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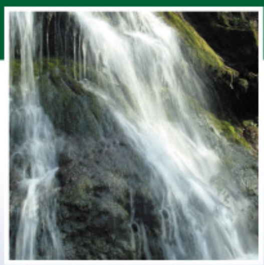

Chapter 9
Anaerobic Digestion

TIPPERARY INSTITUTE

NDP
NATIONAL DEVELOPMENT PLAN

EUROPEAN UNION
STRUCTURAL FUNDS

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9 Anaerobic Digestion

Clifford Guest, Tipperary Institute

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9.1 Objectives

Having completed this section of the training course and manual, learners should:

- Understand the theoretical background to anaerobic digestion.
- Be aware of the current usage of AD at Global, EU and Irish levels.
- Understand the basic process conditions for anaerobic digestion.
- Be able to perform basic sizing calculations.
- Be familiar with the profile of and potential for anaerobic digestion in Ireland.

9.2 Anaerobic Digestion - Background

9.2.1 What is Anaerobic Digestion?

Anaerobic digestion is a natural process during which bacteria breaks down the carbon in organic material. This process produces a mixture of methane and carbon dioxide, a mixture called biogas. The process occurs only in the absence of oxygen, hence the term "anaerobic" (literally meaning "without air"). Anaerobic digestion occurs naturally in the sediments at the bottom of lakes and ponds, in bogs and in the intestines of ruminant animals such as cows.

Figure 9.1 Farm Scale AD Plant
Figure 9.2 Centralised AD Plant
(Tipperary Institute)

This ability of bacteria to produce methane from organic material can be harnessed in specially constructed anaerobic digestion plants. At the core of these plants is the digester tank - an airtight tank in which digestion takes place. The digester takes in organic matter and produces biogas and digestate. The digestate consists principally of fibre and nutrient rich water. The digestate can be passed through a separator, which separates a fibre fraction from the liquid. The liquid fraction is a liquid fertiliser containing the valuable nutrients nitrogen, phosphorus and potassium, in a more plant available form than undigested slurry. The fibre can be composted to produce a high quality, nutrient rich soil conditioner, with similar properties to peat in horticultural products. The biogas can be used to produce heat only in a gas boiler, electricity and heat using an engine and generator or as an automobile fuel.

Thus, an anaerobic digestion plant has three main products; energy, liquid fertiliser and fibre for compost. Anaerobic digestion plants can be constructed to operate at any scale. On-farm digestion plants generally treat slurry arising on the farm and other co-substrates. Biogas may be burned in a boiler to supplement farm and home heating requirements or used in an engine for Combined Heat and Power (CHP). Large-scale anaerobic digesters to which organic matter from a variety of sources is brought are called “Joint Biogas Plants” or “Centralised Biogas Plants”. Biogas from such plants is generally passed through a CHP engine with electricity generated fed into the national grid, while heat is used locally, often in a district heating network.

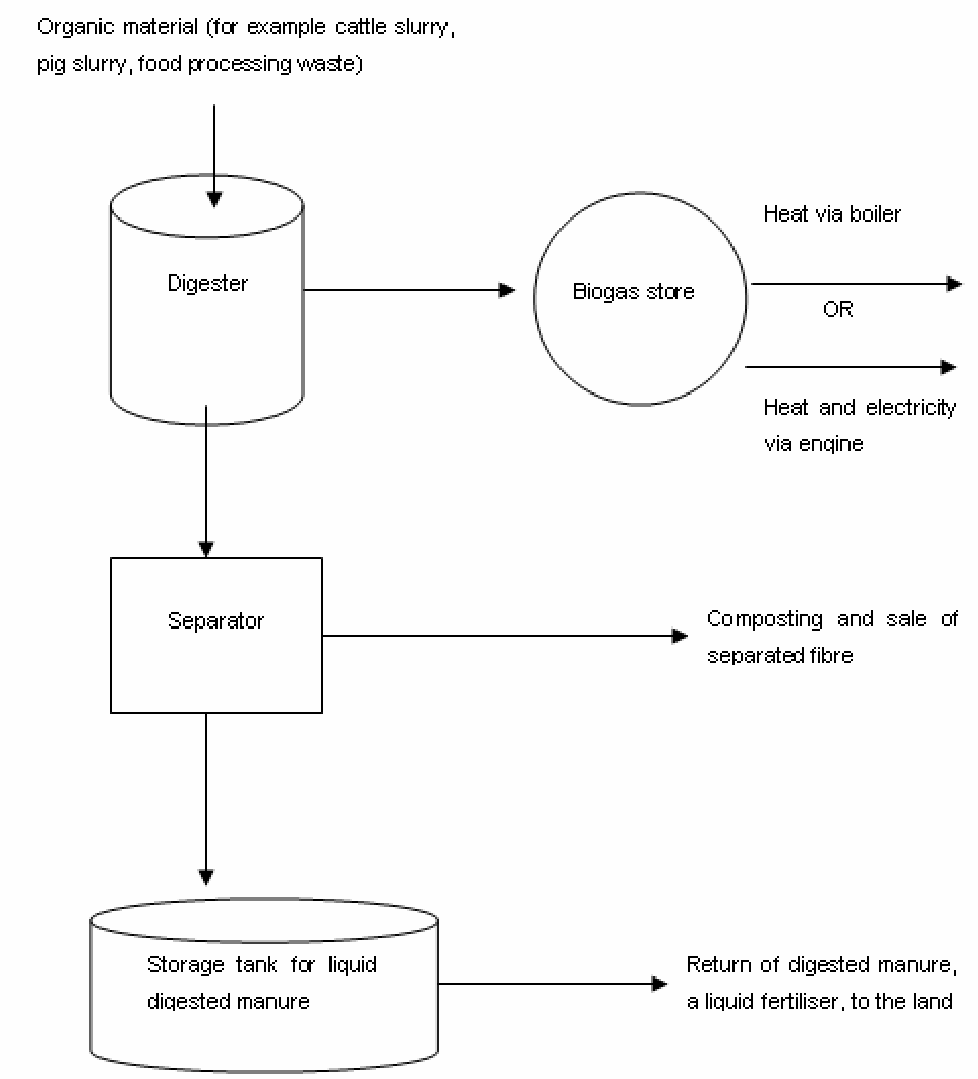

Figure 9.3 Basic Components of an AD Plant
(IrBEA, 2000)

9.2.2 Benefits of Anaerobic Digestion

There are many benefits associated with agricultural anaerobic digestion systems, these include;

The reduction of odour by as much as 80%. Compounds associated with offensive odours are degraded into methane and carbon dioxide by the anaerobic bacteria.

- The production of indigenous renewable energy and the reduction in green house gas emissions from fossil fuels.
- Reduction in pathogen levels and weed seeds due to the high operating temperatures. AD plants which fall under the EU animal by-products regulation (1774/2002) must be fitted with pasteurisation units operating at 70˚c for one hour.
- Improvement in the proportion of nutrients immediately available for plant uptake. During the digestion process nutrients are mineralised, thus the nitrogen that was tied up in the organic matter converts to the ammonium form.

9.2.3 Current Usage of AD, Globally and in the EU

Small biogas plants for human and other animal wastes are in widespread use in China and India. These plants are generally small in scale and of low cost design. Since the 1970s, China has been promoting the use of underground, individual household scale, anaerobic digesters to process rural organic wastes. There are approximately five million households using anaerobic digesters in China (Henderson, no date).

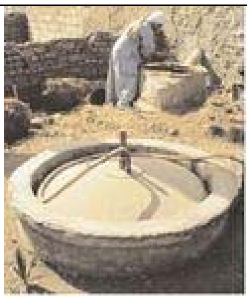

Figure 9.4 Small Scale Digester, India, (Wikipedia, 2006)
Figure 9.5 Small Scale Digester, China, (Wikipedia, 2006)

In Europe, a number of countries have taken a significant lead in the development of biogas plant. Among them are Denmark, Sweden and Germany.

9.2.3.1 Denmark:

The AD industry in Denmark has two distinct sectors, large scale centralised anaerobic digester plants (CAD) and more than 50 farm scale plants. It is in the area of CADs in particular that Denmark has become an international leader and has built up considerable expertise through targeted support programmes, information sharing, technical training and a commitment to ongoing research and development. There are now 22 CAD plants operating in Denmark (the largest number found in Europe) with digester capacities ranging from 540m^3 to 6,900m^3 and daily capacities ranging from 50-500 tonnes of biomass substrate per day (Hjort-Gregersen, K. 1999). Approximately 80% of the biomass to these plants is manure (mainly slurry) and this is co-digested with 20% organic waste made up of plant residue and agro-industrial waste. The biogas is mainly used for combined heat and power generation, with the heat generated being used locally for district heating.

The initial driver for AD in Denmark was the development of alternative energy in the context of the first oil crises in the 1970s. This saw an initial development programme for farm scale plants with the first plants built in 1975, while the first centralised anaerobic digester (CAD) was built in 1984 (NIRAS, 2000). In 1987, an action plan on developing centralised biogas plants was initiated, with a development and demonstration programme started and followed up with programmes that ensured that experience was collected and communicated to all those involved in the industry. All the plants received investment grants ranging from 30-40% in the late 1980s dropping to 20%. The focus is now on further economic improvements, which will enable new plants to be built without state aid. Other key areas for further development have been identified as; reduction in the cost of plants, improved operational reliability and improved plant control, achievement of higher gas yield per m^3 of feed stock and improved control systems and training of plant managers and personnel (Al Seadi, 2001).

9.2.3.2 Sweden

There are seven farm-scale plants in Sweden and 10 co-digestion plants. The biomass used at these CADs is mostly derived from source-separated municipal solid waste and organic waste from industry. Animal manure has to date been a minor fraction of the substrate. There is significant interest and experience in using biogas as a vehicle fuel in Sweden. In 2001 four of the ten co-digestion plants upgraded the biogas produced and used it as a vehicle fuel. In two of these plants (Uppsala and Linköping), vehicle fuel was the main form of gas utilization (WFE-net V, 2000). In addition, there were 24 locations throughout the south of Sweden where biogas was available in filling stations. At least 4000 vehicles are being operated on biogas including local authority buses. The upgrading of biogas to a standard where it can be used as a vehicle fuel is covered by Swedish quality specifications (Da Costa Gomez, C. 2006).

9.2.3.3 Germany

Germany currently has the highest number of farm-based biogas plants in Europe. The German Biogas Association estimates that there are approximately 2,700 farm based plants, 400 small and medium sized enterprises providing services to the sector and over 8,000 people employed in the biogas sector overall (Da Costa Gomez, C. 2006). A key reason why the biogas sector has grown so substantially in Germany is the generous “feed in” electricity tariffs. If the full technical energy potential from energy crops and agricultural residues was utilised, it is estimated that it would produce 430 Petajoules per year and around 33 Terawatt hours of electricity (Hartmann et al. 2002). Using these figures there is the potential for the employment of more than 100,000 people in the German biogas sector.

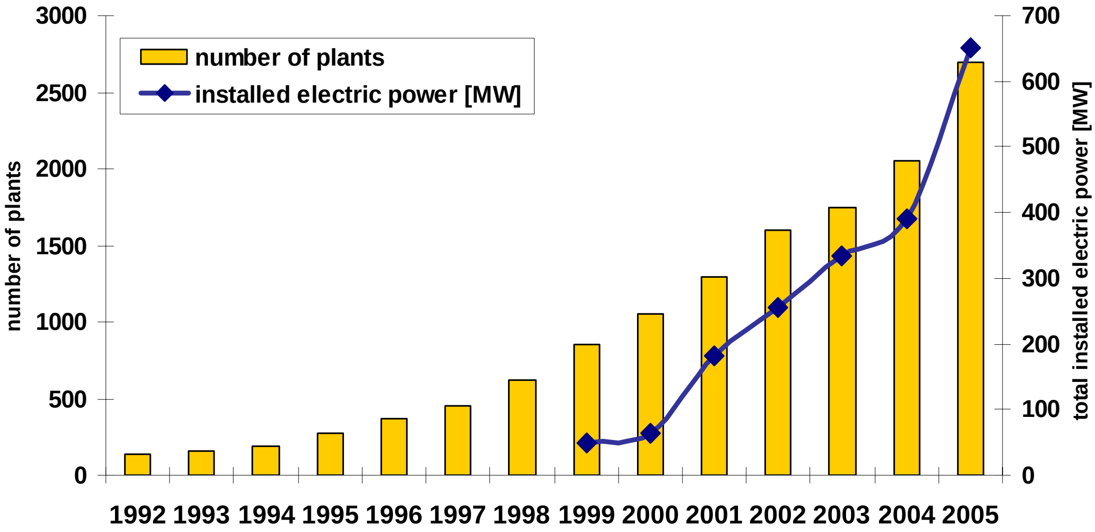

Figure 9.6 Biogas Plants in Germany and Installed Electrical Capacity (German Biogas Association, 2004a)

9.3 Anaerobic Digestion – Process Conditions

Operating Temperatures

There are three main temperatures ranges in which specific strains of bacteria are most active.

Psychrophilic (<30˚C): This is the lowest temperature range and is used in small, low cost plants found mainly in developing countries. Typically, surrounding ambient temperatures are relied on as the only heat source.

Mesophilic (30˚C-40˚C): This temperature range is favored by most farm-scale digesters, as it is less sensitive to changes in temperature and substrate. Mesophilic systems require retention times of 15-30 days.

Thermophilic (40˚C-55˚C): This higher temperature is favored by larger biogas plants where monitoring equipment and skilled operators are available. The active bacteria quickly break down the organic matter which means that shorter retention times and consequently smaller digester tanks are possible. These systems are more sensitive to changes and require a higher energy input and a greater degree of monitoring.

Retention Time

This is the time which the substrate remains inside the digester. The required retention time depends on the operating temperature. Psychrophilic temperature range requires the longest retention time while thermophilic requires the least.

Moist Conditions

Moisture content in the substrate of at least 50% is required by the bacteria (DGS, Ecofys 2005).

pH

The ideal pH level in a digester is 7.5. It is very important when adding additional biomass such as food waste that attention is given to maintaining the correct pH level.

Organic Load

The bacteria which break down the organic material in the substrate need a minimum organic load to survive. The organic load acts as a food but if too much organic material is put into the digester the bacteria can be overfed. The organic load should be between 0.5kg to 5kg organic matter per m^3 per day ($OM/m^3/day$).

Mixing

Mixing is necessary to maintain an even temperature gradient; to maintain a homogeneous and even supply of substrate to the bacteria; to prevent settlement of solids and to avoid crust formation. Biogas will only surface if there is less than 5% dry matter in the substrate.

Consistent Conditions

The bacteria in the digester do not react well to rapid changes in their environment. Input of fresh substrate should be done gradually, especially if it is of high organic load or at a pH level above or below the norm.

9.3.1 System Components

Digester Tanks

Digester tanks must be sealed in order for anaerobic digestion to take place. In most instances, digester tanks will be heated and mixed. If a digester is being heated, insulation is normally used to retain heat and improve efficiencies.

Horizontal Plug Flow Digester

Plug flow systems consist of long steel or concrete tanks where the substrate moves along as a plug. These systems are suitable for substrate with higher dry matter content (11%-13%). Horizontal digesters incorporate heating in the stirring device. These types of digesters tend to be used for smaller biogas plants. Their relatively low height can be an advantage if planning is an issue.

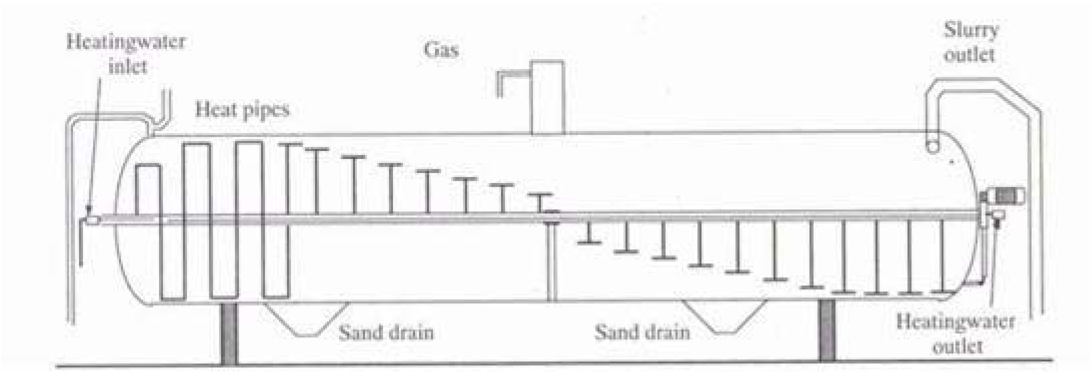

Figure 9.7 Horizontal Plug Flow Digester
(Biogaskontor, 1997)

Vertical Completely Mixed Digester

Consists of a large concrete or metal tank where fresh material is mixed with partially digested material. Heating can be through wall heating, with the heating pipes attached to the inside of the wall of the digester. In the case of metal digesters, heating pipes can be attached to the outside of the tank. Floor heat can also be used, but is not common due to the risk of a sediment layer building up on the bottom of the tank and reducing the effectiveness of the heating. These systems are suitable for substrate with lower dry matter content (4%-12%).

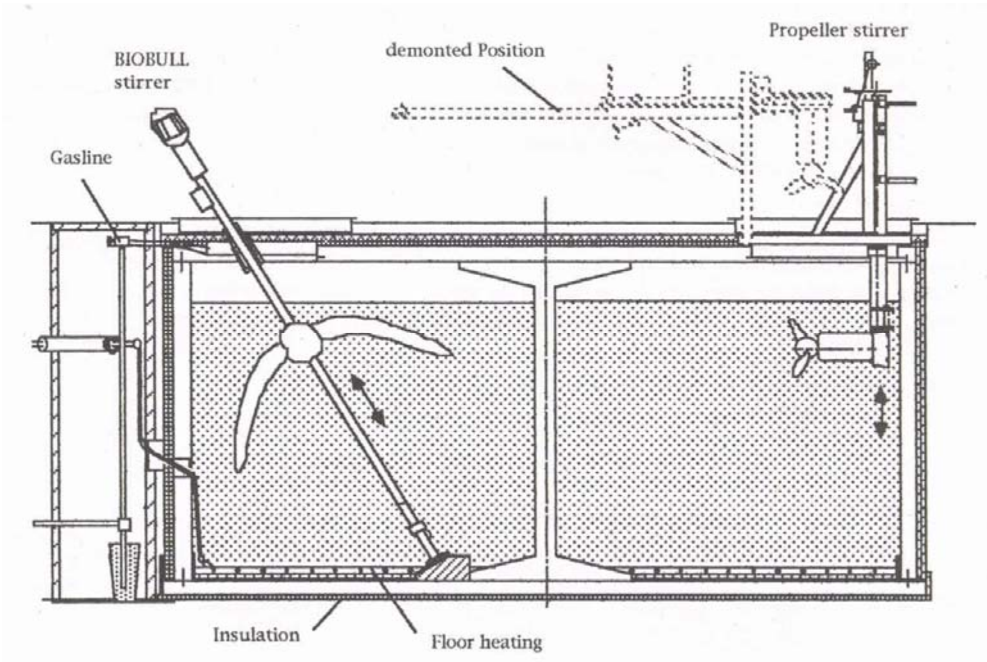

Figure 9.8 Vertical Completely Mixed Digester
(Biogaskontor, 1997)

Biogas Storage

Biogas produced in the digester can be stored either directly above the digester tank by means of a flexible foil (a membrane 1-2mm thick) which expands as biogas is produced or externally in a gas bag. Biogas tends to be stored at low pressure, which requires a larger volume than conventional gas storage cylinders.

The Boiler/Gas Engine

The most straightforward way to utilize biogas is to combust it in a gas boiler for heat. Alternatively, the biogas can be used to fuel an engine which drives an electrical generator. In this system, electricity is generated, and heat from the engine is also captured for utilization. A normal piston engine loses heat to the atmosphere via the exhaust system and engine cooling water. In a combined heat and power (CHP) configuration, the heat is recovered by means of heat exchangers, thus increasing the efficiency of the system. Producing electricity generally means better financial returns, as the price paid per unit of electricity is higher than that for a unit of heat. Engines suitable for biogas plants are four-stroke engines. These can be either gas engines or a duel fuel engine which starts on diesel then switches to a mix of 80%-90% biogas.

Mixing Systems

As previously stated, it is very important in the majority of systems that there is an efficient and easily maintained mixing system. There are a variety of options as detailed in the following Figure 9.9.

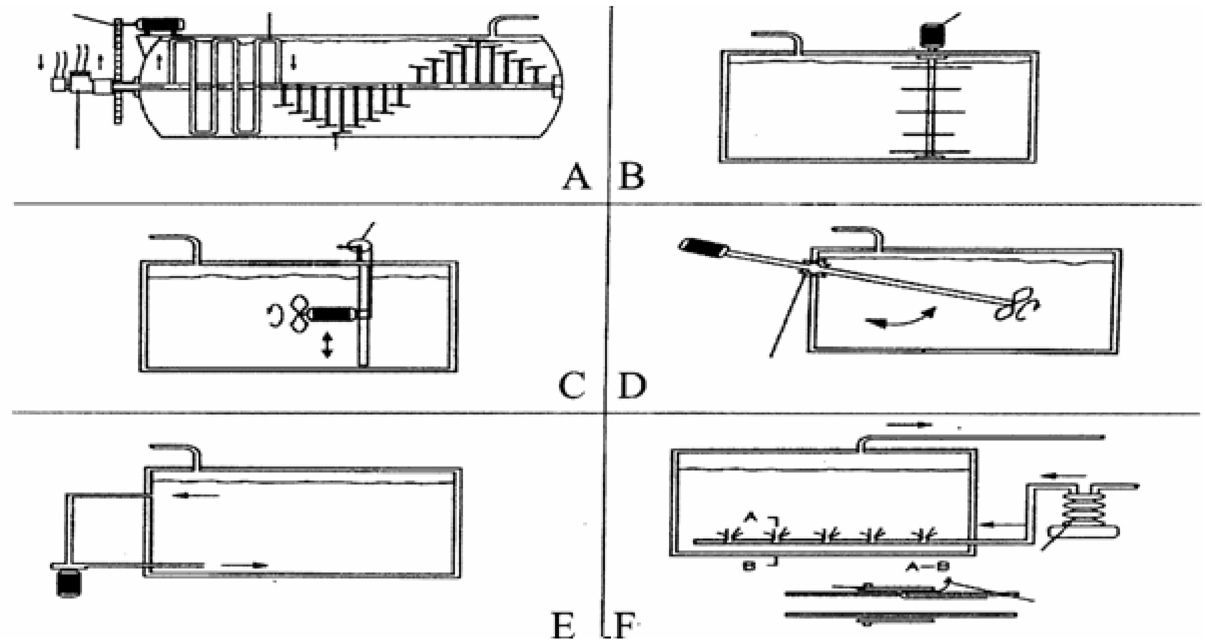

Figure 9.9 Different Types of Digesters and their Mixing Systems (German Biogas Association, 2004b)

A: Horizontal digester with horizontal paddle stirrer

B: Vertical digester with vertical paddle stirrer

C: Vertical digester with adjustable propeller stirrer

D: Vertical digester with propeller mixer on a swivel arm

E: Vertical digester with hydraulic mixing

F: Vertical gas mix digester

Post Digestion Tanks

When the substrate has been retained in the digester tank for the correct length of time it is transferred to a post-digestion tank or tanks. It remains in these tanks until it can be used. These tanks are normally covered to collect any additional biogas which may occur and also to avoid nitrogen losses.

9.3.2 Methane Potential of Different Substrates

Biogas plants based on farms usually use agricultural manures (from cattle, pigs or poultry) as the majority substrate(s) to be digested. These materials are well suited to digestion and have low to average biogas yields (c25m^3/t wet – 50m^3/t wet). Other substrates are often co-digested with animal manures to increase biogas yields and in some instances to earn gate fees for waste organic material. In Germany and Austria, there is a growing trend of growing energy crops such as maize to co-digest with farm slurries. This is supported with favourable additional tariffs given per unit of electricity produced. Table 9.1 below which has been adapted from DGS and Ecofys, (2005) gives the characteristics of different substrates from animal manures and selected substrates.

Feedstock	Dry Matter DM (%)	Organic Matter (% of DM)	Biogas Yield (m3/t ODM)	Biogas Yield (m3/t wet)	Average Biogas Yield (m3/t wet)
Cow Manure	7-15	65-85	200-400	9-51	25
Pig Manure	3-13	65-85	350-550	7-61	27
Chicken Manure	10-20	70-80	350-550	24-88	51
Vegetable Waste	10-20	65-85	400-700	25-120	75
Maize Silage	15-40	75-95	500-900	55-340	200
Grass Silage	30-50	80-90	500-700	120-315	220
Fat and Flotation Slurry	8-50	70-90	600-1300	30-585	310

Table 9.1 Characteristics of Different Substrates for Biogas Production (Adapted from DGS and Ecofys, 2005), Reproduced by kind permission.

9.3.3 Types of Biogas Plants

Small Scale Plants: These plants are used for small quantities of substrates (5-100m^3) and are found most frequently in Asia where they are designed without insulation, heating or stirring facilities. Small scale systems are not common in Europe.

Farm Based Plants: These plants are usually designed for one farm's manure or for the manure from a number of nearby farms. Frequently, co-digestion of additional substrates is carried out in order to increase biogas yield and/or gain gate fees. Where electricity is being produced, it is frequently exported to the grid, while heat is used as a replacement for traditional heat requirements of the farm. Farm based digesters can vary greatly in scale, most would have a capacity of between 100-800m^3.

Centralised or Joint Plants: These plants are large in scale and use agricultural manures from a number of farms as their main substrate. They also use additional substrates from various sources for co-digestion. Capacity would tend to be above 800m^3. Digested manure is often transferred to de-centralised tanks which allow for easier handling for land application. Ownership will often involve the group of farmers supplying the farm manures. Denmark has a considerable number of these centralised or joint plants.

Industrial Plants: These plants are normally large in scale (above 800m^3). They are unlikely to operate on a majority of farm manure instead they would be designed to handle waste from a particular industry, for instance, wet organic wastes such as waste water from their own processes, organic waste from food processing, or the separated organic fraction of municipal solid waste.

9.3.4 Sizing Calculations

Sizing a Biogas Plant

The following formula can be used to calculate the required size of a digester;

$$\text{Digester Volume } (m^3) = \frac{[\text{manure } (m^3/yr) + \text{co-substrate } (m^3/yr)]}{365} \times \text{Retention Time (Days)}$$

<u>Example</u>:

5000 m^3 of pig slurry and 1,000 m^3 of co-substrate are annually digested with a retention time of 28 days. The digester volume will need to be at least:

$$[(5000 + 1000) \div 365] \times 28 = \underline{460\ m^3}$$

Example 9.1 Calculating digester volume

Calculating Biogas Production per Annum

The biogas production from a particular material is determined by the dry matter content (DM), the organic fraction of the dry matter (OM/DM) and the biogas production per kg of OM. The following formula can be used to calculate the biogas production per annum.

$$\text{Biogas Production} = [\text{Manure (t/yr)} \times DM_{ps} \times \frac{OM_{ps}}{DM_{ps}} \text{ biogas/kg } OM_{ps}) \times 1000] + (m^3/yr)$$

$$[\text{Co-substrate (t/yr)} \times DM_{cs} \times \frac{OM_{cs}}{DM_{cs}} \times (m^3 \text{ biogas/kg } OM_{cs}) \times 1000]$$

<u>Example</u>:

Assume pig slurry with a density of 1.0 t/m^3 has a DM of 8%, an OM/DM of 75% and a biogas yield of 0.45 m^3/kg OM. Assume organic waste (co-substrate) with a density of 0.8t/m^3)has a DM of 30%, an OM/DM of 70% and a biogas yield of 0.55 m^3/kg OM.

Note that the biomass resources are given in m^3 per year, but biogas production for a particular material is given on a per kilogram basis. The density data is used to deal with this.

Biogas production (m^3/yr) = [(5000 X 1) (t manure/yr) x 8% x 75% x 0.45 x 1000] + [(1000 x 0.8) (t waste/yr) x 30% x 70% x 0.55 x 1000]

= 135,000 + 92,400

= 227,400 m^3/yr

Example 9.2 Calculating biogas production per annum

Calculating the Size of a CHP plant

The following formula may be used to estimate the size of the CHP plant to be installed;

$$\text{CHP Capacity} = \frac{\text{Biogas production } (m^3/yr) \times \text{calorific value of biogas in kWh per } Nm^3}{\text{Operational full load hours } (h/yr) \times \text{Electrical efficiency}} \ (kWe)$$

Example:

An average value for the calorific value of biogas is 20 MJ/Nm^3 ("normal" cubic metre), equal to 5.56 kWh/Nm^3. As a rule of thumb, an electrical efficiency of 30% is used. For CHP units bigger than 50 kW_e, the efficiency may increase; for CHP units smaller than 30kW, it may decrease. If the CHP unit is used full-time, the number of operational hours will be around 7,500 per year (20.55 hours per day).

5,000 m^3 of pig slurry and 1,000 m^3 of co-substrate are digested annually and produce 227,400 m^3/yr. The CHP unit required is;

$$\frac{227{,}400 \times 5.56 \times 30\%}{7{,}500} = 50.6\ kW_e$$

Example 9.3 Calculating size of CHP Plant

The above formulae and examples are adapted from DGS & Ecofys, 2005 by kind permission.

9.4 National Potential

In theory, very large amounts of digestible material are available in Ireland. However, all these resources have competing uses. The important analysis is that of estimating what proportions of these materials are likely to go to the AD process. Cattle spend on average 16-20 weeks indoors during the winter, meaning that some 30-40% of cattle slurry is stored and therefore available for AD (EPA, 2005). Not having a year round supply of feedstock is an obvious hindrance to the development of a year round enterprise such as an AD plant. This may mean that intensive sectors such as the poultry, and in particular, the pig sector may be in a stronger position to develop co-digestion AD plants. The map in Figure 9.10 contains estimated stored cattle slurry and the location of EPA licensed sites engaged in intensive agriculture and food/beverage processing. For these wet agricultural residues, management is normally by means of land spreading. With the Nitrates Directive, there is an increased emphasis on nutrient management planning, particularly for pig and poultry. Due to the Landfill Directive, the organic fraction of municipal solid waste going to landfill has been substantially reduced. While a considerable amount of this material is now being composted, it could also find its way to AD plants. Food and catering residues are generally considered wastes and are also readily available as inputs into AD, as is sewage sludge.

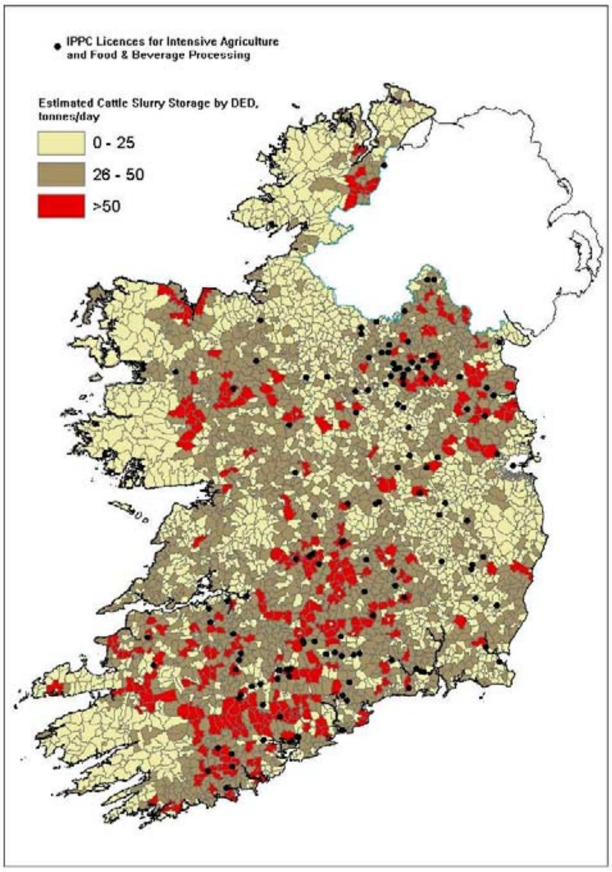

Figure 9.10 Cattle Slurry & EPA Licensed Agriculture and Food Processing Sites (EPA, 2005)

9.5 National Installed Capacity

Although there is considerable potential for the utilisation of animal and green wastes for the production of biogas in Ireland, the development of AD at the single farm or centralised level is significantly behind many of the leading EU states. Four on-farm biogas plants have been developed in recent years and are detailed in table 9.2 below. These plants have developed independently and for different reasons. They have not benefited from a national AD development support programme or national strategy. Anaerobic digestion is used in a growing number of Irish waste water treatment plants (approximately eight), and is also used on an intensive duck farm and a number of industrial plants.

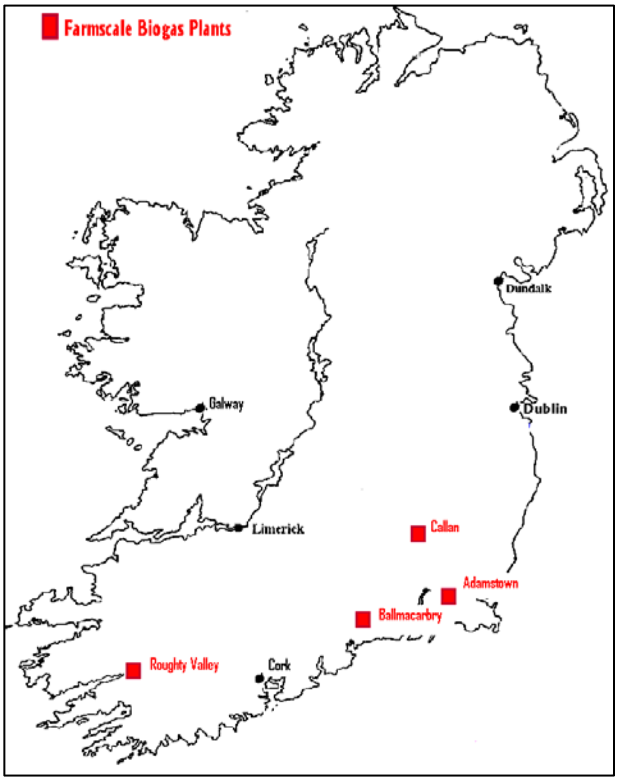

Figure 9.11 Location of Irish On-Farm Biogas Plants

Location	Year Built	Digester Size	Feedstock	Energy Utilisation
Adamstown, Co. Wexford	1995	300m^3	Cow slurry, Kitchen waste, Grease trap waste	Hot water for cheese production plant. 100kWe CHP plant installed
Ballymacarbry, Co. Waterford	1996	2 digesters of 72 m^3	Cow and pig slurry, farm yard manure, chicken litter, organic sludges	Digester and domestic gas boiler
Callan, Co. Kilkenny	1999	150 m^3 and 450 m^3	Cow slurry and organic wastes	Two 85kW$_{th}$ boilers & one 200kW$_{th}$ providing heat to a community district heating system
Roughty Valley, Co. Kerry	2003	1,350 m^3	Pig slurry	Heat for pig houses. 100kWe CHP plant installed

Table 9.2 Irish On-Farm Biogas Plants
(Da Costa Gomez and Guest, 2004)

9.6 Barriers to Adoption

Technical barriers to the development of AD in Ireland include; the seasonal availability of cattle manure; the complex legislation and restrictions of using many organic substrates identified as waste and animal by-products; the lack of familiarity with the technology; the limited number of working examples to create confidence in the sector; high capital costs; low prices offered for electricity produced; high cost of gaining access to the grid; lack of internalisation of wider environmental benefits; the difficulty in accessing project finance and the lack of an integrated public support framework (EPA, 2005).

9.7 Relevant Policy and Legislation

9.7.1 Policy

National Climate Change Strategy Ireland (2000); Anaerobic digestion is mentioned specifically in the agriculture chapter of the strategy. Under the heading "Animal Waste", the following is stated;

> "*The use of anaerobic digesters with energy recovery will be integrated with measures to promote renewable energy…. There are a number of technical and financial barriers to the extensive use of anaerobic digesters, and in the implementation of the strategy, these will be explored by the relevant Government Departments with interests in promoting bioenergy production in order to remove any unnecessary obstacles to the deployment of the technology at farm and community level.*" (Department of the Environment and Local Government, 2000, p65).

Green Paper towards a Sustainable Energy Future for Ireland (2006);

The Green Paper, while not specifically setting targets for anaerobic digestion, has targets for renewable sources to supply 30 per cent of all electricity by 2020 and for biofuels to supply 5.5 per cent of transport demand by 2010. It states;

"The potential of biomass is significant in Ireland. The advantages of biomass as a contributor to electricity generation is that it is indigenous, renewable and fully dispatchable" (Department of Communications, Marine and Natural Resources, 2006, p72).

9.7.2 Legislation

Conditions for Treatment of Animal By-Products in Approved Composting or Biogas Plants in Ireland

The Department of Agriculture and Food published the third version of these conditions in December 2005. The document lays out the standards which must be adhered to for the approval and operation of a biogas plant treating animal by-products. It states;

"Regulation (EC) No. 1774/2002 of the European Parliament and of the Council of 3 October 2002 lays down health rules concerning animal by-products not intended for human consumption. This regulation defines animal by-products as 'entire bodies or parts of animals or products of animal origin…not intended for human consumption'. Under the Regulation a biogas plant is defined as 'a plant in which biological degradation of products of animal origin is undertaken under anaerobic conditions for the production and collection of biogas'…..Article 15 of Regulation (EC) No. 1774/2002 requires that biogas plants and composting plants shall be subject to veterinary approval by the competent authority."

A key feature of the animal by products legislation is that digestion residues from the processing of animal by-products can not be spread on pasture land. Further information available at;

http://www.compostireland.ie/docs/1205animalbyproducts_conditions.doc

Waste Permit/Licence

Under the above conditions, applicants seeking approval to treat animal by-products in biogas or composting plants under S.I. 248 of 2003 must also apply for a separate waste permit/licence from the local authority/EPA.

Planning Permission

The construction of a biogas plant will be subject to planning permission from the relevant local authority.

9.8 Government Supports

Scheme of Investment Aid for Demonstration On-Farm Waste Processing Facilities:

The scheme is designed to support the demonstration of new and emerging technologies to further assist the agriculture sector in meeting the requirements of the Nitrates Directive. The new Scheme will provide grant-aid for up to ten projects throughout the country which will demonstrate the advantages of new technologies, including anaerobic digestion, for the processing of livestock manure or mushroom compost. The maximum amount of investment eligible for grant-aid under the Scheme is €1 million per project. The rate of grant is 40%. Accordingly, the maximum grant payable in respect of any individual project can not exceed €400,000. The Scheme formed part of the National Development Plan 2000-2006 and the scheme closed for applications on 31 December 2006. Further information is available at; http://www.agriculture.gov.ie/schemes/OFI/FWM/PilotprocessingMay2006.doc

ReFIT

On the 1st of May 2006, the Irish Government launched the Renewable Energy Feed in Tariff (ReFIT) scheme which is operated under the Department of Communications Marine and Natural Resources. The programme will provide support of €119 million to renewable energy projects over a fifteen year period. The price set for the support of “other biomass” including anaerobic digestion is 7.2 eurocents per kWhr.

Further information is available at;

http://www.algoodbody.ie/energynaturalresourcesrefit/#4

LEADER

One of the Irish on-farm biogas plants (Camphill Community, Ballytobin, Callan) received grant aid from their local LEADER Company (Barrow-Nore-Suir Rural Development Ltd.).

9.9 *Financial Viability*

In a recent paper, the strategic policy unit of the EPA carried out an analysis on the financing of a centralised anaerobic digester in Ireland (EPA, 2005). The analysis was carried out with reference to detailed data on the operating costs and statistics of a number of centralised AD plants in Denmark. http://www.epa.ie/NewsCentre/ReportsPublications/DiscussionPapers/).

In this study, the following assumptions were made:

- Co-digestion with agricultural slurries with an assumed 80:20 ratio of agricultural and non-agricultural wastes.
- Biogas production yield assumed to be $40m^3$ per tonne.
- A price of €0.08/kWh for electricity produced.
- A gate fee of €60/tonne on non-agricultural wastes.
- Operating costs estimated at €15/tonne.
- A 5% interest rate and a 15 year investment period.
- Adjusted Net Present Value figure taking account a 50% capital grant.

Based on these assumptions, financial outcomes for three hypothetical AD plants are presented in Table 9.3 below.

AD Plant	Unit	A	B	C
Wastes Intake	tonne/day	187.5	312.5	500.0
- Agricultural (80%)	tonne/day	150.0	250.0	400.0
- Non-agricultural (20%)	tonne/day	37.5	62.5	100.0
Gas Production	tonne/day	2.74	4.56	7.30
Electricity Generation	Gigawatts	5.02	8.36	13.38
Non-Agricultural waste intake fees	€m	0.89	1.48	2.37
Electricity Revenue	€m	0.40	0.67	1.07
Operating Costs	€m	1.03	1.71	2.74
Plant Infrastructure Cost	€m	3.38	5.63	9.00
Tanker & Storage Cost	€m	0.56	0.94	1.50
Net Present Value (NPV)	€m	-1.80	-3.01	-4.81
NPV (inc. 50% grant on plant and storage)	€m	0.53	0.88	1.41

Table 9.3 Economic Analysis of Hypothetical Centralised AD Plants
(EPA , 2005)

9.10 Case Study – Filskov Centralised Biogas Plant

The Filskov centralised biogas plant in Denmark was built in 1995; it is a combined heat and power plant linked to a district heating system. It is owned and operated by a local co-operative energy company, made up of the heat consumers and slurry suppliers. The company collects the manure from the farms and also additional substrates. Digested manure is returned to the farmers and to three decentralised storage tanks. There are approximately 140 residential consumers for the heat and two large scale consumers (a school and nursing home). The electricity is sold to the national grid. In addition to the CHP plant, there is a wood chip boiler for additional heat. Agricultural manures come from 10 dairy farmers and 1 pig farmer with additional substrates coming from chicken, pig and cattle abattoirs.

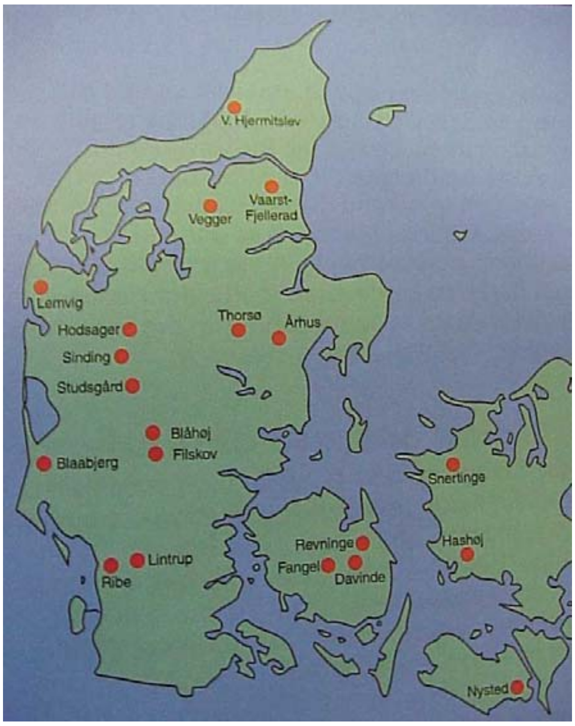

Figure 9.12 Location of Filskov Plant
(Danish Institute of Agricultural and Fisheries Economics, 1999)

Alternative biomass	18 tons/day
Digester capacity	2 x 440 m^3
Process Temperature	53C (Thermophilic)
Biomass Storage	3000m^3
Gas Storage Tank	100m^3
Utilisation of biogas	CHP plant/gas boiler
Electricity generation	375kWe
Av. transport distance	4 km
District heat customers	140
Electricity sale	National grid
Wood chip boiler	1000 kWth
Stand by gas & oil boiler	1600 kWth

Table 9.4 Technical Data - Filskov Biogas Plant
(Danish Institute of Agricultural and Fisheries Economics, 1999)

Figure 9.13 Filskov Centralised Biogas Plant
(NNR, No date)

Figure 9.14 Vacuum Tanker Collecting Fatty Waste
(Tipperary Institute)

	Details	1000 Danish Kroner	Euros *'06 exchange rate of 7.45745 used
Investments	Biogas Plant	9500	€ 1,273,894
	Vehicles	700	€ 93,866
	Storage Tanks	1000	€134,094
	Wood Chip Plant and District Heating System	12000	€ 1,609,129
	Total	23200	€ 3,110,983
Financing	Investment Grants	2500	€ 335,235
	Grants Ratio	11%	NA
	Indexed Loans	17700	€ 2,373,465
	Bank loans	3000	€ 402,282
	Total	23200	€ 3,110,983

Table 9.5 Financial Data, Filskov Biogas Plant
(Danish Institute of Agricultural and Fisheries Economics, 1999)

9.11 Sources of Further Information

AD Net: http://.adnett.org/index.html

University of Southern Denmark: http://websrv5.sdu.dk/bio/

IEA Biogas: http://www.iea-biogas.net/

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