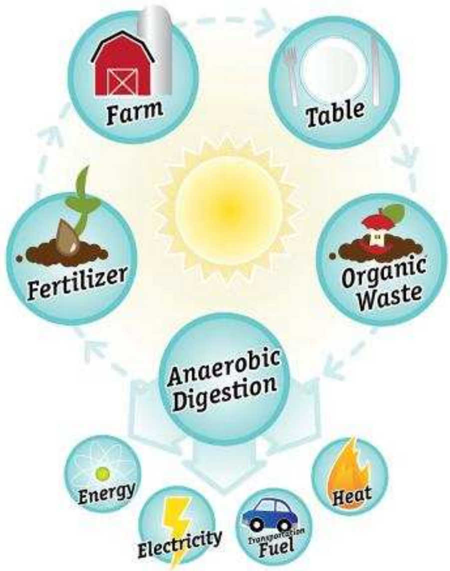
Anaerobic Digestion in Rural Ireland

Learning from European Leaders



A report for

NUFFIELD IRELAND

Farming Scholarships

By Tadhg Healy, 2008 Nuffield Scholar

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Scholar Contact Details:

Timothy (Tadhg) Healy
Address: Garralacka
Clonakilty
Co. Cork
Ireland
Phone: 0872357352
Email: tadhghealy1@eircom.net

NUFFIELD IRELAND Contact Details:

Matt Ryan,

Executive Secretary,
Rathmartin Road,
Nenagh,
Co. Tipperary
Phone: 00 353 87 2355179
Email: ryanmatt.ryan@gmail.com

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Abbreviations

ABP: Animal By-products

AD: Anaerobic Digestion

CHP: Combined Heat and Power

CO_2: carbon dioxide, a greenhouse gas.

c.: circa

FIT: feed-in tariff

kW: kilowatt

kWe: kilowatt electrical

kWh: kilowatt-hour

MW: megawatt (1000 kW)

Nm3: normal cubic meter

R&D: research and development

RHI: Renewable Heat Incentive

RTFO: Renewable Transport Fuel Obligation

ROC: Renewable Energy Obligation Certificate

Tpa: tonne per annum or per year

IrBEA: Irish Bioenergy Association

REFIT: Renewable Energy Feed in Tariff

Introduction

This report presents the results of the research carried out on anaerobic digestion for energy generation in the framework of the Nuffield Ireland Farming Scholarship. I began my farming career in 1990 when I took over the running of the family farm after my father became ill. At that time, the farm's activity centred on dairy but soon afterwards a broiler growing enterprise was developed.

A number of years ago, I began investigating ways of using the manure from the broilers to heat the sheds. First, combustion was looked at but at the time that was not a runner and Anaerobic Digestion (AD) became of interest. Two of the only three farms in Ireland where AD was used were visited. They were most helpful but it was quickly realised that I would have to look at what was happening elsewhere in Europe to develop a better understanding of the technology. This gave me the impetus to apply for the Nuffield Scholarship to support this investigation, which I secured in 2008.

In the course of my research, I travelled to the UK, Austria, Germany, Denmark where I visited a wide range of farm and community-based AD projects. By talking to project developers, I was able to get a practical insight into how AD works, the kind of innovations undertaken by farmers and the AD industry in these countries, and how the legislative and policy framework shaped its development there.

My objective was to demonstrate how we can take advantage of the lessons learned from pioneer countries to accelerate the development of AD here. By pushing for the right policy framework to be put into place and by reinforcing their technical ability, Irish farmers can play an important role in establishing AD and maximise the benefits this renewable energy technology provides. The research conducted is relevant to farming organisations, the agro-industry and the waste management sector, as well as policy-makers and the relevant government departments and agencies.

Executive Summary

This report presents the results of the research carried out on anaerobic digestion (AD) for energy generation in the framework of the Nuffield Ireland Farming Scholarship. Anaerobic digestion is a series of processes in which micro organisms break down biodegradable material in the absence of oxygen and produce biogas, a combustible gas rich in methane. Biogas can be used to produce heat and power, or can be upgraded to produce a transport fuel. There are millions of small-scale digesters in Asia primarily used to produce lighting and cooking fuel. In Europe, the AD sector is going through a dynamic period of growth, with Germany leading the trend with almost seven thousand commercial plants installed.

In the framework of this report trips were undertaken to the UK, Austria, Germany, Denmark where a wide range of farm and community-based AD projects were visited in order to get a practical insight into how AD works in Europe and the framework supporting it.

The benefits of AD are multiple.(1) It offers a diversification opportunity for farmers to generate energy, adding value to existing organic wastes (slurries and manure) or crops such as grass or maize silage. (2)Digestate, a by-product of AD, is an excellent fertiliser with high plant absorbability which reduces chemical fertiliser costs, increases yields and help better manage the nutrients cycle on the farm. (3)AD also avoids the release of methane (a potent greenhouse gas) from slurry pits and the substitution of fossil fuels with biogas reduces CO_2 emissions.

The equivalent of 8.35 million tonnes of oil in biogas has been produced in 2009 across Europe. About half of that total was produced in Germany (resulting in 44,500 jobs and an annual turnover of 5.9 billion euro) and c.21% in the UK, while Ireland is 15th in the European biogas league. During the last decade, the development of AD in some European countries has been strongly driven by favourable feed-in tariffs (FITs) remunerating the export of electricity from biogas plants, with guaranteed payments for a period of up to 20 years.

Among the 18 AD projects visited by the scholar, four are detailed as case studies in the report. There were a number of important lessons learned from this research:

- Most projects visited are owned by farmer co-operatives rather than individual farmers, pulling larger amounts of feedstock and generating significant economies of scale;
- The majority of AD plants use a combination of feedstock such as energy crops, municipal and industrial organic waste in addition to manures. Gate fees are an important source of revenue, compensating at least partly for the cost of energy crops. Increased yields and reduced fertilisation costs due to digestate land application was mentioned as a key benefit in most projects.
- AD is a dynamic technology that has built on over 20 years of successful development, with ongoing technical improvements and innovative practices. Lab and 'on plant' research play an important role in increasing biogas yields and reliability. Technical guidance by public agencies has also proven highly beneficial to the sector.
- Financial incentives such as funding, low-interest loans and most importantly feed-in tariffs play an essential role for the development of AD. However, it is essential that incentive schemes are reliable and stable over time to avoid the devastation of roller-coaster policy-making.
- All project operators met, most of them farmers, appeared very proud of their achievement and were very supportive.

In Ireland, the AD sector is at an early stage of development, with a handful of farm-based projects and about 25 municipal or industrial AD plants. Recent approval of the new feed-in tariffs and better visibility on waste and animal by-product regulations will help the sector, Ireland cannot boast a supportive framework for AD project developers.

The main conclusions and recommendations arising from the research conducted are as follows:

- AD is a mature technology and project developers should be confident that they can access the technical and project management capability required to bring their AD project to fruition;
- The science of AD continues to evolve and innovation is ongoing, and project developers should keep up-to-date with the latest technical development to design and optimise their project;
- A detailed analysis of feedstock availability and cost at an early stage of AD projects is critical.
- The co-operative model has proven successful in that regard and the involvement of community stakeholders in such AD projects can be very beneficial in terms of public attitude, funding, synergies, etc.
- Policy-makers should give priority to AD in the framework of renewable energy, waste management and rural development policy.
- Policies and regulations should be put into place for the introduction of a Renewable Gas Obligation for gas distribution utilities, setting ambitious but achievable targets for a minimum renewable gas content in natural gas supplied via grid and as transport fuel.
- Financial incentives in the form of feed-in tariffs, subsidies and/or low interest loans should be put in place to increase the viability of AD projects.
- Relevant authorities and regulatory bodies should work together to streamline the approval process for AD projects and simplify compliance with waste and ABP regulations.
- Further research and development and demonstration support is required to support innovation and efficiency in the AD sector.
- Community stakeholders have a key role to play in supporting AD projects in terms of raising awareness and improving public attitude about AD.

In conclusion, AD is a multifaceted solution that can offer significant benefits for wider community.

Objectives

The objectives of the research undertaken were to:

- Understand the technology of AD and its application in the farming sector and the benefits it can provide;
- Investigate the development of AD in selected European countries and identify key success factors;
- Review the current status of AD in Ireland, its potential and the barriers affecting its development, as well as the role for community-driven AD projects in rural Ireland;
- Make recommendations for the development of AD in rural Ireland.

Methodology

Having taken an interest in AD as a potential solution for valorising the chicken manure produced on our family farm, and visiting some small scale plants in Ireland it was realised there was a need to learn more from other European countries to fill the significant knowledge gap that existed here in Ireland.

On that basis, study tours were undertaken to the UK, Germany, Denmark and Austria. Each visit was an opportunity to interview the main project developer, obtain technical information on the system in place and understand the context in which the project was undertaken.

The visits also offered an opportunity to gain an insight into how an AD project fits within the day-to-day operation of the farms visited and how the AD process is integrated into the overall management of the farm, notably in terms of effluent and nutrient cycles. In addition, it gave an opportunity to see the practical implications of the policy and regulatory framework surrounding AD.

The research conducted during the study tour was completed by a review of published information from trusted sources such as the Sustainable Energy Authority of Ireland, International Energy Agency, relevant European projects, other Nuffield Scholarship reports, etc. Whenever possible, relevant seminars and conferences were attended.

Anaerobic digestion in agriculture

What is anaerobic digestion?

Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen. The process produces biogas, a flammable gas containing typically 50-80% of methane and 20-50% of carbon dioxide, with trace amounts of hydrogen sulphide, nitrate, nitrogen and other volatile organic compounds. The gas is saturated with water vapour. Approximately 70-80% of the chemical energy in the organic material is conserved in the biogas produced. The richer the biogas is in methane, the higher its heating value (or net calorific value (NCV)). At a standard concentration of 60% of methane, one cubic meter of biogas has a NCV of approximately 6 kWh (equivalent to the energy content of 0.6 litre of oil).

How does a typical agricultural AD plant work?

A biogas plant is a complex installation, consisting of a variety of elements. The layout and design of an AD plant depends to a large extent on the types and amounts of feedstock supplied.

Feedstock supply: Organic substrates (also referred to as feedstock) such as manure, slurries, energy crops, etc. are collected, stored and pre-treated before being fed to the digester. The pre-treatment can consist in breaking down the substrates into smaller particles and homogenising the mixture. When certain substrates are used e.g. food wastes, pasteurisation of the digestate can be required by regulation.

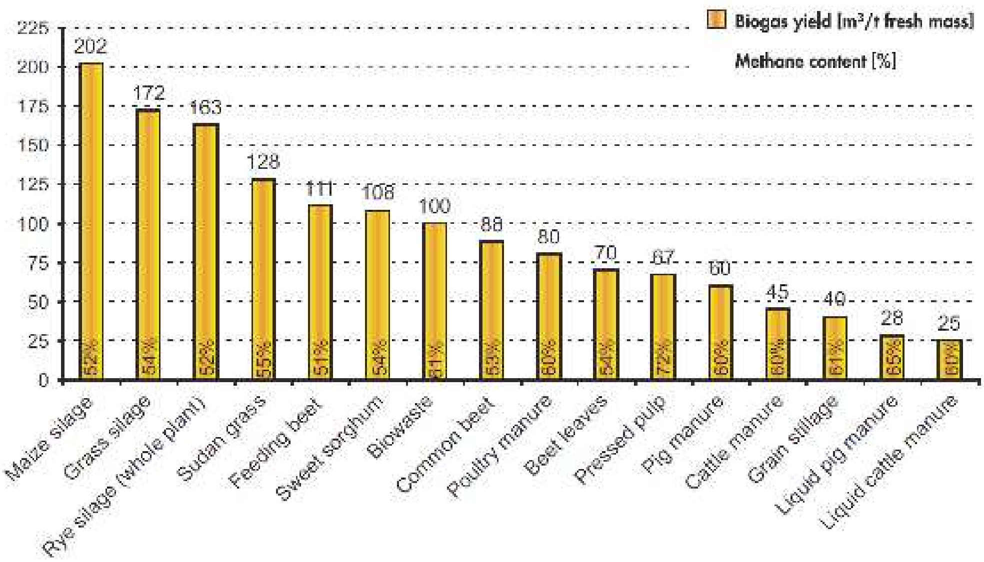


Figure 1: Biogas yield and methane concentration of common AD feedstock

Biodigestion: The feedstock is inoculated with suitable bacteria and digested in a large vessel where anaerobic (absence of oxygen) conditions are then maintained and temperature is held at a constant value by the supply of heat to the digester. The content of the digester is stirred around mechanically to mix new and existing substrates, homogenise conditions within the vessel and optimise the digestion process. Sand and other sediments need to be removed regularly. The retention time of the substrate within the digester is a key factor for the biogas yield and is determined according to the digester design and the nature of the substrate.

Biogas storage and treatment: Biogas is stored to compensate variations in production and fluctuations in demand. For smaller biogas plants, the biogas is stored over the digester and underneath a gas-tight membrane also acting as a cover. For larger plants, a separate storage facility might be required. The majority of biogas storage is at low pressure. Biogas treatment normally consists in desulphurisation (removal of H2S, a corrosive with a distinctive rotten egg smell) and drying by cooling the biogas to condense its water vapour content. Upgrading the biogas to a quality and methane concentration similar to natural gas is required if the gas (often referred to as biomethane) is to be used as vehicle fuel.

Digestate treatment and storage: The digestate from the AD process is an excellent fertiliser. It is generally stored in tanks or lagoons, and should be covered with a gastight membrane to recover the residual biogas produced (up to 20% of biogas potential) and avoid the release of methane in the atmosphere. If the digestate is stored out in the fields, the liquid should at least be covered with a floating natural layer (e.g. straw) to minimise ammonia volatilisation (Seadi, 2008). The digestate can be separated into a liquid fraction and a fibrous fraction. The liquid fraction can be returned to the land as a fertiliser and the solid fibre used as a soil conditioner (EPA, 2005).

Renewable Energy production: The biogas produced by the AD process can be captured and utilised as a renewable fuel to produce heat only in a boiler, or to produce heat and power in a combined heat and power (CHP) unit. Part of the heat produced (about 25%) is used onsite to maintain the digester temperature, and similarly part of the electricity generated is used to drive the plant (c.10%). The remaining heat output can be used onsite or exported via a district heating network, and excess electricity is injected into the grid. Biogas can also be upgraded and used as a vehicle fuel, or injected into the natural gas grid.

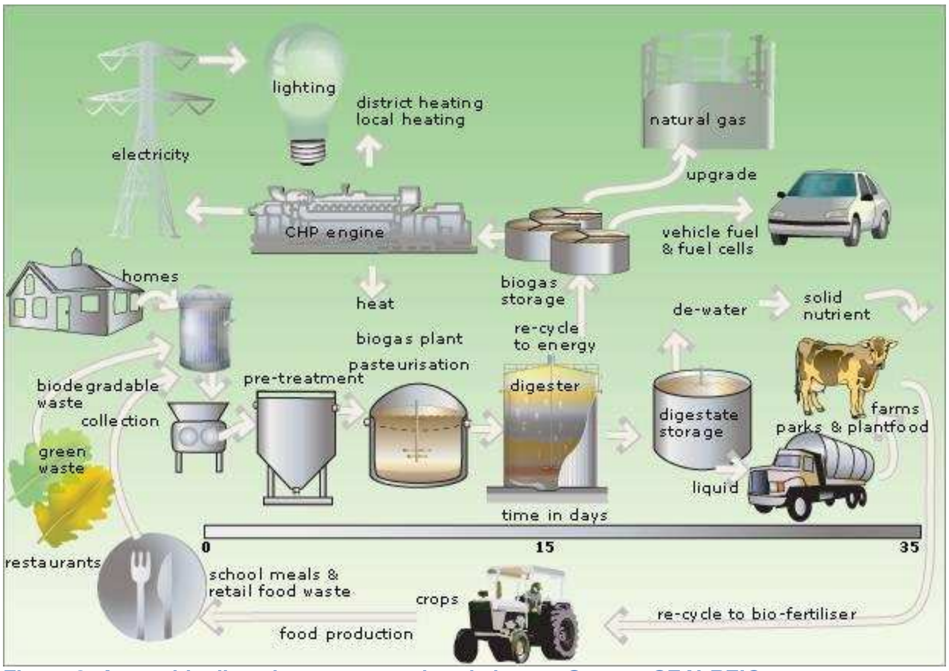


Figure 2: Anaerobic digestion system and cycle layout. Source: SEAI-REIO

How is AD applied in agriculture?

The production and collection of biogas from a biological process was documented for the first time in United Kingdom in 1895. Since then, the process has been further developed and broadly taken up in agricultural, industrial or municipal applications. The focus of this study and report is on agricultural biogas installations as a key sector for AD development today.

In Asia alone, millions of family-owned small-scale digesters are in operation in countries such as China, India, Nepal and Vietnam, producing biogas for cooking and lighting. Thousands of agricultural biogas plants are in operation in Europe and North America, many of them for several decades, and their number is continuously increasing. In Germany alone, more than 5909 agricultural biogas plants were in operation by June 2011 (Gavigan, 2011).

Manure and slurries from cattle, pig and poultry production are the basic feedstock for most agricultural biogas plants in Europe (Seadi, 2008) due to their zero or sometimes negative cost. However, there are an increasing number of plants running on energy crops in countries where the value of the biogas produced is sufficient to cover the cost of producing these crops. In many projects, organic waste from industrial (food processing, distillery, etc.), municipal or commercial (wastewater sludges, food waste, etc.) sources can form an important part of the feedstock and generate substantial gate fee revenue.

In an Irish and European context, there are essentially two approaches to agricultural AD installations:

Farm-scale AD plants servicing one farm and using substrates mostly produced on the farm, although in some cases, it can also take substrates from neighbouring farms. Farm-scale plants can vary widely in size, design and technologies, ranging from the small and simple to the large and complex. In most cases, the biogas is used on site for heating only or for heat and electricity production using a combined heat and power (CHP) unit. Part of the heat produced is required to maintain the digester temperature and the rest is either used on site to heat the farmhouse, animal sheds, dry grains, etc. or exported to neighbouring heat users. Similarly, the electricity generated can be used on site e.g. to run the AD plant itself and power the farm, and/or exported to electricity utilities via the distribution grid. The digestate from the plant is used as a high quality fertiliser on the farm land or on neighbouring farms. In some cases, the solid fraction of the digestate is separated and can be composted.

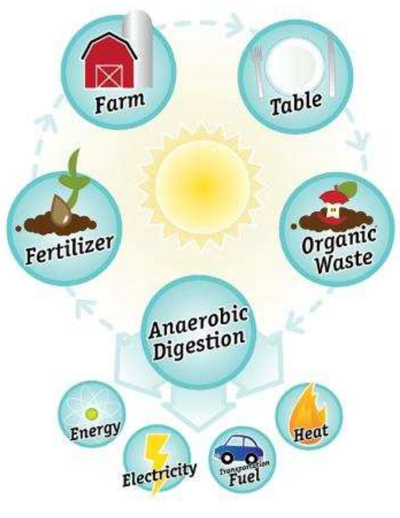
Co-digestion in centralised AD plants taking a combination of animal and vegetal feedstock from several farms and often co-digesting a variety of other co-substrates from industrial (food and drinks processors) or municipal (household wastes, sewage sludge, etc.) sources. The plant is centrally located in such a way as to reduce transport time and costs for the feedstock and the digestate. These large plants often export heat via a small/medium district heating network or can be equipped with biogas upgrading facilities to produce transport fuel or to be injected in the grid. The size of the plant is such that significant economies of scale can be achieved in capital and operational costs. However, beyond a certain size, economies of scale can be negated by feedstock and digestate transport costs, the cost associated with additional regulatory burdens (planning, health and safety, emission controls, etc.) as well as grid-connection delays and costs.

What are the benefits of AD?

From the farmer's point of view:

- AD provides a diversification opportunity valorising existing by-products (organic waste) or crops (grass or maize silage) to produce renewable energy, which can then be used onsite to reduce farm energy costs or exported to generate an additional income.
- The digestion of animal manure and slurries improves their fertiliser value for a number of reasons. (1)Manure and slurries from different animals (cattle, pig, poultry etc.) are mixed and codigested, providing a more balanced content of nutrients. (2)AD breaks down complex organic material such as organic nitrogen compounds, increasing the amount of plant-available nutrients.
- The improved fertiliser value and absorbability by plants reduces the use and cost of chemical fertilisers and the risk of leaching into the water cycle.

From the local and wider community's point of view:



- AD avoids the release of methane from natural anaerobic digestion in slurry pits, ponds or tanks (AEA Technology, 2005). Methane is one of the strongest greenhouse gases and between 65 kg and 150kg of CO_2 equivalent are saved (between 1.3 and 3 euro worth of CO_2 credit at €20/tCO_2) per tonne of biomass treated in the AD process.
- Using biogas as a renewable fuel replaces fossil fuel, thereby avoiding CO_2 emissions. In addition, the application of digestate as a high quality fertiliser replaces natural gas and petroleum-based fertilisers which have a high carbon footprint.
- Transforms wastes and by-products into productive resources, and can provide a viable alternative to land filling of certain wastes such as food, animal by-products, etc. The nitrogen content of digestate is more absorbable by plants, leading to less pollution of our water resources;

- Finally, A Joint Oireachtas Committee on Climate Change and Energy Security report (2011) states that 8,250 jobs could be created in the AD sector in 10 years.

Review of AD in selected countries

Introduction

This chapter presents the findings of a comprehensive review of AD in selected EU countries, primarily based on study tours conducted in the UK, Denmark, Austria and Germany. This was complemented by a desktop study of published information, available as reports, conference proceedings and website content. The objective of the review was to assess the state of play of AD in these countries and understand the strengths and weaknesses of AD development in their farming sector. The map below shows the extent of AD development across Europe and the role played by different AD segments in the production of energy from biogas.

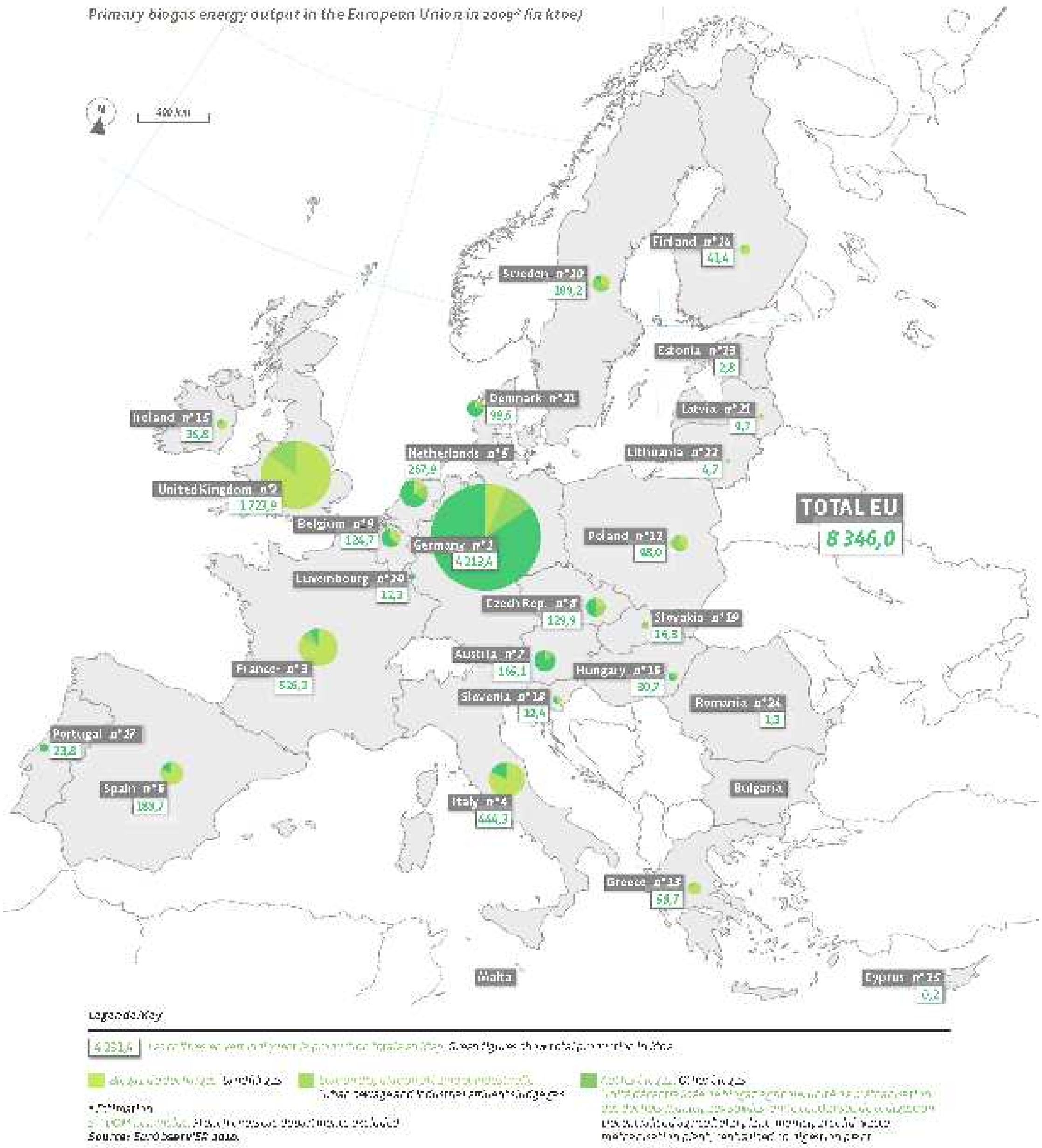


Figure 3: EU Map of Primary Energy Production from AD by sector in 2009. Source: EurObserv'ER, 2010.

In total, the equivalent of 8.35 million tonnes of oil of biogas has been produced in 2009 across Europe. About half of that total was produced in Germany and c.21% in the UK, while Ireland is 15th in the European biogas league. While AD has traditionally been developed in the context of organic waste management, particularly through the capture of landfill gas and the biodigestion of industrial and municipal waste water treatment sludges, AD plants in the agricultural and municipal solid biowaste sectors represent about half of biogas production in Europe and leads growth in the AD industry.

Current status of AD in selected countries

Germany

Germany is by far the EU leader in terms of biogas production as seen above. AD development in this country is particularly exemplary in that growth is largely driven by agricultural plants supplied with energy crops such as maize. It is expected that c. 7000 AD plants will be in operation by the end of 2011, with a total electricity generation capacity of 2730 MW, enough to supply the equivalent of 5.1 million homes' annual electricity consumption or 3.1% of the national electricity consumption. The sector currently employs approx. 44,500 people and has an annual turnover of 5.9 billion euro (Gavigan, 2011).

The development of AD in Germany has been strongly driven by favourable feed-in tariffs (FITs) remunerating the export of electricity from biogas plants, with guaranteed payments for a period of 20 years. Since 1 January 2009, the basic rate applied to biogas production (excluding wastewater plant biogas) is €0.1167/kWh for installation capacities of up to 150 kilowatts. It drops to €0.0918/kWh for plants up to 500 kW, €0.0825/kWh for up to 5 MW and €0.0779/kWh for up to 20 MW. A premium of €0.07/kWh is added to these rates if energy crops are used, another of €0.01/kWh if at least 30% of manure is used, with an additional €0.03/kWh for cogeneration (CHP), €0.02/kWh if the waste is sourced from landscaping and environmental maintenance and by €0.01/kWh if non-methane hydrocarbon emissions are reduced. The payments combined with premiums are due to decrease by 1% per annum over the 20-year contractual period (EurObserv'ER, 2010).

Since an incentive law giving biomethane[1] suppliers priority to the grid came into force in February 2008, Germany has also started feeding biomethane into the natural gas grid. The law also transfers responsibility for a major part of the associated costs to the grid operators instead of being borne by the biomethane suppliers. The outcome has been outstanding growth in biomethane injection, with an estimated 60 plants currently in that category (Gavigan, 2011) producing a total of 308 million Normal cubic meter[2] (Nm^3) of methane per year (EurObserv'ER, 2010). A further 85 plants are under construction or in the planning process

Germany also invests heavily in research and development to support its booming biogas industry, with a focus on improving digesters design and operation, monitoring and control, valorisation of digestate, economic and ecological optimisation of projects, etc. A network of agencies and professionals also support project developers through technical advice and financial support. Other initiatives are encouraging 'bioenergy communities' through networking, research and development, integrated policy making at a local level, etc (Linke, 2011).

[1] Biogas that has been upgraded to a high methane concentration at a quality similar to that of natural gas is often referred to as biomethane.
[2] The Normal cubic meter is a unit used to measure the volume of a gas at normal atmospheric pressure (not compressed) at a defined temperature (15°C or 0°C depending on the standards).

The biogas industry in Germany has grown tremendously (2.3 billion turnover according to the German Biogas Industry Association) and has become an international player in this field.

UK

Biogas production in the UK is largely dominated by landfill gas (85.5% in 2009), which was one of the main beneficiaries of the Renewable Energy Obligation Certificates (ROCs) in 2008-2009 (c.25% of all ROCs issued). ROCs are the main support scheme for large-scale (>5MW) renewable electricity projects in the UK[3]. AD receives 2 ROCs per MWh generated, with the price of ROCs depending on market conditions but currently being auctioned at an average of £46 per ROC.

Since April 2010, AD facilities of less than 5MW are eligible for the Feed-in-Tariff which guarantees a fixed price for the electricity generated over a period of 20 years. The FIT for AD projects with a generation capacity of less than 250 kW is 14 p/kWh, 13 p/kWh between 250 and 500 kW and 9.4 p/kWh above 500 kW generating capacity.

In addition to the FITs, the Renewable Heat Incentive (RHI) provides a fixed income (per kWh) to generators of renewable heat, and producers of renewable biogas and biomethane. AD facilities completed after 15 July 2009 are eligible for the RHI, which is guaranteed for 20 years. The current RHI for AD is as follows:

- Biogas combustion up to 200 kW scale receives 6.5 p/kWh.
- Biomethane injection to the grid receives 6.5 p/kWh.

In addition, the Renewable Transport Fuel Obligation (RTFO) requires suppliers of fossil fuels to ensure that a specified percentage of the road fuels they supply in the UK are made up of renewable fuels. Biogas is eligible for Renewable Transport Fuel Certificates provided that it is dutiable and produced wholly from biomass. The guaranteed buy-out + duty incentive was 30p/l. in 2010/11.

On top of the ROCs and FITs, funding in the form of grants or low interest loans is available from a number of government agencies.

DEFRA (Department of Food and Agriculture) gives a statistic of 32 on-farm AD installations by April 2011 and 22 off-farm with an output capacity of 35 MW electrical, and another 50 plants (70 MWe) have planning consent. It is noticeable that despite what is considered to be sufficient financial incentives being in place, the level of project development remains very low compared to the situation in Germany for example.

Austria

In 2009, biogas production was 525 GWh in Austria or circa 1% of the total electricity demand. By the end of 2009, there were a total of 95 MW of installed generation capacity fuelled by biogas. There were an estimated 350 farm-based AD plants in Austria by 2008,

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3 ROCs are green certificates issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier.

producing in the region of 180 million Nm3 of biogas per year (or 45% of the national total). There are a total of 7 biogas upgrading plants in operation in Austria (Bochmann, 2011).

By 2009, the average AD plant size was 280 kW in electrical generation capacity. A larger plant of 500 kW electrical is considered more economical to build and operate, but would require approx. 260 ha of energy crop cultivation. In an Austrian context, this is difficult to achieve considering that the average holding is c 20 ha. This explains why AD plants are generally located in plains and most recent ones are often owned by a co-operative of farmers pulling their feedstock together and using a combination of feedstock. A large proportion of the AD feedstock used comes from maize (c.60%) and grass (c.10%) silage, with additional feedstock coming from agricultural (slurries and manures), industrial (food processing and brewing) and municipal (food waste).

The feed-in tariffs in Austria are relatively advantageous, with 3 different tariffs depending on the size of the plant: 18.5 Cent/kWh up to 250 kWe, 16.5 Cent/kWh from 250 -500 kWe, 13 Cent/kWh above 500 kWe. A premium of 2 Cent/kWh is given if biogas is upgraded and 2 Cent/kWh if heat is used efficiently. Up until 2005, the Austrian biogas sector was buoyant and supported by an integrated policy framework articulated around the needs of agriculture, energy and economic development. However, biogas development in Austria remained stagnant between 2005 and 2010 due to changes and uncertainty in energy policy, and in particular feed-in tariffs, which hampered investor confidence. In recent years, Austrian biogas policy has focused the development of the sector on biomethane (upgraded biogas) as a vehicle fuel or for grid injection, with a target to replace 10% of the natural gas consumption (800 million Nm3/yr). It is not known if the recent incentive and policy changes introduced in 2010 have reversed the situation for AD.

Denmark

In Denmark, there are 76 agricultural AD plants and 91 municipal or industrial AD plants, and it is estimated that there are 36 agricultural AD projects in the pipeline (IEA Bioenergy Task 37 , 2010). Biogas production in the agricultural sector has more than doubled between 2000 and 2009. While the scale of the biogas sector in Denmark isn’t remotely close to what it is in Germany, it has a long history with the first farm-based plant established in 1975, and has successfully developed a strong export market. It is fifth in Europe in terms of biogas energy produced per head of population (EurObserv'ER, 2010). The farming community has a large stake in the biogas sector, with all but 4 plants owned by farmers.

Interesting trends can be observed in the history of the Danish biogas sector. First of all, a strong emphasis on commercial viability was there right from the start, without the distortion that can be felt when the market is too strongly driven by financial incentives. This meant that AD technology was optimised over the years for robustness, simplicity and efficiency. The fall in energy prices after the recovery from the 2 energy crises of the late last century meant that revenue had to be complemented by the treatment of industrial organic waste attracting gate fees – a reality for the majority of AD plants in Denmark. In the early 80’s farmers also capitalised on the introduction of the regulatory slurry storage for up to 9 months to establish AD plants jointly with the storage facilities. In the 90's and early 00's, the trend has been for very large plants and plants designed to meet the heating requirements of small rural communities using district heating.

According to Ravena & Gergersen (2005), three factors have been important for the status of biogas plants in Denmark: "First, the Danish government applied a bottom-up strategy and stimulated interaction and learning between various social groups. Second, a dedicated social network and a long-term stimulation enabled a continuous development of biogas plants without interruptions until the late 1990s. Third, specific Danish circumstances have been beneficial, including policies for decentralised CHP, the existence of district heating systems, the implementation of energy taxes in the late 1980s and the preference of Danish farmers to co-operate in small communities." They also argue that the current setback in biogas plants is mainly caused by a shift in energy and environmental policies and limited availability of organic waste.

The introduction of feed-in tariffs for biogas in 2008 has started to change this picture, with a guaranteed price of 10.3 c€/kWh or an additional payment of about 5.4 c€/kWh for using biogas together with natural gas for the generation of electricity. The tariff is adjusted by 60% of the price index increase. Upgraded biogas is remunerated at about 40.30 c€/m³ methane. Furthermore, the sale of waste heat which occurs through the production of electricity is exempt from energy and CO_2 taxes. This framework is considered a good legal basis for planning and financing biogas projects. In Denmark 60% of all private households are connected to a district heating system. Biogas plants which are connected to a Danish district heating system are legally regarded as being a part of it and therefore receive the same financial and legal support.

The government has a set up a green growth plan setting a target of 4 large-scale co-digestion plants to be built per year until 2020. Also, by 2020, 50% of the animal waste shall be digested (today it is 3-6%). The overall objective is to triple the production of biogas by 2020.

Case studies from selected countries

A number of AD plants were visited as part of the research undertaken in the framework of the Nuffield Scholarship. These include:

- 8 visits in Germany and 2 visits in Austria during a study tour organised by the International Biogas and Bioenergy Competence Centre (IBBK) in September 2008. This study tour also included a visit to the Bavarian Central Agricultural Festival (ZLF, Munich) and a 5-day training course on AD at the University of Hohenheim, Stuttgart;
- A study tour undertaken personally by the author in North Germany and Denmark in July 2009, including visiting 1 AD plant in Germany, a meeting with the Danish Biogas Association and visiting 2 AD plants in Denmark.

- A study tour to England and North Wales, including visiting 3 farm-based AD plants.

Table 1: Summary of AD plant visits, page 26 summarises the main characteristics of the AD plants visited. The next sections present a succinct report of 4 case studies selected among the AD plants visited.

Bioenergie Laupheim, Germany:

The biogas plant in Burgrieden near Laupheim was set up by a co-operative of 21 farmers from the area in partnership with EnBW, an energy utility. The plant supplies about 5 million Nm3 of biogas to an upgrading facility operated by Erdgas Sudwest, a subsidiary of EnBW, out of which 2.8 million of biomethane (97% methane concentration) are injected to the natural gas grid and supply the equivalent of 1000 houses in the region. The AD plant is supplied with maize silage (80%) grass and wholegrain crops (20%) grown on a total area of 1200 ha. The facility has a feedstock storage silo of 22,800 m^3 capacity and the AD system consists of 1 pre-digester (314 m^3), 2 digesters (1884 m^3 each) and 1 post digester (1884 m^3), as well as 3 digestate stores (8596 m^3). The AD plant produces approx. 600 m3/hr of biogas, which is then upgraded in a centralised plant and 300 m3/hr of biomethane is injected in the natural gas grid.

The motivation for the farmers involved to invest in the plant was to develop an alternative farming enterprise to conventional cereal growing when the price of grain was low in 2005-2006. The driver for the gas utility was to comply with the German legislation setting 6% target for 2020 and a 10% target for 2030 for Germany's gas demand to be met with biomethane. There is also an obligation on gas network operators to give priority for access, grid-feed and transport to biomethane producers.

Graskraft Reitbach, Austria;

This AD plant is situated at the foothills of the Alps in Austria. The plant is owned by 4 farmers who set up a co-operative in 2003 to invest in and manage the project. The initial plant was established for combined heat and power (CHP) generation (100 kW electric), using 45 ha of grassland for biogas production. The plant uses a wood chip boiler to meet peak loads in the district heating system and to provide back-up. In 2007, they extended the capacity of the AD plant, taking feedstock from 60 ha of grassland, and installed a biogas upgrading and biomethane filling station for compressed natural gas (CNG) in the area.

The project is another good example of co-operation between neighbouring farmers and with the local community which is provided with heat and transport fuel produced locally using renewable resources. This project was set up in response to deteriorating economic conditions for farmers in the livestock and dairy sector, using grass as feedstock with minimal disruption to their agricultural practices and the local rural landscape. It was clear during the site visit that this was a profitable enterprise and that the owners were actively working at expending and upgrading the operation. The pride of the farmers in their achievement was visible and it was explained that this venture had secured their jobs and was creating added-value for them and the local community. A lot of attention was given by the promoters to project a clean and modern image, notably through the architecture of the plant. The project seemed to have injected a 'new energy' in the life of this rural community.

Linkogas, Denmark

The LinkoGas Biogas Plant (near Lintrup, Denmark) treats approximately 200,000 tonnes per year (tpa) of organic wastes, making it one of the largest biogas plants in the world. The plant is owned by an independent co-operative society set up by 60 local farmers, who supply the slurry (approximately 150,000 tpa, 62% cattle slurry and 38% pig slurry). The plant also receives approximately 50,000 tpa of sewage sludge, glycerol from biodiesel production, slaughterhouse waste and hospital food waste, for which it receives a gate fee.

The plant was built in 1989 – 1990, and rebuilt in 1999 when the plant was converted from mesophilic to thermophilic operation and was added a post-digestion phase. LinkoGas has 8 employees in total, four of these are tanker drivers, a manager and assistant manager, as well as two maintenance engineers. Staff work Monday to Friday. The plant is run automatically under normal circumstances.

The main aim of the co-op was to build and operate a slurry-based centralised co-digestion plant, which would help its members meeting their legal demands with regards to slurry storage and handling, as well as reduce odour nuisance from slurry application to land. The manure is produced on the surrounding farms, which are all within a 7 km radius of the plant. The benefits of the structure are that it offers a centralised organic waste management system with the coop managing the nutrient cycle and balancing nutrient supply with requirements among the participating farmers. Excess nutrients are exported to other tillage farms.

The plant produces approximately 6 million m^3 of biogas per year. A small portion of the biogas is used on-site to fire a combined biogas and oil boiler (0.9 MW), which provides the heat required on-site, including for the digestion process. The rest of the biogas is stored in a biogas storage tank with a volume of 5,000 m^3 and piped via a low pressure gas transmission system (7 km) to the nearby Rødding CHP plant. At the CHP plant the biogas is utilised in two biogas engines to produce electricity (2.1 MW) and heat (maximum 2.6 MW), which is used in a district heating scheme.

The total investment for the plant was €5.5 million and a €2.12 million subsidy was received from the Danish authorities. While no specific data was provided on the financials of the project at the time of the visit, they were described as challenging owing to the relatively low feed-in tariff of 12 cents/kWh received at the time. However, the longevity of the operation (in place since 1989) is a testament to its robustness and simplicity, and the quality of its management and operators. It is worth noting that the biogas production increased by 30% following the arrival of an experienced manager and the establishment of a close collaboration with universities for the monitoring and optimisation of the plant.

Owen Yeatman N.Sch, UK

Owen Yeatman is a dairy (400 head) and arable farmer (500 ha) from Dorset. Following research conducted in the framework of his Nuffield Scholarship, which include site visits in Germany and the USA, he embarked on the development of an AD plant on his farm. The plant, commissioned in 2007, uses the farm's manure as well as chicken manure from a neighbour's farm and some apple pomace from a local cider producer. The biogas produced is used to power a combined heat and power unit with an electrical capacity of 340 kW. The CHP unit generates enough electricity to power around 450 homes in the UK. With an investment of £750,000, the project returns 19% - a yield on investment that is expected to go up as the value of bioenergy continues to increase (Farming Futures). In addition to the good economics of the renewable energy project, the application of the digestate on his land considerably reduced his fertiliser costs and improved the viability of his farming enterprise.

Figure 4: Digester at Lowbrook Farm. Source: Farming Futures

According to Owen, "the banks are wary of new technology in business so we brought in equity from other investors and through grants, as well as asset finance for the Combined Heat and Power unit. The Government's support, through things like the Energy White Paper announcement, the doubling of the ROC entitlement for the price for electricity from anaerobic digestion (AD), and the Feed-in Tariff (FIT) all help to underwrite the economics of the project. The electrical output is now priced similar to that received by German farmers."

Lessons Learned From Abroad

The research conducted during the study tours and site visits of AD plant in Germany, Austria, Denmark and the UK gave a tremendous insight into the development of AD in these countries and the experience of individual or groups of farmers who embarked in AD projects. Among many others, the following lessons learned stand-out:

- Most projects visited are owned and operated by a co-operative of farmers rather than by individual farmers. This allows pulling in larger amounts of feedstock, achieving economies of scale in capital investment and operational costs, as well as sharing the risks and the extra burden on existing farm activities.

- Most projects are relying on a mixture of feedstock, including slurry and manure, energy crops and often organic by-products from agri-food industry and municipal waste management. Co-digestion of organic wastes attracting gate fees often improves the economics of AD projects, although generally requiring larger scale plants and specific sanitary precautions. Regulatory requirements in that regard are often burdensome and increase capital and operating costs.

- However, co-digestion participates to a more localised and sustainable management of organic waste and nutrient cycles, delivering significant socio-economic benefits in the region.

- AD technology is reliable and has undergone continuous innovation since the first commercial scale projects in the 80's. While the early history of AD is littered with technical problems, it was encouraging to see a number of plants having operated successfully for over 20 years.

- Research and development continues to bring new technical solutions and innovative practices that increase reliability and efficiency. The science of feedstock digestion is particularly important in that regard and it is important to note the work carried out by Jerry Murphy and his team at the University College Cork in that regard.

- Monitoring of operations and testing of key elements of the biological process play a key role in improving the performance of the plants, notably in terms of biogas yield.

- Successful AD development is generally supported through technical guidance provided by public agencies at early project development stage. Networking with experienced AD operators also plays an important role and is actively encouraged by government and industry.

- Financial incentives such as funding, low-interest loans and most importantly feed-in tariffs play an essential role for the development of AD. However, above enabling the profitability of AD projects, experience from pioneer countries shows that it is critical for investor confidence and the AD industry to have incentive schemes that are reliable and stable over time. Roller-coaster policy making in renewable energy development has proved to be devastating.

- The role of AD in improving the nutrient cycle on farms has been seen as a key success factor for the farmers visited. Balancing NPK inputs, availability of liquid and solid fertilisers, and increased yields were discussed as important benefits for the productivity of the farm. The composting and packaging of the solid fraction of digestate adds value to this by-product, and enables the export of excess nutrients from the farm and generates an important additional income.

- All farmers that embraced AD are very proud of their achievement and were very generous with their time in sharing their experience. It was also noticeable in many cases that AD projects lead to reinforced co-operation between AD farmers and their local community, notably through supplying competitive energy from local, renewable resources.

- Countries such as Denmark and Germany have developed a very strong industry employing tens of thousands of people in AD and now very active internationally in export markets. This offers many opportunities for diversification and off-farm income.

Table 1: Summary of AD plant visits

AD Plant Identifier	Location	Feedstock	Digester type	Heat out put	Electricity output	Gas to grid Transport fuel	Capital cost	Year constructed
Germany								
Jens Geveke	Westerstede,	Grass + some cattle slurry	Wet Fermentation	Drying wood, district heating in future	500 kW	b	€1.8 m	2005
Anton Seilbeck	Geisberg,	Maize silage, rye grain silage, slurry	Wet fermentation	To farm house	100 kWe		200 keuro	2006
Munich Zoo	Munich	Zoo animal dung (2000 t/year) + biowaste	Dry fermentation	40 kW towards zoo heating	74 kW			2006
Altheim Distillery	Essenbach-Altheim	Distiller's wash, starch pulp, pig slurry	Wet fermentation	1 GWh, to distillery processes + adjacent buildings	2 x 85 kW			
Josef Moritz	Marquartstein	food residues, lawn, grass, draff, distiller mash	Wet fermentation	Surplus heat supplied to nearby hotel	80 kW		120 keuro	1996
Bioenergie Schlitters GmbH	Bernau	Food waste, biowaste or expired food from supermarkets	Wet fermentation		330 kW		3 million euro	2007
Family Holland (organic farm)	Ochsenhausen	Clover grass, pig manure	Wet fermentation	To farm	To grid			
Bioenergie Laupheim	Burgrieden	1200 ha of energy crops	Wet fermentation			5 mio. Nm3 of biogas upgraded by		2008

		(maize, grass and grain)				centralised plant (2.8 Mio biomethane injected in NG grid)		
Thomas Karle	Kupferzell	Rye & corn silage, pig & cattle slurry, mash and leftovers from fruit juice production (DM = 15-20 %)	Wet fermentation	Surplus heat used for drying digestate and pig housing	320 kWe (gas engine) + 130 kWe (microgas turbine)			2001-2007
Biogas plant	Wolpertshausen	Food waste & grease trap waste, slurry	Wet fermentation	360 kW to local district heating to nearby residential and commercial users	250 kW producing 1400 MWh/yr			1996
Austria								
Graskraft Reitbach	Eugendorf	Fresh grass, hay and grass silage (60 ha)	Wet fermentation, mesophil / thermophil (43°C)	500 kW, of which 400 kW to district heating	100 kW	Gas upgrading for filling station since 2008	650 keuro	2006
Association for sewage treatment	Roppen, West Tyrol	Waste Water Treatment Plant sludge	Wet fermentation, thermophilic (50°C)		330 kW			
Denmark								
Linkogas (co-op)	Lintrup, Denmark	Pig & cattle slurry + fish & food waste	Wet fermentation, thermophilic	2.6 MW peak, for district heating	2.1 MW peak, 15.5 GWh/ year	Biogas transported to centralised CHP plant	5.5 million euro	1990
Organic Farm	North Denmark	Potato processing waste + grass	Wet Fermentation	To heat vegetable growing beds	350 kW		Unknown	2009

		silage		for early vegetables				
United Kingdom								
Trevor Lea Breaden Heath	North Wales	Cattle slurry	Wet fermentation	Dwelling heating and farm hot water				1989
Lodge Farm	Wrexham UK	Cattle slurry	Wet fermentation	Under construction	Under construction			2009
Owen Yeatman Lowbrook Farm	Dorset UK	Cattle slurry + chicken litter, silage	Wet fermentation	Dwelling heating and farm hot water	340 kW		£800,000	2007
Crouchland Farm	West Sussex, UK	Under construction	Wet fermentation	Under construction	1MW	Under construction	Under construction	

Anaerobic Digestion Development in Ireland

Introduction

This chapter presents a review of the status of anaerobic digestion in Ireland. It is looking at its market development until recently as well as the nature and size of its industry, and assesses technical, financial, regulatory and socio-economic factors affecting this development. It looks at the potential of AD in Ireland based on an interpretation of published information and opinions collected from key stakeholders.

Current Market Status

The AD sector in Ireland could be described as being in its infancy although it has been in the making for several decades now. The first farm-based AD system was commissioned in 1995 at the Ballyshannon Farms in Adamstown, Co. Wexford. In total, there is an estimated 5 farm-based AD in operation in Ireland, 15 industrial or municipal AD facilities and 7 landfill gas projects (IEA Bioenergy Task 37, 2011).

Most farm AD plants were built pre-2000 and are relatively small, however the most recent and largest one was commissioned this year and has an electricity generation capacity of 250 kWe. According to the Irish Bioenergy Association, as of November 2011, there are 20 additional projects with planning permission and grid connection offers in the pipeline (Gavigan, Economics of Bioenergy, 2011). According to the European Barometer on Biogas, Ireland produces 35.8 thousand tonnes of oil equivalent in biogas energy, and ranks 15th in the EU27 biogas production league (EurObserv'ER, 2010).

Bord Gais, the main natural gas utility in Ireland, has made a strong commitment towards biogas and has called for the introduction of feed-in tariffs for biogas injection into the gas grid (Bord Gais, 2010). There is also a strong R&D capability in the field of AD in academic and other public institutions. The Environmental Research Institute at the University College Cork plays a leading role in that regard, with a number of research projects in the area of resource assessment, cost analysis, environmental impact assessments, digestion processes optimisation, etc. Teagasc,conducts research into improving the production and use of grass silage as feedstock at its Grange Centre. The Bioresources Research Centre (BRC) in University College Dublin conducts research into small scale gasification and the optimisation of AD processes. The University of Limerick is also carrying out a range of bioenergy research including thermochemical conversion of biological waste. Research is funded by a number of departments and agencies, including the Department of Agriculture, the Sustainable Energy Authority of Ireland (SEAI), the Environmental Protection Agency (EPA), Bord Gais, etc. The Irish Bioenergy Association (IrBEA) is working hard for and with its members to advance the case for a strong AD industry in Ireland.

The potential for AD in Ireland

Like with many other renewable energy options, it can be frustrating to contrast the current level of AD development in Ireland with the scale of the resource. In a recent report, Bord Gais outline the theoretical potential of biogas as follows: "In 2007, Ireland produced about 40 million tonnes of biodegradable wastes (i.e. slurry, slaughter waste and organic household waste) suitable for anaerobic digestion. In addition, Ireland has significant unexploited resource potential in the form of grass, with 91% of agricultural land, or 3.9 million hectares, being used to grow this potential energy crop (Bord Gais, 2010)."

In the same report, the authors present an assessment of the technical potential (all suitable feedstock used for AD) and a baseline potential (realistic proportion of feedstock diverted to AD). Under this assessment, there is a technical potential to meet 33.2% of Ireland's current natural gas demand, or 11.4% of total final energy demand with biomethane by 2020. Under the baseline scenario there is the potential to meet 7.5% of Ireland's current natural gas demand as shown in table 2 below, or 2.6% of total final energy demand with biomethane by 2020.

	Technical potential		Baseline potential	
	Biomethane	Energy[e]	Biomethane	Energy[e]
Source	Mm^3/a	PJ	Mm^3/a	PJ
Agricultural slurry	423.8[a]	15.53	51.3	1.88
OFMSW	61.7	2.26	15.6[b]	0.57
Slaughter waste	37.4[c]	1.37	18.6	0.68
Surplus grass	1,298.3	47.58	325.7[d]	11.9
Total	1,821.2	66.74	410.2	15.03
% of total current Irish gas demand		33.2%		7.5%
% of 2020 final energy demand in white paper scenario		11.4%		2.6%

Source: Adapted Singh A, Smyth BM, Murphy JD, Renewable and Sustainable Energy Review, Volume 14, Issue 1, January 2010, Pages 277-288.
Notes:
a. 32,000,000 tonnes agricultural slurry x $12.8 m^3$ methane (CH_4) per tonne x 1/0.97= 423.8 Mm^3 biomethane per annum (with 97% CH_4 content).
b. 870,000 tonnes OFMSW x 25% recoverable x 69 m^3 CH_4 per tonne x 1/0.97= 15.6 Mm^3 biomethane per annum.
c. 420,000 tonnes slaughter waste x 86 m^3 CH_4 per tonne x 1/0.97= 37.4 Mm^3 biomethane per annum.
d. 97,500 hectares x 3,240 m^3 CH_4 per hectare x 1/0.97 = 325.7 Mm^3 biomethane per annum.
e. Conversion assumes biomethane has an energy content of 36.8 MJ/Mm^3

Table 2: Technical and Baseline Potential of AD in Ireland. Source: Bord Gais, 2010.

Using a different approach, a report by the Joint Oireachtas Committee presents a scenario of a thousand farm-based AD plants with an average generation capacity of 380 kWe, each requiring 8000 tonnes of grass silage plus 1300 tonnes of maize silage, along with 4000 tonnes of slurry (feedstock cost of €250,000 per year). This would require 380 acres of land for each AD plant. A total capacity of 380 MW of AD capacity in place would generate approximately 3 Terawatt-hours of electricity per year or c. 10% of the projected electricity generation for 2020 (Oireachtas JC CCE Committee , 2011). The Joint Oireachtas Committee report also states that this level of development could generate 8250 jobs within 10 years.

The Irish Bioenergy Roadmap published in 2010 by SEAI reveals the extent to which it is believed by public authorities and academics that biogas will play a key role in the future of energy supply in Ireland. First of all, below shows how predominant grass as a feedstock for AD is in the bioenergy resource assessment conducted by SEAI.

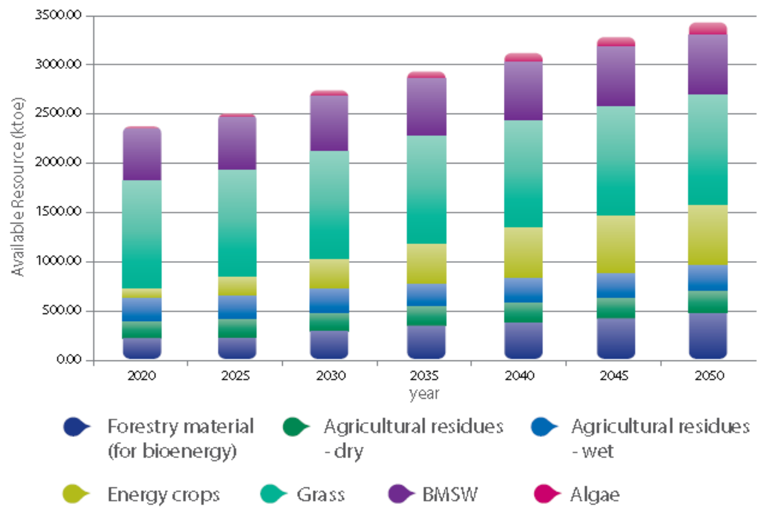
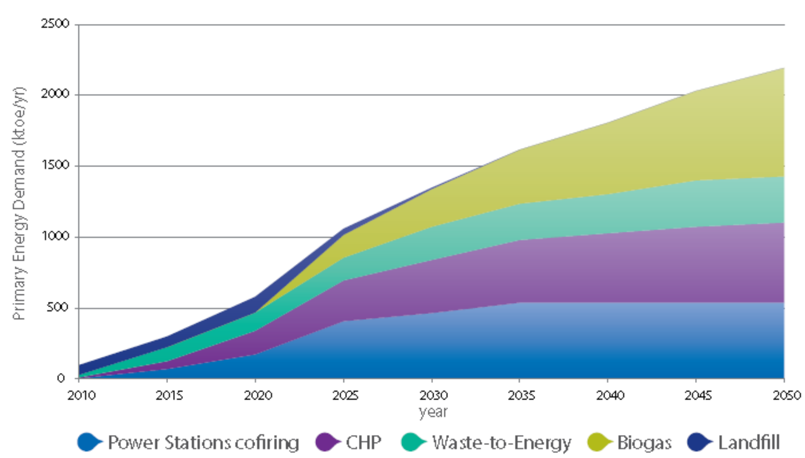


Figure 5: Total biomass resource for bioenergy to 2050. Source: SEAI, 2010.

Secondly, it shows that in the long-term it is expected that biogas will be a strong contributor to electricity generation from bioenergy in Ireland (up to 1 million tonnes of oil equivalent in primary energy demand by 2050), with only a timid start in the second part of this decade.



Barriers to be overcome

How then, if everybody agrees on the strong potential for AD, why isn't it further developed in Ireland? The reasons are multi-fold and we are going to review the prominent ones hereafter.

The economics

The financial viability of an AD project depends on a number of factors:

- Capital costs or initial investment for setting up the AD plant, including project development (feasibility studies, engineering, planning, etc.), obtaining grid connection, construction of feedstock handling, treatment and storing facilities, digesters, biogas treatment, digestate stores, etc. This might also include heat distribution networks (e.g. district heating). The capital cost will obviously depend on the scale of the system but also on the technology used (e.g. dry or wet fermentation) as well as the complexity of the process (e.g. pasteurisation in codigestion, biogas upgrade).

- Ongoing operating costs including cost of buying in or harvesting/transporting feedstock, energy costs (heat and electricity), repairs and maintenance, management, rent and leases, insurance, licenses, cost of finance, disposal/transport of digestate, waste disposal, etc.

- Revenues from the sale of biogas or biomethane, or the sale of heat and/or electricity, as well as the sale of digestate (liquid and solid fraction) or substitution of chemical fertilisers. In addition, gate fees can be an important source of income if organic wastes from industrial or municipal sources are used as feedstock.

A key item in all European countries with a dynamic AD sector, the feed-in tariff for the electricity generated and exported to the grid in Ireland is currently at 15 cents/kWh for AD projects smaller than 500 kWe and 13 cents/kWh for projects above 500 kWe. A comparison of these Irish tariffs with those in application in other EU countries shows that they are among the lowest in Europe (Oireachtus JC CCE Committee , 2011):

Country	FITs in application (€/kWh)
UK	€0.18
Northern Ireland	€0.22
Germany	€0.18-0.28
Austria	€0.16-0.18
Italy	€0.22-0.28
Latvia	€0.16 (30% capital grant)
Czech Republic	€0.15-0.20
Republic of Ireland	€0.13-0.15

The same Oireachtas report presents a basic assessment of the viability of a standard farm-based AD project using slurry and energy crops (grass + maize silage) and concludes negatively on the financial viability of such projects on the basis of the sale of heat and electricity at the current feed-in tariff. The reports concludes that "Without an increase in the REFIT price by the Irish Government, the status quo will continue and almost certainly result in the AD industry failing to develop in the Republic, whilst thriving in Northern Ireland where they have the benefit of the higher tariff." There is evidence that large AD plants across the border are starting to contract farmers and other providers of organic material for the supply of feedstock from the South.

It is worth noting that recent farm or community-based projects in Ireland generally include organic wastes attracting gate fees (food waste, waste water treatment plant sludges, grease traps, etc.) in their feedstock. In two community-based projects in West Cork for which feasibility studies have been published (see www.wcdp.ie) and showed positive results, gate fees amounted to 40% of total revenue in Bantry and 60% in Kinsale. The most recent farm-based AD project at David Mc Donnell's farm in Co. Limerick treats almost 3,000 tonnes of food waste per year (see case study on SEAI's website[4]). Only in the Bantry AD project is grass silage included in a small proportion to the feedstock plan.

The Environmental Research Institute of UCC has demonstrated through a number of studies that using grass silage for the production of biomethane can be financially viable if the biomethane is used as vehicle fuel, in particular if the project also attracts gate fees. However, there is currently no compressed natural gas (CNG) vehicle fleet in Ireland. Injecting biogas or biomethane in the gas grid is also an option but only if attractive incentives in the form of a feed-in tariff such as in Germany are put in place.

Regulatory Requirements

Many materials suitable for AD, either on their own or as a co-substrate, are animal by-products (ABPs). ABP refers to "… bodies or parts of animals or products of animal origin … not intended for human consumption". ABPs can pose a threat to animal and human health via the environment if not properly disposed of, potentially causing disease and contamination of the food and feed chain. The collection, transport, storage, handling, processing, and use or disposal of all ABPs is tightly controlled by the ABP regulations.

The regulations divide ABPs into three categories based on their potential risk to animals, the public or to the environment, and set out how each category must or may be disposed of. Category 1 is high-risk material and may not be used in an anaerobic digester. Categories 2 and 3 may be used as feedstock for AD:

- Category 2 material comprising milk, manure, digestive tract content.

[4] http://www.seai.ie/Publications/Renewables_Publications/Anaerobic_Digestion-Shanagolden_Case_Study_2010.pdf

- Category 3 material comprising former foodstuff s, catering waste (including cooking oil), feathers, milk, certain fish and fish products, shells, hatchery by-products, egg by-products, processed animal protein.

The ABP regulations lay down requirements for treating (i.e. pasteurisation) ABPs and for the disposal of digestate (e.g. grazing restrictions and the type of crops that can be grown on land fertilized with digestate). The level of treatment required and the restrictions regarding digestate disposal depend on the plant size, the type and quantity of ABPs, the source of ABPs (on-farm or imported), and the end use of the digestate. Compliance with the regulations can add significant costs and must be weighed against the gate fees received for the ABPs. The strict requirements pose challenges for the development of AD in Ireland and have been a stumbling block for the industry (BM Smyth, 2010). For further information on ABP regulations, see http://www.agriculture.gov.ie/agri-foodindustry/animalbyproducts/

Planning and public attitude

Planning is recognised as being an important barrier for AD projects in Ireland. The Oireachtas Committee report on AD recognises that the lack of awareness among planners about AD needs to be tackled to facilitate its expansion in Ireland. Anecdotal evidence from AD projects undertaken so far shows that there is a heavy bias against such projects in the planning process, notably because they are regarded as waste management projects without due consideration to the environmental and socio-economic benefits of AD (Bioverda, 2006).

Grid-connection and generation licensing

As with all renewable generation projects, obtaining grid connection can be a serious hurdle, with costs ranging from €100,000 to as much as €500,000, depending on the grid infrastructure and how close to the grid the plant is located (Irish Farmers Journal, 03/07/2010).

A grid connection application for an AD plant of less than 5 MWe can be processed without the need for grid interaction studies, and the overall time lines have decreased from years to months (CER, 2009). In addition, AD projects fall within the 'of public interest' category and are processed outside of the Group Process Approach (Gate 3 currently) – a definite advantage for AD compared to wind. (See http://www.seai.ie/Renewables/Bioenergy/Anaerobic_Digestion/How_to_get_grid_connection/ for further details).

The merits of co-operative, community-scale projects

The case for the establishment of AD plants under the co-operative model with farmers and possibly community participation is strong. First of all, grouping feedstock resources and processing them in a centralised plant will allow sizing the digester up and generate significant economies of scale in terms of capital investment and operational costs. Dividing ownership between shareholders also reduces the financial risks for individuals. In addition, having several farms involved means a larger pool of land for the spreading of digestate and more flexibility in nutrient management, in particular if tillage farmers are also involved. A study carried out by a Masters Student at DIT suggests a co-operative model whereby 20 farmers within a 10 km radius would come together, providing slurry from 1500 cattle as feedstock co-digested with organic waste (Ni Ruanaigh, 2011).

It is worth noting that both West Cork AD projects discussed earlier have been initiated by community groups and propose a co-operative structure with mixed shareholding including community representatives, farmers, local businesses, local authority, etc. The proposed AD facilities will treat commercial, municipal and domestic organic wastes, as well as agricultural feedstock. This type of approach can be beneficial on a number of fronts:

- Better ability to provide an integrated solution dealing with the waste management, energy supply and nutrient management at a community-scale;
- Leveraging the environmental and socio-economic benefits of the project for the wider community is often considered an essential part of the project, sometimes on a par with financial return on investment;
- Community-based projects are more likely to attract support from local authorities (e.g. in Bantry, the digester is to be located on a County Council site) and a more favourable attitude by planners;
- Community-based projects are likely to be more acceptable to the broader community as they are perceived to have more concern for the welfare of the community as opposed to private developers. This can help in alleviating public opposition and NIMBY (Not In My Back Yard)ism;
- Co-digestion projects with community ownership are more likely to be able to secure the supply of feedstock for which gate fees can be received in the long-term as the holders of this feedstock might be shareholders in the projects themselves or value more the economic benefits of the project. This is considered an important point in a volatile waste management sector, primarily driven by costs;
- This type of projects is more likely to offer synergies between different activities and needs within the perimeter of influence of the project, notably in terms of opportunities to utilise the heat output of the AD plant (if using CHP) and its digestate. For example, the proposed AD project in Bantry would include a horticultural production facility in its proximity using the heat from the plant for early growing of vegetables and the digestate as a fertilizer.

Conclusions

The following recommendations can be made on the basis of the information and knowledge acquired in the framework of this Nuffield Scholarship and presented in this report:

1. AD is a renewable energy technology with decades of experience behind it worldwide and in particular in Europe where the AD sector is very dynamic and constantly innovating.

2. The science of anaerobic digestion continues to evolve, notably in the area of optimisation of feedstock mixes and treatment for biogas yield and stability. This effort is supported locally by a good research and development capability in our universities, institutes of technology and state agencies, supporting innovation and adaptation to Irish conditions.

3. Using AD and biogas as a renewable fuel replaces fossil fuel, thereby avoiding CO_2 emissions.

4. AD is a renewable energy technology with a wide range of benefits from a socio-economic and environmental point-of-view. It produces biogas, a clean, renewable fuel from local resources and converts organic waste into high-value energy and fertiliser. Considering this and the inherent potential for high quality jobs AD should be much higher on the political agenda at local and national level.

5. The feed-in tariffs in application in Ireland do not compare favourably with most other EU countries in terms of their level and their lack of distinction between types of feedstock.

6. Community-driven initiatives promoting renewable energy in their area (so called Transition Towns and Sustainable Energy Communities) should consider the role of AD for their renewable energy supply and organic waste management strategies. They should take inspiration from similar initiatives around Ireland and Europe and work with relevant stakeholders in their community to support the development of AD projects within their area.

7. Community leaders have an important role to play in raising awareness and educating their fellow citizens about the benefits of AD and encourage a proactive attitude towards AD projects in their area. They should also seek to influence local decision-makers, e.g. in the framework of the planning process, local and regional development plans, etc.

8. From a farmer's perspective, AD is an integrated technology which offers the prospect of rebalancing, at least partially, the energy and nutrient flows within the farm. The current model of intensive farming is very dependent on fossil fuels for mechanisation and fertilisation to produce food that is almost entirely exported out of the farm. This makes it very vulnerable to the vagaries of energy supply and price, as well as fluctuations in international food commodity prices. Without wanting to be retrograde, it is worth reflecting on how this relatively recent situation contrasts with agricultural models of less than a century ago where cultivating fodder for draught animals was an essential part of the energy cycle on the farm and there was a much higher degree of self-sufficiency in food and nutrient requirements at the farm level, or at least at community scale. AD should also be looked at as a modern strategy to making the farm enterprise more self-sufficient, resilient and sustainable.

9. The current status and success of AD in Germany, Austria, Denmark and UK is highlighted between pages 17 and 28 of this report and the development of AD in Ireland is documented in pages 29 to 35. From these pages one can only conclude that government policy in some European countries is very encouraging towards the development of AD whereas here in Ireland that encouragement is not yet fully in place.

Recommendations

1. Ireland should have a shared integrated approach to policy making for AD.

2. A "One Stop Shop" for the co-ordination of government departments and agencies and the implementation of shared policies must be put in place to assist the development of projects.

3. A detailed strategy for the development of AD should be put in place, based on a broad consultation with relevant stakeholders, defining clear policy objectives and targets in the context of the National Renewable Energy Action Plan, Climate Change Strategies and other relevant legislation. The AD strategy should articulate detailed measures to remove technical and non-technical barriers to AD and funding mechanisms for their implementation. The strategy should make provision for development of renewable gas production and consumption via the natural gas grid and as a transport fuel.

4. Financial incentives should be broadened to support renewable energy applications other than electricity generation, and promote innovative AD applications such as upgrading to biomethane for gas grid-injection or usage as transport fuel. These incentives should also differentiate between the types of feedstock used and reinforce the financial viability of using those that have particular socio-economic or environmental benefits such as energy crops. In addition, grid operators should capitalise on the fact that AD plants can offer

dispatchable[5] generation and recognise financially its contribution to dealing with the intermittency of other renewable energy technologies such as wind power.

5. Teagasc should be a leader in the development of anaerobic digestion using the template of the BETTER dairy farm programme.

6. Policies and regulations should be put into place for the introduction of a Renewable Gas Obligation for gas distribution utilities, setting ambitious but achievable targets for a minimum renewable gas content in natural gas supplied via grid and as transport fuel

7. Further investigation into the potential for rural AD projects for the production and distribution of biomethane as a transport fuel should be undertaken by our university Masters and PHD programmes.

8. AD project developers should conduct detailed feasibility studies at an early stage of their project, considering carefully the nature and quantity of feedstock available and their costs. In that regard, priority should be given to feedstock attracting gate fees (negative cost), then free feedstock (typically on-farm organic waste such as slurry and manure) and finally feedstock with a net cost such as grass or maize silage. Again, synergies with organic waste producers and waste management companies can be of benefit for project developers and the wider community.

9. AD projects should aim to achieve a sufficient size by pooling enough feedstock and generate economies of scale for the construction and operation of AD plants. AD project developers should consider carefully joining forces with other farmers and stakeholders in the community through the co-operative model to increase access to feedstock, improve their financial and operational capability, and maximise the socio-economic and environmental benefits of the project.

10. Policy makers also have an important role to play in supporting innovation and technical capability in the AD sector. A detailed plan for education, training and technical support should be put in place, involving the relevant agencies and third level education sector. Further, continued support should be given to applied and fundamental research and development to foster innovation, efficiency and added value in the sector.

11. Relevant authorities and legislative bodies should recognise AD plants as strategic infrastructure for the sustainable treatment of organic waste and renewable energy supply. The planning process should consider the many benefits provided by AD plants, (provision renewable energy job creation) beyond the strict interpretation of AD as a waste treatment mechanism. An effort should be made at national level to raise the

[5] **Dispatchable generation** refers to sources of electricity that can be dispatched at the request of power grid operators; that is, generating plants that can be turned on or off, or can adjust their power output on demand.

awareness about AD and to educate planners on the specifics of AD projects. The relevant departments (Agriculture, Environment, Energy, Communications and Natural Resources) have also an important role to play in communicating more effectively the Animal By-Products and Waste Management regulations and streamlining their enforcement.

Finally

Conducting this research has been a very enriching experience. It is hoped that others, particularly in the agricultural sector, will find this report valuable. AD is a multifaceted solution that can offer significant benefits for project developers and the wider community. However, further steps need to be taken by the various stakeholders, in particular policy makers, to finally unlock its full potential to contribute to Ireland’s renewable energy revolution and sustainable development.

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Bibliography

AEA Technology. (2005). Assessment of Methane Management and Recovery Options for Assessment of Methane Management and Recovery Options for. DEFRA.

ARUP. (2011). Review of the generation costs and deployment potential of renewable electricity technologies in the UK. Department of Climate Change and Energy (UK).

Bioverda. (2006). Response to Energy Green Paper.

BM Smyth, H. S. (2010). Modeling and Analysis: Grass biomethane – an economically viable biofuel? Biofuels, Bioprod. Bioref. , 10.1002/bbb.

Bochmann, G. (2011). Update on biogas in Austria. Istanbul: IEA Bioenergy Task 37.

Bord Gais. (2010). The Future of Renewable Gas in Ireland.

CER. (2009). Treatment of Small, Renewable and Low Carbon Generators outside the Group Processing Approach.

DEFRA & DCCE. (2011). Anaerobic Digestion Strategy and Action Plan.

EurObserv'ER. (2010). Biogas Barometer. Paris: Systemes Solaires.

Farming Futures. (n.d.). Case Study #16: Renewable Energy Focus - OWEN YEATMAN. http://www.farmingfutures.org.uk.

Gavigan, N. (2011). Economics of Bioenergy. SERVE Project Conference. Thurles: Irish Bioenergy Association.

Gavigan, N. (2011). The Economics of Bioenergy. SERVE Conference Dec. 2011. Thurles: IrBEA.

IEA Bioenergy Task 37 . (2010). Biogas Country Report, Denmark.

IEA Bioenergy Task 37. (2011). Ireland Country Report. Turkey.

Linke, B. (2011). Biogas Country Report - Germany. Cork: IEA Bioenergy Task 37.

Ni Ruanaigh, A. (2011). Developing Anaerobic Digestion Cooperatives in Ireland. Masters Dissertation. Dublin: Dublin Institute of Technology.

Oireachtus JC CCE Committee . (2011). BIOGAS ENERGY IN IRELAND. Joint Committee Climate Change and Energy.

Ravena, R., & Gergersen, K. (2005). Biogas plants in Denmark: successes and setbacks. Renewable and Sustainable Energy News.

Seadi, T. A. (2008). Biogas Handbook. Big East – Biogas for Eastern Europe.

SEAI. (2011). Energy Forecasts for Ireland to 2020. Cork: SEAI.