SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Anaerobic Digestion for On-farm Uses - Overview

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1. Introduction

1.1 Anaerobic digestion for farm-waste management and climate-change mitigation

Ireland's extensive agricultural and food industry is a large source of greenhouse gas emissions. With a global warming potential about 25 times greater than that of carbon dioxide (CO_2), methane (CH_4) emitted by livestock and livestock manures is of particular concern. These industries also produce significant amounts of other biodegradable wastes, such as dairy, brewing and food processing wastes, which require appropriate management.

Ireland has a long-term vision for a low-carbon energy system. Its goal is to reduce greenhouse gas emissions from the energy sector by 80-95% (compared to 1990 levels) by 2050.[1] To achieve this, Ireland will need to radically transform its energy system: reducing energy demand and moving away from fossil fuels to zero or low-carbon fuels and power sources.

Anaerobic digestion (AD) is the controlled use of biodegradable organic materials to produce renewable energy in the form of biogas and organic fertiliser. The process could have numerous benefits for the agricultural sector.

AD facilities can process biodegradable organic wastes from the agricultural and food industry, other food waste, and suitable and sustainable energy crops grown specifically for energy production, such as grass silage. Energy crops with high lignin content, such as willow coppice, are not suitable for AD, being too slow to biodegrade. Usable food wastes include rejected or out-of-date products from manufacturers or retailers, and wastes from commercial and domestic kitchens. Such wastes, however, usually come with the challenge of removing items, such as packaging, bones and cutlery, that can cause operational problems and contamination.

On-farm AD provides a means of recycling waste organic matter into organic fertiliser, thus reducing costs, diverting wastes from landfill, reducing CH_4 emissions (thereby mitigating climate change), and generating a low-carbon renewable energy source. Using the biogas in gas engines to generate electricity and heat can save on farm purchases of electricity and fossil fuels, whilst any excess electricity or heat can provide additional revenue. Biogas can be upgraded to biomethane, that is suitable for injection into the natural gas network or compressed into containers for use as a fuel in other applications, such as road transport.

Key benefits of AD to the agricultural sector:

- **Presents a clean manure- and waste-recycling route to conserve resources;**
- **Production of improved organic fertiliser, cutting the outlay on chemical fertilisers and reducing the wider environmental impacts of producing artificial fertilisers;**
- **Reduces environmental pollution through better waste management;**
- **Reduces greenhouse gas emissions, particularly from livestock, thus helping to mitigate climate change; and**
- **Produces renewable electricity and heat for on-farm use, potentially creating an additional source of income from sales of heat, electricity or biomethane as renewable energy.**

A farm-based AD system needs to be developed as an integrated system; therefore, many factors must be considered together. The key considerations include:

- The characteristics of the feedstocks to be used;
- The scale and design of the anaerobic digester;
- The use of the biogas generated, whether for energy production or upgrading to biomethane; and
- The management of the digestate to maximise the nutrient benefits available.

This overview document introduces AD to those who are unfamiliar with the technology but may be interested in using it. A farmer who produces large quantities of animal manure, for instance, might consider the controlled processing of the manure in an AD facility to improve environmental performance and reduce expenditure on energy.

[1] https://www.dccae.gov.ie/en-ie/climate-action/publications/Documents/5/National%20Climate%20Policy%20Position.pdf

More detailed guidance is presented in the three accompanying documents:

- The **Implementation Guide** provides guidance on the steps to implement an AD facility, from initial conception through to commissioning of an operational facility.
- The **Technology Guide** describes the main types of technologies that may form part of an AD facility.
- The **Operation and Maintenance Guide** provides guidance on how to operate and maintain an AD facility to ensure it provides a high level of performance during its lifetime.

Together these guides provide a comprehensive starting point for anyone wishing to better understand the technology, its implementation and ongoing management.

1.2 Purpose of this overview

This guide has three principal aims:

- To provide the reader with a sound appreciation of what AD is and what it produces. It is assumed that readers are interested in the potential benefits of using AD, but do not have a comprehensive knowledge of it.
- To provide the reader with a sound introduction to the numerous factors that should be considered. These include: environmental impacts and benefits; legislation and regulation; and commercial opportunities and challenges.
- To direct the reader to further sources of more detailed information on specific aspects of the technology.

1.3 Scope

This guide concentrates mainly on farm-based AD systems fed with farm-derived feedstock such as:

- Animal manures;
- Purpose-grown energy crops and crop residues; and
- Other suitable biodegradable wastes and food processing residues that can be brought onto the farm as feedstock.

However, the principles can also be applied to AD systems in other, off-farm settings.

Outside the scope of these guides are the Support Scheme for Renewable Heat (SSRH) terms and conditions. The SSRH is a government-funded scheme to encourage the installation of renewable sources of heat in non-domestic applications in the Republic of Ireland. These guides will help applicants identify the appropriate standards and best practice for on-farm AD uses. These guidelines provide an applicant with guidance on good practice only. The Ministerial Terms and Conditions, the Grant Scheme Operating Rules and Guidelines and the Tariff Scheme Operating Rules and Guidelines, where relevant, set out the basis on which the support scheme for renewable heat will operate.

Figure 1.1: Farm-based AD system

2. What is anaerobic digestion?

Anaerobic digestion is a process which harnesses natural bacteria to treat biodegradable materials in the absence of oxygen, producing a methane-rich biogas which can be captured and used to generate electricity and provide a source of heat.

Anaerobic digestion (AD) is the microbial breakdown of organic material in the absence of oxygen to yield a methane-rich gas and digested material. These outputs are known as 'biogas' and 'digestate' respectively: biogas can be used as a fuel, digestate is the residue of the organic matter after AD and can be used as organic fertiliser and soil conditioner.

The biological process is not dissimilar to that which takes place in a stomach or in a landfill that has received waste containing organic biodegradable materials. Best practice application of AD technology is an effective way of managing on-farm waste and producing renewable energy.

Biogas is mainly a mixture of methane (CH_4) and carbon dioxide (CO_2) with some other trace gases. Typically, the CH_4 content of biogas is between 55% and 60%. As CH_4 is combustible, it can be used to produce heat and electricity. When CH_4 is upgraded to biomethane, it can replace natural gas.

2.1 How and why is biogas produced?

Plants use energy from the sun to convert CO_2 from the air into complex organic carbon compounds as they grow. When plants are burned, this energy is released, and the CO_2 that they have collected while growing, is emitted. These CO_2 emissions can be offset by new plants that consume CO2 during growth. The combustion of fossil fuels, on the other hand, releases carbon that has been locked away in the ground for millions of years.

In simple terms, the combustion of material derived from plants that are replaced over a short time cycle does not lead to increased greenhouse gas levels in the atmosphere, so energy generated in this way is considered to be renewable. This simple cycle does not occur in isolation, but requires significant management for cultivation, fertilisation, harvesting, transport and other processes that can involve the use of fossil fuel and so lead to a net increase in greenhouse emissions, as well as to harmful direct and indirect land use changes. Bioenergy is renewable and can reduce greenhouse gas emissions, but only when produced sustainably. The EU and others have set benchmarks to ensure that AD and other bioenergy developments save emissions when all the factors are considered (further details of this are provided in the Implementation Guide, Section 4.6.1).

The following sections describes the principles of the microbiology and chemistry of biogas production.

2.1.1 Principal difference between anaerobic digestion and composting

Microbial decomposition of organic matter in the presence of air (composting) also results in the conversion of the complex carbon in organic matter to CO_2. This biological oxidation process (sometimes referred to as bio-combustion) releases energy as heat. This process is slower than AD. Because the energy is released as low-temperature heat that cannot readily be used, it is effectively lost.

With AD, the microbial decomposition takes place in the absence of air and the carbon in the organic matter is first biologically reorganised and decomposed to a mixture of CO_2 and CH_4. As there is no oxygen used at this point, there is no oxidation. This means that far less energy is released and lost. The energy of the original organic matter is concentrated in the CH_4, which can then be combusted to release the energy in a usable form. As CH_4 combustion converts the carbon to CO_2, the net change is the same as direct combustion or composting (the complete oxidation of organic matter to CO_2. However, with AD, splitting the process up allows the capture of energy in a usable form (as a biogas that is rich in CH_4).

2.1.2 Microbial production of biogas

The AD of organic matter, and associated biogas production, occurs widely in nature. Drained land, slurry tanks and landfill sites are common sources of biogas, as are the digestive systems of animals. CH_4 is about 25 times more potent as a greenhouse gas than CO_2. Agriculture and landfill sites are therefore a significant source of greenhouse gas emissions, particularly due to fugitive emissions of CH_4 from manures and slurries, and from livestock themselves.

The use of AD allows these natural processes to be harnessed and optimised to produce energy. AD plants are controlled and enclosed environments that allow almost all of the biogas produced to be captured and used to generate energy.

The overall greenhouse gas impact from these sources is greatly reduced because:

- There is no change in atmospheric CO2;
- The associated production of energy reduces the requirement for fossil fuels;
- CH4 emissions are reduced; and
- The use of the leftover digestate as a fertiliser avoids greenhouse gas emissions from land spread with raw slurry and chemical fertilisers.

2.1.2.1 Conditions needed for anaerobic digestion

The anaerobic digester needs to provide all the conditions for the anaerobic micro-organisms to thrive and carry out the decomposition of the feedstock to produce the biogas. These include:

- A suitable temperature;
- A suitable pH;
- Nutrients for the micro-organisms (nitrogen (N), phosphorous (P), potassium (K) and trace elements);
- A suitable salinity;
- An absence of toxic substances that can inhibit the micro-organisms; and
- A suitable biodegradable feedstock amenable to rapid decomposition under anaerobic conditions.

2.1.2.2 Micro-organisms involved in anaerobic digestion

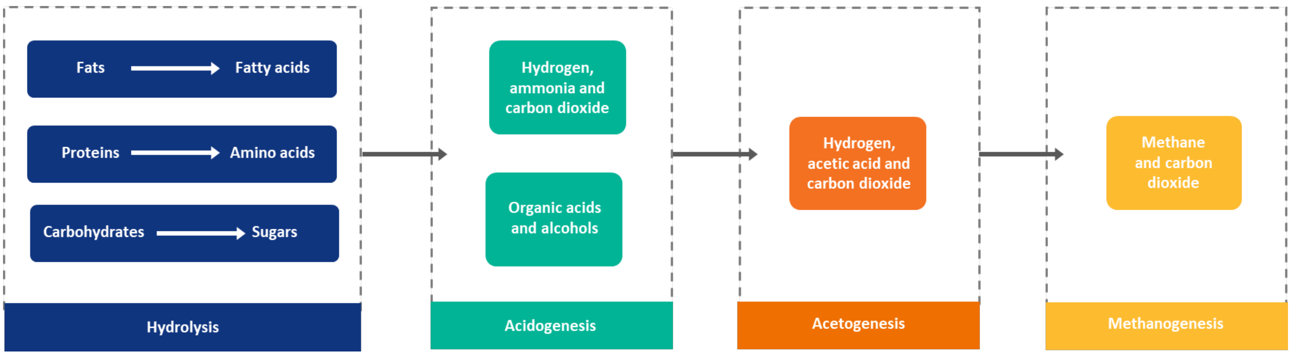
The micro-organisms involved in AD work together as a community to transform organic matter to biogas. Many of these micro-organisms are strict anaerobes, which means they cannot live when oxygen is present. This is why the process is called ‘anaerobic’ digestion. The output of one group in the community provides the food for another group in a food chain: what one set of organisms excrete; the next set eat. This means that the communal process is sensitive to individual disruption.

The microbial community acts together by progressively degrading a wide variety of large and complex organic materials into a limited number of small compounds (hydrogen and acetate), which are the immediate precursors of CH_4 production.

AD facility operators need to ensure the conditions are suitable for all the components of the microbial community. The main microbial groups are fermentation bacteria, acetogens and methanogens (see *Figure 2.1*). Collectively, these undertake four main stages in the microbial breakdown process. These stages are described below in the order of occurrence:

- **Hydrolysis** is when fermentation bacteria break down large biopolymers (carbohydrates, starch, cellulose, fats and proteins) into small molecules (sugars, fatty acids and amino acids).
- **Acidogenesis** is when fermentation bacteria break down the small molecules into smaller acids and alcohols (for example, butyrate, ethanol and propionic acids) and lactate (fermentation products).
- **Acetogenesis** is when acetogenic bacteria break the fermentation products down into hydrogen, CO_2 and acetate (acetic acid).
- **Methanogenesis** is the final stage, and involves methanogenic bacteria converting acetate, hydrogen and CO_2 to CH_4.

Figure 2.1: Microbial degradation of organic matter to biogas during AD



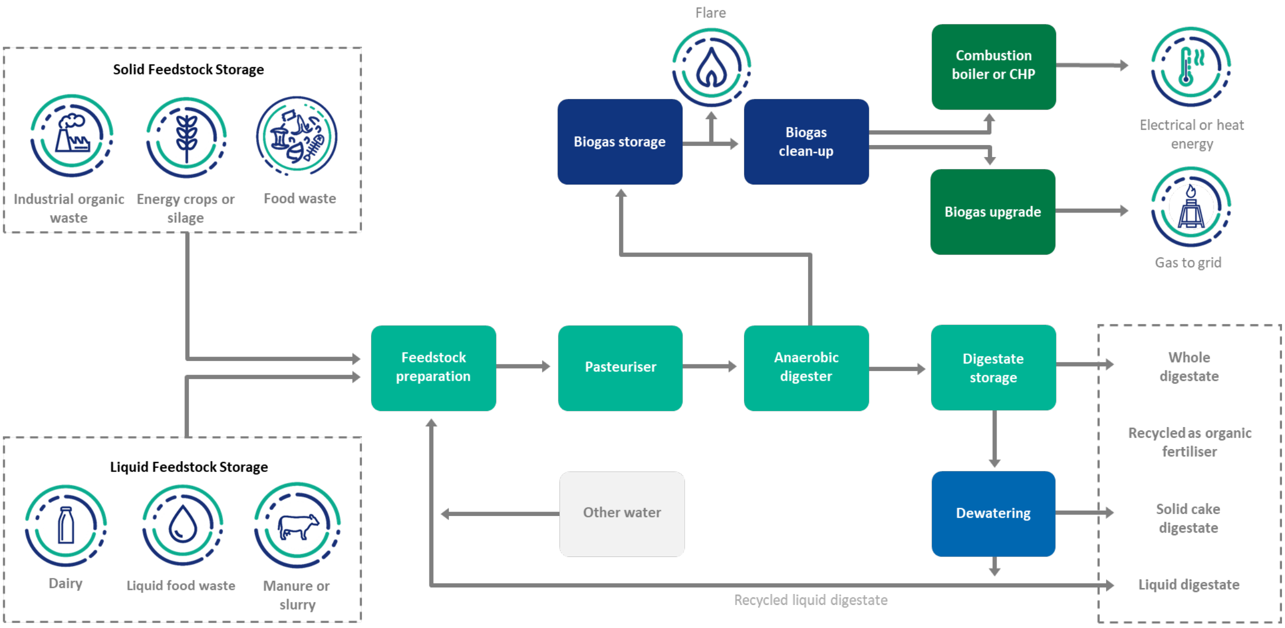
2.2 Main components of an anaerobic digestion system

An AD facility includes many linked processes that enable the overall process – from feedstock reception to biogas utilisation. There are many variations of detailed facility design, which need to be considered in depth. AD may be carried out either as a 'dry' process, where the feed is dry enough to be handled and stacked, or as a 'wet' process, where the feed is a moist enough to be moved by a pump through pipes. Wet AD, slurry, is far more prevalent in Ireland and the United Kingdom.

Anaerobic digesters typically operate in either of two separate temperature ranges: the lower 'mesophilic' range of 30ºC to 40ºC; or in the higher 'thermophilic' range of 50ºC to 60ºC. Operating at thermophilic temperatures often results in pasteurised digestate. However, more of the biogas must be burnt to generate the heat required to operate the digesters at these higher temperatures.

Figure 2.2 shows a simple configuration for a farm-based AD facility receiving a variety of feedstocks. The configurations are similar for both types of temperature ranges. Actual facilities may differ in the number and type of process units, and the process flow scheme. Further details of the technologies involved with different AD configurations and designs are described in the accompanying Technology Guide, Section 4.

Figure 2.2: Simplified process-flow scheme for a farm-based AD facility



As well as the main anaerobic digester, an AD facility may include some of the components shown in *Table 1*. The equipment indicated in *Table 1* is explained further in the Technology Guide, Section 4.

Table 1: Common AD facility components

Component	Purpose and additional notes
Liquid feedstock storage tanks	If the feedstock is viscous or prone to solidification at low temperatures (fats), these tanks may need to include heating and mixing to keep the liquid fluid.
Solid feedstock storage area	For storing seasonal energy crops for year-round use.
Feed preparation area	This system may include washing, mashing and blending different feedstocks prior to use in the anaerobic digesters so that the prepared infeed is uniform in physical and biological characteristics.
Food waste de-packaging	Bespoke processes are necessary for de-packaging waste food and beverages arriving in packaged form. This is to prevent packaging material such as plastic, metal and glass entering and damaging the anaerobic digester and being present in the digestate applied to land.
Pasteurisation equipment	It is sometimes necessary to heat the feedstock or digestate (pasteurisation can occur before or after digestion) to kill any microbial pathogens. Pasteurisation may be required if the feedstock includes animal by-products or animal manures from other farms.
Biogas collection and storage	A system must be in place to collect the biogas produced and store it in the short term.
Biogas preparation and cleaning equipment	The raw biogas requires some clean-up.
Biogas upgrading equipment	Special equipment is needed if the biogas is to be upgraded to biomethane for injection into the natural gas grid or as a containerised fuel for vehicles or other uses.
Emergency flare	This is a method for the safely disposing of biogas in an emergency.
Digestate dewatering equipment	This equipment is used to separate solids in the digestate, producing liquid ('liquor') and solid ('fibre') digestate fractions for alternative methods of application.
Covered digestate storage facilities	Digestate storage is required if digestate is to be used in agriculture as it cannot be applied all year round. Covering the digestate avoids emissions of the potent greenhouse gas CH_4 and mitigates nuisance odours.
Biogas engine, combined heat and power system or boiler	This equipment is used to combust the biogas and generate power or heat, or both. Energy generating systems need associated infrastructure to transmit the heat and power to users.
Wastewater treatment facility	This facility is required if excessive amounts of wastewater are generated and require treatment before being discharged.
Air treatment facility	If the AD is situated near sensitive areas (residential areas), an air treatment facility is required to control odour.

Facilities vary in size and capacity in terms of input feedstock tonnages and their energy output from the biogas produced. Typically, anaerobic digesters are described in terms of their electrical energy production, although this may not describe all AD processing options, for example, if the output biogas is only used to generate heat. Farm-based facilities may be at scales of less than 100 kilowatt-electric (kWe), equating to approximately 400,000 m^3 of biogas and less than 5,000 tonnes of feedstock per annum.

Large-scale facilities may have a capacity of several megawatt-electric (MWe) with input tonnages of as much as 100,000 tonnes per annum (tpa). However, the main components of a dry or wet AD facility are similar whatever the scale. The main differences are the size and number of individual units, which are discussed further in the Implementation (Section 4.6) and Technology Guides (Sections 2.2 and 2.3).

2.3 Feedstocks that can be used to produce biogas

Feedstocks should be readily biodegradable under anaerobic conditions so that the amount of biogas produced is maximised (see blue box below). Generally, feedstocks high in proteins, carbohydrates (such as sugars and starch) and fats are good materials for AD. Cellulose is a common carbohydrate contained in plant material and generally degrades more slowly than proteins, starch and fats. Organic materials not suitable for AD are those composed of poorly biodegradable material, such as textiles, leather and material with a high lignin content (such as woody waste).

The outsides of feedstocks like root vegetables (for example, waste potatoes, waste carrots, and waste parsnips) and whole grains are often resistant to microbial degradation and provide a small surface area for the micro-organisms to attach to and degrade. Such feedstocks may need preparation, such as milling, mashing or maceration, to break open the outer protective layer and reduce the particle size to give the microbes access to a larger surface area, and to the more biodegradable insides.

Typical feedstocks used in AD:

- **Organic farm wastes such as manures and slurries, spoilt or unusable crops such as root vegetables, hay, silage and straw;**
- **Farm energy crops – crops grown specifically as feedstock, such as grass silage, corn silage and clover crops;**
- **Food and drinks manufacturing waste from dairies, brewing, or fat and oil production;**
- **Retail food waste – out-of-date supermarket (packaged) food and beverages;**
- **Catering food waste – from restaurants and residential households; and**
- **Sewage sludge generated from sewage treatment.**
  Co-treatment of sewage sludge with other organic materials is being considered in Ireland (see Section 7.1, Reference 5)

Different feedstocks have different characteristics, such as levels of moisture and organic matter, what months of the year they are available in the locality, and how much biogas they will produce. Biogas production rate is an important factor and is often referred to as the biogas yield. Anaerobic digesters should be operated at consistent biogas production rates. This means that the type of feedstock, and how much of each type is loaded into the digester every hour or day, are key factors for proper operation.

Figure 2.3: Examples of AD feedstocks

Root crops

Silage

2.3.1 Animal manures and slurries

Although farmyard manures and slurries are produced in large amounts and may be used as AD feedstocks, they do not have a high biogas yield. This is because much of the biodegradable content of the animal feed has been digested by the animal and the manure contains those parts that are less digestible.

However, using manures recovers some useful biogas, and reduces fugitive emissions of CH_4 and ammonia (NH_3) during storage – and, if pasteurisation is included, kills off potential pathogens. **The controlled AD of manures and slurries has many benefits although an AD facility fed solely on such manures and slurries will not produce high biogas yields and often requires the addition of other feedstocks**.

Farmers and project developers considering AD projects need to assess the amounts of slurry and manure based on the amounts stored under the current farming practice, rather than on the total amount of animal manure produced. This is because stored animal manure produces more CH_4 and is therefore more environmentally damaging than digestate or animal manure dropped in the fields. It is important that an AD project does not result in an increase in the amount of animal manure stored in tanks, nor in the duration of time it is stored for. Rather it should aim at processing the animal manure through the AD as quickly as possible so that any necessary storage is focused on treated digestate (with a low potential for emissions) rather than untreated animal manure (with a high potential for emissions).

Further details on feedstock characteristics, and how these need to be assessed and managed to optimise the AD performance, are described in the accompanying Implementation Guide and Operation and Maintenance Guide.

2.4 Co-products and wastes from anaerobic digestion systems

While the focus of interest here is on waste management for maximum biogas production, it is important to recognise that any AD facility will produce other outputs and waste streams that need to be managed appropriately. The most important of these is digestate, which has considerable value as an organic fertiliser.

2.4.1 Digestate

The management of the digestate output material from the anaerobic digester is an important success factor for AD projects. Digestate is rich in plant nutrients, particularly nitrogen, phosphorous and potassium, and remaining organic matter and can be used as an organic fertiliser on agricultural land in a similar way to animal manures and slurries. This digestate requires land for spreading but offers many cost and nutritional advantages over the use of raw slurries and chemical fertilisers.

The digestate output from an AD tank, for example whole digestate, may be applied directly to agricultural land in the form in which it arises. In some processes the whole digestate is treated to separate the solids material into a solid cake (sometimes called fibre or cake digestate) from the liquid fraction (sometimes referred to as liquid digestate). This is often referred to as ‘dewatering’, and may be carried out by several means, such as filter presses or centrifuges (see the Technology Guide, Section 6, for further details). Both the solid and liquid fractions may also be used as fertiliser. Solid cakes are a convenient option when there is a significant distance to travel between the AD and the receiving land, because it avoids the cost of transporting large volumes of liquid digestate, most of which is water. Solid cakes can be applied to the surface of the soil, and then ploughed in. Liquid digestate has a lower viscosity than whole digestate and may infiltrate soil more rapidly if applied to the surface of grassland. This means it produces lower emissions after application.

For relatively dry feedstocks processed using wet AD, dilution with significant amounts of water may be required so that the infeed to the digester is in a suitable wet-slurry form. This would mean that the weight of digestate produced may be more than the weight of the input feedstock, and the sizing of the digestate storage tanks needs to take this into account. In some facilities a proportion of the liquid digestate may be recycled in the plant as dilution water for incoming dry feedstocks, which may reduce the amount of digestate produced overall and the digestate storage capacity required.

Digestate factors to consider:

- **What form of digestate will be produced – whole, liquid or solid cake?**
- **What digestate treatment equipment is required?**
- **What loading of digestate needs to be applied to fields?**
- **Is there enough agricultural land available for the digestate that will be produced?**
- **What quality of digestate is required?**
- **How and when will the digestate be applied?**
- **What digestate storage capacity is needed?**

During AD, the decomposition of the organic matter results in most of the plant nutrients being transformed into mineral compounds like those typically present in chemical fertilisers. These compounds are immediately available for crops when the digestate is spread on the land. Therefore, digestate can be used reliably as part of a controlled fertiliser regime, as the nutrient quality can be accurately determined and provides significant savings on chemical fertiliser costs. This helps to avoid the application of excess nutrients that may leach from the soil and contaminate groundwater. Additionally, digestate has a lower viscosity than animal slurries and infiltrates the soil more readily when applied to the surface, reducing the risk of surface run-off and water pollution. If digestate is injected into the soil, there is less spillage onto the surface, and higher infiltration rate.

As with all fertilisers, digestate application to land is controlled by EU statutory regulations. These are described in Statutory Instrument No. 605 of 2017, Good Agricultural Practice for Protection of Waters, [2] and its amendment[3] of 2018. They indicate, limits on digestate application rates and periods when digestate may not be applied to agricultural land.

These regulations consider both manures and digestate as organic fertilisers, but some of the rules apply differently to manures. For example, although there are periods when manures cannot be applied to agricultural land, these differ slightly to those that apply to other organic fertilisers, including digestate, and chemical fertilisers as shown in *Table 2*. Also, there are three different zones for which different application periods apply so these rules need to be carefully considered if a farm uses its manures in an AD process and produces digestate.

Overall, the application of digestate as agricultural fertiliser has financial and environmental benefits if carried out appropriately and is the primary route for the use of digestate. Further details of digestate management are considered in the accompanying Implementation Guide, Section 4.5.

Table 2: Fertiliser application closed periods

Zone	Chemical fertiliser	Organic fertiliser	Manures and slurries
In counties Carlow, Cork, Dublin, Kildare, Kilkenny, Laois, Offaly, Tipperary, Waterford, Wexford and Wicklow.	15 Sept-12 Jan	15 Oct-12 Jan	1 Nov-12 Jan
In counties Clare, Galway, Kerry, Limerick, Longford, Louth, Mayo, Meath, Roscommon, Sligo and Westmeath.	15 Sept-15 Jan	15 Oct-15 Jan	1 Nov-15 Jan
In counties Cavan, Donegal, Leitrim and Monaghan.	15 Sept-31 Jan	15 Oct-31 Jan	1 Nov-31 Jan

Source: SI No. 605 of 2017 (Please refer to primary source for updates)

[2] https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/2017/SINo605271217.pdf
[3] http://www.irishstatutebook.ie/eli/2018/si/65/made/en/print

Figure 2.4: Digestate application to land

2.4.2 Carbon dioxide

For AD facilities producing biomethane, high-purity CO_2 may also be recovered as this is stripped out of the biogas during the upgrading process to produce the biomethane. This high-purity CO_2 may be recovered as a valuable by-product in pressurised and transportable gas cylinders to be used in various applications, such as in the food and drink industry, where it is economically viable.

2.4.3 Other wastes

If the AD is based solely on farm generated materials such as animal manures and agricultural crops, then other waste outputs that need to be managed should not arise. Also, the digestate should be free of undesirable materials such as plastics and metals and be suitable for spreading on land. However, if other feedstocks are included then these might need pre-processing before feeding to the AD, thus generating other waste streams that need to be managed.

If the input feedstock to the facility includes packaged food waste, for instance, then pre-processing is needed to break open the packaging and release the biodegradable organic matter. This packaging material constitutes solid waste, for example, plastics, paper, cardboard, glass and cans. The best option for managing these waste outputs would be to send them for recycling. With such feedstocks, the pre-processing needs to be very efficient to avoid any packaging entering the AD process. Packaging could damage the AD equipment, and any packaging material entering the digestate might make it unsuitable for application to land due to the resulting contamination of the soil. Contaminated digestate can be a cause of microplastics in soil, which is an environmental issue of some concern.

Some feedstock-washing processes (for example, to remove soil from root crops) also generate a waste-sludge that needs to be managed appropriately. However, as the washings would be mainly soil material, they would often be usable on farms.

For information on the correct procedures to manage wastes generated from the AD process, those concerned should contact the local council and the Environmental Protection Agency.

3. How can biogas be used?

Raw biogas from an anaerobic digester is very moist. It may also contain undesirable contaminants such as ammonia (NH_3), hydrogen sulphide (H_2S) and siloxanes (man-made silicon compounds used in, for example, food manufacturing) as well as the main components of methane (CH_4) and carbon dioxide (CO_2). It is necessary to remove these contaminants as they can cause pollution and damage to equipment. NH_3 and H_2S, for instance, generate the pollutants nitrogen oxides (NO_x) and sulphur dioxide (SO_2) when combusted. Siloxanes are oxidised to silicon oxide in gas engines and this effectively generates hard sand material that can cause extensive damage to the engines. This is why biogas engine and boiler suppliers normally specify maximum acceptable concentrations for contaminants in the fuel.

Typically, the biogas is 'cleaned up' before further use, which may involve several stages of treatment such as chilling the biogas to condense-out moisture and passing the biogas through activated carbon filters to remove contaminants. The cleaned biogas can be used directly as a fuel in a gas boiler or gas engine to produce heat and electricity or upgraded into biomethane, which is virtually pure CH_4, and used as a substitute for natural gas and other fossil fuels.

To operate efficiently, most AD facilities require on-site electrical and heat energy ('parasitic' energy) of 10-20% of the energy produced from the biogas generated on site. Even if the main intended output from the facility is biomethane, most AD facilities will have an on-site gas engine that uses some of the biogas.

Figure 3.1: Options for biogas use

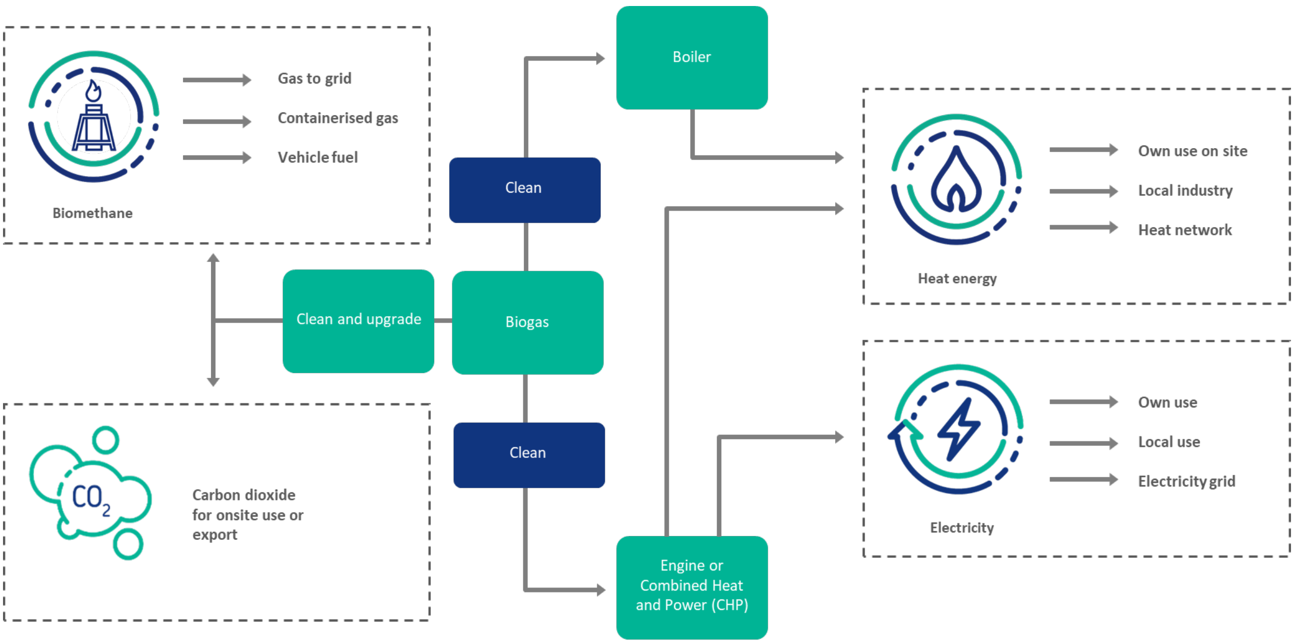


Figure 3.2: Containerised biogas combined heat and power unit

3.1 Biogas boilers and combined heat and power

Biogas can be combusted in gas boilers to produce heat energy, for example, as hot water or high temperature steam, which may be used to generate electricity in steam turbines. Biogas is often used to fuel gas engines that produce electricity, or both heat and electricity. When the gas engine is set up to produce heat and electricity it is known as a combined heat and power (CHP) plant. If electricity and district heating grids are available to connect to, then excess heat and electricity may be used off site and the owners of the AD can sell this energy. For most AD sites, district heating networks are not available, and the heat produced is ideally used on the AD site itself or close to it, for example, in nearby farm operations.

3.2 Biomethane

An alternative to direct use of the biogas in combustion plants is to upgrade it to the standard required for the gas grid. Upgraded biogas is known as biomethane – and is made up almost entirely of CH_4. The upgrading process removes most of the other gases, especially CO_2. The biomethane is then a high calorific fuel that can be injected into a local or national gas grid, used in portable compressed gas containers or as a vehicle fuel.

Where markets are available, the CO_2 from the upgrading process can be recovered and sold. CO_2 is widely used in the food and other industries – see also Section 2.4.2.

4. What are the benefits of using biogas?

Potential benefits of farm-based AD:

- **Waste treatment facility to recycle farm wastes into a valuable fertiliser (digestate);**
- **Reduces farm-based environmental issues, such air pollution from manures;**
- **Reduces the negative impact of farming on national environmental targets;**
- **Provides a renewable energy source (biogas) for farm use;**
- **Cost savings on chemical fertiliser and energy purchases;**
- **Potentially offers additional farm income streams from sale of excess electricity or heat; and**
- **Contributes to local community development.**

A farm-based AD process may have some disadvantages associated with the implications of changed land use, especially if some of the farm is changed to AD feedstock crop production, such as hay and silage. The AD process generates CH_4, which is highly flammable and can form explosive mixtures with air, so care must be taken to design and manage a process that can mitigate these risks.

4.1 Waste management

The implementation of an AD facility can improve the management of waste on a farm and its associated environmental impacts. This is largely due to AD being a controlled, closed system that contains and treats the wastes and minimises emissions.

Some potential benefits of using AD for waste management are listed below:

- The process facilitates better resource recovery from farm wastes in the form of biogas and organic fertiliser.
- The environmental and health and safety risks are lower compared with the open storage of equivalent amounts of wastes, especially those from large amounts of manures and slurries. The AD process mitigates environmental risks from accidental spillages entering and polluting surface waters, and from the release of CH_4 and ammonia (NH_3) emissions into the air.
- Manure spreading is associated with the risk of microbial pathogens contaminating surface waters. If the AD facility is thermophilic or includes a pasteurisation step, this risk is mitigated, allowing waste to be safely used as fertiliser. In this way, AD facilities can benefit the quality of local freshwater and marine environments.

4.2 National benefits

Agriculture is a significant component of Ireland’s economy, accounting for about 8% of employment and about 11% of exports. Ireland has indicated its intention to use its agricultural resources more productively, to increase self-sufficiency and boost the national economy. This expansion comes with environmental costs, and some of Ireland’s largest publicly listed companies that are supplied by the sector aim at reducing their environmental impact.
Therefore, the widespread uptake of farm-based AD may have a part to play in improving the sustainability of the sector and the supply chains of Ireland’s agri-food sector.

Sustainable AD projects offer many broader national environmental benefits, principally associated with the production of renewable energy, conservation of natural resources, and avoidance of emissions.

Some benefits of AD projects that mirror the local benefits are listed below:

- Using sustainably produced biogas as a renewable fuel to displace fossil fuels mitigates the effects of climate change and will help Ireland to achieve its greenhouse gas emissions reduction targets. If biomethane is used as a fuel, it also reduces Ireland's fossil fuel imports. In particular, Ireland is examining the potential for using biomethane to help supply the national gas grid and as a fuel for long haul vehicles.
- Processing various farm wastes through an anaerobic digester in a controlled way:
  - Contains the waste, which reduces the risk of accidental spillages and the pollution of surface water and groundwater;
  - Avoids uncontrolled emissions of CH_4 that arise from existing stockpiles of manures and slurries, and from landfilled organic wastes; and
  - Minimises fugitive emissions of NH_3 from open stores of manures. Agriculture is one of the main sources of atmospheric NH_3 emissions.
- Processing farm wastes, especially manures, in an anaerobic digester decreases the risks of pathogens being dispersed in the environment (including freshwater and marine environments).
- Using digestate as a fertiliser, conserves and recycles the mineral nutrients in organic matter such as nitrogen, phosphorous and potassium, and displaces the use of artificial chemical fertilisers, thereby reducing the environmental impacts of their manufacture.
- AD reduces the risk of death from falling into open slurry tanks.

4.3 Commercial benefits

A farm-based AD project may offer several commercial benefits to the farmer, depending on the project concept.

Potential commercial benefits to the farmer include:

- Reduced chemical fertiliser costs from the use of the digestate as an organic fertiliser;
- Reduced on-farm energy costs where biogas is used to generate electricity or heat for direct use on the farm;
- Better resource recovery from farm wastes (for example, management of manure, dairy whey and unusable crops) enabling recovery of some of the costs associated with production and management of these wastes;
- Income from revenues associated with the sale of heat, electricity, biomethane, digestate, or digestate-based products or any combination of these, with the potential to enhance income through fiscal incentives to promote renewable energy; and
- The capacity to accept external feedstocks and charge a gate fee for their treatment, thus increasing income and gaining additional nutrients for the farm.

However, if the project involves switching farmland use to energy crops for AD, the loss of revenue from the current agricultural use of the farmland will of course be a significant factor in any commercial decisions.

4.4 Local community benefits

Farming provides employment for a significant proportion of Ireland's population. An AD project is likely to provide additional local employment, as well as supporting industries involved in its construction, operation and maintenance. An AD facility may also stimulate other local industry and residential development by presenting the opportunity to use the renewable heat and power produced.

The local community may also benefit from other environmental benefits, such as improved surface water quality and reduction in the odours associated with slurry spreading.

5. Managing environmental issues

Section 4 highlights some of the environmental benefits of an AD process. These arise largely from the management of the waste in a closed and controlled process. However, AD is a relatively complex process that involves:

- Deliberately generating methane (CH_4), a potent greenhouse gas that is highly flammable and may form explosive mixtures with air; and
- Processing large amounts of organic matter, which may cause extensive pollution if poorly managed.

Therefore, an AD facility must be operated and managed to comply with all relevant legislation and must control environmental risks.

A comprehensive Environmental Impact Assessment (EIA) is required as part of the planning permission and permitting or licensing of an AD facility together with ensuring appropriate control measures are in place.

Main environmental risks associated with AD processes include:

- **Microbial pathogens;**
- **Wastewater emissions;**
- **Digestate quality (potential to cause soil contamination);**
- **Air emissions (including biogas, bioaerosols and engine or boiler exhaust);**
- **Nuisance (including odour, litter, vehicle movements, vermin and noise); and**
- **Feedstock sustainability.**

5.1 Microbial pathogen risks

Organic wastes may contain human, animal and plant pathogens, which can pose a risk to site workers, nearby residents and the environment. Processing organic waste often releases small amounts of waste as microscopic particles that can disperse through the air as bioaerosols. These may contain allergens as well as micro-organisms. The design of the AD facility should minimise exposure to pathogens and bioaerosols by including measures to control such emissions. Bioaerosol monitoring and control measures may be a requirement of planning permission and permitting or licensing.

Some wastes, particularly animal by-products (ABP), may contain notifiable pathogens (for example, foot and mouth), which ordinarily survive the AD process and appear in the digestate. When applied as fertiliser, this digestate could widely disperse microbial pathogens. Along with other EU countries, Ireland has specific requirements for managing animal by-products as feedstocks for AD, including sanitation (pasteurisation), and for the subsequent use of the digestate. The requirements vary depending on the size of facility, feedstock sources and where the digestate is intended to be used. Further details are described in Section 6, in the Implementation Guide, Section 4.6.4, and Technology Guide, Section 4.12.

5.2 Wastewater treatment and disposal

Farm-based AD facilities may have large storage areas for feedstocks. Other areas subject to rainfall may produce surface water run-off contaminated by the feedstocks, which will need to be treated before it can be discharged from the site. Potentially, some of this water may be used as process water within the facility, although there is still likely to be significant amounts of surface run-off. Bund walls may be needed in certain areas to control and contain accidental spillages of digestate and other process chemicals.

The facility itself, especially if it has digestate dewatering, can produce an effluent that is not destined for use as a fertiliser and needs to be disposed of. If this is the case, the effluent may need to be treated before it can be discharged from the site. Alternatively, it might be taken by tanker for treatment at a nearby approved wastewater treatment works.

5.3 Digestate quality

Given the importance of digestate as a fertiliser and to the overall economics of AD schemes, it is key to ensure that it is of a suitable quality and does not cause harm to the agricultural land it is applied to, or to the surrounding environment. This requires consideration of aspects such as:

- Determining the nutrient composition of the digestate (nitrogen, phosphorus and potassium) so that application rates match intended crop fertiliser requirements;
- Ensuring the composition of the digestate is within acceptable limits (for example, there are no unacceptable levels of plastic fragments, sharp metal fragments and toxic elements such as lead and mercury); and
- Minimising the application of excess digestate, which is a potential source of pollution, and ensuring that the application method is appropriate and in compliance with regulations such as the Animal by-products Regulation (EC Regulation No 1069/2009) and Statutory Instrument No. 605 of 2017, Good Agricultural Practice for Protection of Waters and its amendment.

5.4 Air emissions

The AD facility itself, as a process that produces biogas, may be a source of fugitive CH_4 emissions from leaks and material (digestate) stored in the open. These emissions must be minimised, and a high level of preventive maintenance carried out.

In addition to biogas, other harmful gases may be produced during the AD process (for example, hydrogen sulphide and ammonia). The risks from harmful gases when working or carrying out maintenance in confined spaces should be assessed and appropriate controls put in place. Potential impacts on sensitive habitats nearby must also be considered.

On-site use of biogas in boilers and gas engines may mean that the pollutants in the exhaust gas are subject to strict limits and controls, which would be specified through the operating permit. Combustion plants of greater than 1 MW thermal capacity may have to comply with emission limits described in EU Directive 22015/2193 as transposed into the European Union Statutory Instrument No. 595 of 2017, Medium Combustion Plants.

5.5 Odours, flies, noise and other nuisances

Whilst farming activities are not without their own nuisance impacts, an AD facility can exacerbate some of these and be the source of additional nuisances to nearby residents. The design and operation of the facility should mitigate these as much as is reasonably possible.

Feedstocks for AD facilities include manure, waste food and crops. These can attract vermin and flies and can be a source of unpleasant odours.

The site may also require frequent additional vehicle use, for example, to deliver feedstocks and take away digestate by-products. These may be a nuisance to neighbours, especially in rural locations with narrow country roads. Additionally, being farm based, the vehicle movements may be seasonal and peak at times of crop harvesting and digestate applications, although such seasonal traffic movements are frequently a feature of farms without an AD facility.

Noise nuisance may be associated with vehicle movements and specific AD facility equipment such as tank stirrer motors, digester feeding hoppers and gas cleaning plants.

Measures to control such nuisances may be required as part of planning permission and permitting, depending on the location of the site. These can affect specific aspects of the facility design and operation, such as enclosing feedstock and waste areas; storing, collecting and treating odorous air; noise suppression measures; and restricting opening times for vehicle movements.

5.6 Feedstock availability

An AD facility generally operates most effectively on a consistent feedstock as the micro-organisms will naturally adapt to degrade this feedstock efficiently. Frequent changes to the feedstock will require the micro-organism to adapt frequently, which may reduce performance.

However, if the feedstocks are largely farm based (manures and silage) then this may mean a less diverse farm cropping regime. The impact on the soil quality and productivity would need to be considered to avoid detriment to the soil from repetitive use, potential reduction in yields, and ultimately the long-term sustainability of feedstock availability.

5.7 Emerging environmental issues

Operators of AD facilities should be aware of new and emerging environmental concerns that the industry may have to face. Some inbuilt flexibility in the design of the facilities can reduce the risk of the operation being compromised by an emerging issue. For example, there is widespread concern regarding plastic pollution, and in particular, microplastics being introduced into the environment and food chain. Digestate can be a source of such plastics, especially if the feedstock is contaminated with plastic packaging from retail food waste.

6. Overview of anaerobic digestion legislation

Sustainable AD has many benefits and, when implemented correctly, fits well as part of EU measures to implement many national and international initiatives that aim at reducing greenhouse gas emissions, encouraging renewable energy and resource efficiency, and promoting self-sufficiency. These EU initiatives are translated into national plans, policies and regulations.

These plans and policies drill down into specific regulations affecting AD facilities and associated issues such as agricultural land use and environmental protection. As a typical AD facility entails the extensive involvement of agriculture for digestate management and potentially waste management, the areas of regulation go beyond the boundary of the AD facility.

Key regulatory aspects of AD:

- **Planning permissions;**
- **Environmental permits;**
- **Animal by-product regulations;**
- **Digestate use in agriculture;**
- **Waste management regulation;**
- **Biogas utilisation; and**
- **Sustainability.**

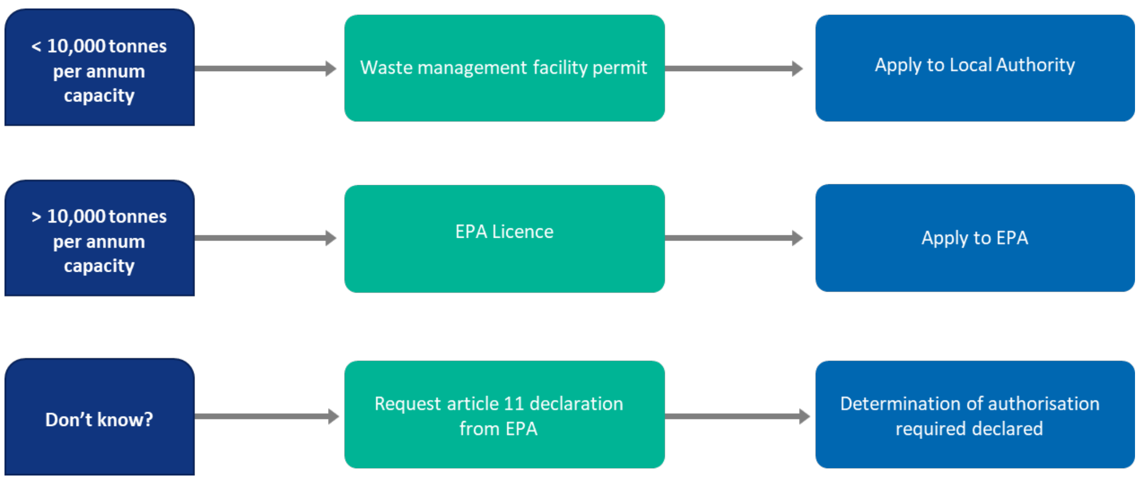
6.1 Planning permission

Planning permission for an AD facility will be required from the local planning authority. Obtaining planning permission is likely to impose some environmental and other controls on the facility, such as including an Environmental Impact Assessment in the application. Further details are described in the accompanying Implementation Guide, Section 4.6.4.

6.2 Environmental permits and licences

In addition to planning permission, all operators of an AD facility require consent to operate in the form of a permit from the local authority or a licence from the Environmental Protection Agency under Statutory Instrument No. 821 of 2007, Waste Management (Facility Permit and Registration) Regulation[4] and its amendment of 2008[5]. Whether a permit or a licence is required is determined by the capacity of the facility. For small facilities (less than 10,000 tonnes intake per annum) the **permit** is obtained from the local authority. For larger facilities, the **licence** is obtained from the EPA (see *Figure 6.2*).

Figure 6.2: AD facility scale and waste permitting authority



[4] http://www.irishstatutebook.ie/eli/2007/si/821/made/en/print
[5] http://www.irishstatutebook.ie/eli/2008/si/86/made/en/print

A permit or licence may include limits on, for example, the activities, and the types of feedstock that can be treated, environmental emissions and digestate quality. Further details are discussed in the accompanying Implementation Guide, Section 4.6.4.

6.3 Animal by-products

If an AD facility accepts and processes inputs that are classified as animal by-products, there is a requirement under the Animal By-Product Regulation [6] (1069/2009) to ensure that the facility processes such inputs adequately, to mitigate the risk pathogens and disease being transmitted through the digestate. This is enforced via Statutory Regulation No. 187 of 2014[7] and means the AD facility must employ an acceptable heat treatment pasteurisation step. Animal by-products are classified according to their risk of containing pathogens, with the highest risk being Category 1 and the lowest risk Category 3.

In Ireland, certification (if required) of an AD facility under the Animal By-Products Regulations is obtained from the Department of Agriculture, Food and the Marine[8]. Different certification requirements are needed depending on the type of facility and its inputs. Although manures are classified as Category 2 animal by-products, the regulation requirements may be less strict if the AD facility only processes manures, waste crops and energy crops that are produced on the host farm, and the digestate is used only on that farm. Different requirements then apply to different types of facility, which are fed with different feedstock and have different treatment processes within the design (*Table 3*).

If the feedstock includes Category 3 catering waste, then pasteurisation and an Animal By-Products Regulation certificate is required to use the digestate on agricultural land (and other similar applications such as land restoration). If Category 3 waste is used as feedstock and there is no pasteurisation, then the digestate may only be incinerated or sent to landfill. Where pasteurisation is required, the pasteurisation process should meet the conditions of a maximum particle size of 12 mm and exposure to a temperature of 70°C for at least one hour.

Table 3: Common AD facility animal by-products licences

Animal by-product facility type	Processing applied	Main feedstock	Digestate outlets
1	≤12 mm particle size. Heated at ≥70°C for ≥1 hour	Category 2 manures and Category 3 catering waste	Land in Ireland and within EU
2	No heat treatment applied	Only manures from the farm and non-animal by-product feedstocks also from the farm	Land in Ireland only
3	No heat treatment applied	Category 3 catering waste	Cannot be used on land and must be incinerated or landfilled

Regardless of what the intended feedstock material for an AD facility, facility owners may wish to consider the benefits of designing it as a type 1 animal by-products plant (refer to *Table 3*). This allows the facility to process animal by-products in the future, without having to retrofit pasteurisation units. This would allow flexibility to bring Category 2 or 3 ABPs to the facility at a later stage, although there would be impacts on the capital and operating costs of the facility to consider. Further details on animal by-products are provided in the accompanying Implementation Guide, Section 4.6.4.

6.4 Digestate quality

There is no national digestate quality standard in Ireland. However, digestate quality is of critical importance, particularly if the digestate is to be used as fertiliser on agricultural land.

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[6] Regulation No. 1069/2009, which lays down health rules as regards animal by-products and derived products not intended for human consumption (Animal by-products Regulation). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R1069

[7] http://www.irishstatutebook.ie/eli/2014/si/187/made/en/print

[8] https://www.agriculture.gov.ie/

Compliance with the Animal by-products Regulation includes testing for, and meeting limits for, some micro-organisms in the digestate. These limits are defined by the Department of Agriculture, Food and the Marine in document CN18: Conditions for a plant approved to process category 3 animal by-products.[9] Additionally, the site should be designed so that the digestate cannot be contaminated by any unsanitised raw material (also described in document CN18. See the Technology Guide, Section 4.12, for more details).

An environmental permit may include a site-specific digestate quality requirement, such as monitoring of and limits for potentially harmful materials including heavy metals (for example, cadmium, copper, chromium, mercury and zinc) and other contaminants (for example, glass, metals and plastics). Additionally, the digestate should be routinely monitored for the key fertiliser nutrients of value, particularly nitrogen, phosphorus and potassium. This information is required so that the digestate may be applied correctly in appropriate amounts to the agricultural land (described in Statutory Instrument No. 605 of 2017). It can also increase the market value of the digestate and make it more saleable to other agricultural enterprises.

6.5 Digestate application

Digestate application to agricultural land is regulated to ensure the digestate is applied appropriately, in consideration of the risk to the environment. It is of critical importance to contact the Environmental Protection Agency and Department of Agriculture, Food and the Marine at an early stage of the project.

Digestate derived from feedstocks classified as animal by-products, which has been produced in an AD facility certified under the Animal by-products Regulation, is subject to restrictions on its use. Specifically, land cannot be grazed by livestock or animal fodder crops cannot be harvested within 21 days of the application of the digestate. This further mitigates the risk of spreading animal pathogens as these tend to die off in the soil over time.

Statutory Instrument No. 605 of 2017 European Regulations, Good Agricultural Practice for Protection of Waters, provides key requirements for minimising the pollution of waters caused by fertiliser applications, including organic fertilisers such as digestate.
This includes the following main provisions:

- Monitoring the soil quality of receiving fields to determine its existing nutrient content;
- Determining the fertiliser requirements of the crop to be grown in the field;
- Determining the balance of fertiliser that can be added to make up the difference between the existing nutrient content, and the crop nutrient requirement which, together with an analysis of the nutrient content of the fertiliser, then allows calculation of the application rate;
- Conditions for the application method including rules for when and where not to apply, such as during adverse weather, vicinity to water courses and boreholes, and on sloping fields;
- Conditions on the maximum quantity of nitrogen and phosphorous that may be applied to grassland (soils that already have a high phosphorous content may not be able to receive digestate for its nitrogen content because the digestate would also contain phosphorous); and
- Restrictions on digestate spreading during certain periods in the year, notably about three months during the winter when the application of digestate is not permitted on agricultural land.

This regulation imposes restrictions on the application of digestate, which then affects the design and operation of any AD facility, most notably in terms of the requirements for digestate storage.

6.6 Waste regulations

As indicated in Section 2.4, a farm-based AD facility might import waste materials as feedstocks (for example, waste food and beverages) and export waste materials (for example, waste plastics, paper, glass and metals from the de-packaging of packaged food waste). The movement of waste is regulated and controlled by the Waste Management Act 1996,[10] as amended, and related regulations. Wastes can only be transported by a holder of a Waste Collection Permit, which is issued by the National Waste Collection Permit Office.[11]

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[9] https://www.agriculture.gov.ie/media/migration/foodindustrydevelopmenttrademarkets/animalby-products/applicationformsconditionsforabpprocessingoperations/conditionsforms/CN18ConditionsPlantAppProcessCategory3ABP050218.pdf
[10] http://www.irishstatutebook.ie/eli/1996/act/10/enacted/en/html
[11] https://www.nwcpo.ie

6.7 Connections to utility networks

The connection of power generation equipment to the national electricity network, the export of electricity to the network, and the export of biomethane to the national gas network, requires agreements with the respective network management organisations, for electricity connections, this is ESB Networks at a voltage at 38 kV or less. Gas Networks Ireland are the operators of the national gas network and should be contacted for prospective biomethane export.

6.8 Sustainability

Sustainability, in simple terms, can be described as operating in a manner that protects or improves the outcome for the environment, economy and society. The main goal of climate policy is to reduce the absolute level of greenhouse gas emissions. Therefore, technologies that can be classified as renewable energy producers must be shown to avoid significant amounts of greenhouse gas emissions, and the policies that support them must show a reduction in emissions compared to what would have occurred in other likely scenarios. However, not all actions that at first seem positive for sustainability may prove beneficial. Careful consideration of the sustainability impacts is required in policy making and at individual site levels.

Farming and farming practices affect sustainability in both positive and negative ways. Farming is a large part of the rural economy, but in Ireland the agriculture sector is responsible for a significant portion of the country's greenhouse gas emissions. The use of AD has the potential to improve the environmental performance of farming if the policies are designed and implemented to ensure it does not lead to an increase in activities that are environmentally damaging. If adhering to a policy means having to increase the use of fertiliser, for instance, then the overall sustainability impact of the process would be compromised.

The EU Renewable Energy Directive (EU Directive 2009/28/EC)[12] set targets for renewable energy use in Member States in 2020, including specific targets for the transport sector. In order ensure that the biofuels used to meet the targets are produced sustainably, it also set sustainability criteria for liquid and gaseous biofuels used in the transport sector. These criteria included greenhouse gas savings compared to conventional transport fuels which the biofuel must achieve, and the type of land that feedstocks could be produced on. This is to ensure that production on areas of high biodiversity, or high carbon stock such as peatlands, is avoided. The targets were extended to 2030 in the recast Renewable Energy Directive 2018/2001/EU. From 1 January 2021, the sustainability criteria for greenhouse gas savings to electricity; heating and cooling produced from solid and gaseous biomass comes into effect.

The EU set legislation to safeguard against unsustainable supply chain operations. This includes:
- Mandatory criteria on land use, forest management and greenhouse gas emissions savings;
- Sustainability requirements for solid and gaseous biomass in installations of a certain size; and
- Sustainability requirements for liquid biofuels.

What is a sustainable biomass fuel?

The sustainability of biomass fuels is typically assessed against environmental, economic and social criteria. To be sustainable, a biomass fuel should:

- **Save large amounts of greenhouse gas emissions when compared alongside fossil fuel alternatives; and**
- **Avoid negatively affecting land use, food security, water resources, biodiversity and livelihoods.**

SEAI have assessed the sustainability of biomass, including biogas (see Reference 3 in Section 7.1).[13] [14] These compare the sustainability of a number of AD facilities and show the importance of feedstock selection and digestate management options on sustainability. Sustainability is likely to be an important factor that permitting authorities will consider when approving AD facility designs.

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[12] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive
[13] https://www.seai.ie/technologies/bioenergy/sustainability-criteria-o/
[14] https://www.seai.ie/technologies/bioenergy/biomass-in-ireland/

6.8.1 Manures and slurries

Ireland's agricultural base is dominated by grassland and livestock (for meat and dairy products). This generates large quantities of manures and slurries. As outdoor grazing is the dominant farming method in Ireland, much of the manure produced is dropped by animals in the fields and is therefore not available for AD. Emissions from this source are largely unavoidable but, as this manure is deposited in small amounts and is exposed to oxygen, it becomes aerobic, which inhibits methanogenesis and consequently produces far less methane (CH_4) than stored manures. Emissions of ammonia (NH_3) are still significant.

Conventional open slurry tank storage leads to significant fugitive emissions of CH_4 and NH_3. The material still contains some potential to biodegrade and the large bulk of the slurry pit keeps the manure anaerobic so that conditions for methanogenesis are ideal. The storage of slurries and manures in closed vessels and prompt processing through an AD process results in the controlled degradation of the biodegradable content of the material. The digestate, having passed through the AD, contains little remaining biodegradable material and so produces much less biogas when stored. Storage of digestate in enclosed tanks allows for this to be recovered. Consequently, the prompt AD of slurries and manures results in a significant reduction in these emissions and effectively captures the CH_4 as a renewable energy source.

6.8.2 Sustainability for grass silage and energy crops

Manures and slurries are not feedstocks that generate high biogas yields, and it may be beneficial from an AD design perspective to add a crop such as grass silage which has a high biogas yield. However, careful consideration needs to be given to the impact that this may have on sustainability. Switching from grassland as an animal fodder crop to an energy crop, such as grass silage, would be a significant change in the use of agricultural land.

As discussed above, cutting greenhouse gas emissions in line with the recast Renewable Energy Directive, will mean using biomethane for transport and electricity, and large biogas plants for heating. The use of agricultural inputs such as nitrogenous fertilisers to produce grass silage and other energy crops, means that biogas produced from these footprints has higher greenhouse gas emissions associated with it than biogas produced from manures and slurries. Greenhouse gas savings from the use of this biogas are therefore reduced. The recent SEAI report on sustainability (see Section 7.1, Reference 3) indicates that an AD facility using only grass silage as a feedstock or co-digesting a high proportion of grass silage with manure, may not meet the greenhouse gas savings thresholds required by the Renewable Energy Directive, unless a low input silage production system (red clover grass) is used, and fugitive gas losses from the AD plant and digestate storage are minimised.

6.8.3 Digestate storage

Digestate storage is required when digestate application to land is prohibited (in the winter). Large covered storage tanks or lagoons should be used to prevent emissions to air from the stored digestate. Storage of digestate in open tanks is not best practice as stored digestate still generates some biogas and the fugitive emissions from open tanks are significant. However, if digestate is stored in enclosed tanks, the biogas can be recovered as part of the overall biogas yield. Therefore, the design of digestate storage is an important factor in reducing greenhouse gas emissions and AD plants should cover their digestate storage tanks.

6.9 Health and safety

Health and safety requirements at AD facilities will include special measures that take account of CH_4 and potentially toxic gases such as hydrogen sulphide and ammonia. Health and safety is also important during the construction of the AD facility and the associated requirements should be met by the main contractor.

Health and safety is regulated by the Health and Safety Authority. The principal legislation is the Safety and Welfare at Work Act 2005.[15]

Health and safety during operation and maintenance is discussed further in the accompanying Operation and Maintenance Guide, Section 3.

[15] Summary requirements for the client (owner) during the construction of an anaerobic digestion facility can be found at www.hsa.ie/eng/Your_Industry/Construction/Construction_Duty_Holders/Client

7. References and other sources of information

7.1 References to other additional resources

- The Anaerobic Digestion and Bioresources Association, 'The Practical Guide to AD'. Available at: http://adbioresources.org/library/purchase-the-practical-guide-to-ad/

- Composting and Anaerobic Digestion Association of Ireland, 'Guidelines for Anaerobic Digestion in Ireland', January 2018. Available at:http://www.cre.ie/web/wp-content/uploads/2018/03/Guidelines-for-Anaerobic-Digestion-in-Ireland_Final.pdf

- Irish Water, 'National Wastewater Sludge Management Plan'. Available at: https://www.water.ie/docs/Final-NWSMP.pdf

- SEAI, 'Sustainability Criteria Options and Impacts for Irish Resources'. Available at: https://www.seai.ie/technologies/bioenergy/sustainability-criteria-o/

- Statutory Instrument No. 605 of 2017, European Union 'Good Agricultural Practice for Protection of Water' Regulations 2017. Available at: http://www.irishstatutebook.ie/eli/2017/si/605/made/en/print

7.1.1 Environmental regulation

- Department of Agriculture, Food and the Marine: https://www.agriculture.gov.ie/

- Environmental Protection Agency: http://epa.ie/

7.1.2 Health and safety

- Health and Safety Authority: www.hsa.ie/eng/Legislation

Glossary

Anaerobic	Absence of free oxygen.
Anaerobic digestion (AD)	The process of anaerobic microbial degradation of organic matter to produce biogas.
Anaerobic digester	Vessel (tank, reactor) in which AD takes place. Sometimes referred to as a fermenter or bio-digester.
Animal by-product (ABP)	Animal carcasses, parts of animals, or other materials which come from animals but are not meant for humans to eat (includes catering waste).
Biogas	Mixture of methane and carbon dioxide produced by AD.
Biomethane	Methane product produced by separating methane from biogas.
Boiler	Equipment for heating hot water or producing steam.
By-product	Material of value co-produced with the main output from a process. In this context digestate is considered a by-product of AD.
Combined heat and power (CHP)	Combustion plant used to generate both electricity and usable heat.
Digestate	Anaerobic digester output of digested feedstock.
Whole digestate	Digestate from the anaerobic digester.
Liquid digestate	Liquor produced from dewatering of whole digestate.
Solid digestate	Solid digestate produced from dewatering of whole digestate. Sometimes referred to as cake or fibre fraction.
Dried digestate	Solid digestate that has been thermally dried to a low moisture content. Sometimes referred to as dried cake.
Facility	Refers to the whole integrated infrastructure associated with the AD process.
Feedstock	Organic materials suitable for and used in AD.
Energy crops	Crops such as grass and silage grown specifically for use as AD feedstock.
Food processing waste	Solid and liquid organic waste derived from food processing.
Gas engine	Reciprocating engine designed to run on a gaseous fuel, such as biogas or natural gas.
Kitchen waste	Waste food from home and catering establishments (may or may not include animal by-products).
Manure	Farm livestock manures and slurries.
Packaged waste	Packaged waste food and drinks.
Waste crops	Farm crops that are unsuitable for their intended uses and considered as a waste by the farms, for example, old unusable silage, root crops such as potatoes, carrots and parsnips, rejected by the food industry as unsuitable for human consumption.

Sustainable Energy Authority of Ireland
Three Park Place
Hatch Street Upper
Dublin 2
Ireland
D02 FX65

e info@seai.ie
w www.seai.ie
t +353 1 808 2100

@seai_ie