of many renewable energy schemes. Generators below 50 kW are considered as micro-generators and are excluded from valuation for rating. Rateable value is not purely based on the size of the installation as a number of other factors are taken into account and at the time of writing (Autumn 2017) there did not appear to be any consistency in the rateable values being set for individual plants with RVs for 500 kW CHP plants ranging from £60k to £132k.

Trends

With a reduction in incentive payments available to new projects and government policies looking more favourably on schemes using wastes and residues as feedstock rather than energy crops, careful consideration of the financial viability of new projects is necessary.

Small scale schemes using only slurry and manure have the potential to be viable where heat and/or electricity produced can be used on site to offset imported fossil fuel energy and therefore provide maximum benefit for each kWh produced. Simple packaged, small scale, low cost plants being developed will help keep installation costs low and grid connection for small schemes should be easier and less expensive to obtain. The incorporation of this type of scheme with provision of new slurry storage will also help to keep costs down. At the time of writing (Autumn 2017) viable sites for this type of installation are limited but this is an area that may develop in the future. Large scale gas to grid installations can also be viable where a substantial proportion of the feedstock comprises of wastes and residues and therefore attracting the maximum level of incentive payments (FITS and RHI).

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