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Developing Anaerobic Digestion Cooperatives in Ireland

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Masters of Science in Energy Management

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ABSTRACT

Anaerobic Digestion (AD) is a natural process of decomposition and decay that takes place in the absence of oxygen and by which organic matter is broken down to its simpler chemical components

AD plants could help Ireland meet its requirements under a number of EU Directives as landfills release far more greenhouse gas emissions than other forms of waste treatment. It is estimated that 37 million tonnes per year of animal manure are stored on farms before disposal. There are also 676,000 tonnes of municipal food and garden waste produced annually. This waste could be used in AD plants to produce electricity which would be considered to be a renewable technology. The objective of this study is to determine if cooperatives for anaerobic digestion (AD) could be developed. The study will address the feasibility of an anaerobic digestion cooperative using the following influencing factors: economical, financial, logistical, participation of farmers and local communities, sizing perspective, waste material required, assistance from government and related agencies and national and EU legal requirements. The impact anaerobic digestion plants could have on the rural domestic electricity network will be discussed. A model will be proposed addressing the above. There is no cooperative such as this in Ireland; therefore the ideas behind cooperatives for AD in Europe will be examined.

Declaration

I hereby certify that the material, which is submitted in this project is entirely my own work and has not been submitted for any other academic assessment other than as part fulfillment of the assessment procedures for the programme Masters of Science in Energy Management DT015.

SIGNATURE ____________________________

Aoife NÍ Ruanaigh

DATE 11/01/2011

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NOMENCLATURE

ABP – Animal By Products

AD - Anaerobic Digestion

AG – Attorney General

DAFF – Department of Agriculture, Fisheries and Food

DCMNR – Department of Communication, Marine and Natural Resources

DEHLG – Department of Environment, Heritage and Local Government

EA UK – Environmental agency UK

EC – European Commission

EIA – Energy Information Administration

EPA – Environmental Protection Agency

IEA – International Energy Agency

WCLA – Waterford County Local Authority

CHAPTER 1 INTRODUCTION

'A civilization built on renewable resources, such as the products of forestry and agriculture, is by this fact alone superior to one built on non-renewable resources, such as oil, coal, metal, etc. This is because the former can last, while the latter cannot last. The former co-operates with nature, while the latter robs nature. The former bears the sign of life, while the latter bears the sign of death'
E. F. Schumacher 1911-1977

The aim of this chapter is to provide an overview of the background behind the title. The aims will be set out, the methodology and a summary of chapters will be provided.

1.1 BACKGROUND

The aim of this study is to develop a plan for AD cooperatives in Ireland. Anaerobic Digestion is a natural process of decomposition and decay that takes place in the absence of oxygen and by which organic matter is broken down to its simpler chemical components i.e. biogas. AD plants can be on farm or can be centralised. This study will propose centralised AD plants using a cooperative model. AD plants will reduce our greenhouse gas emissions and also enable farmers to produce electricity from a renewable resource. AD plants are an accepted renewable energy technology throughout Europe. The government supports anaerobic digestion through various incentives and national programmes; these will be discussed in detail. Legislative requirements must be addressed before an AD cooperative could be considered and these will be discussed below. The cooperative model will enable farmers and communities to become sustainable and to generate an extra income. If the plant is large enough, they should generate enough electricity for their own community. If there was surplus, it could be sold to the electricity pool. Anaerobic digestion plants will help facilitate Ireland meeting the landfill directive targets and the recently set renewable energy targets.

1.2 Objectives

- Establish the feasibility of an anaerobic digestion cooperative using the following influencing factors:
    - Economically
    - Financially
    - Logistically
    - Farmer and local community participation
    - Sizing perspective
    - Waste material required
    - Assistance from government and related agencies
    - National and EU Legislation
- Analyse the energy requirements of rural areas and evaluate the impact an AD plant will have on the grid.
- Implement a model
- Critically review the research and model.

1.3 Methodology

This research was undertaken in a professional and ethical manner. The majority of the data was obtained online. Specialists in the field were contacted. A site visit was undertaken to the AFBI plant in Northern Ireland. It had been intended to visit the Ballyshannon plant but this did not happen. A survey was conducted using the online forum Survey Monkey. The survey was circulated among acquaintances with agricultural contacts.

1.4 Chapter Summary

Chapter 1 provides an introduction to the topic. Chapter 2 provides a detailed review of the literature surrounding anaerobic digestion and anaerobic digestion cooperatives. It includes the AD process, legislation, the cooperative model, case studies, economics and government assistance. Chapter 3 contains the proposed model for an anaerobic digestion cooperative. Chapter 4 contains a discussion and review of the literature and the proposed model. Chapter 5 contains the conclusion.

CHAPTER 2 LITERATURE REVIEW

This chapter explores the process of the anaerobic digestion under numerous headings. Section 2.1 focuses on the anaerobic digestion process and describes the complexity of the system. Section 2.2 sets out the legislative requirements. Section 2.3 to section 2.6 focuses on the availability of raw processing materials, the resultant energy produced, cooperatives are discussed and finally case studies are explored. Section 2.7 discusses the potential of anaerobic digestion in Ireland and the potential slurry that would be available. Section 2.8 provides an overview of commercial interest and finally section 2.9 discusses the economics.

2.1 ANAEROBIC DIGESTION

This section explains the anaerobic digestion process. It examines the temperatures at which anaerobic digestion is carried out. It provides an outline of how an anaerobic digestion plant would fit in on a farm. The aim of this section is to explain what anaerobic digestion is and how it works.

Anaerobic digestion is a natural process of decomposition and decay that takes place in the absence of oxygen and by which organic matter is broken down to its simpler chemical components i.e. biogas. It is mostly a mixture of methane, carbon dioxide and water vapour.

The following are the four 4 steps involved in anaerobic digestion (AD)

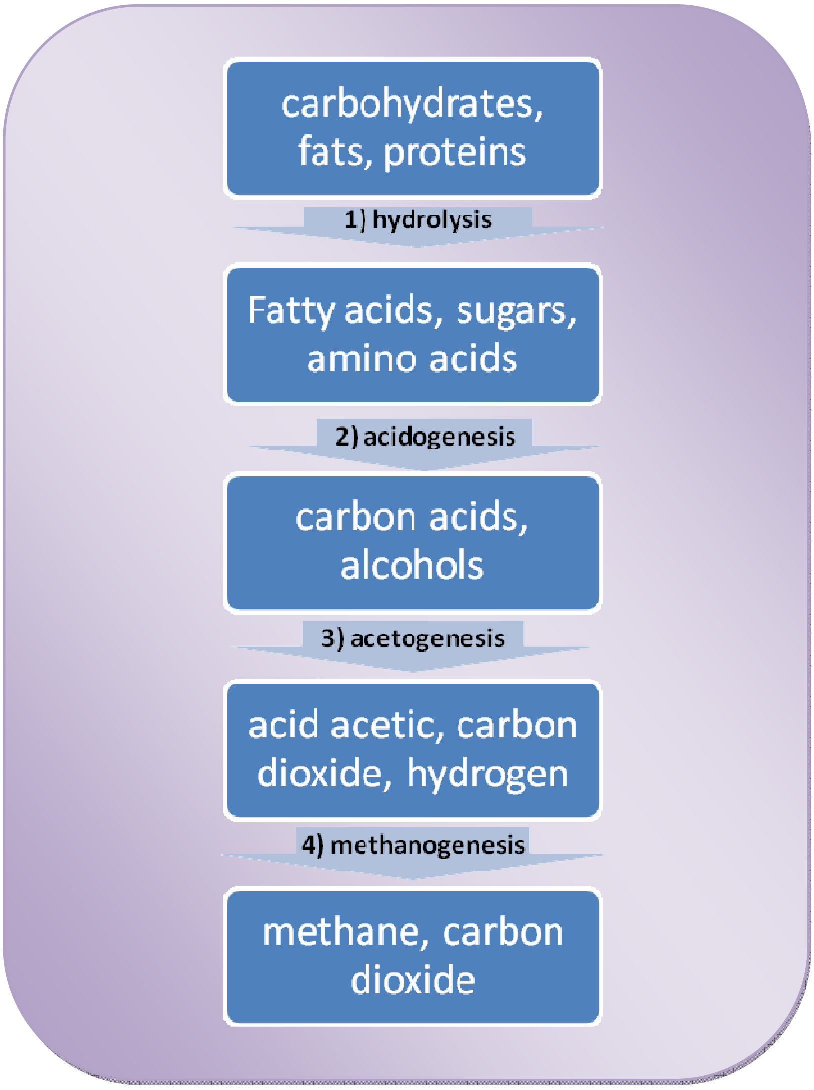


FIGURE 1.

1. Hydrolysis: Organic matter is decomposed into smaller units
2. Acidogenesis: the smaller decomposed units are converted into methanogenic substrates
3. Acetogenesis: Carbon chains are oxidised into acetate, carbon dioxide and hydrogen.
4. Methanogenesis: During this stage, hydrogen is converted into methane. 70% of the methane originates from acetate, 30% is produced from conversion of hydrogen and carbon dioxide according to the following chemical equation:

Methanogenic bacteria

Acetic acid ⟶ methane + carbon dioxide

Methanogenic bacteria

Hydrogen + carbon dioxide ⟶ methane + water

The last step is a critical step in the AD process as it is the slowest biochemical reaction of the process. It is heavily influenced by operating conditions such as feedstock composition, feeding rate, temperature and ph level. Methane will not be produced if the digester is overloaded, if there are temperature changes or if there is a large entry of oxygen.

Anaerobic Digestion takes place at 3 different temperatures:

Name	**Temperature (°C)**	**Minimum retention time (days)**
Psychrophilic	< 20	70 – 80
Mesophilic	30 – 40	30 – 40
Thermophilic	43 – 55	15 – 20

Table 1.

According to the Denmark biogas handbook (Teodorita Al Seadi and Silke Volk, 2008) the thermophilic temperature is the most popular in Denmark as it has more advantages over the other two. However the literature indicates that mesophilic temperature is the most popular outside of Denmark. The most significant advantage of the thermophilic temperature range is the lower retention time which is the length of time the feedstock spends in the digester. However the thermophilic temperature range requires more input energy. The report states that thermophilic plants have a higher gas yield.

Several pieces of literature have shown that thermophilic AD is better than mesophilic AD for co- digestion. Codigestion is when manure is processed in the anaerobic digester with another material. Denmark favours thermophilic AD with a retention time of 11-22 days. No one piece of literature really compares different feedstocks biogas yields at thermophilic and mesophilic ranges. According to a study carried out by Cavinato et al, (Cavinato et al., 2009) the biogas yield for thermophilic range has a 15% increase compared to the mesophilic range. Vindis et al (P. Vindis, 2009) compared mesophilic and thermophilic AD using 3 different maize varieties. Vindis et al discovered that biogas yield for mesophilic ranged from 315-409Nl kg VS^{-1} and biogas yield for thermophilic AD ranged from 494-611 Nl kg VS^{-1}. Vindis also states that the biogas quality produced in thermophilic temperature range is better than biogas quality produced in mesophilic ranges and has a higher biogas yield. It was shown that Municipal Solid Waste (MSW) at a thermophilic range produced 2 to 3 times the gas compared to the mesophilic range (Cecchi et al., 1991)

Mackie et all (Mackie and Bryant, 1995) compared the gas production of manure in mesophilic and thermophilic ranges. The following table shows their results:

Loading rate (gVS^{-1} reactor volume per day)	**Total gas production Mesophilic (1day $^{-1}$)**	**Total gas production Thermophilic (1day $^{-1}$)**
3	3.18	3.60
6	5.58	6.67
9	6.45	9.74
12	7.22	11.68

Table 2.

As previously stated methane will not be produced if there is a temperature change. Thermophilic digesters can sustain a +/- 1°C change, mesophilic digesters can sustain a +/-3°C change (Teodorita Al Seadi and Silke Volk, 2008)

The following picture depicts how an anaerobic digester would be situated on a farm (2005)

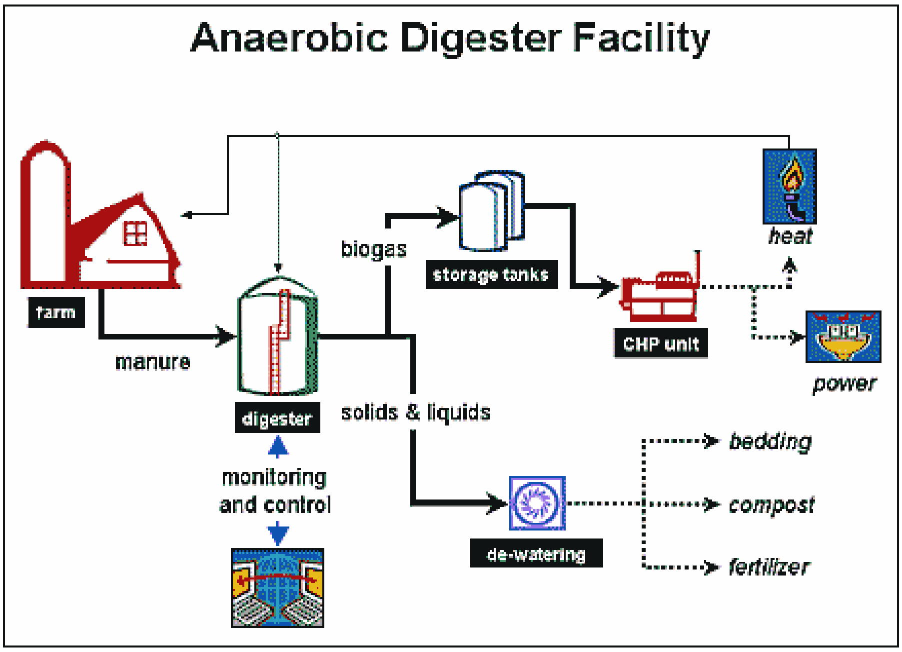


FIGURE 2.

Process:

1. Manure is collected in a pre storage tank, close to the digester and can be pumped into the digester. The digester is a gas tight tank made of steel or concrete, with draw off points for the biogas. It is insulated to maintain the necessary constant temperature. A heating system is used to maintain optimum temperature. The digester is heated by circulating hot water through a heating exchanger located in or outside of the digester. The hot water is produced by a biogas boiler or a CHP unit.
2. Biogas is produced from the methane and can be used in a combined heat and power (CHP) unit for electricity and heat production. The biogas is stored in the biogas storage tanks.
3. The solids and liquids are called effluent and are stored in digester tanks. The digester contains a stirring system which is responsible for mixing and homogenising the substrate and it also minimises the risk of swimming layers and sediment formation. There would also be a method for loading and unloading digestate.

4. The liquid digestate can be spread on land as a fertiliser. The solid digester can be used to spread on land as a fertiliser but can also be processed further and sold as a compost

The following picture indicates the area required for an AD plant. This one is in Nysted, Denmark and processes 227m³ per day and 35 farmers are involved in the plant(Hjort-Gregersen, 1999).

FIGURE 3.

In summary anaerobic digestion is a natural occurring process. It involves a four step process that can be undertaken at 3 temperatures. Manure and other materials are placed in a tank for 15 – 30 days. As the material is broken down a biogas is produced which is utilised for energy production. A digester effluent is also produced and this is stored in digester tanks.

2.2 LEGISLATION

This section describes the legislation that would impact anaerobic digestion and it also describes the legislation that could be impacted due to anaerobic digestion. One of the difficulties with implementing an anaerobic digestion cooperative is the extent of legislation that must be followed and as the legislation forms the basis of the concept, it will be discussed in detail. The aim of this section is to examine the EU Directives and National laws that need to be considered.

2.2.1 NITRATES DIRECTIVE: DIRECTIVE 91/676/EEC CONCERNING THE PROTECTION OF WATERS AGAINST POLLUTION CAUSED BY NITRATES FROM AGRICULTURAL SOURCES (EC, 1991)

The aim of this directive is to reduce water pollution caused or induced by agricultural sources and to prevent further such pollution. Article 3.2 specifies that Member States shall designate all known areas of land in their territories which drain into the waters as vulnerable zones. Member States were required to notify the Commission of initial designation within 6 months and may revise or add to the designation of vulnerable zones at least every 4 years. Member States do not have to designate vulnerable zones if they establish and apply an action programme to the entire territory, as per article 5(2).

Article 4 requires Member States to establish codes of good agricultural practice which should be implemented voluntarily by farmers. The Directive contains recommended provisions regarding the codes of good agricultural practice. Examples of these provisions are (a) periods when land application of fertiliser is inappropriate and (b) capacity and construction of storage vessels for livestock manures (Annex IIA). It is also recommended that a training and information programme is set up for farmers; this links in with the education principle of a cooperative, which will be discussed in detail further on.

Article 5.1 specifies that each Member State must establish an action programme regarding designated vulnerable zones. Action programmes must take the following into account:

(a) Available scientific and technical data, with reference to respective nitrogen contributions originating from agricultural sources.

(b) Environmental conditions in the relevant regions of the Member State concerned.

As previously stated Member States do not have to designate vulnerable zones if they apply the action programme to the entire territory. According to a report, from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources for the period 2004-2007, ten Member States applied Article 5(2) including Ireland.

Article 5.4 states that the action programme must be implemented within 4 years of its establishment and must consist of a number of mandatory measures. These measures include rules relating to periods when applying certain types of fertiliser to land is prohibited, rules relating to the capacity of storage vessels for livestock manure and rules around the limitation of land application of fertilisers which must take into account soil conditions, climate conditions, rainfall and the foreseeable nitrogen requirements of the crops. Nitrogen helps crops and plants to grow but high concentrations of nitrogen are harmful to humans and the environment. The main measure that must be observed is that the amount of livestock manure applied to the land each year, including the animals themselves, shall not exceed 170kg of nitrogen per hectare. Member States may apply for derogation on this amount if certain criteria are met such as long growing seasons and crops with high nitrogen uptake. The action programme must also contain measures around the codes of good agricultural practice established in Article 4.

In 2006 Ireland submitted a request to allow the application of 250kg nitrogen per hectare per year on farms which comprise of at least 80% grassland. The Commission agreed in Article 5(1) (EC, 2007) that 'the amount of livestock manure from grazing livestock applied to the land each year on grassland farms, including by the animals themselves, shall not exceed the 250 kg nitrogen/hectare, subject to certain conditions'. These conditions include each farm keeping and maintaining a fertilisation plan, analysing the nitrogen and phosphorus content of the soil every 4 years, and not spreading manure in the autumn before grass cultivation. One of the requirements of the fertilisation plan is to include the amount and type of manure delivered outside the farm or to the farm. This requirement would have an impact on the amount of paperwork a farm participating in an AD cooperative would have to complete if they were one of the farms under the 250kg/hectare. It is important to note that farmers must individually apply, annually, to the competent authority (i.e. The Department of Agriculture and Food, the relevant local authorities and the Environmental Protection Agency (EPA) are the competent authorities in Ireland for the purposes of implementing the action programme) for the 250kg/hectare allowance.

Article 5.6 requires Member States to design and implement monitoring programmes to gauge the success of the action programme.

2.2.1 (A) NATIONAL ACTION PROGRAMME UNDER THE NITRATES DIRECTIVE 28TH JULY 2005

Ireland's action programme under the Nitrates Directive is given statutory effect by the European Communities (Good Agricultural Practice for the Protection of Waters) Regulations 2009 (DEHLG, 2005)

The Nitrates Directive requires Member States to include rules relating to the following in their action programme:

- Periods when the land application of certain types of fertiliser is prohibited
- The capacity of storage vessels for livestock manure
- Limitations on the land application of fertilisers consistent with good agricultural practice
- Limits to the amount of manure applied per year per hectare; 170kg of nitrogen per hectare; 250kg in Ireland as per the conditions discussed above.

The Republic of Ireland has been divided into 3 zones based on soil type, rainfall and length of growing season.

Zone A: Carlow, Cork, Dublin, Kildare, Kilkenny, Laois, Offaly, Tipperary, Waterford, Wexford, Wicklow.

Zone B: Clare, Galway, Kerry, Limerick, Longford, Louth, Mayo, Meath, Roscommon, Sligo, Westmeath.

Zone C: Cavan, Donegal, Leitrim, Monaghan.

Table 3 below shows periods when application of certain types of fertiliser is prohibited (inclusive of dates)

Zones	**Chemical Fertiliser**	**Organic Fertiliser**	
		All Organic Fertilisers Excluding Farmyard Manure	Farmyard Manure
	Grassland and Other Land	All Land	
A	15 Sept. to 12 Jan.	15 Oct. to 12 Jan.	1 Nov. to 12 Jan.
B	15 Sept. to 15 Jan.	15 Oct. to 15 Jan[1].	1 Nov. to 15 Jan.
C	15 Sept. to 31Jan.	15 Oct. to 31 Jan.	1 Nov. to 31 Jan.

Table 3.

These dates show that manure must be stored from 1st Nov to 12th, 15th or 31st Jan depending on the zone. The storage capacity should be adequate for the full housing period and should provide an ample level of storage for difficult years. Livestock holdings shall have the following minimum storage capacity for bovine livestock manure:

Zone A – 16 weeks

Zone B – 18 weeks

Zone C – 20 or 22 weeks. 20 weeks for Donegal and Leitrim due to the high water quality and less intensive agricultural production.

The minimum storage capacity with respect to sheep, goats and deer is 6 weeks. Pigs and poultry are 26 weeks. If there are less than 100 pigs; the storage capacity is the same as the bovine capacity.

All livestock manure, other organic fertiliser, soiled water and silage effluent must be collected and stored in an appropriate storage facility prior to application to land or other treatment.

2.2.2 Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption.

This is possibly one of the most important and complex laws around AD as it lays down the rules around what can and cannot be used in an AD plant. This regulation refers to health rules concerning animal by products (ABP) not intended for human consumption (EC, 2002). This regulation is 170 pages and there are 14 subsequent amendments so an overview will only be provided on relevant data.

Article 2 defines ABP as 'entire bodies or parts of animals or products of animal origin referred to in Article 4, 5 and 6 not intended for human consumption, including ova, embryos and semen'. It is necessary to ensure that all ABP used in AD plants have sufficient pathogen reduction and that recontamination is prevented. This will ensure safe application of the treated material.

ABP are divided into 3 categories.

Category 1 material is not allowed to be processed in biogas plants due to its nature. A detailed description of Category 1 materials and Category 2 materials can be found in Appendix A.

Manure, digestive tract content, milk, colostrum are Category 2 materials and can be processed in a biogas plant.

Category 3 material can be processed in a biogas plant. Category 3 material is comprised of ABP of the following description, or any material containing such by-products. Only the relevant points are included.

- Parts of slaughtered animals, which are fit for human consumption but are not intended for human consumption for commercial reasons
- Parts of slaughtered animals, not fit for human consumption and have no signs of diseases
- Former foodstuffs of animal origin, other than catering waste, which are no longer intended for human consumption for commercial reasons
- Raw milk originating from animals with no signs of diseases
- Fish or sea mammals caught in the open sea
- Shells, hatchery by-products and cracked egg by products showing no signs of diseases
- Blood, hides and skins, hooves, feathers, wool, horns, hair and fur origination from animals showing no signs of diseases
- Catering waste other than international catering waste.

The following table provides an overview of the different categories, the potential use, recovery methods and constraints.

Category	**Potential Use**	**Disposal or recovery method**	**Constraints**
1.	Nothing	Incineration or approved processing plant	n/a
2. Manure, digestive tract content, milk, colostrum	Biogas plant	Processed in a biogas plant, disposed of in a landfill site, composted	Must adhere to the National Standard approved by the DAFF. Max particle size: 400mm Min temperature: 60°C Min time in the unit: 48 hrs Manure and digestive tract content requires no pre-treatment, while all other materials in category 2 must be sterilised with steam pressure.
3. Feather, former foodstuffs, raw milk, fish or fish byproducts, shells, hatchery by products, cracked egg by products, catering waste	Biogas plant	Processed in a biogas plant, disposed of by landfill, or composted	Must adhere to the EU Standard. Max particle size: 12mm Min temperature: 70°C Min time in the unit: 1 hour

Table 4.

The EC considers catering waste as waste from premises on when food is produced for direct consumption. This includes restaurants, catering facilities and kitchens. It may include sandwich outlets producing food for direct consumption. It does not include supermarkets or food factories that produce food for retail sale; this is referred to as former food stuffs.

Article 7 refers to rules around collection, transportation and storage of ABP. Member States may decide not to apply the rules around the transportation of manure between 2 points on the same farm or between farms and users located in the same Member State. Extensive research did not provide any clarity as to whether Ireland applies Article 7. However manure is exempt from licensing or permit requirement under the Waste Management Acts 1996 to 2008 (Acts). ABP must be collected and transported by approved licenses hauliers; the licenses are issued by the DAFF

Article 15 refers to the approval of biogas and composting plants. Approval of biogas and composting plants will be considered if the plant meets the requirements in Annex VI, Chapter II, Part A. This chapter covers specific requirements for a biogas plant regarding premises, hygiene requirements, processing standards, digestion residues and compost. It has been amended by Commission Regulation (EC) No 208/2006 amending Annexes VI and VIII to Regulation (EC) No 1774/2002 of the European Parliament and of the Council as regards processing standards for biogas and composting plants and requirements for manure (EC, 2006). The amended regulation states that biogas plants must have a pasteurization/hygienisation unit that cannot be bypassed.

Biogas and composting plants in Ireland are subject to approval by the competent authority, which is the Department of Agriculture Fisheries and Food. The use of ABP must be approved by the DAFF by completing an application form. As shown in the above table ABP used in a biogas plant must adhere to the EU standard or the national standard depending on the category.

The animal by products application to anaerobic digestion plants is highly complex. The document entitled 'Conditions for approval and operation of Biogas Plants treating Animal By-Products in Ireland' sets out the requirements for a biogas plant in Ireland that accepts ABP. (DAFF, 2009)The document lists the permitted ABP that can be processed in a biogas plant in accordance with the EU Directive and National Law and can be found in the table above.

The document covers specific requirements on location, equipment required at the plant, hygiene requirements, processing and treatment standards, record keeping requirements, HACCP plans, collection and transport of materials, and restrictions around organic fertiliser.

The Irish National laws under EU Regulation 1774 are:

2.2.2 (A) SI No 252 OF 2008. EC (TRANSMISSIBLE SPONGIFORM ENCEPHALOPATHIES AND ANIMAL BY PRODUCTS) REGULATIONS 2008 (OAG, 2008B).

The regulation refers to the sale and supply of ABP and the import of ABP. It states that 'a person shall not operate a biogas plant other than in accordance with an approval granted for the purposed of Article 15 of the ABP Regulation.

2.2.2 (B) SI No 253 OF 2008. DISEASES OF ANIMALS ACT 1996 (TRANSMISSIBLE SPONGIFORM ENCEPHALOPATHIES) (FERTILISERS AND SOIL IMPROVERS) ORDER 2008 (OAG, 2008C).

The regulation refers to the control and use of fertilisers and soil improvers. One is not allowed use a biogas plant to produce a soil fertiliser or soil improver that consists of animal proteins, except if an animal protein fertiliser licence has been granted.

Farmed animals are not allowed have access to land where a fertiliser or soil improver has been spread that consists of category 2 material, other than manure, or category 3 material for (a) 21 days or (b) 60 days for pigs after spreading.

Farmed animal are not allowed have access to a fertiliser or soil improver that consists of category 2 materials or category 3 materials and fertiliser and soil improvers are not allowed come in contact with animal feedingstuff.

Hay or silage cannot be made on land where fertiliser or soil improver containing category 2 or category 3 materials, has been spread in the previous 21 days.

The document 'Conditions for approval and operation of Biogas Plants treating Animal By-Products in Ireland'(DAFF, 2009) confirms the above conditions that organic fertiliser/soil improvers produced in a plant from the list of permitted ABP can be spread on land under the following conditions:

- Farmed animals (apart from pigs) must not be allowed access to the land for at least 21 days following land application
- Pigs must not be allowed access to the land for at least 60 days following land application

2.2.3 SI No 12 of 2009 Diseases of Animals Act 1996 (Prohibition on the use of swill). (Amended) Order 2009(OAG, 2008a).

This SI is an amended version of SI 597/2002 to allow collection, assembly, processing and storage of swill at approved composting and biogas plants. Swill includes eggs, table waste, catering waste, kitchen refuse, and fish waste.

2.2.4 Council Directive 99/31/EC of 26th April 1999 on the landfill of waste (EC, 1999)

The objective of this Directive is to prevent or reduce, as far as possible, the negative effects on the environment for the landfilling of waste, by introducing requirements for waste and landfill. The Directive focuses on the pollution of surface water, groundwater, soil and air.

There are different categories of waste defined in Article 2 of the directive:

(a) Waste is defined as any substance or object covered in Directive 75/442/EEC which has since been codified and can be found in Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006.

(b) Municipal waste is defined as 'waste from households, as well as other waste which, because of its composition or nature, is similar to waste from households.

(c) Hazaderous waste which is defined in the Waste Management Act 1996 and 2001.
(d) Non hazardeous waste
(e) Inert waste defined as waste that does not change or alter in anyway. The pollutant content must be insignificant and not endanger the quality of surface water and/or groundwater.

Article 5 (1) requires Member States to set up a National Strategy for the implementation of the reduction of biodegradable waste going to landfills. The strategy must include measures on how to achieve the targets set out in Article 5(2) by recycling, composting, biogas production or materials/energy recovery.

Article 5(2) must ensure that biodegradable waste going to landfills must be reduced to:

- 75%, of the total amount of biodegradable waste produced in 1995, by 2006
- 50%, of the total amount of biodegradable waste produced in 1995, by 2009
- 35%, of the total amount of biodegradable waste produced in 1995, by 2012

If Member States sent more than 80% of waste to landfill in 1995, they were allowed postpone the attainment of the above targets by 4 years. Ireland applied for, and was granted, this 4 year extension and therefore, the following target apply to Ireland:

- 75%, of the total amount of biodegradable waste produced in 1995, by 2010
- 50%, of the total amount of biodegradable waste produced in 1995, by 2013
- 35%, of the total amount of biodegradable waste produced in 1995, by 2016

The EPA has combined a consolidated collection of the European Waste Catalogue and the hazardous waste list and three subsequent amendments. It sets out the classification of waste and hazardeous waste and the legislation associated with each (EPA, 2002)

Figure 4 below is an extract from the document referred to above of a hazardeous waste flowchart.

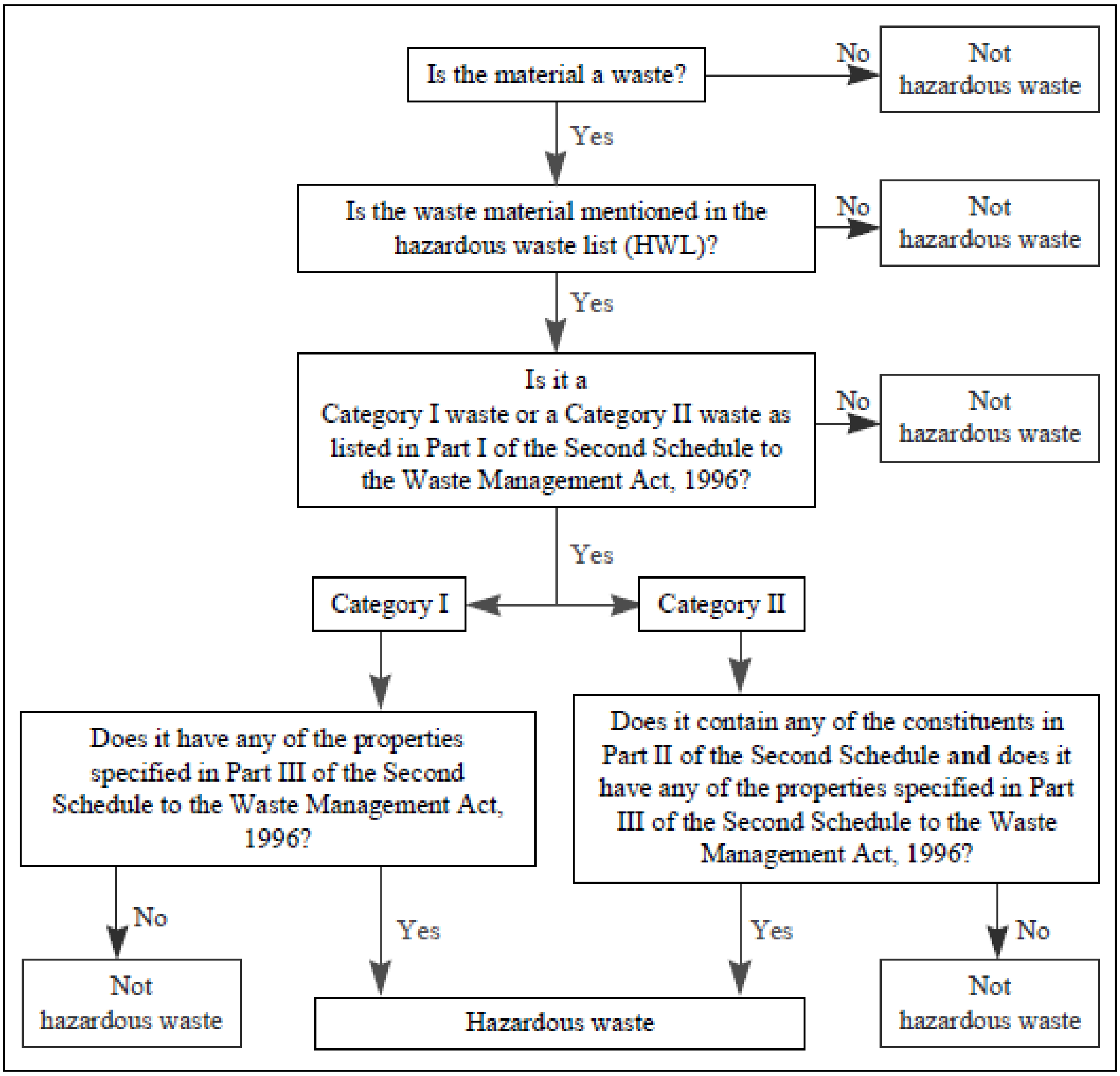


Figure 1 Hazardous waste flowchart

FIGURE 4.

2.2.4 (A) National Strategy on Biodegradable Waste 2006

As stated above Article 5 of the landfill directive requires Member States to produce a National Strategy on Biodegradable Waste. Ireland's National Strategy on Biodegradable Waste was published in April 2006. It contains measures to progressively remove biodegradable municipal waste from landfill sites in accordance with the Landfill directive.

The National Strategy on Biodegradable Waste 2006 (DEHLC, 2006) states that 'biodegradable waste accounts for approximately three-quarters of the municipal solid waste produced by homes and businesses'. The main biodegradable components of municipal waste are paper, cardboard, foodwaste and garden waste.

The policy statement entitled 'Waste Management Changing Our Ways' advises that there is scope for public/private partnership in all areas of waste management (DEHLC, 2006)The report states that 'private participation can contribute capital investment in infrastructure, specialist expertise in the application of alternative and energy technologies. The report suggests (pg 14 7.6) that the scope for the application of the AD process in Ireland should be examined.

The government policy statement on 'Preventing and Recycling Waste - Delivering Change' (DEHLG, 2002)recommends that the following should be addressed for each potential form of biological treatment:

(i) Capability to control the quality of raw materials
(ii) Flexibility of AD systems
(iii) Initial capital costs
(iv) Proven reliability of performance of technology of the required capacity
(v) Security of supply of raw materials
(vi) Adaptability of the national grid
(vii) Economics of scale
(viii) Strategic situated facilities.

The waste management hierarchy depicts the most suitable way for waste handling.

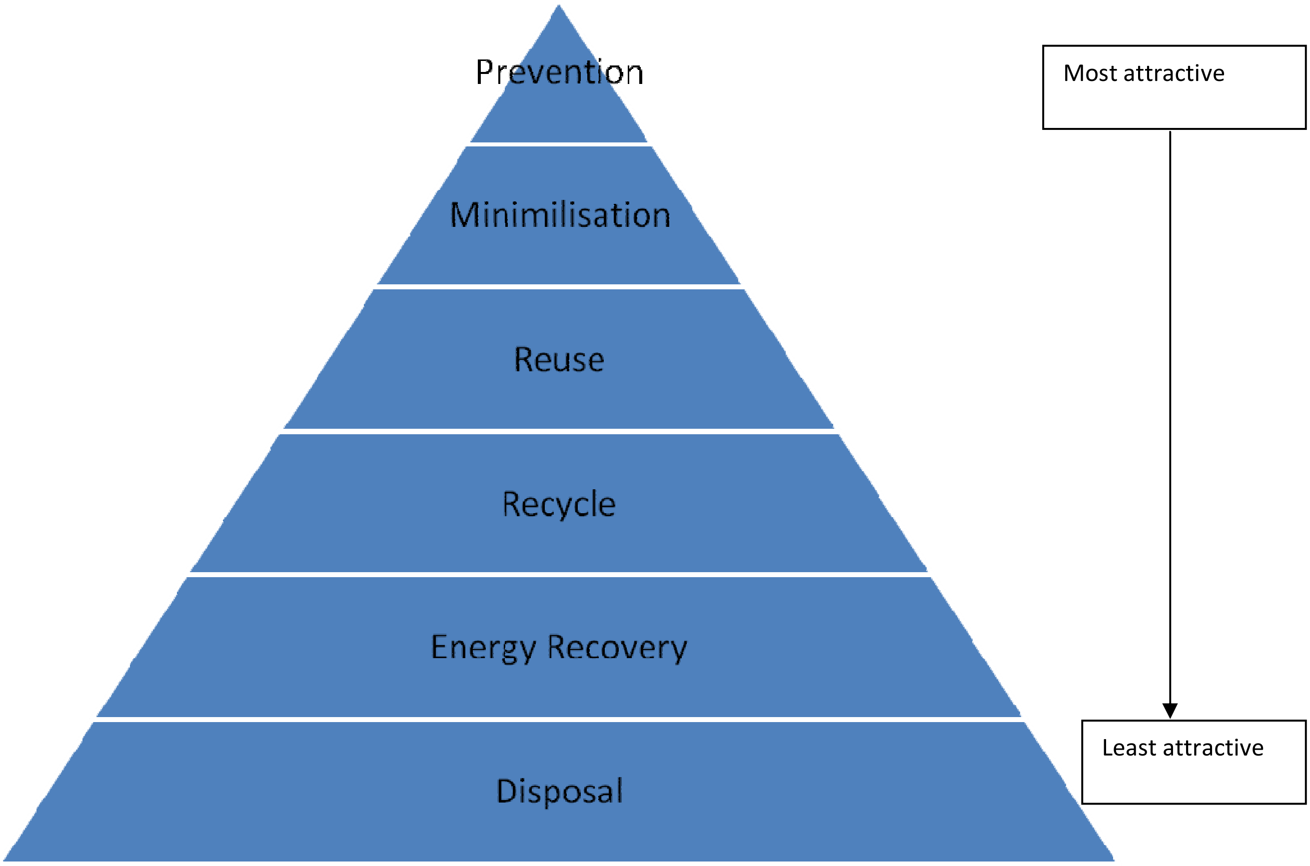


FIGURE 5.

In July 2010 Minister John Gormley opened a public consultation on a draft statement for waste policy. The draft statement identifies that the municipal waste recovery increased from 28% in 2003 to 38% in 2008. Key objectives of the policy statement are:

- Implement a sustainable production and consumption approach to waste management
- Maximise economic benefit, including the revenue that can be gained from maximising the resource potential of waste
- Maximise opportunities for enterprise in reuse, remanufacturing and reprocessing
- Minimise climate impacts.

Submissions were accepted until 1st October 2010 so the outcome is currently unknown.

2.2.5 Directive 2009/98/EC on the promotion of the use of energy from renewable sources (EC, 2009)

This directive repeals 2001/71/EC and 2003/30/EC. It creates a framework to use renewable energy sources to reduce greenhouse gas emissions. Under the directive, Member States are required to set a renewable energy target for 2020. The directive also requires Member States to establish a National Renewable Energy Action Plan (NRECP) using a template devised by the European Commission. The purpose of the NRECP is to ensure that Member States adhere to the Directive.

The Irish National Renewable Energy Action Plan has been submitted for approval. Ireland has set a target of 40% of electricity to be produced from renewable sources, and 12% of heat produced to come from renewable sources.

2.2.6 Kyoto Protocol

The Kyoto Protocol set binding targets on reducing greenhouse gas emissions for 37 industrialized countries and the European Community (EPA)Ireland agreed to limit the growth in greenhouse gas emissions to 13% above 1990 levels under the Kyoto Protocol by 2012. It is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) and 184 parties of the Convention have ratified the Kyoto Protocol to date.

A press release from the EPA in October 2010 declared that although Ireland's position with the Kyoto Protocol targets won't be known until after 2012, the EPA has estimated that after the 1st two years (2008-2010) Ireland is currently a total of 6.2 million tonnes above target when the impact of the EU Emissions trading scheme and approved forest sinks are taken into account.
Ireland's greenhouse gas emissions fell by 5.4 million tonnes (7.95) in 2009. Ireland's limit under KP is 62.84mt for the period 2008-2012. These figures show that Ireland's combined emissions in 2008 and 2009 were 6.2 million tonnes above this limit when account is taken of the Emissions trading scheme and approved forest sinks. Dr Mary Kelly, Director General of the

EPA, has said that this 7.9% reduction 'is welcome in terms of meeting our KP targets….and we should not rely on a recession to meet our future targets'. This was specified as there was a 20% reduction in greenhouse gas emissions in the industry sector in 2009, which has been attributed to the downturn in the economy.

2.2.7 Copenhagen Accord

The second last meeting of the UNFCCC took place in December 2009 in Copenhagen. It was an opportunity for the international community to agree a successor to the Kyoto Protocol. However, it failed and there is no new binding agreement. The Copenhagen Accord was 'noted' by the relevant parties. It sets out a goal of limiting global warming to below 2°C above pre-industrial times. It leaves each nation to set its own targets for 2020.

2.2.8 Cancun Agreement

The most recent meeting of the UNFCCC took place in December 2010 in Cancun. It was more successful than its predecessor but still requires more work if a successor to the Kyoto Protocol is to be agreed next year. The main themes to emerge out of the Cancun Agreement are (1) the Kyoto Protocol's clean development mechanisms have been strengthened to drive more major investments and technology into environmentally sound and sustainable emission reduction projects in the developing world, (2) a set of initiatives and institutions will be launched to protect the vulnerable from climate change and to deploy the money and technology that developing countries need to plan and build their own sustainable future, (3) a initial fund of $30 million has been set up, to come from industrialised countries, (up to 2012) to support climate action in the developing world and an intention to raise $100 million by 2020, (4) a scheme to provide financial support for countries to preserve their forests, in a bid to combat deforestation which accounts for almost a fifth of global annual emissions .

2.2.9 Integrated Pollution Prevention and Control Licensing

Legislation covering IPPC licensing is a codified IPPC Directive; 2008/1/EC (EC, 2008). The purpose of the Directive is to have an integrated prevention and control of pollution arising from Annex 1 of this Directive. It sets out measures to prevent or, where it is not practical, to reduce emissions in air, water and land.

The Environmental Protection Agency Act 1992 was amended in 2003 by the Protection of the Environment Act 2003 and this gave effect to the IPPC Directive. The EPA is fully responsible for the IPPC licensing process. The aim of the IPPC licence is to prevent or reduce emissions to air, water and land, to reduce waste and use energy resources efficiently. An IPPC licence is a single integrated licence and covers all emissions from the facility and its environmental management.

IPPC licenses are required for an AD plant and an application must be made to the EPA. Legislation to obtain an IPPC licence is set out in the EPA (Licensing) Regulations, 1994 (SI no 85 of 1994 and amendments SI 76 of 1995, SI 240 of 1996, SI 394 of 104, SI 382 of 2008).

A waste collection permit is required to move organic material on to a site. Waste Management (Collection Permit)(Amendment) 2008 (SI 87 of 2008) 2(j) states that 'the nominated authority shall attach to each waste collection permit granted by it conditions requiring the permit holder to ensure that where biowaste collected under the waste collection permit is transferred to a biogas facility for the purposes of treatment and where ABP from all or part of that biowaste, that the facility has been approved by the nominated authority and there is in force an appropriate veterinary authorisation'.

2.2.10 Planning Permission

Planning permission must be obtained for an anaerobic digestion plant and an environmental impact statement will be included in this. Planning permission in Ireland can be slow especially for non straightforward buildings. It is estimated that planning permission for an anaerobic digestion plant will take approximately one year.

2.2.11 Energy White Paper 2007 Delivering a Sustainable Energy Future for Ireland. The Energy Policy Framework 2007 – 2020.

The Energy White Paper (DCMNR, 2007) aims to promote a sustainable future for Ireland. The paper declares that the government is 'committed to harnessing the full potential of our renewable and bioenergy resources'. Strategic goal 3.8.4 of the paper is to 'deliver an integrated approach to the sustainable development and use of bioenergy resources'. It also states that there will be an investment in specific research and development and the supply side will be addressed.

2.3 Cooperatives

The literature testifies that cooperatives have been in existence since the beginning of mankind. Cooperatives are formed for a variety of reasons but the main reason in modern farming is to provide sources of supplies at a reasonable cost that would be otherwise unattainable. An example of a well known cooperative in Ireland is the Credit Union. The first agricultural cooperative in Ireland was established in Co Limerick by Sir Horace Plunkett in 1889. His motto was 'Better farming, better business, better living. Interestingly, he and his colleagues had observed how cooperative creameries had raised farming standards in Denmark since 1882. Kerry Group PLC started out as a cooperative in 1974 and had sales of €29 million that year.

The Irish Cooperative Organisation Society (ICOS) defines cooperatives as 'an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise'.

Cooperatives are based on the values of self help, self responsibility, democracy, equality, equity and solidarity. The cooperative principals are based on guidelines by which cooperatives put their values into practice. They are as follows:

1. Voluntary and open membership
2. Democratic member control: members are involved in policy making decision
3. Member Economic Participation:
4. Autonomy and Independence: self help organisations controlled by the members. If they enter into agreements with other organisations including governments or raise capital from external sources, they do so on terms that ensure democratic control by their members and maintain the cooperative identity
5. Education, training and information
6. Cooperation among cooperatives: cooperation among the cooperative movement by working together through local, national, regional and international structures
7. Concern for community: cooperatives work for the sustainable development of their communities through policies approved by their members.

There are 4 different types of cooperatives:

1. Customer
2. Producer
3. Employee owned
4. Community operated
5.

The Waterford County local authorities are involved in a project called the Energy Self Supply in Rural Communities (WCLA). It is a pilot rural self supply cooperative/network in Ireland, Wales, Portugal and Bulgaria. The energy self supply cooperative aims to support farmers in developing sustainable energies

- Electricity generation
- Heat production
- Producing sustainable fuels
- Developing a market for renewable energy

However, the outcomes of this project are not yet known.

There are 725 million people worldwide who are cooperative members. In 1998 US farming cooperatives achieved their highest ever market share, marketing one third of the nation's farm commodities. The report identifies biodiversity as a reason why cooperatives are becoming popular again. Using cooperatives, communities can build unique solutions to specific problems, as well as making it possible for local businesses to creatively participate in the global economy. In Ireland an anaerobic digestion cooperative could contribute to security of supply

Kerry Group had the 6th highest turnover of the European Cooperatives in 2003. They have now grown to be one of the leading food supply groups in Ireland and also export vast quantities to the UK and beyond.

In 2010 Cooperatives Europe had 123 million members owning 160,000 cooperatives and represented a force for economic growth and social change. These 160,000 cooperatives employed 5.4 million citizens (Scribd, 2010)

The following table shows the differences in cooperative enterprises in Ireland, Germany and Denmark. Germany and Denmark were selected for comparison as they have the most successful AD cooperatives in Europe. Denmark also has a similar population and country area size.

	Ireland	Denmark	Germany
Enterprises	183	523	7,415
Members	152,000	1,840,803	20,509,973
Employed	18,869	70, 757	830, 258
Population	4.5 million	5.5 million	82 million
Total area	70,000km²	43,094km²	356,854km²

Table 5.

2.4 AD COOPERATIVES

Anaerobic digestion cooperatives are widely successful in Europe. Case Studies will be used to show that they can also be successful in Ireland.

Energy4all is a UK company who claim to be the UK's leading expert in community owned renewable energy systems. It was established in 2002 in order to expand the number of renewable energy cooperatives in the UK. Energy4all was created out of Baywind Cooperative, which was set up (in 1996) to allow a Cumbrian community invest in a local wind farm. Baywind carried out two share offers which raised over £1.9 million. They used local contractors for site development, maintenance and support. The first wind farm is located in Harlock Hill in Cumbria and has been producing electricity since 1997. It has generated between 2,188MWh to 5,817MWh per year. All of the profits from electricity generation are paid back to the share holders.

Westmill Wind farm is the first wind farm to be constructed in the South East of England and it is 100% community owned. There are 5 turbines that produce electricity for over 2,500 homes.

Kedco Plc is an energy company in the UK and Ireland that specializes in anaerobic digestion to name one. They have set up a business model to go into partnership with farmers to establish an anaerobic digestion plant. It is a 50:50 partnership where the farmer provides the land and feedstock supplies and Kedco supply the technical expertise. The returns are split 50:50.

2.5 CASE STUDIES

Denmark

Denmark is seen as a leader in anaerobic digestion plants, as well as most other renewable energy technologies. Denmark has 20 CAD plants and 60 on farm plants (Holm-Nielsen, 2008)

Ribe Anaerobic Digestion Plant (Holm-Nielsen, 2008) (NYSERDA, 2006)

- Built in 1990
- Produces 18,000m^3 of biogas per day
- Overall capacity of 150,000 (424,752m^3) tonnes per year; 120,000 manure, 30,000 organic waste
- Cost $5.5 million dollars

Ribe in Denmark is run as a cooperative and was established in 1990.

There are 17,000 people living in the Ribe commune. The plant uses the manure from 69 livestock farmers, and the organic waste to provide power to the town's central heat and power plant. The facility collects manure in one large tank and two smaller ones. The trucks offload the manure and reload with digester effluent. Industrial and food wastes are taken into the facility and put into a separate feed tank. Feed from the 2 waste tanks is pumped into 3 parallel anaerobic digesters every two hours. The digester effluent is stored in 2 ground covered tanks which are not aerated. The gas is stored in a balloon tank with a 4 hour capacity. Ferric chloride is added to the process to reduce the sulfide content of the biogas; this is done as sulplur can damage engines. The effluent is transported to storage tanks near the fields where it will be spread. The tanks are standard open top tanks made of precast concrete panels and ribs. They are used throughout Denmark and can store 9 months of digester effluent. The biogas is transferred via power lines to a power plant 3km from the biogas plant. The power plant produces 2MW of electricity and 1.8MW of heat from the biogas.

The plant is owned by a cooperative and divided out as follows:

- 40% member farms
- 20% fish processing
- 20% green investors
- 20% insurance companies

The composition of the member farms is 80 animal farms: (70% dairy, 30% pig), and 40 agrifarms (no animals but crops are grown). Each farm put in $2,500.

Germany

Germany has the most anaerobic digestion plants in Europe. The German government amended their Renewable Energy Sources Act (EEG) in 2009 to guarantee fixed feed in tariffs for electricity for 20 years with a bonus for heat utilisation (Government, 2008). The Act states 'the tariff paid for electricity from biomass shall amount to:

1. 11.67 c/kWh for the 1st 150kW of output
2. 9.18 c/kWh for 150kW – 500kW
3. 8.25 c/kWh for 500kW – 5MW
4. 7.79 c/kWh for 5MW – 20MW

The tariffs above will increase for electricity which is generated in CHP by 3c/kWh.

Jühnde Anaerobic Digestion Plant

- Built in 2006
- Produces 6,500MWh per year heat and 5,000MWh electricity per year
- capacity per year 18,178 tonnes per year
  Liquid manure: 9,000 m^3 per year = 3,178 tonnes
  Energy crops: 15,000 tonne per year = 42,475 m^3
- Cost €1.3 million

Jühnde is a village in lower Saxony in Germany with 800 inhabitants and is Germany's first bioenergy village. The village contains a biogas CHP plant, fed with liquid manure and whole plant silage of different crops. In the winter, there is a wood chip boiler to supply high heat demand. The system is backed up by a conventional oil boiler. The heat is distributed via a district heating grid providing 145 houses. The electricity produced is fed into the local public utility grid. (IEA)

The project in Jühnde was part funded by the German Ministry of Food, Agriculture and Consumer Protection. It was selected for the project due to economy, infrastructure, nature and society in the location. The village founded a cooperative to plan the project and to obtain the investment subsidies. 70% of the inhabitants are members and each paid a €1,500 fee for voting rights.

The energy plant comprises:

(a) Biogas plant located on the edge of the village
(b) Wood chip fuelled boiler
(c) A district heading network for the 145 houses

Sizing:

- Digester volume: 3,000m³
- Storage tank: 4,400m³
- CHP: 700kWelectric, 750kWthermal
- Wood chip boiler: 550kWth
- Wood chips: 350 tonner per year
- Peak load oil boiler: 1,600kWth

AFBI Plant Northern Ireland

- Built in 2008
- Produces 8681.6m³ of biogas/month
- Capacity 559.7 tonnes slurry/month
- Cost is unknown.

A visit was undertaken to the anaerobic digestion plant in the Agri Food and Biosciences Institute. The Agri Food and Biosciences Institute (AFBI) was created in 2006 as an amalgamation of the Department of Agriculture and Rural Development Science Service and the Agricultural Research Institute of Northern Ireland. It carries out research for government departments, public bodies and commercial companies. It is a similar set up to Teagasc in the Republic of Ireland.

The AFBI installed an AD plant to conduct research into the performance and economics of an on farm AD plant. The plant was installed in 2008. It took 6 months to get planning permission (I asked Dr Frost this when up there). The main research objectives are as follows:

1. Determine the baseline performance of on-farm digestion utilising, in the first instance, dairy cow slurry.
2. Research methods for enhancing digester performance.
3. Research post digestion treatments of digestate.
4. Research methods for efficient use of energy produced.
5. Determine the contribution of AD to plant nutrient management.
6. Determine lifecycle benefits of AD.

Staff have completed objective 1 above which took 19 months, and they are working on 3-6. Objective 2 has not yet begun due to a delay from the plant supplier (AFBI)

The AD plant contains an insulated digester tank of 600m³ which is a continuously stirred tank reactor (CSTR) operating at a mesophilic temperature of 37°C. There is a secondary digester but this is for research purposes only.

Over the 19 month period, the digester:

- Processed 10,634 tonnes of dairy slurry
- Produced 164,950m³ of biogas with an energy value of 920.2MWh.

This equates to 559.7 tonnes slurry/month, 8681.6m³ of biogas/month, 48.4MWh/month.

It is noted in the interim report that ‘performance figures for the digester were at the low end of the commonly quoted ranges, which are often based on laboratory studies using small scale digesters'. This provides additional evidence that proposed models should be based on real life plants.

On average, in the plant, 1 tonne of slurry produced $15.5m^3$ of gas with an energy value of $5.5kWh/m^3$ of gas. 37% of the biogas produced is used to maintain the temperature of 37°C, and 5.4kWh per tonne is used for pumps and mixing.

1 tonne = $15.5m^3$ biogas = 5.5kWh per m^3 of biogas.

$15.5m^3$ biogas = 85.3kWh – this concurs with the figure in the report.

37% of 85.3kWh is used to maintain the temperature, which leaves 53.8kWh minus the 5.4kWh leaves a total of 48.4kWh, which is 56% of the total amount of biogas produced left for use.

<u>Case study in Minnesota, USA.</u>

- Built in 1999
- Produces $1,950m^3$
- Capacity $75m^3$ per day of manure only
- Cost €319,500 ($355,000)

Haubenschild farm is a 1000 acre site which has been owned and operated by the same family for four generations. The Haubenschild's wanted to expand their dairy operation from 100 cows, to 500 cows to 1000 cows (Carl Nelson, 2002) AgSTAR is a national programme in the United States and is sponsored by the EPA, The Department of Energy and the Department of Agriculture. A charter farm is set up and used to demonstrate the digester system at various livestock farms. The farm was accepted as an AgSTAR 'Charter farm'. They received some funding from various government agencies and nonprofit agencies as the family agreed to allow it as a study reference site. It is a mesophilic AD plant. It is important to note that there are no tankers required in such a venture and therefore it will have a lower cost than other AD plants. The report states that the electricity generation is 5.5kWh per cow per day. The US operates its electricity system differently to Ireland. According to the US Energy Information Administration there are 3,273 traditional utility companies in the US (EIA). The electric utility companies can be investor-owned, publicly-owned, cooperatives, and Federal. The Haubenschild's entered into a contract with a local electric cooperative called East Central Energy and it was the first company in the entire US to offer such a contract for electricity generated from digesters; they call it 'cow power'! It may be considered easier to get grid connection when there is more than one electricity utility company.

<u>Holsworthy AD Plant UK</u>

- Built in 1998
- Produces 4 million m^3 biogas
- Capacity 100,000 tonnes
- Cost €8.2 million

Holsworthy biogas plant, Devon, is a CAD plant which began operation in 1998 and was the first CAD plant in the UK. As of 2006, it was the only operational CAD in the UK (K. D. Monson and Dinsdale, 2006)It is now owned by the Summerleaze Group. It processes manure, food waste and abattoir waste. The case study (K. D. Monson and Dinsdale, 2006)shows that, in 2006, the plant processed approximately 100,000 tonne per year = 283,168m^3

The manure is collected in tankers, similar to the ones seen in the AFBI AD plant, from 17 farms in a 6 mile radius. The slurry is collected 5 days of the week which equates to 85 tanker trips per week for the manure. Holsworthy is a traditional Devon market town, located near the sea and Devon would be on the UK tourist trail. The plant is located 2km outside the town and is not visible from the public road.

The plant adheres to the 12mm particle size and waste being heated at 70°C for an hour. It is a CSTR with a retention time of 27 days. It operates at the mesophilic temperature range but there is no reason given as to why. As this plant is commercial, there is no money exchanged between the plant and the farmers but the slurry is collected and digestate delivered (and paid for) by the plant. The digestate is stored on site and delivered to the farms when required. It also reduces the smell of slurry when it is applied to the land. Such a plant requires the cooperation of farmers. The farmers do not receive any monetary compensation but they benefit as they do not have to store the digestate and will save on fertiliser costs.

The case study states that 100,000 tonne of waste per year will produce approximately 40m³ biogas per tonne which is 4 million m³ biogas produced in one year. 90% of the energy produced is exported to the National Grid; the remaining 10% is used within the plant. The case study acknowledges that it was difficult to obtain a loan for the project and it was funded by a grant of 50%. It is noted that this plant cost €8.2 million (in 1998). The case study states that 14.4 million kWh electricity will be produced.

2.6 FEEDSTOCKS

Feedstocks are the material that is used in an anaerobic digester. A variety of feedstocks can be used in an anaerobic digester. The SEAI suggests slurry, energy crops, food waste, canteen waste, silage and ABP. The aim of this section is to explain how feedstocks impact the biogas yield.

There are 3 million tonnes of municipal waste generated in Ireland each year. In 2005, 23% of this was recycled or composted which leaves 67% as potential feedstock.

According to IEA Bioenergy report there are over 1.2 billion tonnes per year, in the EU, of potential feedstock. Manure and slurry are rich in plant nutrients as animals do not use nutrients efficiently. The SEAI is currently designing a calculator that will enable users to see how many kWh can be produced from different feedstocks. An AD cost calculator has been created by Andersons centre on behalf of The National Non Food crops Centre (NNFCC) in the UK. It is a very comprehensive tool which allows one to input a range of feedstocks, the DM content, the potential biogas yield, the amount of tonnes expected, revenue from REFIT, capital costs and annual running costs. It seems to be an excellent tool.

The following table shows the biogas yield from feedstocks (Biogasinfo):

Feedstock	Dry Matter (%)	Biogas Yield m^3/tonne	kWh
Cattle slurry	10	15-25	85 – 138
Pig slurry	8	15-25	85 – 138
Poultry	20	30-100	165 – 550
Maize silage	33	200-220	1100 – 1210
Grass silage	28	160-200	880 – 1100
Maize grain	80	560	3080

Table 6.

(The kWh was worked out using Dr Peter Frosts observation that 1m^3 of biogas = 5.5kWh)

Dr Frost deduced from experiments using manure, discussed above, that 15.5m^3 biogas = 85.3kWh.

It is evident from reading the literature that there are different values for different feedstocks. A paper by Pöschl et al uses empirical values from Becker et al to describe the biogas yield from 3 different feedstocks; agricultural waste, energy crops and municipal solid waste (MSW). They assumed a wet mesophilic two stage AD process. However the figures in this are different to Dr Frost's figures and the figures above from biogasinfo.co.uk.

Each tonne of food waste produces approximately 100 – 150m^3 of biogas which in turn has the potential to generate 300kWh of electricity (Ireland, May 2009)

Composition of feedstocks is variable and as previously stated feedstock quality will affect biogas yield. Codigestion of feedstocks will also produce a higher gas yield.

Quality Protocol Anaerobic Digestate. End of waste criteria for the production and use of quality outputs from anaerobic digestion of source segregated biodegradable waste. (UK, 2009)

A Quality Protocol (QP) by the Environmental Agency and the Waste and Resources Action Programme (WARP) and is applicable in England, Wales and Northern Ireland. It sets out criteria for the production and use of quality output from AD of source-segregated biodegradable waste.

It is well documented that there is uncertainty over the definition of waste in the Waste Framework Directive 2006/12/EC and when waste ceases to be waste. Numerous case law exists over the definition of waste and using this it is now possible to identify when waste is no longer waste.

This QP identifies when waste is not a waste and can be reclassified as a product as long as the waste has been through a complete recovery operation. The purpose of the QP is to

- Identify the point when waste management controls are no longer required
- Provide users with assurance that the digestate conforms to an approved standard
- Protects human health and the environment as per the WFD by using good practice for digestate production

Under the QP, digestate is no longer considered a waste when

- It has been produced using only input materials listed in Appendix B of the QP
- It is destined for use in one of the designated market sectors which are agriculture, forestry, soil/field grown horticulture and land restoration

It is important to note that no plant is obliged to implement the QP. Plants can implement the QP and receive certification from an approving body through the PAS 110:2010.

PAS 110:2010 Specification for whole digestate, separated liquor and separated fibre derived from the AD of source – segregated biodegradable materials (BSI, 2010)

The PAS 110:2010 was developed in conjunction with the Renewable Energy Association (REA), the Association for Organics Recycling and in collaboration with the British Standards Institution. The purpose of the PAS is to ensure that appropriate waste is processed in AD plants, and provides a quality assurance scheme to ensure to end users that the digestate is safe to use and will not damage the environment. The PAS outlines legislation, quality management system, hazard analysis and critical control point (HACCP) system, process management and storage, process monitoring, sampling of digester materials, and validation.

The PAS report states in 11.1.2 that 'in order to validate the efficacy of the elements of the HACCP plan and verify that the digestion process is under control and achieving the required digestate quality results, the producer must monitor the quality of the samples and amend the HACCP plan if necessary. The PAS includes methods of testing and an upper limit for feedstocks.

According to Biogasinfo.co.uk the PAS enables digestate to become a product and can be sold under the name 'Biofertiliser'. When validating the digestate, for each parameter, the 3 most recent sample test results must not exceed the corresponding upper limit. There is one exception to this; ABP will have 5 sample test results. If the digestate complies with all the requirements, it is considered a product, and not a waste.

It should be noted that the PAS 110 refers to the digestate product, the QP is about the safeguards and processed needed to achieve the PAS.

2.7 Potential of AD Cooperatives in Ireland

In 2002 the EPA commissioned a feasibility study for 'Centralised Anaerobic Digestion (CAD) in sensitive catchment areas in Ireland' (Dr. Therese Mahony and Curtis, 2002b)

The main proposals in the report are

- Transport slurry from farms in a limited catchment area to a CAD to be codigested with organic waste originating in the catchment area.
- Develop a national code of practice for the hygienisation of CAD feedstocks and/or digestate in line with those in other European countries.

The authors carried out a survey in each county and addressed soil type, digestate spreading, level of interest in AD from local authorities. Using a weighted system they decided that Co. Monaghan was the best location for a demonstration CAD plant. They then conducted a survey within Co. Monaghan to assess areas with organic waste, availability of land for spreading digestate, farmer and industry interest; and then picked Lough Egish as the best location in Co. Monaghan.

A detailed design plan for the CAD plant was drawn up to process 150 tonnes (424m^3) of waste per day. The design included waste offloading, pasteurization facilities, 2 anaerobic digesters (2,000m^3 each and mesophilic), a biogas storage tank, a CHP unit for electricity and heat recovery, and 23 decentralised digestate storage tanks (each of 1,500m^3 capacity).

A further detailed report (Dr. Therese Mahony and Curtis, 2002a) recommends a comprehensive breakdown of an entire CAD. It recommends 2 tanks at mesophilic range. 2 tanks are suggested to allow for flexibility of operation (non-feeding of one reactor in times of low load). Mesophilic is suggested based on the quality of available waste and on the experience gained in CAD plants in Denmark.

<u>Potential slurry in Ireland</u>

Dr Peter Frost estimates that if all the slurry in Northern Ireland was used in AD it could provide 7% of the electricity requirement for Northern Ireland. The dairy cows in the AFBI plant are indoors for 6 months of the year so it is assumed that it is the stored slurry that would provide the 7%.

There were 1,107,000 dairy cows in Ireland in 2009 and each cow produces 47kg of slurry per day. If we assume 35% of this is available when cows are indoors:

Each dairy cow produces 47kg of slurry per day = 17,155kg slurry per year, 35% of this is 6,000 kg of slurry for AD per year per dairy cow.

1,107,000 dairy cows x 6 thousand kgs = 6,642,000 tonnes

It is important to note that this figure could increase if the manure was codigested with another suitable feedstock.

2.8 COMMERCIAL INTEREST

Bord Gais Éireann Report

In August 2010 Bord Gais Éireann (BGÉ) launched a report entitled 'The Future of Renewable Gas in Ireland'. It was written in association with UCC and Ernst & Young (BGE, 2009)

The report estimates that biogas could potentially deliver 7.5% of the national gas demand; this would heat 300,000 homes per year.

BGE state that biogas would help to fulfill the requirements under the landfill directive. The report states that 'in order to meet the EU landfill directive, Ireland needs to deliver waste infrastructure to divert 900,000 tonnes per year of biodegradable municipal waste from landfill by 2016. In 2008, 4% of the national final energy use was from renewable sources. In 2009, 11.8% of electricity came from renewable sources, and 11% of this was from wind.

BGE envisage producing biogas and using it for CHP, onsite or putting it onto the national grid. Biogas is 'upgraded' to reduce CO2 and hydrogen sulphide (H, little2, S) and produces Biomethane. The BGÉ report implies that the energy generated can be used more efficiently if used off site i.e. CHP or heat use rather than onsite electricity use). It also states that security of supply would be gained getting Biomethane from AD.

2.9 ECONOMICS

A project must be economically viable or investors will not be interested. A common tool investors use to assess the viability of a project is called the Net Present Value (NPV). The NVP must be positive or it is deemed to be a bad investment. There are a couple of issues that make it hard for an AD project to appear financially viable and these will be discussed in Chapter Analysis. Two studies have been conducted in Ireland on the economic feasibility of a CAD plant in Ireland. Both studies questioned the economic feasibility of CAD plants in Ireland but both studies also acknowledged that a lot of the benefits of an AD plant are not counted in an economic feasibility study. The EPA discussion paper (EPA, 2005) contains an economic analysis of a hypothetical CAD plant. The report was written in 2005 so it has been adapted to reflect the new REFIT and landfill levy. The discussion paper states that 1m³ biogas = 1.7kWh electricity and 2.5kWh heat. They indicate a conservative estimate of biogas yield to be 40m³ per tonne.

The EPA paper state that they received quotes from various companies and a wide range was returned. The total projected cost of the CAD plant was £2,614,328 excluding the cost of the site. The extra parts were 46 decentralised storage tanks and 2 commercial tanker vehicles for feedstock and digestate transport; this came to £2,070,175 which left a total of £4,684,503 = €7,426,000

This equates to a cost of £653 per m³. They costed labour at €118,500 and this provides for a plant manager, a lab technician and 2 tanker drivers.

The sterling was converted to euro using the average exchange rate from 2002 (£1 = € 1.58)

The EPA analysis yields a negative NPV which becomes positive with a grant of 50%. The SEAI offer a grant of 30%. It is noted in the EPA paper that 40% funding is available for anaerobic digestion through the Farm Waste Management Scheme. However as is previously discussed this is not actually the case.

Barry Caslin has a very different set of financial accounts which illustrates that it is hard to access hypothetical AD plants(Caslin, 2009).

Poschal and his colleagues put together a table of the energy requirements necessary for an anaerobic digestion plant (Pöschl et al., 2010)

	Electricity demand	**Heat demand**
Small scale biogas plant		
• Energy input as proportion of electricity produced in CHP (%)	4	25
• Energy input as proportion of biogas produced (%)	1.3	12.5
Large scale biogas plant		
• Energy input as proportion of electricity produced in CHP (%)	7.5	20
• Energy input as proportion of biogas produced (%)	3	9.6

Table 7.

CHAPTER 3 MODEL

There is a significant amount of literature on anaerobic digestion and the amount of biogas and resultant energy is can produce. However, most of it is based on pilot small scale AD plants or on assumptions.

Therefore, this model will be based on the case studies in Ireland, Northern Ireland, Germany and Denmark. The case studies previously discussed have been amalgamated below to facilitate references.

	Ballyshannon farm	**Northern Irl**	**Ribe, Denmark**	**Jühnde**	**Filksov**
Built	1995	2008	1990	2006	1995
Capacity (t/yr)	Not stated	6,716	150,000	18,178	28,835
Digester size (m^3)	200	660	5325	3,000	880
Biogas production (m^3/yr)	219,000	104,178	4,800,000	Not stated	1,300,000
Energy value(Mwh/yr)	1423.5	581	Not stated	6,500 heat 5,000 electricity	Not stated
Temperature	M	m	t	Not stated	t
feedstock	Manure and whey	manure	Manure and organic waste	Manure and energy crops	Manure and organic waste
cost	£60,000	Not stated	$5.5 million	€1.3	23.3million DKK
Set up	Privately owned	Research facility	Privately owned	cooperative	cooperative

Table 8.

3. 1 Logistics and location

The location of an anaerobic digestion plant can depend on the set up i.e. the anaerobic digestion plant in Ballyshannon was set up due to the initiative of one farmer. An anaerobic digestion cooperative could be set up in 2 ways: farmer initiative or by approaching farmers and communities in an informal manner. The majority of cooperatives are set up by communities to either achieve something or obtain something. The concern would be there that the cooperative meaning could be lost if forming the cooperative became too technical.

Once the cooperative is formed, a location would need to be selected which would initially need to ensure that specific criteria could be met such as feedstock availability, potential use of the produced electricity and/or heat. There is no point building an anaerobic digester if the feedstock requirement cannot be met. The generated electricity can be exported to the national grid and this requires grid connection which may take time and will cost money.
The literature indicates that farms participating in an anaerobic digestion cooperative should be within a 10km radius.

Once a location is agreed, a survey would be carried out in and around the location to gauge actual interest levels from farmers. If the survey comes back with positive results, a detailed feasibility study should be carried out. After making enquiries with UCD and Teagasc, it was discovered that neither had conducted a survey on farmer interest in participating in an anaerobic digestion cooperative. A limited survey was undertaken and is discussed below.

3.2 Manure availability and Digester Sizing

The model proposed comprises 20 farmers in the cooperative and an assumption is being made that each farm will have a dairy herd of 75 cows.
One dairy cow will produce 47kg of slurry per day or 329kg of slurry per week.

It is assumed that dairy cows spend 20 weeks indoors. Therefore, the manure available for the anaerobic digestion is 329kg x 20 weeks x 1500 cows = 9,870 tonnes of manure per year.

Dairy cows are inside twice a day for milking and assuming 10% extra potential manure results in 10, 857 tonnes of manure per year which is equivalent to 10,857m³ per year (assuming 1m³ = 1 tonne)

As was evidenced in the literature, codigestion will increase the biogas yield and this model advocates using 50% manure, 50% other feedstock material.

A retention time of 40 days will be used as this covers mesophilic or thermophilic.

Digester sizing is calculated using the following formula (Caslin):

Digester volume = (manure m³ /year + cosubstrate m³/year) x retention time/365 days.

Digester size for this model will be:

(10,857m³ manure + 10,857m³ cosubstrate) x 40/365 = 2,380m³ digester capacity.

Therefore, the digester size would depend on the number of farmers in the cooperative, the dairy herd size and the amount of other available feedstocks.

3.3 Mesophilic or Thermophilic

The literature suggests that the mesophilic temperature is more popular and it is used in the AFBI plant, and the Bally Shannon farm in Co Wexford. The literature affirms that using the thermophilic range produces a higher gas yield. This model proposes codigestion of manure and other organic waste and as is shown below, the thermophilic temperature will produce a higher gas yield.

Appendix B contains details on the AD plants in Denmark. Two of these have been selected to show the difference between the feedstocks and thermophilic and mesophilic temperature and the resultant biogas produced:

	Units	Vaarst/Fjellerad	Nysted
Year of construction	year	1997	1998
Digester capacity	m^3	2000	5000
Process temperature (m/t)		t	m
Mesophilic (m), thermophilic (t)			
Cattle manure	m^3	8458	8841
Pig manure	m^3	6350	45550
Poultry manure	m^3	-	165
Total agricultural biomass	m^3	14808	54556
Organic waste from intestinal contents	m^3	5436	125
Organic waste from fat or flotation sludge	m^3	5355	408
Organic waste from fodder	m^3	8	62
Organic waste from fish processing	m^3	1740	54
Organic waste from fruit & veg	m^3	-	137
Organic waste from dairies	m^3	166	-
Organic waste from sugar industry	m^3	-	1819
Organic waste from bleaching earth	m^3	359	-
Organic waste from tanneries	m^3	27	-
Organic waste from medical industries	m^3	2816	678
Organic waste from other industries	m^3	-	510
Organic waste from households	m^3	582	-
Waste total	m^3	16489	3793
Biomass total	m^3	31297	58349
Biomass per day	m^3	86	160

Biogas production, 1000 m^3		2382	1450
Biogas per day	m^3	6526	3973
Gas yield per day	m^3/m^3	76	25

Table 9.

Table 10 below, is interpreted data from the above table. It can be seen that the plant that uses the thermophilic temperature range, which codigests manure with organic waste, has the higher gas yield. This is in agreement with the literature discussed previously

	Vaarst/Fjellerad	**Nysted**
Temperature range	Thermophilic	mesophilic
% of agricultural waste	47%	93.5%
% of organic waste	53%	6.5%
Biomass processed/day (m^3)	86	160
Biogas produced/day (m^3)	6526	3973
Gas yield (m^3/m^3)	76 from (6526/86)	25 from (3973/160)

Table 10.

3.4 FEEDSTOCKS

It is proposed that a mixture of manure and other waste is used in the anaerobic digestion cooperative.

It is evident from the above table that a mixture of agricultural and organic waste produces a better gas yield. As Nysted processes 93% agricultural waste, it has to use mesophilic temperature range and as previously discussed, this produces less energy than thermophilic temperature range. However, alternative feedstocks are not always available though it is advised. The Ballyshannon farm uses whey from cheese in the winter months to ensure the plant is used efficiently.

A CAD plant in Ireland would need plenty of available manure and other potential feedstocks. Figure 6 below (EPA, 2005) illustrates an estimation of the stored slurry on a county by county basis. A CAD plant would need to be located in a county with a high stored slurry content and in an area where there is a processing plant nearby. The road access would also need to be investigated.

As was previously discussed, a mixture of feedstocks, i.e. manure and food waste, will increase the biogas yield. Figure 7 below shows the slurry storage and the IPPC licenses for intensive agriculture, food and beverage processing (EPA, 2005).

	Thousands Wet tonnes (annual)			Combined Slurries	Hundreds farms		
	CATTLE	PIGS	POULTRY	Tonnes/day	CATTLE	PIGS	POULTRY
Carlow	386	51	0.8	1,200	14.7	0.2	1.7
Dublin	133	0	0.7	366	5.1	0.0	0.6
Kildare	553	67	4.1	1,711	20.2	0.3	2.5
Kilkenny	1,352	149	0.7	4,113	33.6	0.4	3.5
Laois	933	106	0.8	2,849	30.3	0.4	3.6
Longford	512	41	1.1	1,517	26.1	0.2	1.7
Louth	364	44	10.5	1,145	13.3	0.2	1.0
Meath	1,298	93	13.8	3,848	38.4	0.4	3.0
Offaly	882	309	0.3	3,265	32.1	0.4	2.7
Westmeath	824	104	1.5	2,548	31.5	0.4	2.8
Wexford	1,107	165	5.5	3,498	34.5	0.8	3.9
Wicklow	531	65	1.7	1,638	18.3	0.3	2.3
Clare	1,286	37	0.5	3,626	63.8	0.4	6.0
Cork	4,341	895	35.8	14,441	127.5	2.5	10.0
Kerry	1,571	124	7.3	4,663	75.0	0.6	5.5
Limerick	1,723	136	70.8	5,289	58.6	0.6	5.3
Tipperary NR	1,222	112	0.6	3,655	35.5	0.2	3.1
Tipperary SR	1,345	239	0.4	4,340	35.3	0.6	3.1
Waterford	1,034	219	34.2	3,526	24.4	0.4	2.0
Galway	1,853	19	7.1	5,149	124.9	0.4	10.5
Leitrim	454	18	1.2	1,295	34.0	0.2	1.8
Mayo	1,282	62	12.4	3,718	108.8	0.4	9.6
Roscommon	882	60	0.2	2,582	59.3	0.2	3.2
Sligo	549	8	0.4	1,528	40.8	0.1	3.5
Cavan	1,282	922	27.4	6,114	51.3	1.2	3.5
Donegal	762	97	1.9	2,359	61.4	0.6	6.5
Monaghan	1,110	99	218.9	3,911	42.5	0.6	4.0
Ireland	29,568	4,243	461	93,895	1,241.1	12.8	106.5

Source: Based on CSO's Census of Agriculture 2000. * Calculations assume 16 weeks of stored cattle slurry in Leitrim, Cavan and Monaghan and 20 weeks elsewhere. It was assumed that all pig and poultry slurry is managed (stored), therefore potentially available for AD. Combined slurries measured in tonnes/day is calculated as the sum of stored cattle, pig and poultry slurry divided by 365.

FIGURE 6

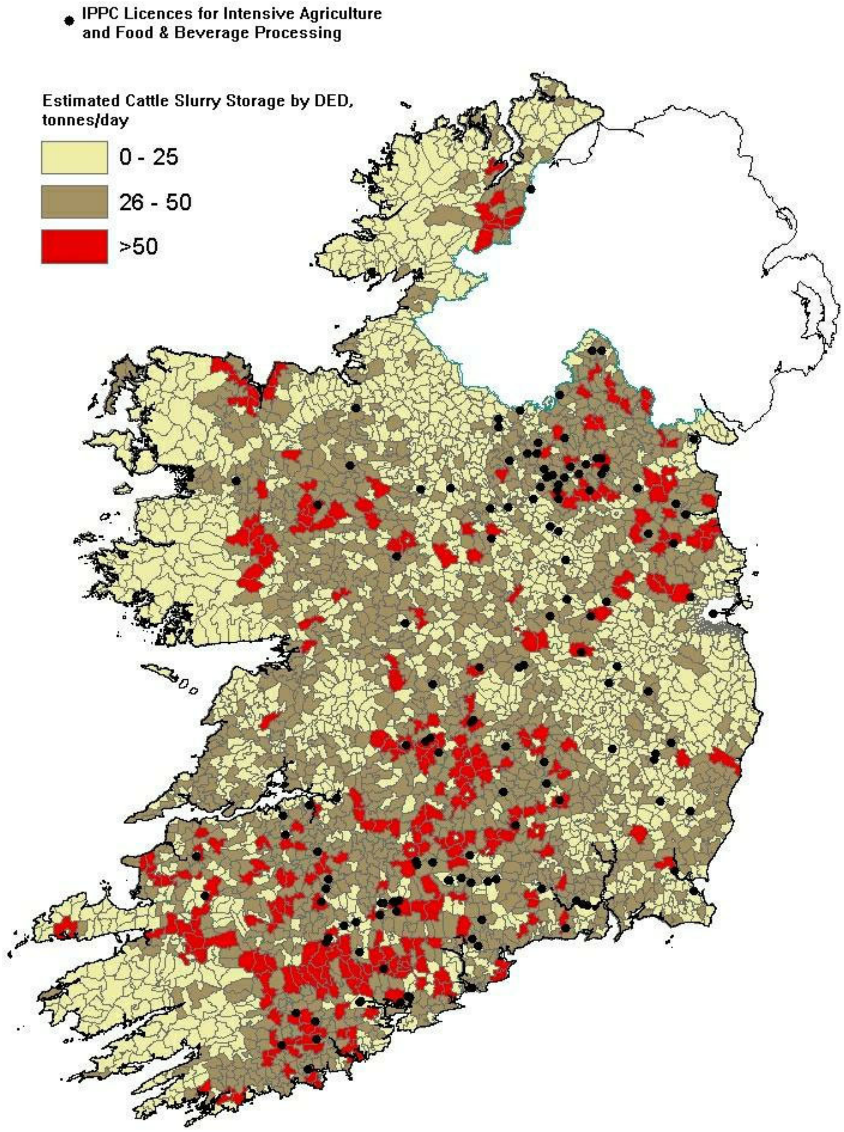


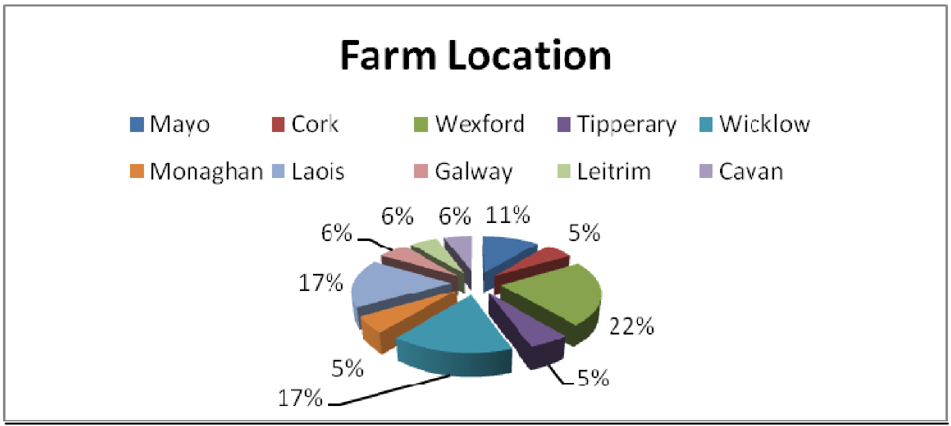
FIGURE 7

3.5 PARTICIPATION OF FARMERS AND LOCAL COMMUNITIES IN THE COOPERATIVE

A renewable energy cooperative is set up so communities can utilise natural resources available to them. An anaerobic digestion cooperative would enable farmers and communities to generate an extra income and to become sustainable. Natural resources provide an excellent way for communities to achieve this. A survey was conducted to see if farmers had any knowledge of anaerobic digestion and cooperatives. An online forum facilitated the survey and

20 farmers responded. The low response is most likely due to the bad weather and the Christmas break. The survey began with an overview of anaerobic digestion and cooperatives and it included the Jühnde case study.

The first question established what counties the participants lived in. The chart below shows the percentage per county.

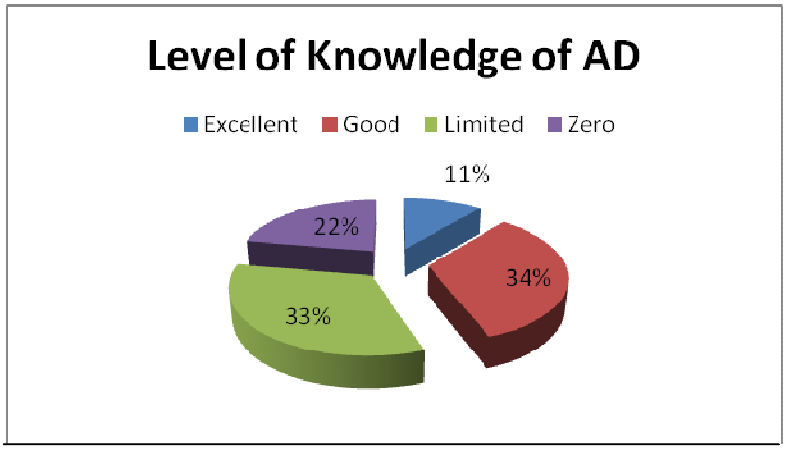


This is important as certain counties will be more aware of anaerobic digestion and interested in anaerobic digestion than others.

The second question asked participants to specify the type of farm they had. The majority of the farms were dairy and/or beef and graph details can be found in Appendix C. 50% of the farms had between 100 and 250 animals which is above the national average. This is relevant as the majority of anaerobic digestion plants are based around dairy farms.

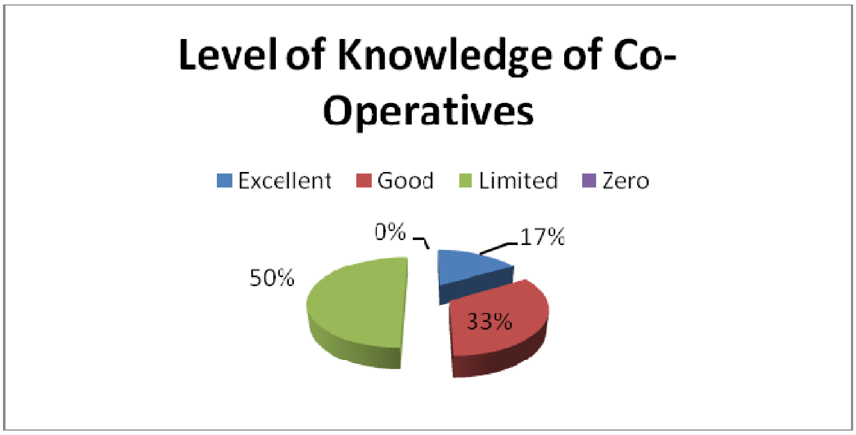
The third question asked participants what their main source of power was on the farms. Electricity was the main source of power and some of the farms had diesel as well as electricity.

The participants were next asked what their knowledge of anaerobic digestion was. The following chart illustrates the results:



This result is encouraging. However, it must be noted that an overview of anaerobic digestion was provided at the beginning of the survey.

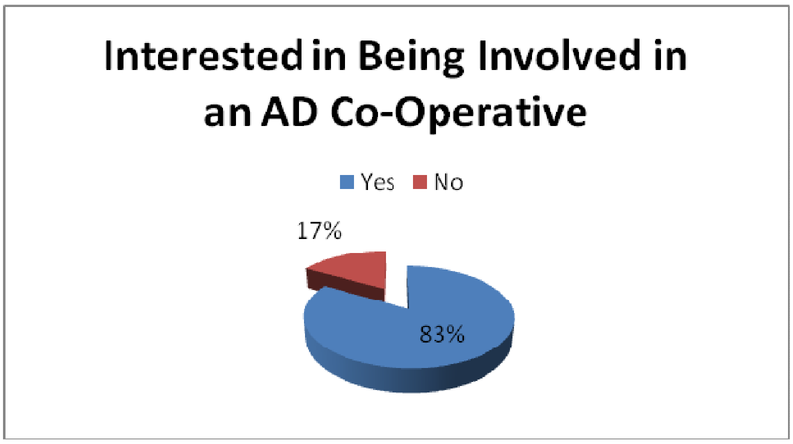
The participants were asked what their knowledge of a cooperative was. This was asked because the cooperative would be the foundation of the model.



The result, above, was surprising seeing as agricultural accounted for 95% of registered cooperatives in Ireland in 2005. It is perhaps a flaw of the survey as knowledge was not defined and participants may have interpreted it differently.

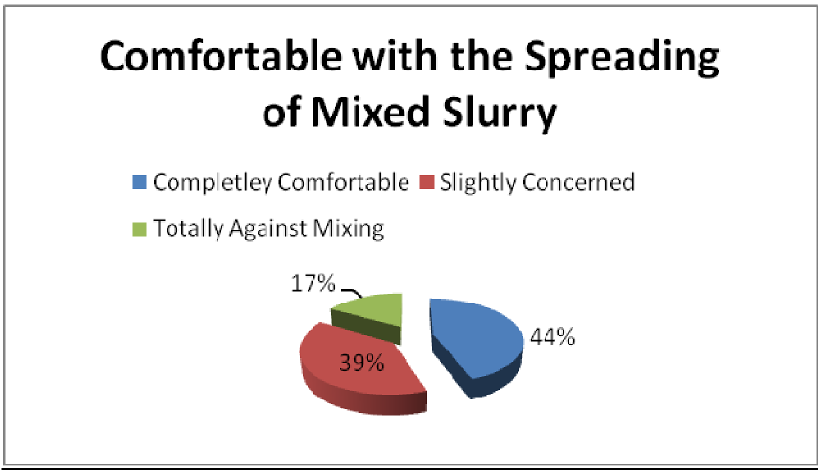
The following question asked participants had they ever been involved in a cooperative and 83% said they hadn't. Within this question, they were also asked to comment on whether they thought a cooperative was successful. Comments made were that is was more economical and more influential due to the larger numbers.

Question eight asked participants if they would be interested in participating in an anaerobic digestion cooperative. This was one of the most important questions of the survey as it defines the interest levels of farmers. As was seen in the case studies, anaerobic digestion cannot take place without teamwork from farmers.



The graph above shows that 85% of participants would be interested in participating in an anaerobic digestion cooperative. This is very encouraging. One participant commented that they had other priorities at this time, and another commented that they wouldn't be interested as they had no knowledge of it. This comment links in with the SEAI finding that knowledge is a barrier to anaerobic digestion. The education principal of a cooperative could be utilised to communicate effectively.

Participants were asked if they would be comfortable spreading a mixture of slurry as long as the slurry had been correctly processed and the bacteria had died. This question was asked as an anaerobic digestion cooperative would necessitate spreading slurry from multiple farms.



As can be seen in the graph above, only 17% were completely against spreading a mixture of slurry. This is a positive result as farms participating in an anaerobic digestion cooperative would have to spread mixed slurry.

The final question put to participants was did they think there were any reasons why an anaerobic digestion cooperative would not work.

The answers indicated that the participants had a greater knowledge than they thought. A detailed table of all of the comments can be found in Chapter Discussion.

A common theme expressed by participants was lack of support from government agencies. Some of the comments are as follows:

- no buy in from DAFF
- current capital funding available from the SEAI is too low
- lack of government incentive to set up a cooperative of this kind
- lack of faith in the system
- grid connection issues
- lengthy planning process

One savvy participant from Tipperary commented that 'grid connection, REFIT and cooperative buy must all be resolved before this type of venture could happen'. One participant from Wexford commented that they can't see any potential issue but they also mention a farmer in Wexford with his own anaerobic digestion plant; they are referring to the Ballyshannon farm.

This shows that having an anaerobic digestion plant in an area increases the knowledge and awareness of the technology.

It is difficult to put a number on the amount of farmers that could participate in the cooperative. The literature and case studies indicate that the participating farms should be within 10kms of the AD plant. As previously discussed, the digester size depends on the available feedstocks. None of the cooperative case studies indicate who owns the land on which the plant is built. This is potentially an issue in Ireland given our history with land. A potential model to follow in this regard could be the community based company in West Clare. 30 families own 3,000 acres on which they want to put 28 wind turbines.

It is envisaged that farmers would agree to participate in the cooperative and a feasibility study would be undertaken to assess the best location on the participating farms for the anaerobic digestion plant. It is suggested that the EPA recommendation of digester storage on each farm is followed as this avoids distribution complication.

Farmers will be asked to pay a nominal fee to become cooperative members and they will receive a pro rata return for the manure they provide.

3.6 Assistance from Government and related agencies

The SEAI gets funding from the government and the EU to facilitate renewable energy initiates that are mostly linked to government energy polices. The funding available for AD CHP is 30% of the capital cost.

In May 2010, an amended set of REFITs were announced for anaerobic digestion and biomass CHP. The tariffs are as follows and are to be offered on a 15 year basis:

AD CHP ≤500 kW €150/MWh

AD CHP >500 kW €130/MWh

AD (non CHP) ≤500kW €110/MWh

AD (non CHP) >500kW €100/MWh

Biomass CHP ≤1500kW €140/MWh

Biomass CHP >1500kW €120/MWh

It is assumed that an anaerobic digestion cooperative would be able to avail of the above tariffs.

The current landfill levy is €30 per tonne and an anaerobic digestion plant could receive this as a gate fee.

The Farm Waste Management Scheme was set up to assist Ireland in complying with the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2005 (SI no 788 of 2005). The scheme provides grant aid for farmers to invest in storage facilities for silage and agricultural waste, and specialised slurry handling equipment. The EPA discussion paper (ref 69) comments that funding, of 40% of the capital cost, is available through the farm waste management scheme.

3.7 Economics

When planning an anaerobic digestion cooperative one must assess the financial feasibility of a plant. The case studies discussed indicate that the capital cost of an AD plant is linked to the tonnes the plant will process. Ballyshannon AD plant cost €1.4 million and processes 12,000 tonnes per year. Ribe in Denmark cost $5.5 million in 1990 and processes 150,000 tonnes per year. Holsworthy plant in the UK cost €8.2 million in 1998 and processed 100,000 tonnes per year.

The capital cost of a plant will depend on a variety of things such as the size of the digester, cost of land if required, cost of tankers, grid connection, and decentralised digester storage tanks on the cooperative members land if required.

It is very difficult to propose a definite cost of an AD plant. Dr Peter Frost advised he has seen AD plants in Europe ranging in cost from €300,000 to €3 million. Kedco Plc estimates that a plant that processes 30,000 tonnes per year would cost approximately €3.5 million. This equates to a capital cost of €116 per tonne.

Mannvit UK Ltd is a renewable energy solutions company and they estimate a plant that processes 14,000 tonnes per year would cost £1.5 million which equates to £110 per tonne.

The financial annual benefits of an anaerobic digestion plant are sale of electricity, sale of the digester effluent, and the landfill levy if applicable to anaerobic digestion facilities.

The literature shows that a higher gas yield is produced by codigesting manure with another material.

It is evident that the proposed model should accept both manure and other organic waste.

This model will assume the €116 per tonne. As discussed in section (digester section) the anaerobic digestion cooperative will assume a capacity of 20,000 tonnes per year. The capital cost of the plant will be 20,000 tonnes x €116 per tonne = €2.3 million.

Barry Caslin and Mannvit quote operating costs between 4% and 8% of the capital cost. This model will assume an operating cost of 8% = €184,000 per year.

Dr Frost's research revealed that 1 tonne of slurry = 86kWh.

1 tonne of food waste produces approximately 300kWh of electricity (Ireland, May 2009)

Using the data in the literature this model is assuming that 50% of energy produced will be available for external use.

	Per year	**units**
Waste input manure	10,000	tonnes
Waste input organic	10,000	tonnes
Energy produced manure	860	MWh
Energy produced organic	3000	MWh

waste		
Total energy produced	3860	MWh
Energy for external use	1930	MWh
Revenue from REFIT	€231,600	€
Revenue from gate fee	€600,000	€

Table 11.

Revenue is calculated using a gate fee of €30 per tonne and a REFIT of 12c/kWh.

Using the data in table above the following is a breakdown of capital cost, operations cost and revenue:

	Cost per year
Operation and maintenance cost	€184,000
Labour and transport	€60,000
Total cost	€244,000
Total revenue	€831,600
Profit	€587,600

Table 12.

It is important to note that the above revenue does not include the potential to sell the digestate as a fertiliser.

The payback period, without the SEAI grant, for the project is annual profit/capital cost = 4 years.

The payback period with the SEAI grant is 2.7 years.

CHAPTER 4 RESULTS AND ANALYSIS

4.1 LOGISTICS AND LOCATION

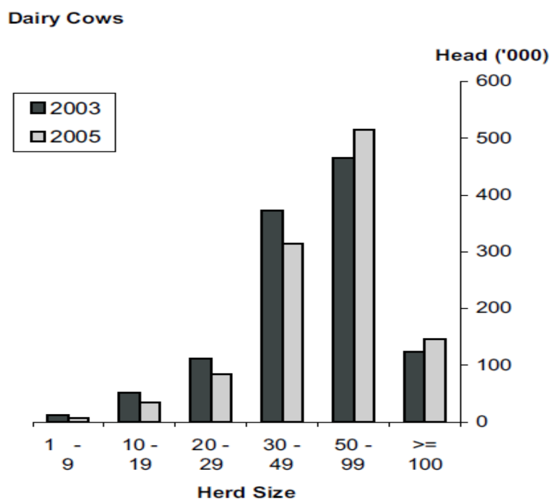
As a location was not selected in the design of the anaerobic digestion cooperative it would be advisable to use the EPA feasibility report but it must be noted that it is 8 years old.

It is likely that the first anaerobic digestion cooperative in Ireland will be set up through farmer initiative. Further plants could then be set up by approaching farmers and communities in an informal manner. It is evident that it would not be very easy for a farmer to set up an anaerobic digestion cooperative. As per the advice in the literature, farms should be within a 10km radius of the plant. It is not clear how many farms there are in Ireland per kilometer. There are 130,000 farms in the Republic of Ireland and the land area is 68,883 sq km which gives a rough approximation of one farm every 0.5 sq km. This indicates that a cooperative would achieve 20 farms within a 10km radius.

A feasibility study would need to be undertaken to assess the suitability of the location and road access. The Holsworthy case study states that the original owners had complaints from locals that the tankers were blocking the rural roads. It is hoped, that with the cooperative model, community involvement would negate most of the complaints regarding traffic.

4.2 MANURE AVAILABILITY AND DIGESTER SIZING

The anaerobic digestion cooperative model proposes 20 farmers each with a dairy herd of 75. This is above the national average of 55 dairy cows per herd (CSO.ie) but as can be seen in the graph below the majority of farms (herds) have between 30 and 99. The survey results indicated that 50% of participants had between 100 and 250 animals.



It is assumed that each dairy cow will produce 47kg of slurry per day. Another source indicated that a dairy cow produces 66kg per day. Therefore the kg per cow would in fact be higher than the assumed 47kg used in the model.
It is assumed that dairy cows spend 20 weeks inside but this is entirely dependent on the weather. An extra 10% was added to the manure yield but this could be of a higher percentage.

It is advised that the digester size would depend on the number of farmers in the cooperative, the dairy herd size and the amount of other available feedstocks.

The model described in Chapter 3 advocates using a mixture of feedstocks. The literature confirms that codigestion will increase the biogas yield. Pöschl et al (Pöschl et al., 2010) maintain that there codigestion yields a 10% higher biogas yield compared to single feedstock digestion. Pöschl et al recommend using single feedstock for small scale plants, and codigestion for large scale plants. It is important to remember that energy will be used transporting feedstocks to a CAD. Pöschl et al (Pöschl et al., 2010) discuss the energy required to transport feedstocks using a tractor and trailer. Cattle slurry, for example, in a 2km – 20km radius from the anaerobic digestion plant uses 2.8 MJ per tonne per km.

4.3 Mesophilic or Thermophilic

The literature shows that both the thermophilic and mesophilic temperature ranges are used throughout Europe. The thermophilic temperature range is most popular in Denmark but is not popular in the rest of Europe. Mesophilic appears to be more popular in on farm AD plants, and thermophilic seems to be used for centralised anaerobic digestion. An anaerobic digestion cooperative would follow the CAD model and therefore use the thermophilic temperature range. As discussed in the literature the thermophilic temperature range produces more biogas but the equipment is more expensive and a higher energy input is required. The most significant advantage of the thermophilic temperature range is the retention time which ranges from 15-20 days; it is 30 – 40 days for the mesophilic temperature. Furthermore, the higher temperature means that the process is completed quicker. The literature indicates that available capital will dictate with temperature range employed. It is unfortunate that a cost comparison was unavailable for an AD plant that uses the thermophilic range versus the mesophilic range.

4.4 Feedstocks

The model proposes using a 50:50 mixture of feedstocks i.e. manure and organic waste. It is highly evident from the literature and case studies that an anaerobic digestion plant will not be financially viable unless codigestion of feedstocks is used. According to the Federal Agricultural Research Centre in Germany (2005), biogas plants in Germany codigest between 3-5 feedstocks per plant. Results of a biogas measurements programme in Germany show that 75% of German biogas plants use cattle manure in codigestion for biogas production. This indicates that the proposed 50% organic waste may be too high. However, the Vaarst/Fjellerad plant in Denmark has a mixture of 47% agricultural waste and 53% organic waste.

As discussed above the size of the anaerobic digestion plant will depend on the available feedstocks. There is the potential to use some of the 3 million tonnes of municipal waste generated in Ireland each year. The model proposed 20 farms in a 10km radius of the plant. This most likely is feasible, but it is not guaranteed that 20 farms would want to participate in the cooperative and some of the farms could be very small.

Figure 7 gives a good indication of potential locations for an anaerobic digestion cooperative based on (a) IPPC licenses for intensive agriculture and food and beverage processing and (b) estimated cattle storage of slurry. It must be noted that this data is from the year 2000 but gives a good indication. It must also be noted that farms in the west of Ireland are smaller than those in the south and east of the country.

The literature maintains that the unsuccessful anaerobic digestion plants in Denmark were unproductive due to lack of feedstocks and improper construction of the plant.

4.4 Participation of farmers and local communities

The success of an anaerobic digestion cooperative lies with the participation of farmers and local communities. If they are not interested it cannot be developed. There are 20 CADs in Denmark; 9 are owned by cooperatives and 5 of them are organised as cooperatives that include heat (or gas) consumers and farmers.

Peter Young, in the Irish Farmers Journal maintains that farmers are more interested in smaller scale on-farm plants. Danish biogas plants with farmer contribution are more successful than those without. The report also states that Danish land use has restrictions on free standing homes not attached to a farm, therefore manure haulage is not an issue (Hjort-Gregersen, 1999)

The survey conducted indicated that a high majority would be interested in participating in an AD cooperative (85%) but most had valid reservations. 22% of survey participants had no knowledge of anaerobic digestion and 45% had a good or excellent knowledge. This was surprising and indicated a knowledgeable survey audience who were aware of emerging renewable technologies. However, it must be noted that an overview of the anaerobic digestion process was provided along with a case study. Survey participants weren't very aware of the cooperative model (50% had limited knowledge) and only 17% had participated in a cooperative.

Survey participants were mostly comfortable with the idea of spreading a mixture of slurry from different farms on their land (83%). However, the survey only specified spreading a mixture of slurry and did not mention other organic waste. It is assumed that if organic waste was defined and explained that a much lower percentage of participants would be happy to spread that on their land. This could potentially put an end to an anaerobic digestion cooperative.

The table 13 below displays the participant's comments. Each comment has been matched to the county and each comment has been linked to financial, economical and social issues. The column entitled legislative concerns contains the legislation the participant commented on.

	Comment	County	Financial	Environmental	social	Legislative concerns
1	Main reasons for it possibly not working would be due to a lack of faith in the system treating any contaminated slurry completely, and also a lack of government incentives to setting up the co op in the first place.	Wexford	✓	✓	✗	Nitrates Directive
2	How much burning of wood chips is required? Will this cause much pollution? Are there any other pollutants from this system?	Mayo	✓	✓	✗	Air emissions
3	Working out how people get paid i would see as a potential problem.	Cork	✓	✗	✗	n/a
4	None, we have a CHP unit, on the cards down here in Wexford, and we also have a farmer who has his own anaerobic digester.	Wexford	n/a	n/a	n/a	n/a

5	There is no buy in from DAFF for this sort of venture, until there is and also capital funding (reasonable amounts - not the SEAI level currently offered) nothing will happen. Issues with grid connection REFIT and cooperative buy must all be resolved before this type of venture could possibly happen.	Tipp	✓	✗	✓	n/a
6	It would depend on the management of the co-op. Irish farmers are not generally good at management.	Wick low	✗	✗	✓	
7	Economics and lengthy planning process	Monagh an	✓	✗	✗	Planning permissio n
8	the slurry may have high levels of p an k in it and according to the Irish p an k scale some farms are too high in it	Wicklow	✗	✓	✗	Nitrates Directive
9	Planning permission may be refused. Spreading of bi products all year round may not coincide with reps rules.	Mayo	✗	✓	✗	Planning permissio n Nitrates

10	I feel that there would not be enough knowledge, trust and cooperation for it to be successful.	Laois	✗	✗	✓	
11	I suppose until I knew all the details I would have concerns. Trying to find enough farms to spread the slurry on as to not break E.U. nitrate directives. Does the mixed slurry smell badly during spreading causing local in or not in the co-operative to complain.	Wexford	✗	✓	✓	Nitrates
12	No none at all	Leitrim	n/a	n/a	n/a	n/a

Table 13.

It can be seen that the majority of participant's comments fall within financial and environmental concerns, which is not surprising. The survey participants commented on legislation that would impact a project like this, they did not comment on how an anaerobic digestion plant would have on the legislation and national action plans. It is likely that they are unaware of these. It would be important to educate potential cooperative members on the legislation as it is the driving force behind anaerobic digestion in Ireland.

4.6 Assistance from Government and related agencies

The most common theme to come out of the survey was lack of support from government and related agencies. This is a huge issue especially seeing as the government is behind renewable energy initiatives that are introduced to meet legislative requirements such as the Landfill Directive. The last few years, having two Green Party TD's, has brought the green agenda to the forefront of Irish politics. It is likely that the government composition will radically change in the next few months, and the current economic climate means that the government will have higher priorities.

The current status of government funding for anaerobic digestion is unknown. The SEAI open call for proposals for Anaerobic Digestion CHP has been closed due to the lack of funding available from the government. There is no indication when it may reopen. The funding available for AD CHP was 30% of the capital cost. This means that future anaerobic digestion plants may not get the 30% funding of the capital cost and this will make a project much less attractive to farmers and potential lenders.

The REFIT, in 2006, for anaerobic digestion was €72/MWh. In May 2010 an improved set of tariffs were introduced for anaerobic digestion and biomass CHP. The DCMNR is awaiting approval from the EU for the new REFIT that was announced in May 2010. It is most likely that this will be approved so future anaerobic digestion plants will receive between €100MW/h to €150MWh.

The current landfill levy is €30 per tonne. It is expected that it will increase to €50 per tonne by 2011 and €75 per tonne by 2012, following the introduction of new legislation. Minister Gormley is also introducing an incineration levy to ensure that the waste hierarchy is adhered to. Draft legislation, is soon to be brought into law The Waste Management Act 1996 and 2001, allows for 'the amount of the levy shall be specified in the regulations…. but shall not exceed an amount of €120 for each tonne of waste disposed of'.

However, it is not clear if anaerobic digestion plants can avail of a gate fee from users that would otherwise have to pay the landfill levy. This would need to be clarified as the proposed gate fee in the model contributes hugely to the profit.

A 2004 report entitled 'Current Progress and Practice in the Adoption of AD in the EU' was presented at the European Biogas Conference. It contains a breakdown of EU countries and their AD development (Claudius da Costa Gomez 2004). It is evident from the report that the EU countries with the most successful AD development have policy makers that drive AD. Denmark has a legislative requirement for nine months slurry storage capacity. There is an availability of long-term low interest loans to build AD plants. The Danish government has set ambitious environmental and energy targets and there is positive public and industry attitude towards biogas plants. Germany offers a guaranteed fixed electricity price for 20 years and this is favourable with banks. The German government offers a bonus system which provides additional funding for (a) electricity that is produced from energy crops, (b) use of heat from CHP, (c) the use of new technology. The report states that if the bonus systems are combined a biogas plant (new technology) with an installed capacity of 150kW, using energy crops and providing heat via CHP, could achieve 21.5c/kWh.
The report also states that 'the DEHLG will engage with the DCMNR to ensure that the benefits of the use of biogas and energy generation for AD are recognised and that procedures for the provision of gas and electricity from such facilities to the respective national grids are clarifies and, where possible, made more accessible'. One would hope that this has already begun to happen.

The DCMNR, under the National Strategy for Managing Biodegradable Waste, set up a Market Development Group to encourage market developments for compost and other recovered waste materials. The Market Development Group identified barriers to development of markets for compost products; these barriers would also apply to the digestate product from the anaerobic digestion process:

- lack of standards/Quality assurance scheme
- lack of education

- no clear policy on when waste becomes a product

The report identifies the need to have a national compost standard; this has been implemented and has just recently closed its public consultation. It is assumed that they will initiate proposals for a compost quality scheme which could extend to digestate also. Please note that this assumption came from an individual in the Queries Unit in the EPA.

The government policy statement agrees with the need to have standards and in 'Preventing and Recycling Waste - Delivering Change' (DEHLG, 2002), it is recommended that the capacity to control the quality of raw materials should be addressed for each potential form of biological treatment.

It has been recognised that waste, after composing or anaerobic digestion treatment, is not necessarily a waste and can be reclassified as a product and put on the market. It may take a few years before a national standard and quality assurance scheme are applied to anaerobic digestion but the process will be in place. The UK Quality Protocol and PAS 110 are very comprehensive and it is assumed that the Irish ones will be quite similar. An Irish Quality Assurance scheme would instill confidence in potential digestate users. It will also promote what the digestate product is and hopefully spark an interest in producing it.

The Farm Waste Management Scheme provides grant aid for farmers to invest in storage facilities for silage and agricultural waste, and specialised slurry handling equipment. The EPA discussion paper comments that funding, of 40% of the capital cost, is available through the farm waste management scheme. However, when the Farm Waste Management scheme is analysed, the following is observed:

- The maximum amount eligible for grant aid is €120,000 per holding.
- With regard to the handling equipment 40% grant aid is available subject to a maximum investment of €40,000.

One would have to get a detailed description of what is available through the farm waste management scheme.

4.7 LEGISLATION

Landfill Directive

The Landfill Directive requires Member States to ensure that biodegradable waste going to landfills must be reduced to:

- 75%, of the total amount of biodegradable waste produced in 1995, by 2010

It is not yet clear if Ireland reached this target. If they do not reach this target the European Commission can take legal action against Ireland and the European Court of Justice would most likely impose high level fines.

In 2004, 780,460 tonnes of municipal food and garden waste was generated where 93.9% of this was sent to landfill and the remainder was recovered. Article 5 of the Landfill Directive required Member States to devise a National Strategy on Biodegradable Waste. The targets in the National Strategy are to divert approximately 43% of organic waste to biological treatment by 2013 and 50% of organic waste to biological treatment by 2016. These targets are to be met using home and commercial composting, and local authorities facilitating composting. The report states that by 2010 all homes should have access to a home composting bin that will be collected by the local authority. In Dublin, Fingal County Council and Dublin City Council claim to have introduced a brown bin service to all homes but this seems to be happening on a very gradual phased basis.

Planning Permission

Obtaining planning permission in Ireland has always been tricky. There are a lot of factors involved in obtaining planning permission for an anaerobic digestion plant in Ireland. Planning applications must be made to the relevant authority. Tom O'Neill of Limerick Co Council planning section suggests requesting a pre planning meeting. An IPPC license will be required for an AD plant and an application must be made to the EPA. A waste collection permit will be required to move organic material on to a site. If the digestate is considered a waste, a waste licence will be required and an environmental impact statement will have to be carried out.

4.8 Cooperatives

There are 4 different types of cooperatives and the model proposes a community operated cooperative. However, depending on government capital funding a 50:50 cooperative may need to be looked at i.e. 50% owned by the community, 50% owned by a private investor. Kedco PLC is a company providing a partnership model with farmers for anaerobic digestion. It is a 50:50 partnership where the farmer supplies land and feedstock and Kedco provide the technical expertise and the returns are split evenly. Kedco state that 30,000 tonnes could produce 1.3GWh per year. They note the cost of installing a system to process 30,000 tonnes per year would be €3.5 million which is in line with other costings.

One of the principals of the National Strategy on Biodegradable Waste 2006 is to develop partnerships with other sectors, including agriculture, to set up cost effective treatment systems suited to Irish conditions. Anaerobic digestion cooperatives are one of these cost effective treatment systems that could be introduced. However the policy statement entitled 'Waste Management Changing Our Ways' advises that local authorities are not particularly interested in involving public private partnerships. The report advocates public private partnerships as they can deliver capital investment and specialist expertise in the application of alternative and energy technologies. One of the comments, from a participant in the survey when questioned on reasons why an anaerobic digestion cooperative might not work, was 'It would depend on the management of the co-op. Irish farmers are not generally good at management'. This indicates that some potential farmers may prefer to have an expert on board not from the community.

4.9 Commercial Aspect

BGÉ conducted a report on the future of renewable gas in Ireland. It is a biased report and focuses on producing biogas and using it as a gas (biomethane). However, only biogas used to produce electricity will benefit from REFIT. BGÉ have identified obstacles and declare they can be resolved relatively quickly with government support and regulatory bodies. However, it must be noted that a commercial company is not going to advertise potential obstacles.

A positive noting in the report is that they advocate a cooperative approach and highlight that the cooperative model has been successfully adopted by farming cooperatives in Denmark and Germany.

The model proposes using the biogas to produce electricity; otherwise the anaerobic digestion plant would not be successful. Biomethane is not eligible for REFIT and would have to rely on the sale of gas at market rates and gate fees if applicable. The REFIT is guaranteed for 15 years and the sale of gas is not guaranteed as it depends on market rates.

There are two methods of tax relief that may be available for investors though it is unclear if cooperative members are considered investors. The first is Corporate Tax Relief for Investment in Renewable Energy Generation. Relief is capped at 50% of all capital investments (excluding land), net of grants, on a single project. The second is the Business Expansion Scheme and would only apply if private investors became involved in the cooperative.

4.10 Economics

The majority of anaerobic digestion plants, if financially assessed, will not be financially viable. The reason for this is that a financial assessment only takes the finance side into account. Two studies have been conducted in Ireland on the economic feasibility of a CAD plant in Ireland. Both studies questioned the economic feasibility of CAD plants in Ireland but both studies also acknowledged that a lot of the benefits of an AD plant are not counted in an economic feasibility study. One of these benefits is the environment. The main component of biogas is methane. In a landfill situation the waste decomposes and produces a biogas which is released into the air and contributes to greenhouse gas emissions. In an anaerobic digestion plant the biogas is captured and utilised and is does not contribute hugely to greenhouse gas emissions. Anaerobic digestion will therefore assist Ireland meeting its landfill directive targets, greenhouse gas emissions targets, and renewable energy targets yet none of this is contained in a financial assessment. A study, commissioned by the EC in 2001, entitled 'Waste Management Options and Climate Change', showed that 'source segregation of municipal solid waste (MSW) followed by recycling and composting/AD given the lowest net generation of greenhouse gases compared to other options for the treatment of bulk MSW'.
Anaerobic digestion plants can also contribute to government policies such as security of supply. Anaerobic digestion reduces the odour of slurry and this is not considered in a financial assessment.

As discussed in the literature is it difficult to put a capital cost on an anaerobic digestion plant as it depends on a number of inputs. The capital cost will depend on the size of the digester, cost of land if required, cost of tankers and grid connection. The financial annual benefits of an anaerobic digestion plant are sale of electricity, sale of the digester effluent, and the landfill levy if applicable to anaerobic digestion facilities. However it is currently unknown if the landfill levy can be applied to anaerobic digestion plants and it might take quite a while for digester effluent to become a marketable product.

The model in Chapter 3 uses a cost of €116 per tonne of feedstock to estimate the capital cost of an anaerobic digestion plant. This was chosen based on the estimates from Kedco Plc and Mannvit UK who build anaerobic digestion plants. The literature and case studies indicated a variety of costs but unfortunately these costs are from a period of 20 years and are in different currencies so a comparison was not possible. The plant in Ballyshannon is 12 years old but has been ungraded and upsized in those 12 years. It processes 12,000 tonne per year at a cost of €1.4 million which equates to €116 per tonne which is exactly what Kedco Plc indicated for the capital cost. It is likely that Kedco were involved in the Ballyshannon plant.
Ref 42 indicates that an AD plant would cost €3 million inclusive of all equipment such as 1MW CHP unit, 2 digesters of capacity 5,000m^3 each. This agrees with the figures above.

The model assumes operating cost of 8% as this was the highest projected operating cost in the literature. It is likely that the operating cost may be lower and this would reduce the cost of running the plant.

As shown in the literature there are a number of financial accounts of anaerobic digestion plants. Barry Caslin assembled an investment cost article in the Irish Farmers Journal in Oct 2009. He assumed an investment sum of €900,000 for the plant which would process 800 tonnes per year. He assumed 10% of the electricity would be used on site and 25% of the heat produced was used on site.
The AFBI case study indicates that 37% of the biogas produced was required to maintain the correct temperature and an average demand of 5.4kWh of electricity per tonne of slurry input.
The Holsworthy plant cost states that it exports 90% of energy produced to the national grid.
The literature indicates that approximately 50% of the produced energy is available for external use. The model assumed the figure of 50% from the literature as this was the highest percentage.

The EPA discussion paper estimated the following waste inputs and biogas production:

	Units	Per year
Waste inputs	Tonnes	54, 750
Biogas production	m^3	2,117,000
Heat for CAD	kWh	423,000
Electricity for sale	kWh	3,239,000
Heat for sale	kWh	3,811,000
Total energy production	kWh	7,473,000

Table 14.

These figures indicate that 1 tonne of waste input produces 136kWh. This is much higher than the figures given by Dr Frost. Biogasinfo.co.uk and the SEAI case study in Ballyshannon. It is important to note that the Ballyshannon AD plant also processes whey in the summer months and this would give a higher biogas yield.

If codigestion was implemented the total energy production is likely to be higher than what is in table above. However using the above figures, the plant only uses 3% on energy produced on site which does not in agreement with the literature and the case study in the AFBI. Therefore in reality, the heat for CAD is likely to be much higher and this will reduce the energy for sale.

The report does not take gate fees for landfill into account.

The model in Chapter 3 uses a gate fee of €30 per tonne in the table x to increase revenue. It is evident, looking at table x, that the plant will not be finincailly feasible without the gate fees.

Using the data in table above the following is a breakdown of capital cost, operations cost and revenue:

	Cost per year with gate fees	Cost per year without gate fees
Operation and maintenance cost	€184,000	€184,000
Labour and transport	€60,000	€60,000
Total cost	€244,000	€244,000

Total revenue	€831,600	€231,600
Profit	€587,600	-€12,400

Table 15.

It is important to note that the above revenue does not include the potential to sell the digestate as a fertiliser.

The payback period, without the SEAI grant and with gate fees, for the project is capital cost/annual profit = 4 years.

The payback period, with the SEAI grant and with gate fees is 2.8 years

The payback period, without gate fees is not feasible.

An AD cost calculator has been created by Andersons centre on behalf of The National Non Food crops Centre (NNFCC) in the UK. It is a very comprehensive tool which allows one to input a range of feedstocks, the DM content, the potential biogas yield, the amount of tonnes expected, revenue from REFIT, capital costs and annual running costs. It seems to be an excellent tool.

The SEAI is also in the process of developing a plant calculator which will allow one to see how many kWh can be produced from different feedstocks, and what gas yield will be produced.

AD plants are not without their problems. A report on CAD plants in Denmark (Hjort-Gregersen, 1999) indicates that 4 plants in Denmark have never performed satisfactorily (their current income is less that break even income). The main reasons for this are inappropriate construction and equipment, and lack of procurement of feedstock (i.e. slurry and/or waste)

4.11 Electricity and Gas Consumption in Ireland

The final electricity consumption in Ireland in 2008 was 26,675GWh; gas consumption was 77021TJ and CHP produced 14% of this. However as previously discussed, gas production is unsuitable as no REFIT; the biogas must be converted to electricity. CHP is combined heat and power and is when heat and electricity are generated, and the heat is recovered and reused.

The SEAI energy balance sheet defines biogas as methane and CO2 produced by AD, and biomass is defined as heat generated by combustion. Therefore, when looking at the energy balance sheet biogas is chosen.

The indigenous production of biogas in Ireland in 2008 was 9ktoe, and in 2009 it was 12ktoe.

The indigenous production of wind in Ireland in 2008 was 207ktoe, and in 2009 it was 254ktoe.

The final energy consumption in Ireland in 2008 was 13,440ktoe, and in 2009 it was 12,247ktoe.

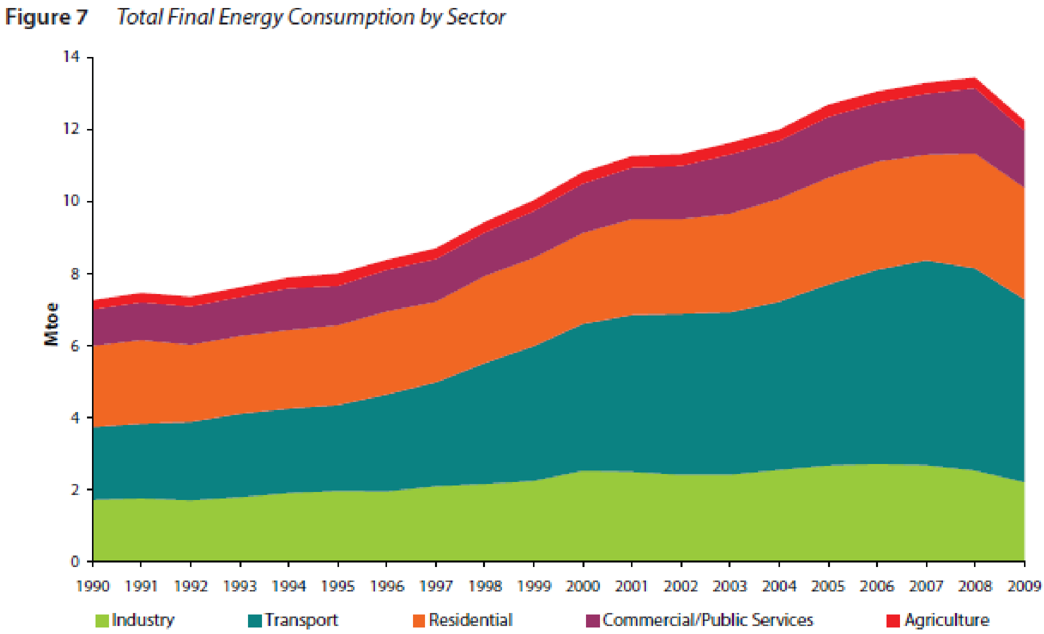


FIGURE 8

Figure 8 above shows the total final energy consumption by sector (SEAI). It is evident that the agriculture sector has had a decrease in energy consumption. All sectors experienced a decrease in energy consumption from 2008 onwards and this is mostly due to the downturn in the economic climate.

ESB Networks was contacted to obtain the rural domestic load for the Republic of Ireland. The figure was 2,511GWh for the period January 2010 to October 2010 which equates to 251GWh per month.

The proposed model indicates that 1930MWh will be produced for external use per year which equals 160MWh per month. Ten anaerobic digestion plants as per the model could generate 1.6GWh per month.

4.12 Comparison to Wind Farms

According to the SEAI there are 110 grid connected turbines (July 2010) with a power output of 1,379MW which provides electricity for 500,000 homes per year. Germany has 25,000MW capacity installed.

Knockawarriga Windfarm applied for planning permission in 2002, it was granted in 2003, construction began in 2006 and generation began in 2008.

It is well known that obtaining grid connection in Ireland is troublesome (IWEA.com). West Clare Renewable Energy is a community based company comprising of 30 families and they have the largest share of a proposed wind farm. The families own 3,000 acres on a hill running from Ennis to Miltown Malbay. The proposal is to build 28 3 MW turbines at a cost of €200 million and it would provide the electricity requirement for the 130,000 people in Co Clare. In August 2010, the Clare County Council granted planning permission for the wind farm but the project now has to wait for grid connection and this could take years (O'Brien, 2010). It is important to note that the proposed site is 1km from the national grid.

Since August 2010, the project has received 7 appeals against it and is awaiting a decision in early 2011.

There are 2 problems with wind which is not an issue with AD:

1. Location of wind farms is generally rural and therefore it is difficult to get grid connection
2. The wind doesn't blow all day every day.

The annual renewable report 2010 from Eirgrid indicates that a limit will be placed on the aggregate wind farm output, called system non-synchronous penetration (SNSP). The ability to manage this will affect the renewable targets set for 2020. It is noted that 6,000MW of electricity generated from wind will need to be connected to the grid by 2020 if Ireland is to meet its targets.

It has been noted that Ireland will need to utilise the energy that is generated from wind. The EU Commission is supporting the idea of a European supergrid which will enable Member States to share renewable energy.

Windfarms, are however, must less complex than an AD farm once constructed as an AD farm must be continuously monitored.

Government support and initiatives have enabled wind energy to increase from 117 MW in 2000 to 1,264MW in 2010 (February).

CHAPTER 5 CONCLUSION

This paper set out to investigate the issues around developing anaerobic digestion cooperatives in Ireland. The objectives are revisited below and each objective is critically reviewed:

<u>Objective 1</u>

Establish the feasibility of an anaerobic digestion cooperative using the influencing factors as per the headings below.

<u>Economically/Financially</u>

The economic literature was reviewed extensively and it was shown that there is a wide range of projected capital costs for an anaerobic digestion plant. It was shown that the capital cost will depend on the size of the digester, cost of land if required, cost of tankers and grid connection. The financial annual benefits of an anaerobic digestion plant are sale of electricity, sale of the digester effluent, and the landfill levy if applicable to anaerobic digestion facilities. The financial assessment of a plant was discussed and it was noted that an AD plant will not be feasible unless environmental benefits are considered. It was also noted that without gate fees an anaerobic digestion plant as per the model will not make a profit.

<u>Logistical/Location</u>

The model suggests that an anaerobic digestion cooperative would most likely be set up under farmer initiative. Once the cooperative is formed, a location would need to be selected which would initially need to ensure that specific criteria could be met such as feedstock availability, potential use of the produced electricity and/or heat. The generated electricity can be exported to the national grid and this requires grid connection which may take time and will cost money. The location would need 20 farms within a 10km radius and this would need to be investigated. The literature does not indicate who owns the land on which a cooperative plant is built and this would need to be investigated. It is well know that Irish farmers can be very protective of their land. Figure 7 demonstrates the potential sites for an anaerobic digestion cooperative. It is ten years old but would still give a good indication.

Farmer and local community participation

It was discussed in the main body of the paper that an anaerobic digestion cooperative can not exist without famer participation. Media articles indicate that farmers are interested in anaerobic digestion. A survey was undertaken to see if farmers had any knowledge of anaerobic digestion and cooperatives and would they be interested in participating in an anaerobic digestion cooperative. As was shown in chapt 3, there is a significant interested from farmers although they do have concerns. The majority of their concerns are financial and environmental. The financial concerns are mostly related to lack of buy in and incentives from government and related agencies. The environmental concerns are related to the Nitrates directive and the lengthy planning permission process in Ireland.

Sizing perspective

The anaerobic digestion cooperative model proposes 20 farmers, each with a dairy herd of 75 and a total of 1,500. The national average is 55 dairy cows per herd but an assumption was made that the 20 farms would total 1,500.

Digester sizing is calculated using the following formula:
Digester volume = (manure m^3 /year + cosubstrate m^3/year) x retention time/365 days.
Therefore, the digester size would depend on the number of farmers in the cooperative, the dairy herd size and the amount of other available feedstocks.

Waste material required

The waste material required is called feedstocks. A variety of feedstocks can be used in an anaerobic digester. The most common feedstock is manure codigested with organic waste. There are 3 million tonnes of municipal waste generated in Ireland each year. Different feedstocks produce different amounts of energy. For example, one tonne of manure will produce 86kWh and one tonne of food waste will produce 300kWh. The model proposes using codigestion of manure and organic waste and this will produce a higher biogas yield which will in turn increase the energy produced. The literature, however, indicates that there are different values for the same feedstock.

Anaerobic digestion takes place at two different temperatures. Mesophilic ranges between 30-42°C and thermophilic ranges between 43-45°C. Thermophilic requires more input energy but will produce a higher gas yield. The model suggests using thermophilic if organic waste is available. It must be noted that the thermophilic equipment is more expensive and mesophilic could be used if cost is an issue.

Assistance from Government and related agencies.

As was discussed in Chapt XX the most common theme to emerge from the survey was lack of support from government and related agencies. This is a worrying seeing as the government is behind renewable energy initiatives that are introduced to meet legislative requirements such as the Landfill Directive.

Up until recently funding up to 30% of the capital cost was available through the SEAI. Unfortunately this has now closed due to lack of funding available from the government. It is now known if it will reopen and this means that anaerobic digestion plants will not currently receive funding and this will make a project much less attractive to farmers and potential lenders.

Renewable energy feed in tariffs in Ireland range from 10c/kWh to 15c/kWh and this is guaranteed for 15 years. An anaerobic digestion plant is likely to last for 20 years so the 5 year gap is worrying. In Germany, the feed in tariff is 21c/kWh and is guaranteed for 20 years. The Irish government needs to apply logic to the guaranteed period.

The current landfill levy is €30 per tonne. It is expected that it will increase to €50 per tonne by 2011 and €75 per tonne by 2012. However, it is not clear if anaerobic digestion plants can avail of a gate fee from users that would otherwise have to pay the landfill levy. This would need to be clarified as the proposed gate fee in the model contributes hugely to the profit.

The Department of Communications, Marine and Natural Resources is supporting the need to have a national compost strategy. A draft document recently closed the public consultation requirement.
It is assumed that this will apply to digestate. The UK Quality Protocol and PAS 110 are comprehensive and are providing a guaranteed standard

The Farm Waste Management Scheme is another way to acquire funding for anaerobic digestion equipment. It would need to be investigated further as it is unclear what equipment would be considered for funding.

National and EU Legislation

The EU legislation and resulting national laws that will impact AD and vice versa are as follows:

- Nitrates Directive and National Action Programme under the Nitrates Directive. This law aims to reduce the water pollution from agricultural sources. Ireland divided the country into three zones and each zone has a specific period where land application of fertiliser is prohibited. Each zone also has a minimum storage capacity requirement for manure.
- The Animal-By-Products EU Regulation. This is complex legislation that contains regulations referring to health rules concerning animal by products (ABP) not intended for human consumption. The document entitled 'Conditions for approval and operation of Biogas Plants treating Animal By-Products in Ireland' sets out the requirements for biogas plants treating ABP's. It lists the ABP that can be processed in a biogas plant in Ireland and the conditions that must be adhered to.
- The Diseases of Animals Act sets out the conditions on which fertiliser of soil improver containing ABP can be land spread. Farmed animals are not allowed have access to land

where a fertiliser or soil improver has been spread that consists of category 2 material, other than manure, or category 3 material for (a) 21 days or (b) 60 days for pigs after spreading. This may be an issue for cooperative farmers.

- The Landfill Directive aims to decrease the amount of waste sent to landfill sites. Ireland must reduce the total amount of biodegradable waste going to landfill to 75% by 2010. It is not yet known if this has been achieved. Anaerobic digestion will enable Ireland to meet these targets.
- 3 government documents on waste encourage anaerobic digestion as a method assist Ireland in meeting various targets.
- The Directive on the promotion of the use of energy from renewable sources creates a framework to use renewable energy sources to reduce greenhouse gas emissions. Under the directive, Ireland has set a target of 40% of electricity to be produced from renewable sources, and 12% of heat produced to come from renewable sources.

Objective 2

Analyse the energy requirements of rural areas and evaluate the impact an AD plant will have on the grid.

It is evident that anaerobic digestion plants could contribute to the renewable energy targets. It is difficult to obtain grid connection due to condition of the national grid. Eirgrid, under Grid 25, are updating the transmission system by installing 1.150km of new lines and upgrading 2,300km of lines. ESB Networks was contacted to obtain the rural domestic load for the Republic of Ireland. The figure was 2511GWh for the period January 2010 to October 2010. This equates to 251GWh per month. Denmark has 20 centralised anaerobic digestion plants and it is unlikely that Ireland would build more than 20. Assuming the proposed model produces 1,930MWh per year, 10 anaerobic digestion cooperatives in Ireland could produce 19.3GWh. Although this is not a big number compared to the rural domestic use, the cooperative idea will assist communities in becoming sustainable and generating an income.

Future research

- The model suggests 20 farms within a 10km radius and a required total of 1,500 cattle. A feasibility study would need to be carried out to assess if this is possible.
- The available grant schemes would need to be investigated.
- Exact biogas yield from feedstocks would need to be investigated.
- Mesophilic and thermophilic temperatures should be compared for cost and feedstock comparison.

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WCLA Waterford County Local Authorities Energy Cooperative.

APPENDICES

Appendix A

1 (a) All body parts of the following animals:

- (i) animals suspected of being infected by a TSE (Transmissible spongiform encephalopathies)
- (ii) animals in which the presence of TSE has been confirmed
- (ii) animals killed in the context of TSE eradication measures
- (iii) animals other than farmed animals and wild animals, including in particular pet animals, zoo and circus animals,
- (iv) experimental animals,
- (iv) wild animals, when suspected of being infected with diseases communicable to humans or
- (v) animals.

(b) Specified risk material

(c) Products derived from animals containing prohibited substances under Directive 96/22/EC

(d) All animal material collected when treating waste from category 1 processing plants and other premises in which specified risk material is removed.

(e) Catering waste from means of transport operating internationally

(f) Mixtures of category 1 with category 2 and/or category 3.

Please note that (e) refers to waste on a ship that docks in a non-EU port and then return to the EU

Category 2 materials can be processed in a biogas plant under specific criteria. Category 2 material comprises of ABP, or material containing the following ABP:

(a) Manure and digestive tract content

(b) All animal materials collected when treating waste water from slaughterhouses or Category 2 processing plants

(c) Products of animal origins containing residues of veterinary drugs and containments listed in Directive 96/23/EC (if these residues exceed the permitted level laid down by Community legislation)

(d) Products of animal origin (other than Category 1 material) that are imported from non member countries and they do not comply with the veterinary requirements for importation into the Community

(e) Animals or parts of animals (other than those mentioned under Category 1) that die other than being slaughtered for human consumption

(f) Mixtures of Category 2 and Category 3 material, including any material destined for processing in a Category 2 processing plant

Appendix B

	Units	V.Hjermitslev	Vegger	Davinde	Sinding-Ørre	Fangel	Revninge	Ribe	Lintrup	Lemvig	Hodsager
Year of construction	Year	1984	1985	1988	1988	1989	1989	1990	1990	1992	1993
Digester capacity	m^3	1500	800	750	2100	3200	540	4650	6900	7000	880
Process temperature(m/t)		m	t	m	t	m	m	t	m	t	m
Cattle manure	m^3	7015	13656	6728	11980	11541	5311	91164	45671	51031	10449
Pig manure	m^3	3595	0	4707	23654	32462	2206	24492	32494	67372	1619
Poultry manure	m^3					2482		917			
Mink manure	m^3				86	48		2347	33	1075	
Other manure	m^3					1971			13097		
Crop residuals	m^3										180
Total agricultural biomass	m^3	10610	13656	11435	35720	48504	7517	118920	91295	119478	12248
Organic waste from											
Intestinal contents	m^3		1150		5797	2276		19695	5567	11673	3898
Fat or flotation sludge	m^3		2613	254		3855	807	11887	591	6441	
Fodder	m^3				59				364	564	275
Fish processing	m^3	5296	1288	501				2515	17705	5012	1874
Fruit & vegetables	m^3					529	837		49		
Breweries	m^3										
Dairies	m^3				2649			5851		7917	
Sugar industry	m^3										
Bleaching earth	m^3		1447		3776						
Tanneries	m^3	340				1527					
Medical industries	m^3		96		448	956	628	3059	7321		
Other industries	m^3		99		994			51	155	256	
Sewage sludge	m^3		205						6118	5046	187
Households	m^3										
Waste total	m^3	5636	6898	755	13723	9143	2272	43058	37870	36909	6234
Biomass total	m^3	16246	20554	12190	49443	57647	9789	161978	129165	156387	18482
Biomass per day	m^3	45	56	33	135	158	27	444	354	428	51
Biogas production, 1000 m^3		1492	2013	282	2348	2275	355	4762	3718	5302	656
Biogas per day	m^3	4088	5515	773	6433	6233	973	13047	10186	14526	1797
Gasyield	m^3/m^3	92	98	23	47	39	36	29	29	34	35

	Units	Hashøj	Thorsø	Århus	Filskov	Studsgård	Blåbjerg	Snertinge	Blåhøj	Vaarst/Fjellerad[1)]	Nysted[1)]
Year of construction	Year	1994	1994	1995	1995	1996	1996	1996	1997	1997	1998
Digester capacity	m^3	2900	4600	7500	880	6000	5000	2800	2800	2000	5000
Process temperature(m/t)		m	t	m	t	t	t	t	t	t	m
Cattle manure	m^3	7822	29432	18413	17655	13908	58650	9949	20821	8458	8841
Pig manure	m^3	17718	45232	103401	841	72567	23703	19055	2120	6350	45550
Poultry manure	m^3		1138								165
Mink manure	m^3								148		
Other manure	m^3	1957	15910	88		760	7207				
Crop residuals	m^3		29		18				194		
Total agricultural biomass	m^3	27497	91741	121902	18514	87235	89560	29004	23283	14808	54556
Organic waste from											
Intestinal contents	m^3	7639	10026	3045	5454	4880		116	159	5436	125
Fat or flotation sludge	m^3	8213	4200	1030	6052	563	5689	6210	4685	5355	408
Fodder	m^3		125	833		33		41	179	8	62
Fish processing	m^3	576	1561	0			7285	25	1792	1740	54
Fruit & vegetables	m^3			49			26	1586			137
Breweries	m^3			0				2208	177		
Dairies	m^3			5460		10515	2507			166	
Sugar industry	m^3										1819
Bleaching earth	m^3			1322		5455				359	
Tanneries	m^3			0			4509			27	
Medical industries	m^3	1264	2308	5247		1036		3118		2816	678
Other industries	m^3	965		403		889	1051				510
Sewage sludge	m^3		5052				4306	1501			
Households	m^3			54		864				582	
Waste total	m^3	18657	23272	17443	11506	24235	25373	14805	6992	16489	3793
Biomass total	m^3	46154	115013	139345	30020	111470	114933	43809	30275	31297	58349
Biomass per day	m^3	126	315	382	82	305	315	120	83	86	160
Biogas production, 1000m^3		2504	3281	3860	1224	5841	3300	1694	1353	2382	1450
Biogas per day	m^3	6860	8989	10575	3353	16003	9041	4641	3707	6526	3973
Gasyield	m^3/m^3	54	29	28	41	52	29	39	45	76	25

Appendix C

The following accompanied the survey.

The aim of this survey is to find out if the farming community would be in interested in participating in an anaerobic digestion cooperative.

Anaerobic Digestion (AD) is a process whereby farmers can generate electricity and gas using slurry and other waste material. It is a way to supplement the farming income using a naturally occurring substance available on farms (slurry). The cost of installing an AD plant between farms in the co op would be repaid within 5-7 years, thereafter all profits from power produced by the plant can be used on the farms or sold back to the power grid.

Anaerobic Digestion

Anaerobic Digestion (AD) is a natural process of decomposition and decay that takes place in the absence of oxygen and by which organic matter is broken down to its simpler chemical components.

- Slurry and waste is transported to farms and put into the AD machine where it is heated and kept in the tank for approx 30 days.
- A biogas is produced which can be used to generate heat and electricity. The remaining product is called a digestate and can be spread on farms. Please note the treated slurry does not contain any bacteria due to heat treatment.
- Treated slurry that has been through the AD process will emit much less of an odour than untreated slurry.

It is estimated that 37 million tonnes, per year, of animal manure are stored on farms before disposal. There are also 676,000 tonnes of municipal food and garden waste produced annually. This waste could be used in AD plants to produce electricity which is considered to be a renewable technology.

Cooperatives

- Cooperatives are companies owned by communities.
- Cooperatives are suited to AD as Irish farms can be small and a cooperative approach would enable a group of farmers to participate in AD.

• They will encourage community involvement in national plans and policies. They will encourage sustainable development and growth in rural areas, and they will enable communities to become self sufficient and reduce the amount of 'outside' electricity required.

• The Irish Rural Link would like energy cooperatives in rural areas to be supported.

Case Study

Juhnde is a village is Germany with 800 inhabitants. The villagers set up a cooperative and became Germany's first bioenergy village. The energy plant is made up of three main elements:

a) A biogas plant for co-fermentation of liquid manure and silage of different energy crops;

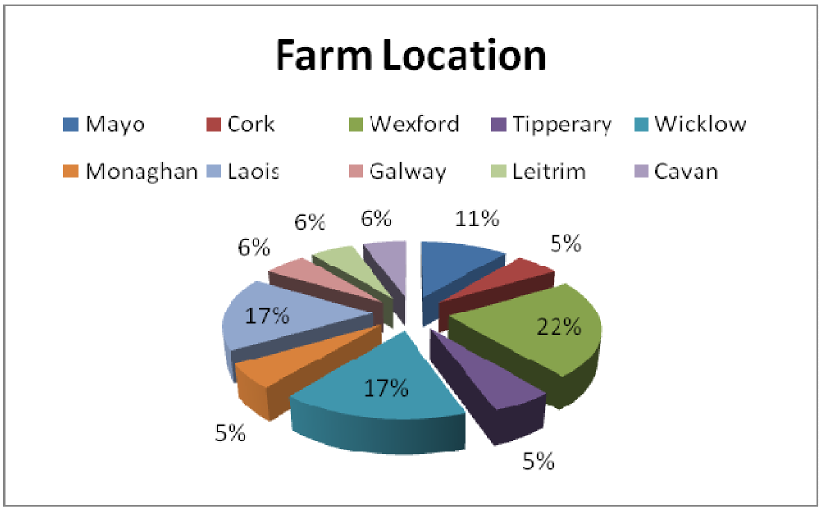
b) A boiler fuelled with regional wood chips and

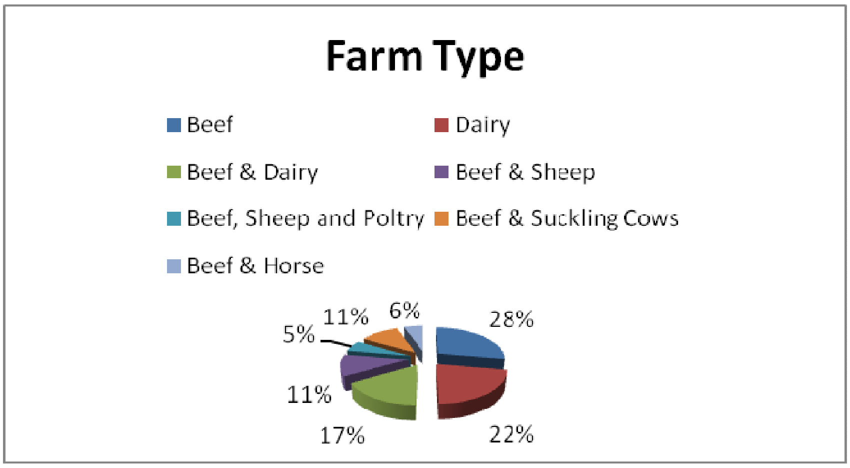
c) A district heating network for 145 houses.

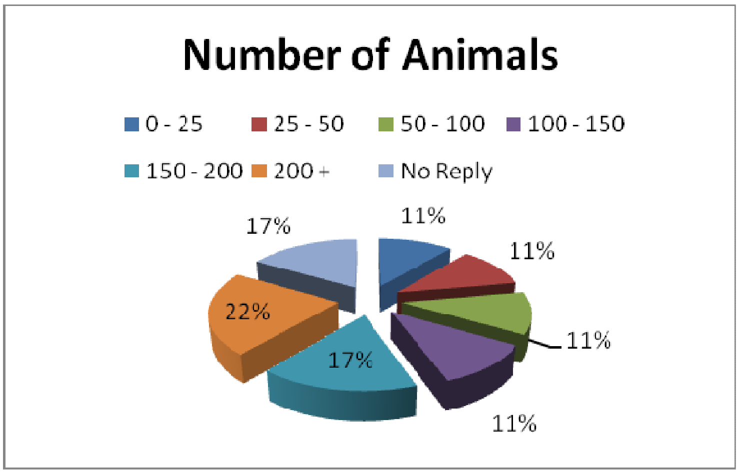
They use 15,000 tons of silage and grass and approx 9,000 m3 liquid manure from cattle and pigs of six animal farms for the biogas plant.

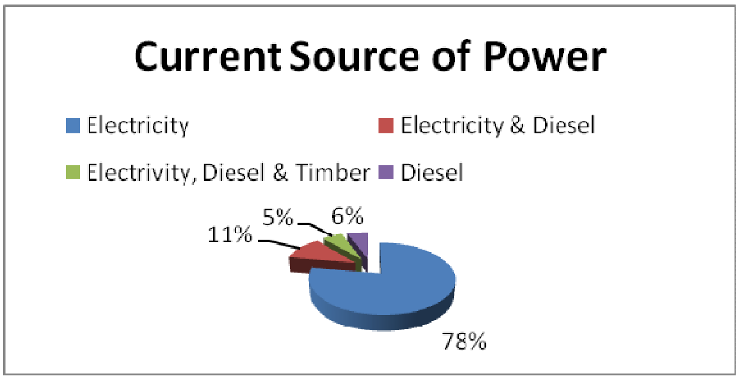
The biogas plant produces approximately 5,000 MWh of electricity per year, which is twice the demand of the village. The amount of heat generated by biogas and wood chips is nearly 6,500 MWhth.

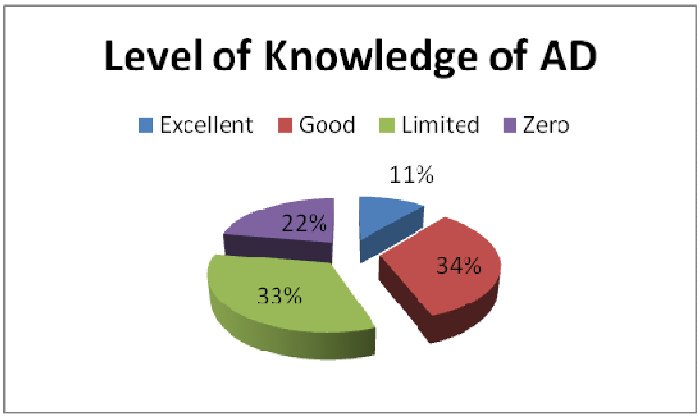
This case study shows that cooperatives for AD can work with the input from the local community.



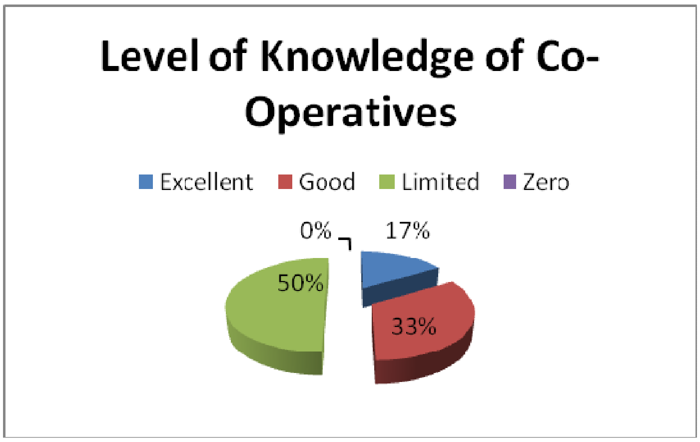

Farm Type
Beef
Dairy
Beef & Dairy
Beef & Sheep
Beef, Sheep and Poltry
Beef & Suckling Cows
Beef & Horse
28%
22%
17%
11%
5%
11%
6%


Number of Animals
0 - 25
25 - 50
50 - 100
100 - 150
150 - 200
200 +
No Reply
11%
11%
11%
11%
17%
22%
17%

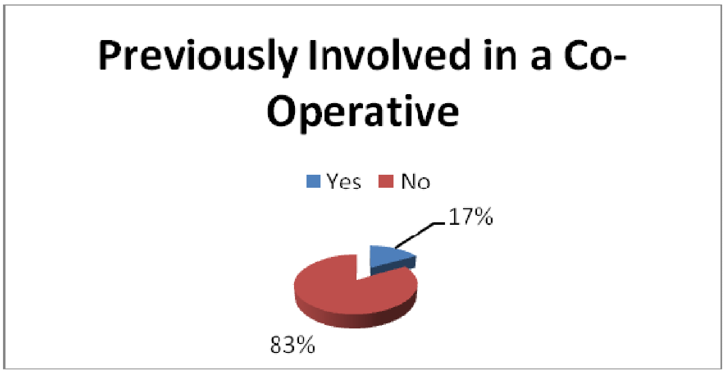

Current Source of Power
Electricity
Electricity & Diesel
Electrivity, Diesel & Timber
Diesel
78%
11%
5%
6%



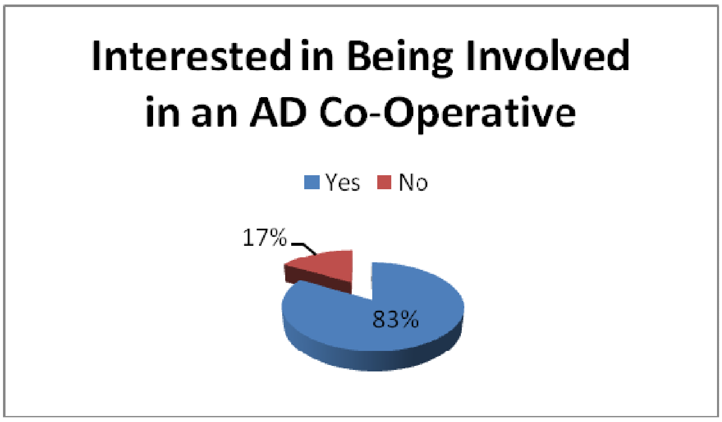
Level of Knowledge of AD
Excellent
Good
Limited
Zero
11%
22%
34%
33%

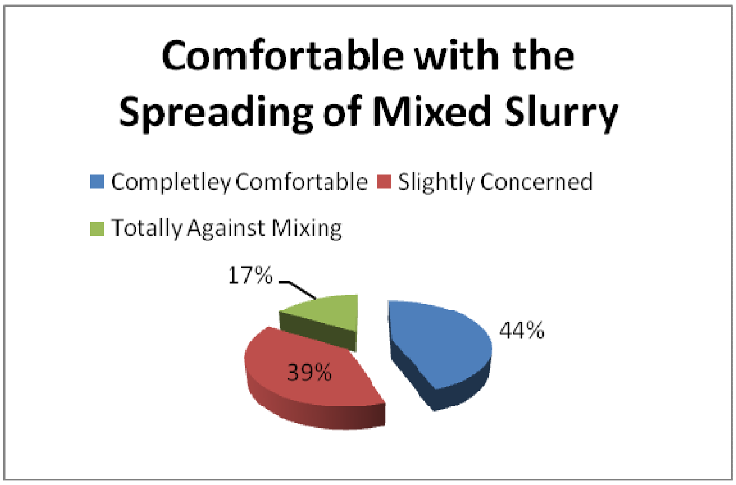


Level of Knowledge of Co-Operatives
Excellent
Good
Limited
Zero
0%
17%
50%
33%



Previously Involved in a Co-Operative
Yes
No
17%
83%





The final question put to participants was did they think there were any reasons why an anaerobic digestion cooperative would not work.

	Comment	county
1	Main reasons for it possibly not working would be due to a lack of faith in the system treating any contaminated slurry completly, and also a lack of government incentives to setting up the co op in the first place.	Wexford
2	How much burning of wood chips is required? will this cause much pollution? Are there any other pollutants from this system?	Mayo
3	working out how people get paid i would see as a potential problem.	Cork
4	None, we have a CHP unit, on the cards down here in wexford, and we also have a farmer who has his own anerobic digester.	Wexford
5	There is no buy in from DAFF for this sort of venture, until there is and also capital funding	Tipperary

	(reasonable amounts - not the SEAI level currently offered) nothing will happen. Issues with grid connection, REFIT and cooperative buy must all be resovled before this type of venture could possibly happen.	
6	It would depend on the management of the co-op. Irish farmers are not generally good at management.	Wick low
7	Economics and lenghty planning process	Monaghan
8	the slurry may have high levels of p an k in it and acording to the irish p an k scale some farms are to high in it	Wicklow
9	PLANNING PERMISSION MAY BE REFUSED. SPREADING OF BI PRODUCTS ALL YEAR ROUND MAY NOT COINCIDE WITH REPS RULES	Mayo
10	I feel that there would not be enough knowledge, trust and cooperation for it to be successful.	Laois
11	I suppose until I knew all the details I would have concerns. Trying to find enough farms to spread the slurry on as to not break E.U. nitrate directives. Is the mixed slurry bad smelling during spreading causing local in or not in the co-operative to complain. What are the	Wexford
12	No none at all	Leitrim