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Energy From Waste on the Isle of Mull:

A Feasibility Study of an Anaerobic Digestion Plant

By

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Declaration of author’s rights

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I would like to dedicate this work to my father, whom I think might have found this topic quite interesting.

Abstract

The project focused on assessing the feasibility of a mixed waste Anaerobic Digestion plant on the Isle of Mull. Information from a waste audit and consultancy report conducted in 2003 was analysed. Energy from Waste technologies, AD biochemical processes and technologies were investigated and evaluated. Waste streams were re-assessed as to their feasibility for inclusion in an AD plant. Biogas yield, energy yield and potential revenue calculations were made from the waste steams identified. Project costs, income generation and funding sources were identified. Existing AD plants were visited in Scotland and Ireland. A location for the proposed plant was identified and an assessment conducted of the energy demand at that location. Policy and legislation relating to sustainable waste management and energy were investigated. Key areas of legislation impacting AD installation, design and operation have been summarised. Liaison has been established with many industry, policy and legislative experts and the case for AD in Scotland investigated and promoted. The potential for AD treatment of sewage sludge has been highlighted to the relevant authorities in light of recent sewage management system proposals. Interest in a key stakeholder and inter-island AD dissemination event has been identified and will be organised in the near future.

Executive Summary

This project is a feasibility study of an anaerobic digestion (AD) system for the Isle of Mull. The study assessed the suitability of different available organic wastes and their applicability to AD options.

AD is a process whereby organic waste is broken down in a controlled, oxygen free environment by bacteria naturally occurring in the waste material. Methane rich biogas is produced thus facilitating renewable energy generation. As a result, materials that are currently going to landfill are utilised; natural methane emissions are reduced and conventional generation with its associated carbon emissions is displaced. The residual nutrient rich liquor and digestate is suitable for use as fertiliser on the farmland surrounding such a plant, reducing the need for artificial fertiliser.

Such an AD system could provide an integrated waste management system on Mull, with the ability to handle various different types of organic waste, and help improve the sustainability of waste management and agriculture on the island. The resulting methane rich biogas could be used for community or small industry heat and electricity needs.

Waste streams such as fish farm waste, agricultural slurry, and sewage waste were identified on the island in a study[21] last year. This project assessed the viability of

these identified wastes, recalculated waste yields and estimated the projected biogas yield in line with potential energy demand by island industries.

The project also focused on identifying potential funding sources, policy objectives and legislative requirements with regards to waste management and treatment for the island. Meetings with the relative legislative bodies and key players were made, where possible, and consultation undertaken with a wide range of industry experts on the issues affecting and impacting on AD in the Scottish and remote isle context.

Existing AD plants in Scotland and Ireland were visited and help obtained from leading experts to assist with the design of a suitable plant for Mull. Options were identified for the island in relation to waste management, plant location, sources of funding and cross community liaison. At present, Scottish Water has identified an urgent need for improvements to the sewage treatment system. This project has established liaison with Scottish Water to highlight how AD could assist with sewage sludge management.

The project has also identified that there exists an opportunity to work with other Scottish islands and small communities in the support and development of AD systems, and hopes to address this by organising an inter-island and interested parties event to facilitate discussion and to highlight similarities of waste management issues on the islands and identify cross-island synergies and benefits.

Contents

1 Introduction

1.1 Project Outline

Sustainable Development is a term that is now commonplace in many waste management, energy generation and rural development plans. It incorporates the ideal that future policy, strategy and development occurs in a manner that is both beneficial to the current population and safeguards resources for future populations.

The need for sustainable policies and technologies in island and rural communities is enhanced above that of mainland communities due to their remote and segregated locations. This project assessed the feasibility of the development of a sustainable technology system, anaerobic digestion (AD), for the isle of Mull and was conducted in conjunction with the Mull and Iona Community Trust (MICT), Mull Environmentally Sustainable Solutions (MESS) and the Waste and Resources Action Plan (WRAP).

1.2 Project Location

Mull is a small island off the west coast of Scotland and has a population of almost 3,000 of which approximately 980 live in the main settlement of Tobermory[1] on the North-Eastern coast of the island. A location map for the island is presented in Figure 1.1.

Figure 1.1 Location Map of the Isle of Mull

Tourism is a major industry on the island, and one that has grown considerably over recent years. Recent figures indicate visitor numbers of over 300,000 tourists per year arriving on the island[2]. Other more traditional industries such as agriculture, forestry, fishing and fish farming continue on the island but tourism is now regarded as the sector that will support the growth and strength of the island economy. In such an environment, infrastructure and services such as energy generation and waste management systems are key to successful island communities. However, these often prove more expensive to implement and run than mainland locations.

1.3 Report Structure

The structure for this report is outlined as follows. Chapter 2 presents a background to the project and assesses the EU, National and local legislation, policies and strategies in relation to waste, energy from waste and renewable energy. Chapter 3 details AD from a biochemical and technology viewpoint. Different types of AD technology and the relevant legislation are reviewed and an assessment made of the most suitable solution for the island of Mull. Chapter 4 details waste audit data from 2003, a consultancy report from 2003, and an analysis of these calculations. The waste data collected during this report is also detailed, as is an assessment of the waste streams available and their feasibility for an AD plant. Chapter 5 presents biogas calculations, both those from work conducted in 2003, and the work conducted this year. An assessment of the energy usage on the farm and the potential for this to be met by AD technology is dealt with in this chapter. Chapter 6 identifies project cost, income and possible funding sources that could be used to help an AD project on Mull. This is then followed by a conclusion and recommendations.

2 Background

2.1 Project Overview

2.1.1 Mull - Waste Management

It was with a focus of sustainable development on Mull that the desire for an integrated waste management system to deal with a variety of organic wastes was conceived. Mull has established a community run abattoir and butcher shop, which would benefit from a more cost effective waste management option than the current route to landfill. Inclusion of other wastes such as fish farm, agriculture, dairy and potentially sewage sludge create a clear argument for an organic waste treatment system on the island. Mull Environmentally Sustainable Solutions (MESS) is an award winning community body that aims to initiate and implement sustainable solutions in both waste management and recycling. In addition to this, there is work underway to design a sewage treatment system for the island. At present sewage is either discharged untreated to sea by long sea outfall pipe or collected in private septic tanks. This project has proposed the treatment of sewage sludge with an on-island organic waste treatment plant to Scottish Water.

2.1.2 Mull - Energy from Waste

Given the island's location and natural resource limitations the potential to generate electricity and heat from waste materials was welcomed by the inhabitants. At present some parts of the island have a heavy reliance on diesel-fuelled generation and there is a desire to replace this with a more sustainable option. To assess the most suitable solution for Mull an investigation into the legislative and environmental drivers for sustainable waste and energy management options was necessary.

2.2 Waste Legislation

To assess the most suitable solution for Mull an investigation into the legislative and environmental drivers for sustainable waste and energy management options was necessary.

Organic waste is that proportion of waste that is biodegradable in nature, and is a waste stream that, at present in the UK, is becoming increasingly regulated and expensive for collection, disposal and treatment. The key legislative documents that relate to biogas plants, both on an EU and UK scale are:

? EU Landfill Directive 1999/31/EC[3].

? EU Animal By Products Regulation 1774/2002[4].

? Scottish and DEFRA Animal By Products Regulations[5].

? Draft Biowaste Document EU[6].

Through the Landfill Directive EU member states are now required to reduce significantly the amount of organic biodegradable waste going to landfill over the next 16 years. The Animal By Products regulations stipulate that any animal derived products will be prohibited from landfill by Dec 2005. The EU Biowaste directive is being written to revise the existing EU Sludge Directive and will define clear guidelines on the collection and treatment of biodegradable waste. All of this legislation will regulate and stimulate sustainable methods of nutrient recycling through organic waste treatment and agricultural applications; encourage the creation of high quality by products from waste treatment technologies and promote energy recovery from waste by technologies such as AD. An analysis of each of the legislative documents has been summarised as below.

2.2.1 EU Landfill Directive 1999/31/EC

Adopted 26 April 1999

The EU Landfill Directive requires Member States to develop strategies for reducing the amount of waste sent to landfill, with the objective of reducing local water and air pollution, and emissions of global greenhouse gases caused by the degradation of organic wastes in landfill sites. Furthermore, it establishes strict targets for reducing the quantity of biodegradable municipal waste (BMW) disposed of to landfill. BMW is municipal waste of organic nature i.e. that is capable of undergoing aerobic or anaerobic decomposition.

For all countries criteria are set using 1995 waste data figures. For the UK the following targets are set as shown in Table 2.1.

Table 2.1 Targets **for diversion of BMW to landfill**

Year	% BMW to landfill
2010	75% of 1995 levels
2013	50% of 1995 levels
2020	35% of 1995 levels

To achieve these targets will require significant changes in the collection, separation and treatment of biodegradable waste. As detailed in the National Waste Strategy Plan[7] (2003), and as shown in Figure 2.1 below, in Scotland in 2002 only 9% of Municipal Solid Waste (MSW) arisings were diverted with 91% of all MSW going directly to landfill. Mull falls under the Argyll and Bute Waste Strategy Area, which has set ambitious targets of 27% diversion of MSW from landfill by 2010, and 50% diversion by 2020[8].

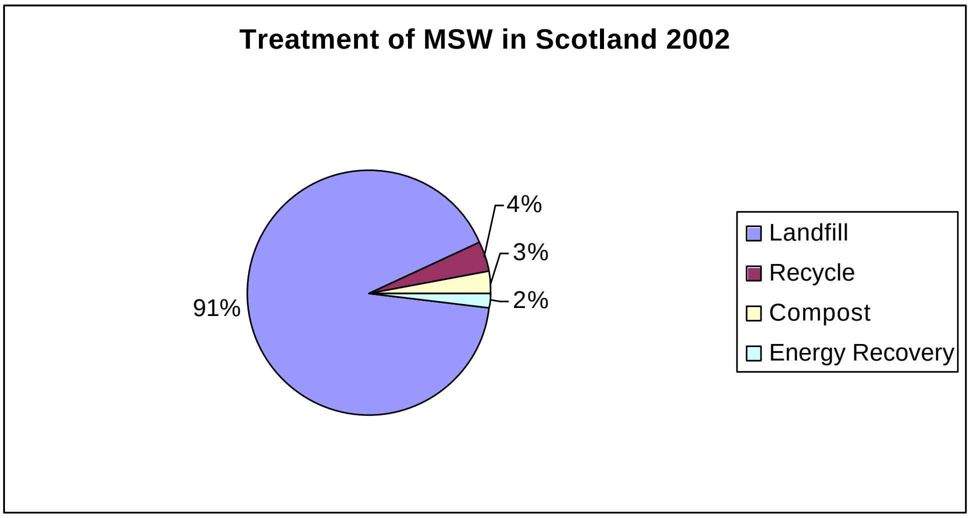


Figure 2.1 MSW Treatment analysis- From National Waste Strategy Scotland 2003

According to recent Local Authority Waste Arising Surveys (LAWAS)[7] surveys approximately 60% of all MSW going to landfill is biodegradable in nature and includes materials such paper and card, putrescible waste (e.g. kitchen food waste and garden waste) and some textiles.

As this would indicate the targets set by the landfill directive will require a major change in waste management practices in Scotland over the coming years. Indeed in 2002, using the 60% Biodegradable content average some 1.76 Mtonnes per annum (mtpa) of BMW was landfilled. This is 0.5 mtpa more than the first Landfill Directive target for disposal to landfill in 2010 and 1.2 mtpa more than the target for 2020. This give some indication of the scale of the challenge presented by the Landfill Directive.

As presented in Figure 2.2 below, to achieve a landfill percentage of just 31% by 2020 will necessitate an increase in recycling, composting and energy recovery practices across Scotland.

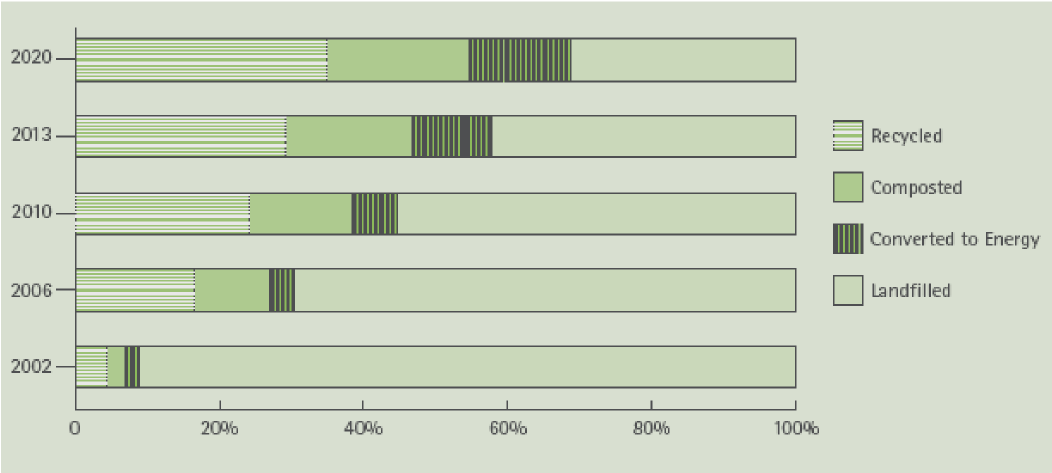


Figure 2.2 Projection of Waste Treatment Practices in Scotland to 2020 - From National Waste Strategy 2003[7]

An approach known as the Best Practicable Environmental Option (BPEO) has been adopted in the assessment of possible future waste treatment options and is defined "*as the outcome of a systematic and consultative decision-making procedure, which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term*" (From National Waste Strategy[7]).

In relation to the Argyll and Bute Waste management plans, the region aims to have achieved a composting rate of 24% of MSW and 26% by 2010. This will include large scale composting of residual MSW (which has had non biodegradable material and recyclables removed) small scale composting of segregated green waste and source segregation of recyclables.

The aim for 2020 is presented in Figure 2.3 below:

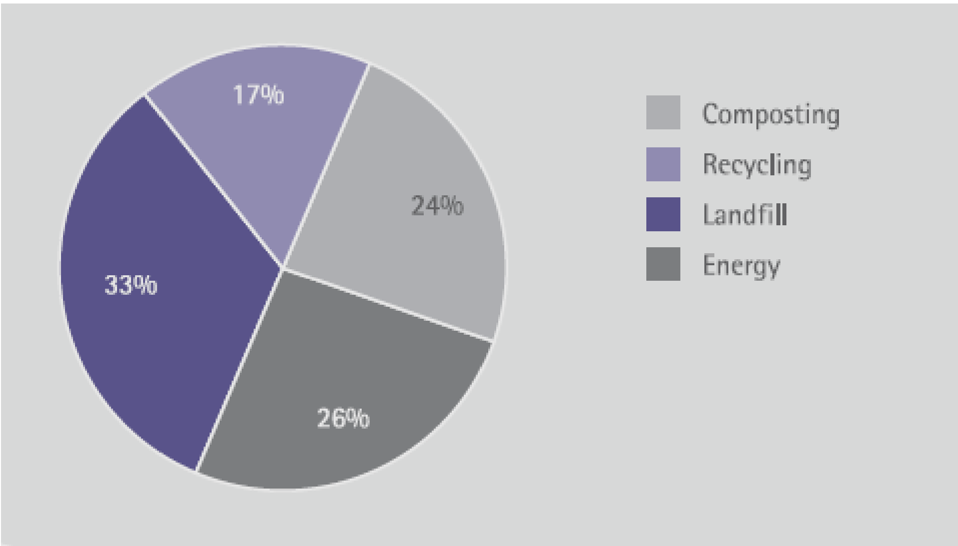


Figure 2.3 Argyll and Bute Proposed Waste Treatment in 2020[8] (REF Argyll)

This details energy recovery accounting for 26% of total waste treatment practices, but a more detailed definition of the waste to energy treatment type is not given, therefore leaving technology options open for some time. It is interesting to note that a high level of composting is envisaged in the area up to and including 2020. At present there are many difficulties in the marketing of the compost produced from residual MSW composting facilities and therefore it would seem that its suitability as a long term solution is unclear. The Scottish Environmental Protection Agency (SEPA) have released recently a position statement[9] on compost from such MSW sources and have stated that local authorities should *"be aware that composting mixed waste is not a long term solution… (be) aware that composted mixed waste is not fully recovered and remains waste …(and)… that in the longer term they should be moving towards segregated collection of biodegradable material …."*

This statement document also stresses the need for source segregation of biowaste material, which can then be further used in composting or other treatment systems.

One further aspect of the Landfill Directive is that the cost of landfilling is to include all the costs involved with construction, operation and decommissioning (over a 30 year period). This will greatly increase the cost of landfilling as a waste management option in the coming years. Therefore, the actions as set forth in the Landfill Directive should act as a major incentive in the utilisation of AD for the treatment of BMW.

2.2.2 EU Animal By-Products Regulation 1774/2002

Adopted 1 May 2003

This is a regulation covering the treatment of Animal and Catering Waste, which acts to safeguard human and animal health by providing enforceable controls for the safe disposal of animal by-products not intended for human consumption. It is now prohibited to dispose of most animal by-products to landfill. ''Animal by-products" are defined as *"entire bodies or parts of animals or products of animal origin not intended for human consumption (includes ova, embryos and semen)*"[4]. Therefore, the legislation includes meat and fish, both cooked and uncooked, and other products of animal origin if they are designated as not for human consumption. Animal by-products therefore arise from food retailers, manufacturers, wholesalers, distributors, convenience stores, butchers, fishmongers, food markets and bakers. Animal By-Product (ABP) Strategies are to be adopted in each Member state in accordance with the legislation. Three categories of waste are defined and these are outlined below.

2.2.2.1 Category 1 material

High risk: Animal by-products presenting a TSE (transmissible spongiform encephalopathy) risk or an unknown risk or a risk related to treatment with illegal substances or to environmental contaminants.

2.2.2.2 Category 2 material

Medium risk: Animal by-products presenting risk related to animal diseases or residues of veterinary drugs.

2.2.2.3 Category 3 material

Low risk: Animal by-products derived from healthy animals.

Only Category 3 material is permitted for direct use in Biogas and AD systems to prevent disease and pathogen transmission. Category 2 material is permitted if it has first been pressure rendered to 133°C/3bar for 20 minutes.

2.2.3 Animal By-Products (Scotland) Regulations 2003. SSI 2003/411

Enacted Oct 1 2003 – National Regulations[5] in compliance with EU Animal By-Products Regulation.

Although disposal to landfill is not a permitted outlet, the UK Government obtained an agreement in Brussels for a transitional measure which permits “former foodstuffs of animal origin” to continue to go to landfill until 31 December 2005 providing measures are taken to exclude raw meat and raw fish. Therefore, the need for alternative disposal methods of organic waste materials is becoming increasingly urgent.

Mull at the moment has consent to landfill fallen animal stock and other animal material[10], but the lifetime of this derogation is not certain and is likely to be reviewed by the EU at some stage in the next few years[11]. It is also unclear how this derogation affects the regulations with regard to the landfilling of foodstuffs. The main body of the ABP regulations adopted in Scotland follow the same guidelines as set forth in the EU document, with a few additional definitions and requirements in relation to premises design and process treatment.

2.2.4 EU Draft Biowaste Directive

The EU Commission had given a commitment that by the end of the year 2004 a Directive on Biowaste, including catering waste, will be prepared with the aim of establishing rules on safe use, recovery, recycling and disposal of this waste and of controlling potential contamination[6].

It has now been proposed to make the development of this document a revision of the Sewage Sludge Directive 86/278/EEC. This will accompany the development of a fully-fledged Soil Thematic Strategy, which was first expected to be adopted in September 2004. At present an extended Impact Assessment of an EU Biowaste Directive is underway and it is likely that the EU commission will take until mid 2005 to produce a Soil Framework Directive. This Framework Directive could comprise a Soil Monitoring Directive, a Compost/Biowaste Directive and a revised Sludge Directive[12].

These documents, in conjunction with the Animal By Products Legislation and the Soil Thematic Strategy, will highlight the value of recapture of nutrients from organic waste, and subsequent recycling of nutrients to agricultural land.

If the directive goes ahead as proposed in the draft document[6] there will be a requirement on member states to collect Biowaste separately and minimise disposal to landfill through an integrated waste management scheme. Investment in and creation of an integrated waste management market and the recovery of energy from waste shall be promoted and required within a legislative document under this directive.

2.3 Renewable Energy Legislation

2.3.1 UK and Scottish Legislation

The UK as a whole has pledged to generate 10% of electricity from renewable sources by 2010, 15% by 2015 and states an aspiration of 20% renewable generation by 2020. This is in line with the UK's Kyoto commitments on carbon dioxide emissions reduction. In relation to Scotland a target for 18% renewable generation by 2010 has been set by the Scottish Executive followed with an aspiration of 40% renewable generation by 2020[13].

2.3.2 Renewables Obligation Scheme

To help achieve this several schemes have been initiated to increase the level of renewable energy generation across the UK. The Renewable Obligation Certificate Scheme (ROC) in England and Wales and the Renewables Obligation Scotland (ROS) has been imposed on electricity suppliers requiring them to source some of their generation from renewable sources. This was set at 3% for 2002/2003 and 10.4% for 2010/2011. This tool has proven to be a very successful in creating commercially viable projects and increasing the demand for renewable generation across Scotland. A breakdown of certificates issued by sector is illustrated in Figure 2.4.

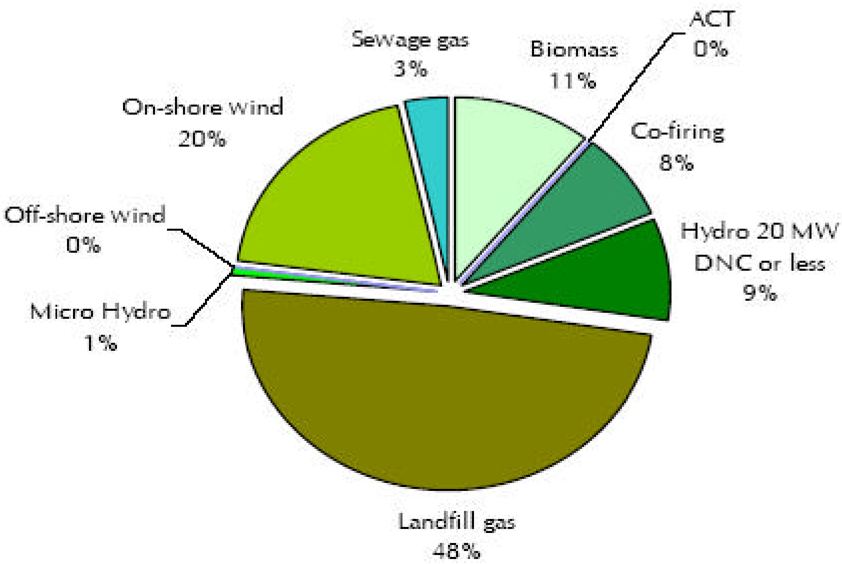


Figure 2.4 Renewable Obligation Certificates issues by technology (after Renewables Obligation Report- Ofgem 2004.)[14]

2.3.3 Renewable Sector Development

In the UK wind energy is the renewables sector that has seen the largest growth and receives a large amount of attention both from the public and business communities. The biomass sector, under which AD is categorised, has seen a much slower growth rate. Financial support for biomass in the UK is available under several different schemes but the emphasis is towards the woodchip and energy crop sectors. In Scotland the recent establishment of the Forum for Renewable Energy Development in Scotland (FREDS) – which acts as an advisory body to the Scottish Executive on renewable development policy and support – has a subgroup devoted to Biomass issues. Again however the focus is on woodchip and AD technologies are not given much attention, at least in work undertaken recently[15]. The large forestry resource in Scotland combined with the decease in forestry revenue generation has created a desire to look at new ways to utilise forestry assets of which woodchip energy is one.

2.4 Energy from Waste

This analysis has reviewed the policy documents and support mechanisms available for energy technologies dealing with waste matter, and other renewable technologies in Scotland, the UK and the EU. SEPA has undertaken research into the acceptability of Energy from Waste technology in Scotland[16]. This investigated public, industry and local government opinions on Energy from Waste options. The study concluded that Energy from Waste was viewed by all sectors as a necessary technology for sustainable waste management when combined with recycling and recovery systems, and that the BPEO principle should be employed when assessing Energy from Waste facility proposals.

Energy from waste is a term used to describe the recovery of energy from waste streams. This normally refers to either the treatment of Municipal Solid Waste (MSW) or Biomass Waste by a technology that either uses combustion of the waste material directly or of a by product of the waste material. Technologies incorporating

Direct Combustion include combustion of MSW and agriculture and biomass waste, and technologies utilising Indirect Combustion includes gasification, pyrolysis and AD.

2.4.1 Combustion of Municipal Solid Waste

MSW waste combustion can either take the form of an MSW mass burn plant or Refuse Derived Fuel (RDF) plant. In an RDF plant the non-combustible materials are removed before combustion. However, in an MSW plant, pre-sorting of materials does not occur and all material enters the combustion phase. Both of these technologies use conventional steam generation technology for electricity and heat generation. The 10.5 MW Waste to Energy plant in Dundee is based on RDF design and incorporates fluidised bed technology, which offers thermal efficiencies of 89% and exports almost 80% of the electricity generated under an Scottish Renewables Obligation (SRO) contract (a financial support scheme for renewable generation)[17].

2.4.2 Combustion of Forestry and Agricultural Waste:

Other materials that can be combusted directly or with some pre drying treatments include forestry and agricultural wastes. Forestry residues, such as brash from forestry operations, or woodchip can be burned to provide both electricity and heat on a small or large scale. Agricultural residues such as poultry litter and straw are used in increasing proportions for energy generation, as environmental regulations require more stringent waste treatment methods. Technologies such as the fluidised bed combustion plant at Westfield in Fife[18] demonstrate that such fuels have a great potential in terms of energy generation and waste treatment. This 10 MW plant uses 115,000 tonnes of poultry litter per year and supplies electricity to the grid under an SRO contract.

2.4.3 Landfill Gas

Landfill waste contains a high proportion of biodegradable waste, and over the lifecycle of a landfill this waste will decompose as a result of microbial action. This decomposition, which is mostly anaerobic in nature, will release a gas and leachate. The gas is comprised mainly of methane and carbon dioxide, which can then be used for combustion and generation of heat and electricity. The Greengairs site in Scotland is a good example of energy generation from landfill gas[18]. At this plant approximately 6000 m^3 of gas/hour are abstracted from over 160 operational gas collection wells drilled into the waste contained in completed areas of the landfill. Almost 12 MW of energy is generated from this one site and illustrates the energy potential that lies within waste that ends up in landfill. The use of landfill gas for energy generation is now an established technology and since its inclusion under UK renewable energy support schemes has resulted in an ever-increasing uptake rate. The most recent figures detailing the breakdown of generation types under the Renewable Obligation scheme to date indicate that the vast majority of renewable certificates issued (approximately 48%) in the UK were to landfill gas installations[14].

2.4.4 Gasification and Pyrolysis

Technologies such as Gasification and Pyrolysis are known as advanced thermal conversion technologies and can offer superior efficiencies compared with conventional combustion for power generation. Gasification and pyrolysis systems are now becoming more commercially viable for use in waste management systems.

Gasification is a thermo-chemical process in which biomass is heated in the absence of air, to produce a low-energy gas containing hydrogen, carbon dioxide and methane. The gas, often called synthetic or syngas can be used as a fuel in a turbine or combustion engine to generate electricity.

Pyrolysis is a high temperature process in which biomass is heated in the absence of oxygen. This causes it to decompose and produces mostly vapours, aerosols and some charcoal. After cooling and condensation, a dark brown mobile liquid or bio-oil is formed which has a heating value of approximately 50 % of conventional fuel oil.

A 60,000 tonne per year plant is due to start construction near Dumfries that will combine both gasification and pyrolysis. This Compact Power plant will take a mixture of non-recyclable municipal, light industrial and commercial wastes including organic, timber and textiles, rubber tyre shreds and sewage sludge screenings and will generate up to 7.8 MW of electricity[19]. It will qualify as renewable energy under the ROS scheme, thus creating an attractive revenue stream from the energy generated from waste.

2.4.5 Anaerobic Digestion

AD is a natural process that takes place in the absence of oxygen. It involves the decomposition of organic waste by bacterial processes with the release of an energy rich biogas and the production of a nutrient rich digestate – which is composed of a liquid portion known as liquor and a solid fibrous material. Controlled digestion of organic wastes has been used for many years in the management of animal and other waste sources and is used extensively in agricultural applications worldwide both on a large centralised scale and in more basic farm specific installations. AD is increasingly used as a technology that can deal with mixed organic waste streams (e.g. animal slurry, sewage, BMW, food processing wastes) and countries such as France, Denmark and Germany are now leading the way in organic waste treatment by AD[20].

The biogas produced typically consists of 60% methane, with the remainder as carbon dioxide (CO_2) with small amounts of hydrogen sulphide (H_2S) and ammonia (NH_3). The methane can be used to fuel a Combined Heat and Power (CHP) system for electricity and heat generation; refined for addition to existing gas supply networks; used as a vehicle gas or used in conventional gas boilers or engines for separate heat or electricity generation. Methane has approximately 21 times the greenhouse gas effect of CO_2. Under natural decomposition the methane would be released to the atmosphere, so AD not only displaces conventional generation it also helps to reduce natural greenhouse gas emissions. Energy generated from AD and biogas combustion qualifies under the Renewable Obligations schemes, which therefore helps to improve financial viability of AD plants if there is sufficient energy generated to export. The digestate liquor is rich in nutrients and can be used as a fertiliser and soil improver. The fibrous component of the digestate can be used as a soil improver or further composted to achieve a compost material suitable for horticultural, land reclamation and agricultural applications.

2.5 Mull and the case for Anaerobic Digestion

AD is a technology that could provide a suitable solution to organic waste treatment on Mull and one that would bring additional benefits to the island in the form of renewable energy and nutrient rich fertiliser. AD would be able to treat much of the organic waste on the island and such a technology also upholds the holistic approach to environmental issues that is characteristic to many of the island's community enterprises and organisations.

The proposal for an AD plant on Mull began in 2003, initially as an investigation of options for waste disposal for the community run abattoir and butcher shop. There is a need to minimise waste treatment costs for the business, and under the guidance of MESS, research into a sustainable solution was initiated. Funding was awarded under the Shell Better Britain Project to investigate the potential of AD and fuel cell integration on Mull. AD was identified as a method that could possibly incorporate both these aims, and the work was started by the completion of a waste audit[21] on the island in August 2003. This was then followed by consultation[22] with Greenfinch Ltd., a company involved in the supply and construction and of AD systems, which included the analysis of the waste data, biogas production projection and initial plant scoping and costing. The results from the waste audit and consultancy report are presented in detail in Chapter 4.

2.6 Project Strategy

The focus of this project was to reassess the work already conducted and determine the best way forward for the creation of a sustainable AD plant and waste management system. It was identified early on that the inclusion of a fuel cell on Mull was not feasible at present due to financial feasibility. With the diversity of resources, environmental issues and funding opportunities relating to a possible AD plant on Mull; the project also attempted to identify the most suitable strategy that could be adopted by the community to move the process forward after the completion of this project.

The methodology used in the project included consultation and communication with all relevant stakeholders including islanders, government agencies, industry, lobby groups, and environmental and regulatory bodies.

2.6.1 Waste Data

This project refined the waste amounts and determined the scale and preferable technology for an AD plant for Mull in line with the waste resources available. A key factor of this waste analysis is to investigate the potential of collaboration with Scottish Water for sewage sludge management on the island. This is in the anticipation of new sewage treatment works required by legislation by December 2005. Sewage sludge could form one of the feedstocks for an AD system providing benefit to Scottish Water in terms of sludge disposal. However, this proposal would require assessment of the available tonnage of sludge and technology issues.

2.6.2 Technology, Biogas Yield and Energy Use

An assessment of the various anaerobic technologies is incorporated in this project to help identify the BPEO for Mull. In relation to biogas and energy yield and the potential for use of the energy generated from the plant, an assessment of the energy demand at a farm and cheese-making dairy has been included.

2.6.3 Policy and Funding

The project was also designed to assess and promote the position of AD in relation to the Scottish Renewables scene, and to ascertain the level of support and potential external funding the island community may be able to access to in order to realise the installation of an AD plant. This involved consultation with policy bodies and key industry figures on the role of AD as viewed and reflected the policies of Scotland

and the UK. It also included attending several relevant conferences and information events in both the renewable and waste strategy and policy fields.

3 Biogas Technology

3.1 Introduction

This section presents an overview of the biological processes involved in AD technology. It also provides a description of the different technologies available in AD plant design and the regulations relating to plant operation and design. The most suitable option for Mull is discussed in the final section.

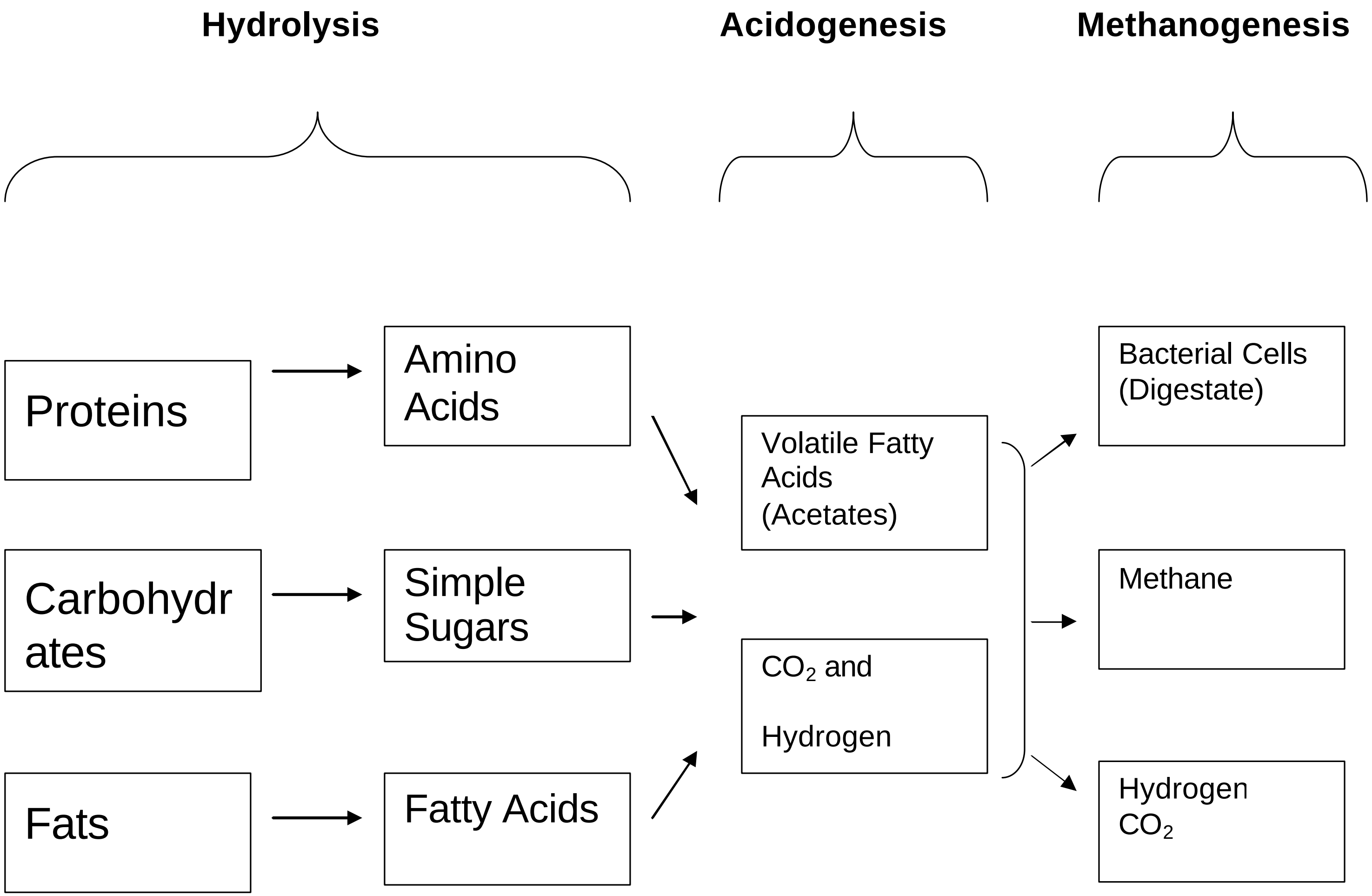
3.2 Anaerobic Digestion- Biochemical Processes

AD is a biological process that involves the bacterial and enzymatic decomposition of organic compounds in organic waste material to methane, carbon dioxide and simpler organic compounds. This takes place in three main stages- hydrolysis, acidogenesis and methanogenesis, which are shown in Figure 3.1 below.

3.2.1 Hydrolysis

The first step in anaerobic decomposition is enzymatic hydrolysis. It occurs in the substrate, as opposed to bacterial cells, by the action of extra-cellular enzymes produced by hydrolytic bacteria. Hydrolysis involves the breakdown of long chain molecules such as fats, proteins and carbohydrates into smaller components such as fatty acids, amino acids and simple sugars, in a format that allows the next stage of acetogenesis to occur.

Figure 3.1 Anaerobic Digestion Biological Processes



3.2.2 Acidogenesis

This stage is also known as the acetogenic or fermentative stage. Acetogenic bacteria break down the hydrolysed products to their final metabolic products of volatile fatty acids (predominantly acetates), CO2, ammonia and hydrogen. The optimum temperature range for this phase is 30ºC. Mixing or agitation of the substrate in this phase enhances this process, as the bacteria require a high contact rate with the substrate.

3.2.3 Methanogenesis

The third stage results in the production of methane by methanogenic bacteria. Using the products from the acetogenic stage, methanogenic bacteria produce methane from one of two processes. Approximately 70% of the methane is formed from volatile fatty acids by acidotrophic bacteria. The remaining 30% is produced from hydrogen and carbon dioxide by hydrogenotrophic bacteria. The hydrogenotrophic bacterial role is very important to the overall digestion process as it removes hydrogen and maintains a low level of hydrogen in the substrate. If hydrogen levels were to rise this would result in a change in the activity of the acetogenic bacteria and biogas production rates would fall off. This phase is also the slowest biological reaction of the digestion and methanogenesis is very susceptible to changes in the digester environment. Overloading of the reactor, temperature changes or large amounts of oxygen entering the digester usually result in the cessation of methane production[23].

3.3 Operating Parameters

AD is a complex biological process with several conditions and variables that affect production rates and process performance. It is necessary to monitor these conditions to ensure the process proceeds in a stable manner with optimal biogas production.

The conditions that are most important and that should be considered when establishing an AD system include:

- pH;
- temperature;
- dry solids content;
- retention time;
- organic loading rate;
- carbon to nitrogen ratio; and
- mixing.

These parameters are now briefly described in the sections below.

3.3.1 pH

The different bacteria types involved in AD have different pH requirements but an optimal range for all is between 6.4 and 7.2. pH values below this range often indicate high concentration of volatile fatty acids and can be toxic to the bacterial populations especially the methanogenic bacteria. Higher pH ranges than 7.2 also inhibit methane production.

3.3.2 Temperature of digestion

AD in controlled applications normally takes the form of either mesophilic or thermophilic digestion. Mesophilic digestion occurs in medium temperature ranges typically within 30-37ºC and a usual operating temperature of 35ºC, whereas thermophilic digestion operates at temperature ranges of 50-60ºC with a typical operating temperature of 55ºC. Thermophilic digestion tends to be more productive in biogas yields, but can be a more costly process due to the higher substrate temperature requirements. It is also more sensitive to environmental variables so can prove more problematic than mesophilic systems. Feedstock composition and operational and economic considerations will often determine the operating temperature design of the system.

3.3.3 Dry Solids content

This depends on the feedstock and the design of the system treating this feedstock. Wastes such as sewage sludge and animal slurry have very low Dry Solids (DS) content typically in the range of 5-8%, whereas MSW type waste is typically over 20%. Optimum range is normally below 35%. Some feedstocks may need water added, or in a co-digestion plant this can be achieved by mixing high DS material with wetter waste types.

3.3.4 Retention Time

During the process a retention time in the digester tank is necessary to achieve sufficient digestion of organic compounds. This retention time varies between the two processes, with mesophilic digestion requiring approximately 20-35 days and thermophilic digestion operating with shorter retention times of 12-15 days.

3.3.5 Organic Loading Rate

The organic loading rate refers to the amount of volatile or degradable solids being fed to the digester and is related to the retention time and digester tank volume. It is usually expressed in volatile solids (VS)/m^3 of digester volume or Chemical Oxygen Demand (COD)/m^3 of digester volume. If there is an excess of biodegradable matter fed to the digester, this can lead to the overproduction of volatile fatty acids, which then leads to a drop in pH and a reduction in methane production.

3.3.6 Carbon to Nitrogen ratio

This is a ratio of the amount of carbon to nitrogen contained in the feedstock material. The optimum range is from 20:1 to 30:1. Rates lower than this indicate that ammonia is accumulating and thus the associated pH rise can destroy methanogenic bacteria. Rates higher than this indicate that nitrogen is being consumed at too fast a rate, and again methane production is affected. Mixed waste or co-digestion is often beneficial in that wastes of differing nutrient content when digested together balance the carbon to nitrogen ratio.

3.3.7 Mixing

Mixing of the substrate maximises the contact between bacteria and organic substances, prevents temperature stratification of the digester contents and prevents crust and scum formation by ensuring homogeneity within the digester. Mixing should be slow, and there are several methods used to achieve this. Some of the more common include stirring by mechanical means with a slow RPM, and re-circulation of biogas through the mixture which removes the need for moving parts within the digester tank.

3.4 Biogas Production and By- Products

Biogas produced by AD typically contains 55-75% methane, with the remainder as CO_2 and traces of hydrogen sulphide, nitrogen, hydrogen and carbon. Of these, hydrogen sulphide (normal concentration range of 200-4000 ppm) is of most importance in relation to the use of biogas for energy generation. It is quite corrosive – forming sulphuric acid during combustion processes and can be very detrimental to equipment. Removal of this gas is achieved by several methods the most common of which is scrubbing with iron salts. Frequent oil changes and use of engine oil with a high alkalinity also offers a solution. Recently a technique using small streams of air bubbled through the top layer of digested slurry in the digester has been used to promote growth of *Thiobacillus spp.* These bacteria oxidise hydrogen sulphide to elemental sulphur that is then retained within the treated slurry [24].

The digestate material is normally separated into two fractions:

- Liquor - a nutrient rich liquid phase and fibre- a compost like material that is suitable for use as a soil improver; and
- Fibre - a compost like material that is suitable for use as a soil improver.

This material is exempt from waste management licensing requirement under recent Scottish legislation[25]. If sewage sludge is part of the AD feedstock, there will be a requirement to comply with the sludge matrix guidelines on application of sewage-derived sludges to land. For agriculture this is a rest period of three weeks between land application and grazing.

This application of digestate from AD to agriculture and horticulture when contrasted with traditional untreated organic waste spreading offers the following benefits:

- Reduction of offensive odours by decreasing the concentration of volatile fatty acids and other odorous compounds.
- Stabilisation of organic matter and hence reduction of COD and BOD.
- Reduction of pathogens and weed seeds, making land spreading of digestate more suitable.
- Increased availability of nutrients for plant consumption by converting less available organic nitrogen to ammonia nitrogen and decreasing C:N ratio by converting carbonaceous compounds to methane and carbon dioxide gases.

- Reduced need for artificial fertiliser usage on agricultural land spread with digestate material.
- Improved characteristics of liquid manure homogeneity and flow by decomposition of solids and decrease of viscosity resulting in better and faster infiltration of digested slurry into the soil.
- Reduced possibility of nutrient run off and environmental pollution in comparison with conventional land spreading of manure and other organic wastes, due to higher infiltration rates.
- Reduced methane emissions to atmosphere by capturing methane released normally during waste storage and decomposition.

3.5 Biogas Technology Options

There are many different biogas systems in operation today, dealing with different waste types and with different environmental and energy criteria. A key feature of the biogas industry today is this diversity in the type of applications available and in use, many of the systems are proprietary in nature, and a detailed analysis of waste feedstock and environmental and economic factors is necessary to identify the most suitable option for each specific case. Two stage digesters are now becoming more common, and have been developed to optimise the acetogenic and methanogenic stages with manipulation of pH ranges. These are ideally used for waste streams that decompose rapidly, e.g. fruit and vegetable waste.

The majority of digesters in use are based upon the continuous stirred tank reactor, which is ideally suited to high moisture content wastes. This process is simple in operation, and uses established technology but will require a larger tank volume in comparison to drier waste systems. Dependant on the mixing system used and the feedstock there may be some need for pre-screening of the wastes, as heavier fractions and contaminants can sink and disrupt the mixing process, which then alters the biological processes.

3.6 AD Process and Premises requirements in Scotland/UK

Following the introduction of the ABP legislation there are criteria defined for AD plants in operation in the EU. The UK legislation relating to AD technologies has added even further requirements. Such requirements have in some cases increased plant costs. A summary of these regulations as they would apply to a new AD installation is detailed below.

3.6.1 Regulations Applicable to Biogas & AD premises

If the Biogas plant is located on a premises where farm animals are kept, it is to be located at an adequate distance to the area where animals are kept and there must be total physical separation between the plant and the animals.

The biogas plant must be equipped with:

A pasteurisation/hygienisation unit, which cannot be by-passed, with:

- installations for monitoring temperature against time;
- recording devices to record continuously the results of those measurements; and
- an adequate safety system to prevent insufficient heating.

Adequate facilities for the cleaning and disinfecting of vehicles and containers upon leaving the facility.

The UK Animal By Products regulation states a few additional requirements in this area, specifically that there shall be:

- a reception area with an enclosed and lockable place or container to receive and store the untreated animal by-products.
- a vehicles and containers cleaning area.
- a clean area in which treated compost or digestion residues are stored.

The clean area shall be adequately separated from the reception area and the area in which vehicle cleaning area so as to prevent contamination of the treated material. This will be that liquid cannot seep into the clean area from the other areas.

Containers and vehicles used for transporting untreated animal by-products shall be cleaned in the dedicated area before leaving the premises and before any treated material is loaded. In the case of vehicles transporting only untreated catering waste only the wheels of the vehicle need be cleaned.

Operators of Biogas AD plants shall be obliged to implement and maintain a permanent procedure developed in accordance with the principles of the system of hazard analysis and critical control points(HACCP). Under this system they should:

(a) Identify and control the critical control points in the plants.

(b) Establish and implement methods for monitoring and checking such critical control points.

(c) In the case of processing plants, take representative samples to check compliance, keep complete records of these for at least two years and ensure traceability of each batch dispatched:

3.6.2 Hygiene Requirements

The plant must adhere to the following hygiene requirements:

? The plant must be designed to prevent cross contamination of raw feedstock and process by products.

? Containers, receptacles and vehicles used for transporting untreated material must be cleaned in a designated area. This area must be situated or designed to prevent risk of contamination of treated products.

? Preventive measures against birds, rodents, insects or other vermin must be taken.

? Cleaning and plant inspection procedures must be documented and established for all parts of the premises.

3.6.3 Processing standards

Pasteurisation of material is required, which, according to the EU document must adhere to the following standards:

- Minimum 12mm particle size; and
- Minimum of 1 hour @ 70 degrees C - can occur before or after digestion process.

UK Legislation states that the pasteurisation of material is defined as either:

- 1 hour at 70?C minimum particle size 6 cm;or
- 5 hours at 57?C minimum particle size of 5 cm.

- There shall be an additional barrier of a minimum of 18 day storage of digestate, which can take place throughout or after the whole process time.

The treated digestate material should adhere to defined microbiological limits for pathogenic bacteria (e.g. Salmonellae and Enterobacteriaceae), which shall be determined by a laboratory on site or by use of an external laboratory.

It would also be prudent to design a system to meet the EU requirements with regard to pasteurisation, as it is possible that the UK regulations may have to change to meet these standards after some time, which would only then require additional process infrastructure and add costs to an existing plant.

3.7 Proposed Biogas Plant for Mull

The main waste sources on Mull are animal slurry, whey, abattoir waste and potentially sewage sludge. With this composition of waste feedstock, the continuously stirred tank reactor design with mesophilic operation temperature would appear to be the most suitable technology for the island. This would be designed to operate on a continuous basis all year round. This design would provide a simple robust solution to AD design better suited to island needs than a more complex thermophilic digester. A basic layout for such a facility is illustrated in Figure 3.2 below and a description of the key components follows thereafter.

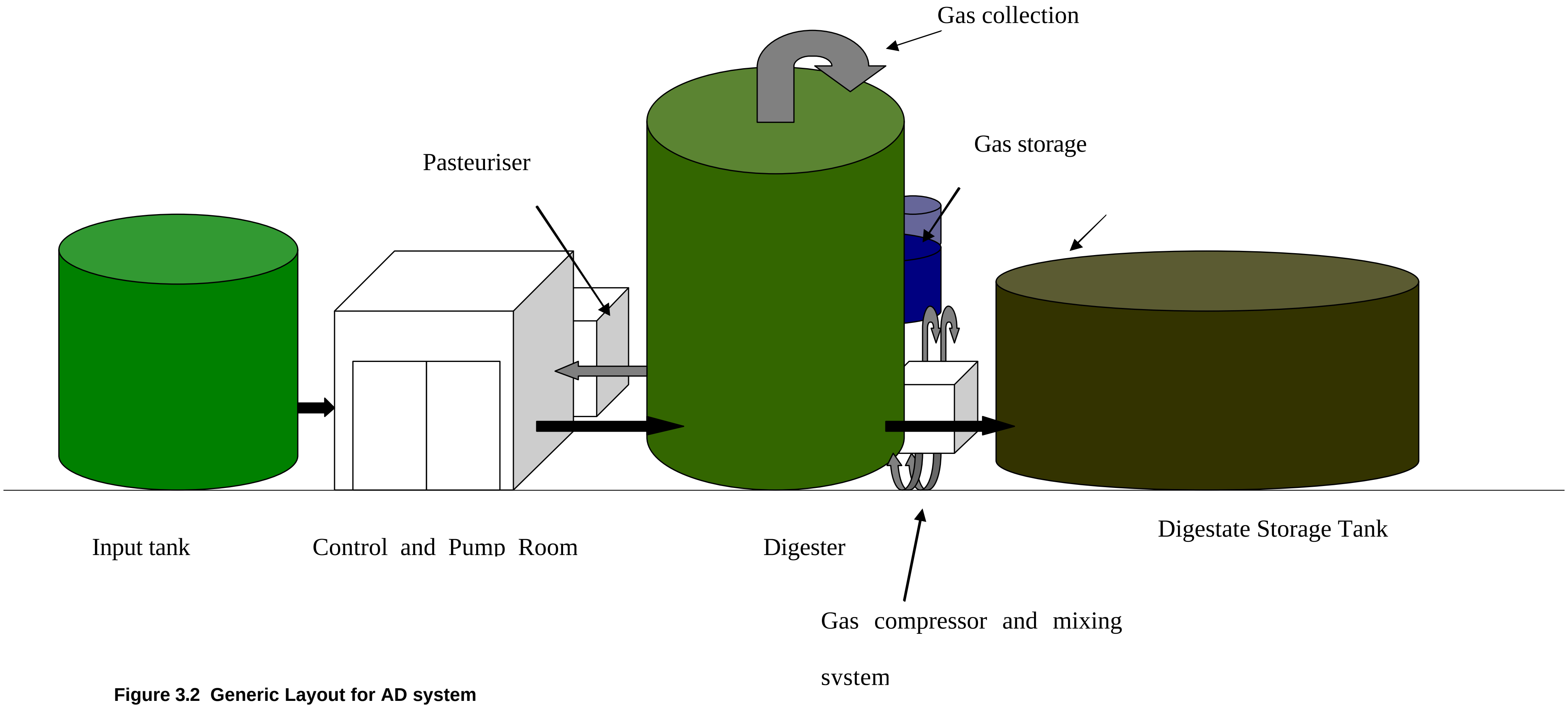


Figure 3.2 Generic Layout for AD system

3.7.1 Waste Reception Area

Waste from external sources to the plant will arrive at the reception area where unloading will occur. Depending on the waste type arriving to the plant, this may feed directly into the buffer tank or require some pre-digestion sorting or processing.

3.7.2 Waste shredding and preparation

The waste will move through a shredder and maceration system where it is reduced to a particle size of 12mm or less (according to ABP regulations).

3.7.3 Raw Waste Buffer Storage

A buffer tank acts as a storage tank for pre-digestion wastes and should be of sufficient size to allow waste storage for several days or intermittent waste delivery before input to digestion tank. This is necessary to be able to cope with digester down time and issues such as public holidays or other cases of delayed delivery.

3.7.4 Anaerobic Digester

The anaerobic digester is an enclosed vessel in which digestion takes place on a continuous basis. The digester should operate on a system of waste input and digestate off-take at regular intervals. This ensures a minimum retention time within the digestion and reduces the risk of short-circuiting (the possibility of an amount of raw waste being removed from the digester in the off-take load before digestion had begun). Mixing within the digester by means of gas recirculation is preferable to a mechanical mixing device, as this removes the need for machinery within the digestion tank itself. This is normally achieved by extraction of some of the biogas produced during digestion, compression of this gas and a rotational pumping of this compressed gas through digester on a continuous basis. This rotational pumping is maintained through a series of several pipes and a rotary valve. Depending on the feedstock volume it may prove beneficial to design a plant with several digesters working in parallel as this allows for greater processing rates and adds a redundancy facility to the system, in case one digester requires maintenance.

3.7.5 Pasteurisation

Pasteurisation at 70 ^{o}C for one hour is necessary to comply with regulations and it can occur either before or after digestion. It is normal to operate such phases at slightly above the necessary temperature to ensure complete pasteurisation. If pasteurisation is to occur before digestion, it may also prove beneficial to have more than one pasteuriser in a particular system. This allows one pasteuriser to discharge treated material while additional pasteurisers are treating or uploading waste. This then allows for a continuous feed stream of pasteurised material to the digester.

3.7.6 Heat Exchangers

There are several heat requirements within the process, the digester itself requires a constant mesophilic temperature of 35-38^{o}C, and the pasteurisation stage requires temperatures of approximately 70^{o}C. To help achieve these temperatures and avoid heat loss the use of heat exchangers is a key part of the design of such plant. Heat exchangers that work with: heat from intake of raw waste through to digestion; pasteurisation heat flows, and heat generated by CHP or boiler use of biogas will increase the efficiency of a plant and minimise energy loss from the system.

3.7.7 Gas Collection and Holder

The biogas generated from the digester, and any additional from the raw waste buffer tank, the pasteurisation tank and the digestate storage tank will be collected and require storage until further use. Suitable types of gasholders include double membrane gasholders or floating head storage systems. From the gas holder the biogas is piped separately to the compressor for biogas digestate mixing and to the CHP unit and boilers.

3.7.8 Digestate Storage

Digested material will need to be stored at the plant until it can be collected for further use. A tank of suitable capacity to allow storage over the winter if land-spreading or other digestate processing is not possible may be required.

3.7.9 Heat & Power Generation

Biogas can be burned in a gas boiler for heat generation, an engine for electricity generation or a CHP (combined heat and power) system for both heat and electricity generation. The size and output of such systems depends on the quantity of biogas produced.

An overview of the basic process and heat flows in a mesophilic AD system with heat exchangers and pasteurisation is shown in Figure 3.3.

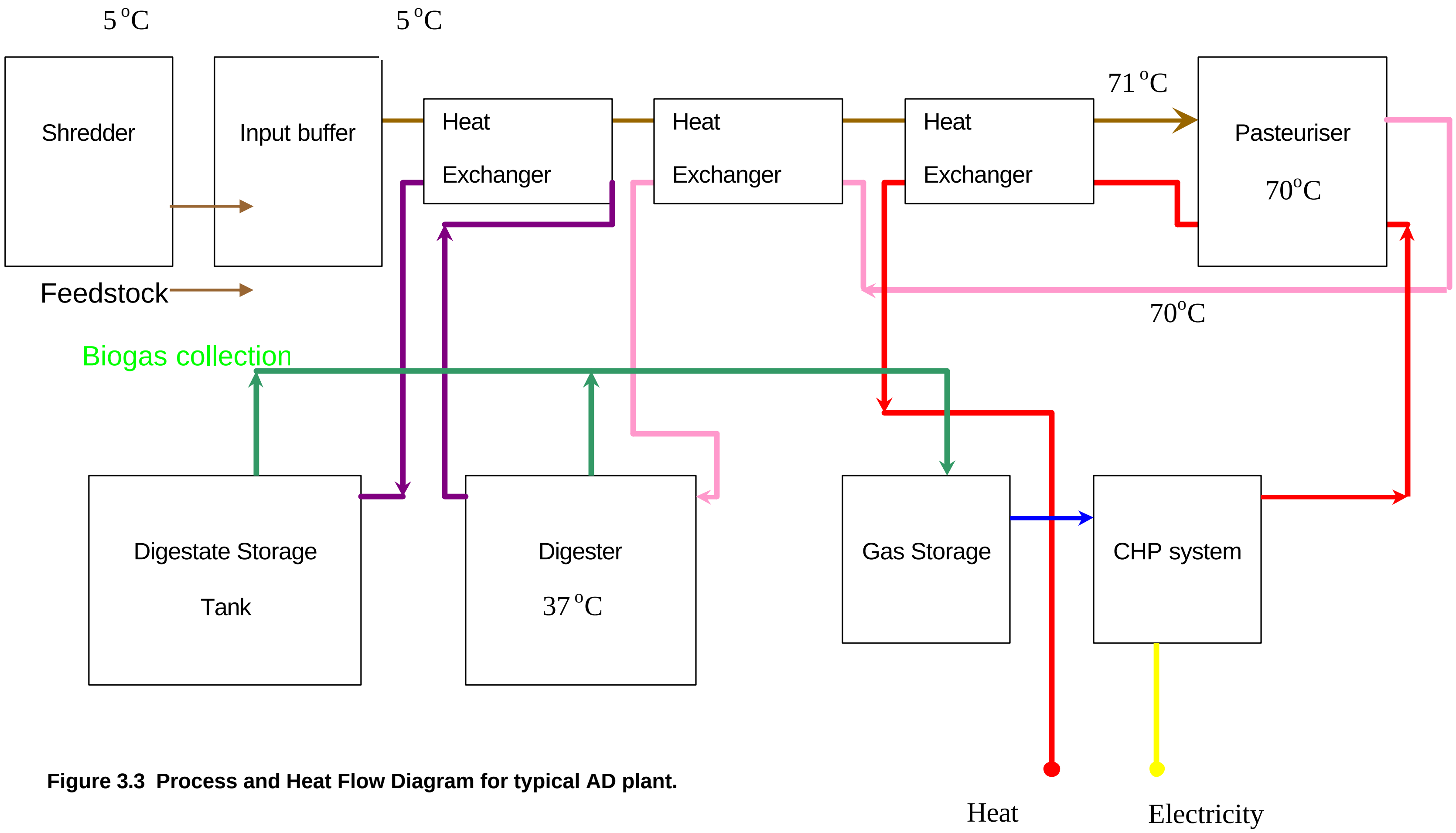


Figure 3.3 Process and Heat Flow Diagram for typical AD plant.

4 Mull AD Potential

To assess the potential of an AD plant on Mull it is essential to try to estimate the biogas yield from the identified waste streams. This then allows assessment of the energy generated by the plant. This requires an assessment of the waste streams on the island, which in conjunction with standard industry figures for biogas generation from specific waste streams allows some analysis of the potential energy yield.

4.1 Previous Waste Audit Data

A waste audit was carried out that identified some key waste sources that could be used within an AD plant. This audit comprises a field study conducted by a research assistant at Strathclyde University that took place during 18th –29th August 2003, and the subsequent report[21]. The waste amounts were recorded in different units, and with different timescales so it is difficult to assess the true character of some of the wastes. The amounts of waste assessed for the island during the study in 2003 were as in Table 4.1 as follows (some attempt has been made to standardise the unit and time period of each waste type):

Table 4.1 Waste Audit Data Isle of Mull 2003

Waste Type	Comments	Amount per week/tonnes	Amount per year/tonnes
Slaughterhouse	Cat 1, Cat 2 and Cat 3 type material- needs further breakdown	0.46	23.92
Fish farm waste	Unclear assessment – rough estimates only	1.09	56.68
Agriculture	Slurry and whey – rough estimates only	85	4420
Food	Butcher shop waste Food as part of MSW- estimate	0.35 7.8	18.2 405.6
Sewage	Using only collected and dried sewage sludge cake	0.381	19.812
Total			**4939.22**

4.2 Waste Audit Data Methodology 2003

The methods used for waste calculation varied according to waste type, and the methods are summarised below. Analysis of this methodology was carried out as part of this thesis as some discrepancies were noted in the validity of data collected, which is described below according to each waste type.

4.2.1 Slaughterhouse waste:

There is a community run slaughterhouse based at Salen, which deals with cattle, sheep and pig meat from the farms on the island.

Three alternative methods were used:

- Waste estimation based on the records and vet estimation of average animal weights.
- Waste estimation based on data from Meat and Livestock Commission.
- Waste estimation based on figures provided by consultant in relation to average amount of raw material from animal.

There was no clear description of the most accurate estimation from the above three methodologies, and no clear definition of the break down between Category 1, 2 and 3 wastes in line with the Animal By Products Legislation.

4.2.2 Aquaculture

Waste calculation was conducted through consultation with Fish Farm business in operation around the island. Four different organisations were consulted. Data regarding the waste generated from these operations was collected and summarised.

4.2.3 Agriculture

Sgriob Ruadh Farm was identified as the key farm on the island generating slurry suitable for AD treatment. All other farms are operated on an outdoor grazing system, with little indoor housing throughout the year. Sgriob Ruadh houses its animal indoors from mid May to Mid Sept, but even in the summer months the animals are housed indoors for approximately 7 hours per day during milking. This results in a large volume of slurry that requires collection and management. At present the slurry is moved from the animal houses to a waste treatment area on the farm, the solids and liquids are separated through a belt liquid extractor. The liquid is then pumped to a large storage tank, and the solids collected under the belt press and then removed as needed for fertiliser use on the land surrounding the farm. The liquid portion is piped out to the fields as a fertiliser through a network of pipes and pumps. The liquid store also receives waste from the dairy operations of the farm, which includes whey. In addition, the tank is open so rainfall is collected diluting the slurry liquids. Records are kept of the amount of hours liquid is pumped to fields.

Analysis of the waste from the farm was calculated by using a back calculation of the amount of liquid pumped to the fields, the flow rate of pumping, milk and whey production figures, and solid waste percentage to arrive at an estimated waste production per week figure.

The method used did not account for rainfall or wash water on the farm, which would seem to form a significant portion of the waste material in the storage tank.

Analysis was also carried out on the potential availability of using fallen livestock in an AD system and some data was assembled on the mortality rates and livestock numbers for the island.

4.2.4 Food Waste

Butcher shop waste, distillery waste, and municipal bio-waste were detailed in the report. The amounts calculated for these waste types lacked sufficient data and would appear to have been based on subjective assumptions alone.

4.2.5 Sewage

Sewage sludge generation on Mull at the time of the study was from septic tank collection only. Data was collected from Scottish Water in relation to this and a rough estimate was made for the annual volume produced. As there is a need for a sewage treatment installation on the island before December 2005, an estimation of sludge generation at a potential primary and secondary treatment works at Salen and Tobermory was included in the audit.. However, this prediction appears to have been based on secondary treatment with regard to population density in the two areas, with no consideration given for tourist numbers in the area.

4.3 Consultancy report

Greenfinch Ltd, a key AD consultant in the UK, was recruited to conduct an analysis and interpretation of the waste data from the Waste Audit. The report[22] produced by the consultancy details dry and volatile solids quantities, biogas production from the estimated waste volumes, proposes an initial design and details costs for this design.

The waste figures as detailed in the Greenfinch report are as in Table 4.3 below. This report also detailed the inclusion of Energy Crops as a feedstock for a digester. The use of “wet” energy crops was suggested in the report as a means of mitigating some of the uncertainty surrounding other waste sources and recommended the use of ryegrass (*Lolium spp*) as a “wet” energy crop suitable for the island. The calculations of wet energy crop yield assumed 20 hectares of land would be available for energy crop production. The report did not consider the use of whey for an AD system despite the fact that whey is a valuable feedstock[26]. Assumptions that were used in the calculations include:

- For the agricultural waste it was assumed that the animals are housed for six months of the year.
- For the purpose of this study it was assumed that kitchen waste from 1,500 households would be available.
- Research work carried out by Greenfinch Ltd into source-separated household kitchen waste resulted in an average collection of 4 kg per household per week throughout the year, i.e. 200 kg per household per year.
- The potential of sewage sludge as a feedstock was investigated. Following indications from Scottish Water at the time that two new sewage treatment works were in planning at Tobermory and at Salen, an estimate of the potential sludge tonnages were calculated.

- Because of the uncertainties arising from the waste audit, it was considered advisable to include the potential of "wet" energy crops. Greenfinch is currently undertaking a research project to investigate ryegrass as an energy crop. Using figures achieved to date, one hectare will yield 12 tonnes of dry matter per year, producing 7,500 m^3 of biogas. The study assumes that 20 hectares could be made available for wet energy crops.

Table 4.2 Waste Data from Greenfinch report. (ref)

Source	**Tonnes per year**
Slaughterhouse	62
Aquaculture	350
Agriculture	3,000
Retail Food	50
Commercial Kitchens	300
Household Kitchens	300
Sewage Sludge	3,000
Energy Crops	1,200
Total	**8,262**

There is some discrepancy between the waste figures calculated in the waste audit and the waste figures detailed in the consultancy report, and it has been difficult to determine the reason for this. No clear explanation has been received on this issue and creates uncertainty in the predicted biogas yields and therefore the initial plant designs as detailed in the report. Comparing the two data calculations as shown below in Table 4.4, there are very large differences in the waste calculations for slaughterhouse waste, aquaculture and sewage sludge. The sewage figures are calculated in the Greenfinch report state they are based on standard industry figures for sewage produced according to population density, but the slaughterhouse waste and aquaculture discrepancies are difficult to attribute to conversion inaccuracies.

Table 4.3 Comparison of Waste Data from 2003 Waste Audit and Greenfinch Report

Source	Tonnes per year – Waste Audit 2003	Tonnes per year- Greenfinch report
Slaughterhouse	23.9	62
Aquaculture	56.7	350
Agriculture	4420.0	3,000
Retail Food	18.2	50
Commercial Kitchens	-	300
Household Kitchens	405.6	300
Sewage Sludge	(dried solids) 19.8	(sludge at 6% DS) 3,000
Energy Crops	-	1,200
Total	**4939.2**	**8,262**

4.4 Waste Data 2004

In reassessing the waste streams available on the island, the following paragraphs detail:

- Legislation requirements with regards to their treatment;
- Regulations according to their treatment within an AD plant;

- Methodology used for calculation, including future waste predictions where suitable;
- Estimated accuracy of calculations; and
- Suitability of waste stream for AD plant and the business involved.

Consultation was held with the businesses on the island, the Waste Management division of Argyll and Bute council, Scottish Executive Environment and Rural Affairs Dept. (SEERAD), SEPA and industry experts to compile this assessment.

4.4.1 Slaughterhouse waste

Legislation and Regulation for collection and treatment

If an AD plant were to process waste from the slaughterhouse on the island the waste types suitable from this industry this would be Category 3 and Category 2 waste. This would require separation of Category 1 type material, i.e. material from any animal that was declared unfit for human consumption, and brain and spinal material from all animals.

If pressure treatment to the ABP standards were part of the biogas plant design Category 2 waste would be suitable for processing also. Any screening trap waste from the washing processes in the slaughterhouse would be regarded as materials of Category 2. However, digestive tract content, slurry, milk and blood (if reliable separation from specific risk material is achieved) are suitable for biogas processing without pressure treatment.

Category 3 material is all other material from animals fit for human consumption.

At the slaughterhouse there is no clear breakdown of Category 1, 2 and 3 types of waste, the only separation that is done at the plant is the collection of the skins and hides of the animals, which are salted and sent for processing. All other waste is classed as Category 1 waste and sent to Glengorm landfill.

Methodology and Accuracy

This waste estimation has been based on records kept at the plant of amount of waste material per animal and numbers of animals processed at the plant during March 2003-April 2004. Calculation of the material available for digestion includes an estimation of AD suitable waste, using data from the 2003 study. This would need further detailed assessment to completely determine the amount of waste available from the slaughterhouse, but in the absence of proper separation of Cat. 1, 2 and 3 wastes the estimates given are as accurate as possible at present.

Suitability

Slaughterhouse waste is a viable and beneficial waste feedstock for AD plants. In co-digestion with animal slurry and sewage sludge it is has been found to increase biogas production[27]. This is a community run business with a need for minimal operational costs for financial viability. While it benefits at the moment from the island derogation in relation to waste management regulations from ABP, the expectation is that island communities will have to apply in the next few years. This would increase waste management costs for the plant considerably. If proper separation of wastes at the plant was instigated and AD treatment of the suitable wastes achieved it is likely that the waste management costs of the plant would decrease.

4.4.2 Aquaculture

Legislation and Regulation for collection and treatment:

Fish waste from fish mortalities on fish farms fall under Category 2 waste under the ABP Regulations and means it will require pressure pre-treatment to 133°C at 3 bar for at least 20 minutes. Fish from fish processing facilities dealing with fish fit for human consumption is Category 3 waste and does not require pre treatment.

A bio-secure method of waste management is needed for fish farm mortalities to avoid potential fish disease transmission. Currently the waste treatment method employed by the fish farms around the island is ensilation of the fish with formic acid. This is stored in an ensilation tank until collection occurs, usually monthly, and this is then transported to Norway for further treatment. Under the PPC regulations fish ensilation is a Part B waste, and falls under the Air Pollution control regulations[28] which depending on the size of ensilation tank can accrue license costs of up to £2400 annually.

Methodology and Accuracy

Waste calculation was conducted through consultation with fish farm businesses in operation around the island. Waste data given was for average weekly waste generation, and did not account for algal bloom mortalities or disease epidemics, which are unpredictable and can be on a large scale.

The waste amounts between the businesses for normal weekly waste generation were similar, so it is assumed the figures given were accurate within reason. However there is no calculation given for the waste tonnage during a period of high mortality rates due to disease or algal bloom occurrences. If this waste was to be treated in a AD system, then a more accurate estimation of the potential volume of this waste would be necessary.

Suitability

Fish Waste is a very beneficial waste to add to co-digestion AD plants. The fish oils present in such material are high in calorific value and can add greatly to biogas yield[27]. It may be however that the tonnages are perhaps too low to warrant the installation of the necessary extra pressure treatment system that would be needed to process Category 2 type waste. One business indicated that the current cost of waste ensilation, collection and transport to Scandinavia was quite low, but that the potential to avail of a local and bio-secure method of waste treatment would be welcomed. The fish farming industry in Scotland is very much subject to marketing pressures and has recently been the subject of negative health and environment discussions. Conversations with the key players on Mull indicated that the opportunity to become involved in an environmentally sustainable venture such as AD would be looked on favourably by the industry.

4.4.3 Agriculture

Legislation and Regulation

Manure, whey and slurry all fall under the Category 2 section of the ABP regulation, but do not require pressure treatment before an AD process. The spreading of own-farm slurry is not subject to any regulations, but is subject to guidelines under the four point plan[29] (SEPA) to minimise agricultural pollution.

Methodology and Accuracy

Farm waste was reassessed from Sgriob Ruadh farm. As the waste from the farm is already collected and separated into solids and liquid matter, an attempt to back calculate, taking into account the amount of wastewater, whey and rainwater was used. As there was not a clear measurement of the volume of wastewater used on the farm, it was decided to use instead calculation based on projected livestock figures (expected livestock numbers to 2006) and whey production records from the farm. These figures are expected to be accurate in line with industry standards, however the estimation of sheep slurry is not well documented so some estimations were made with regard to the equivalent livestock unit number. Conversion figures used are as in Table 4.4 below.

Table 4.4 Calculations for Slurry production on Sgriob Ruadh farm

Animals	LSU Equivalent	m^3 slurry/day	Winter tonnage	Summer tonnage
140 Dairy cows	140	7.0	1470	271
156 followers	110	5.5	1155	-
75 pigs	4	0.2	42	31
200 milking sheep	20	1.0	210	39
Total			2872	341

Suitability

Animal slurry is a good waste for co-digestion as it has high nitrogen content and can therefore act as a buffer to more volatile waste streams. Whey is a valuable waste source also adding to biogas production.

The farm at Sgriob Ruadh is ideally suited to the AD proposal on Mull as:

- It provides a large proportion of the waste identified for AD on the island;
- It has available land for location of a plant;
- It has a high heat and energy load due to the dairying and cheese making processes so could avail of biogas energy generation;
- It has a large land base available for digestate spreading;
- It already has a piping system to transfer liquid wastes to field network, which could easily be adapted to transfer liquor digestate;
- The farm is already involved in renewable energy schemes, process engineering for the dairy operations and have the engineering capabilities to provide operation and light maintenance at a proposed AD plant if necessary.

4.4.4 Food Waste

Legislation and Regulation

Under the ABP Regulations food waste derived form animal sources cannot be sent to landfill after Dec 2005. On Mull the island derogation from this regulation will continue to allow landfilling of animal derived food waste after this date. However, this derogation may change pending review in the EU commission.

Methodology

As there was indication that the extra cost of source-segregated BMW would not be available under the current waste management budget for the island, it was decided not to collect data of individual business and household food waste. An assessment of the quantities available has been based on the amount of biodegradable material in the MSW reaching landfill on Mull. This was done using the tonnages of MSW waste reaching landfill and standard industry figures of biodegradable content of MSW (minus the paper and card content proportion).

Suitability

Food waste and organic proportions of MSW would fit very well into a community AD plant, but at present the funding that would be required by the extra collection and sorting necessary is under question. Mechanical equipment would be needed for separation of biodegradable material from non-segregated MSW. Source segregated waste would provide a more efficient method of collection but even with source segregation there would be a need for sorting of waste to avoid contamination. The study uses the BMW figures as it will be likely that at some point in the future that the ABP derogation for the island will cease and segregated bio-waste collection will be needed.

4.4.5 Paper and Cardboard

Legislation and Regulation

Paper and cardboard waste fall under the Producer Responsibility Obligations (Packaging Waste) Regulations UK. There is a potential to generate income from packaging recovery notes (PRN) if AD treatment qualifies as recovery or recycling.

Methodology

There is source-segregated collection of paper and card on the island, with records kept at Glengorm Landfill. This was included in this study as it is a biodegradable material and is used in many other biogas installations as a feedstock.

Suitability:

Paper and card are beneficial to co digestion of waste in AD. The carbon content of such material can help in balancing the carbon to nitrogen ratio. As there is already source separation on the island, this would be an ideal addition to the feedstock mix.

As noted above income from PRN qualification may further enhance viability as a feedstock.

4.4.6 Cooking Oils

Legislation and Regulation

Used cooking oils fall under the ABP regulation. This states that such waste such be diverted from landfill, but again on the island this is not required under the current derogation.

Methodology

Used cooking oils from businesses on the island are collected and records kept at Glengorm landfill. Figures are taken as accurate for amounts from collectable sources during 2003-2004.

Suitability

Cooking oils are high calorific biodegradable waste, and could increase biogas production in a mixed feedstock plant. The treatment of such waste in an AD plant would remove costly shipping of such wastes that might in the future affect Mull if the derogation is removed.

4.4.7 Sewage

Legislation and Regulation

Sewage sludge is regulated under the EC Sewage Sludge Directive 86/278/EEC with regard to land appilcation and with regard to waste water treatment is regulated under the EU Urban Waste Water Treatment Directive 91/271/EEC. This latter document has set a deadline of December 2005 for cessation of discharge of sewage to open and fresh waters. This is applicable to Mull as there is currrently no sewage treatment on the island apart form some individual septic tank systems. Scottish Water are now designing a solution for sewage treatment needs on the island.

Methodology and Accuracy

Septic tank sludge on the island has in the past been centrifuged and the dry cake disposed at Glengorm Landfill. Figures for this are kept at the landfill station. For this study a calculation of the possible sludge generation from a primary treatment plant in Tobermory on Mull was made using standard industry calculations on sludge generation per head of population. An attempt has been made to factor in the number of tourists visiting the town. This was calculated using the follow assumptions:

- Population in Tobermory 980 [1]
- Tourist numbers to Mull 320,000[2]. All tourists do not visit Tobermory – approximately 120,000 visit Iona, so it was assumed that these visitors did not travel to the northern end of Mull, and Tobermory. Therefore 200,000 visitors travelled elsewhere on the island. As Tobermory is the main town,

with a large proportion of tourist accommodation and tourist attractions it was assumed that 75% of these visited Tobermory. This gives a visitor number of 150,000.

- If the resident population in Tobermory is calculated as annual visitors i.e. 365 days per year this gives 357700 residents days for Tobermory.
- It was assumed that of the 150,000 visitors to Tobermory a certain proportion of these resided in Tobermory for a certain period. This was set at a figure of 3 days which should allow for variations in time stayed in Mull over the whole tourist population and balance out day visitors that would have used waste water systems relatively little. This gives a total resident day figure of 450,000.
- Converting this back to equivalent population numbers to be able to use industry figures for sludge calculations: 450,000/365 gives an equivalent population number of 1233. Thus the extra loading on a sewage treatment system due to visitor population is equivalent to an extra 1233 people living in Tobermory.
- This gives a total of 66kg/day of sludge using figures from an industry standard of 0.03kg/day per person and is equivalent to 24 tonnes per year.

Given that 135 tonnes of centrifuged waste (typically 20% DS) content from septic tank sludge was deposited to landfill, this would mean that a total of 158 tonnes of sludge was collected from septic tank systems around the island. This was added to the figure calculated for Tobermory to give total of 182 tonnes per year of primary sludge (6% DS). As there is long sea outfall in Tobermory and Salen, which altogether account for 40% of island population this would mean that the other 60% of the island generated the sludge equivalent of a population size of 5300.

Suitability

As Scottish Water are working on a solution at present, this project sought to collaborate with them to assess possible sludge production figures from a primary treatment plant. However the proposed current Scottish Water solution is for a facultative lagoon, which is designed to remove the need for sludge treatment. Facultative lagoons operate on a similar principal to AD in that bacterial decomposition reduces the solids content and pathogen load of organic waste. However, there is no capture of the gases emitted and no further treatment of the waste effluent. The plans for the island are for a facultative lagoon at Tobermory, which will also be able to handle waste sludges from septic tanks around the island. If this solution was developed the sewage sludge availability on the island would be nil. This is of significant importance to the development of an AD plant as the sewage sludges would balance the summer deficit in animal slurry production.

The Scottish Water plans are currently in design stage and therefore there is a possibility that such a solution make not be realised on Mull. The local community is not completely supportive of the lagoon proposal.

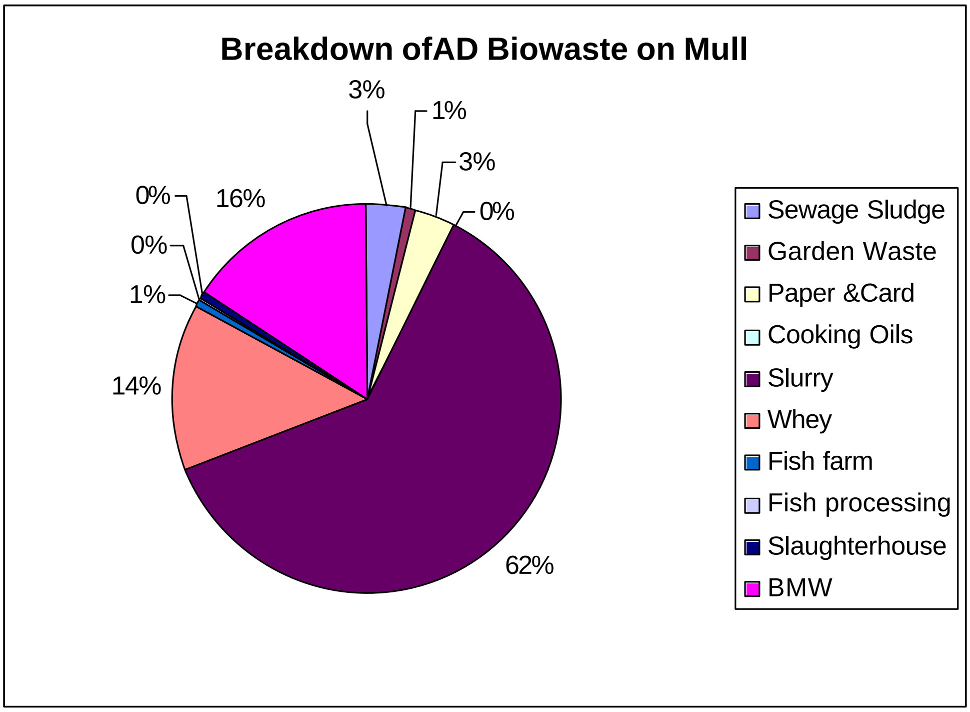
The waste data collected during this report is as detailed in Table 4.5 and Figure 4.5 below.

Table 4.5 Waste Audit Data 2004

Waste Type	**Tonnes/yr**
Dewatered Sewage Sludge[1]	182.0
Garden Waste from commercial	33.0
Paper& Card	175.0
Cooking Oils	10.0
Slurry waste[2]	3 213.0
Whey[3]	735.9
Fish Farm Waste[4]	30.0
Fish Waste – Processing[5]	10.0
Slaughterhouse – Cattle[6]	16.1
Slaughterhouse - Lamb/Sheep[6]	10.5
Slaughterhouse – Pig[6]	4.0
Biodegradable Municipal Waste[7]	837.0
Total	**5 256.6**
Total with estimate of Category 2/3 slaughterhouse waste	**5 231.3**

[1] As per calculations in Section 4.5.7 above
[2] As per calculations in Table 4.5.1 above
[3] Calculated with milk production of 800,000 l per annum. Whey proportion 90% of milk. Density of 1.0221kg/m3
[4] Fish farm wastes from Scottish Sea Farm, Marine Lighthouse and Marine Harvest fish farms Category 2 wastes
[5] Fish processing figures from Tobermory Fish Farm Category 1 waste
[6] 701 sheep @ 15kg waste per animal, 79 cattle beasts @204kg per beast, 80 pigs at 25kg per pig
[7] Calculated from 45% average of MSW and Commercial Waste at Mull Landfill site. Paper collection of 175 tonnes not included in biodegradable estimation

Figure 4.5 AD Waste Breakdown on Mull



5 Energy Calculations

This chapter details biogas yield predictions for the waste streams identified in Chapter 4, and discusses the potential energy yield from this feedstock. An assessment of the energy needs at the farms and how this could be met with biogas energy is included.

5.1 Biogas Yield

Using figures from four different sources: Greenfinch report form 2003[22]; an Agricultural Waste characteristics handbook[30]; a study of AD potential in Ireland[31] and Anaerobic Digestion report from Waste Management Institute the following biogas calculations were conducted as shown in Table 5.1 below. These calculations took into account the Dry Solids (DS) content, Volatile Solids (VS) content.

Table 5.1 Waste Data 2004

Source	Tonnes per year	% DS content	Tonnes DS per year	% VS	Tonnes VS
Paper and card	175.0	95 %	166.3	80.0%	133.0
Slaughterhouse	25.3	15 %	3.8	90.0%	3.4
Aquaculture	40.0	10 %	4.0	90.0%	3.6
Agriculture	3,213.0	8 %	257.0	77.0%	197.9
BMW	837.0	23 %	188.3	92.5%	174.2
Sewage Sludge	182.0	6 %	10.9	80.0%	8.7
oils	10.0	99 %	9.9	89.0%	8.8
whey	735.9	7 %	48.6	85.0%	41.3
Annual Total	**5218.9**	**13 %**	**688.8**	**82.9%**	**571.0**
Average Daily	**14.3**		**1.9**		**1.6**

5.2 Buffer and Digester Tank Storage.

Using figures from the Greenfinch report, with the calculated daily feedstock weight of 14.3 tonnes and a feedstock specific gravity of 1.04, this gives a value of 13.75 per day. This is very similar to the value calculated last year in the Greenfinch report, despite the differing waste volumes. For a daily volume of 13.75 m^3, and allowing for a 3 day input buffer storage this would require an input buffer tank of 45 m^3 capacity. For a process retention time of approximately 21 days, this would then require a digestate tank of 300 m^3.

5.3 Energy Yield

Using the calculation formulas from the Greenfinch report, the following energy yields were calculated using the figures of 1890 kg/day DS and 1560 kg/day VS. A value of 11.04 kWhr/m3 methane was used from energy value of 890.3 kJ per mole of methane. The calculations are attached in Appendix A.

Biogas Production	717.6 m3 per day
Methane content @60%	430.56
Energy yield @ 11.04 kWhr per m3 methane	4753.3kWhrs per day
Electricity CHP production at 35%	1663.65kWhrs per day
Heat generation @ 50%	8555.4 kWhrs per day
Process Heat requirements	3788.82 MJ/day
Heat surplus available	4766.582 MJ/day or 483MWhrs per year
Electricity production -yearly (With downtime and availability factored)	545.2 MWhrs per year

The process heat requirements have been factored into these calculations also. Although a technology type has not been specific to manufacturer type, the Greenfinch process calculations were the most accurate found to date, and so have been used for this report with the smaller feedstock from the 2004 waste audit. The report does mention that there is no heat recovery in the system calculations, so with efficient use of heat exchangers the amount of surplus heat could increase. Although the process technology as identified in the Greenfinch report may be over specified for the requirements of an AD potential plant on Mull, the total electrical process load is the most accurate information available. This has therefore been used to estimate the amo unt of electricity available for use or sale to the grid.

Process electricity requirement	181kWhr per day
	66MWhr /year
Total surplus electricity	545.2 MWhr/year
Total yearly electricity	479.2 MWhr
Latest ROC Price per MWhr[33]	£52
Potential income if excess sold to grid	£24918 per year

5.4 Energy Usage on Sgriob Ruadh Farm

The farm at Sgriob Ruadh was identified as the most suitable location for the AD plant, given the heat and electricity loads present, the availability of land and a willingness of the owners to become involved in the project. There was an assessment made of the energy demand on the farm to ascertain if the energy generated by the plant could be meet the needs of the farm.

5.4.1 Heat Energy

Energy demand from the cheese making processes and the milk cooling are ongoing at the farm. To help recycle some of the heat energy used in these processes, the family have built a swimming pool, which acts as a very efficient (and popular) heat sink.

The energy demands at the farm are as follows:

- 14 milkings per week;
- 10 milkings require cooling from 32°C to 4°C (4 go straight cheese making process); and
- during cheese making the milk is heated to 32°C again, and then to 40°C.

At the moment all the heat requirements are met by steam generated by a diesel boiler and recircling through heat exchangers. The diesel used last year was approximately 32,000 l (which included heating the pool during installation of equipment). Diesel has an energy value of 36.4MJ/l. Therefore the volume used had an equivalent value of 323MWhrs. Assuming this runs at an efficiency of 60% this is equal to 193MW hrs actually used on the farm for heating requirements.

Thus the available heat from an AD system as detailed above would supply more than enough heat for the farm processes at 483MWhrs surplus heat available.

5.4.2 Electricity Requirements

The farm has many different processes running that demand energy. In addition to the cheese making and normal farm and dairying requirements there are 5 households within the family grounds and a bakery. Therefore there is a high-energy demand at the farm and surrounding buildings. Figures for yearly electricity demand have been given as 252,000kWhrs for all requirements.

Therefore it can be seen that an AD plant with an annual generation of 479 MWhr/yr will more than meet the demands of the farm and surrounding businesses. The excess energy can be sold to the grid under the ROC scheme to generate additional income for the farm.

6 Financial Issues

This chapter will detail possible costs for the AD project, possible income and funding sources that may help the island community to realise the project.

6.1 Project Costs

The report[22] issued last year detailed plant costs of almost £1million. This was seen to be prohibitive for the island community, and so it was attempted to investigate the cost scenario and funding possibilities for an AD project.

Following consultation with another industry company, Methanogen, indicative costs of £200,000 were given. More detailed costing was unable to be obtained given the uncertainty of some of the waste streams, especially sewage on the island. This has meant that a full cost analysis has not been possible.

With relation to operational costs it is estimated that this could be up to 5% of capital cost, so for a plant of £200,000 this could be up to £10,000. This would account for maintenance and replacement of spare parts, staff costs if necessary, insurance, transport costs, and license fees. If the plant were to accept waste other than just farm waste, especially with regard to animal derived wastes, there would be a need for waste licence for the plant. The costs of this would depend on the exact make up of the feedstock.

Other costs that need to be considered include project development costs:

- Technical, legal and planning consultants' fees, if necessary during project development and submission, plus the farmer or community representative's own time
- Negotiations with legal and statutory bodies (for example in obtaining planning permission and consulting SEPA)
- Financing and legal costs, including the costs of arranging finance
- Electrical connection costs if export to the grid is achieved

6.2 **Project Income**

The project has concentrated on Sgriob Ruadh farm. As there is a suitable land base (see Fig 6.2 below) for application of digestate liquor and fibre on the land surrounding the farm, there should be a noted decrease in artificial fertiliser use.

This obviously will have associated cost savings, and in some cases can be quite high. The Holsworthy plant in Devon, a large-scale centralised AD plant which processes waste from 25 farms and several food processing facilities has indicated that the digestate has a nitrogen level of 8kg/tonne with a 75% plant availability rate. This is estimated to save in the region of £15000 with regard to avoided application and purchase of artificial fertilisers in the area[34].

Figure 6.2 Possible AD Plant location (courtesy of Sgriob Ruadh Farm)

The key income in an AD plant will be from the generation of heat and electrical energy both in terms of avoided costs and revenue generating sales. The current cost for network-connected generation selling under the ROC system is roughly £52 per MWhr. If a plant were to sell electricity to supply companies a Power Purchase Agreement contract would be enacted. Normally this guarantees the purchase of electricity at a set price for a fixed period of time, and locks both the buyer and generator into a contract with some security.

Income may also be generated from the generation of gate fees from the waste streams imported to the plant. Landfill tax and additional costs are now major cost component for many businesses, and if AD were to offer an alternative to landfill at a similar or slightly lower cost then this can greatly increase the financial viability of a plant. Following consultation with Argyll and Bute council it was established that the landfill costs on Mull at present are £52 per tonne at present for most wastes. If the AD plant were able to offer treatment of organic wastes at for example £45 per tonne, this would be able to create significant income for the plant. Using the figures from the 2004 waste audit, and applying the landfill costs of £52/tonne to all but the paper, farm and green waste (paper and green waste only attribute costs of £17/tonne) a total of £51252.24is spent on Mull on organic landfilling. If the reduced fee of £45 a tonne were applied to disposal in an AD plant this cost would reduce to £44828. Thus AD can offer both a cheaper waste management solution for Mull's businesses and a significant income for the AD plant.

6.3 Project Funding

As there is a high capital cost involved in AD plant installation, this could prove a barrier to the project on Mull. To alleviate some of the costs involved in Renewable energy and sustainable waste management projects several schemes exist that offer grant and funding assistance. Some of the possible sources of finding for the Mull project are below.

6.3.1 Carbon Trust

The Carbon Trust provides funding for genuine innovation in Renewable and carbon reducing technologies through an Open Call process. The program is geared to target and supporting groundbreaking projects that demonstrate a potential to reduce greenhouse gas emissions. Grants of up to £250K towards the cost of the project are available providing the project demonstrates:

- Genuine innovation
- Clear need or demand for the outputs of the project
- Benefits the UK:

The next call for proposals opens on the 4th of October 2004.

6.3.2 Energy Savings Trust

The Community Energy Programme, which is jointly run by the EST and Carbon Trust, has over £50 million of funding to allocate to public sector heating projects by the end of January 2005. Applications can be submitted up to that date. Any public-serving organisations, including local authorities, social housing providers, town halls, leisure centres, universities, colleges and hospitals, are eligible for a grant. This would apply to an AD plant on Mull if it were to supply heat to a community-heating scheme.

6.3.3 Highlands and Island Enterprise

SCHRI-Scottish Community and Household Renewables Initiatives

This is a programme designed to fund small-scale renewables in the Highlands and

Island of Scotland. Communities may apply for funding for technical assistance and capital grants for renewable energy equipment installation and associated costs. The applicant must come under one of the following criteria to qualify:

- ? Applicants must be Scotland based, legally constituted, non-profit distributing community groups.
- ? Consortia of non-profit distributing organisations are acceptable.
- ? Private industrial or commercial organisations collaborating as part of consortium bids with non-profit distributing bodies will also be accepted, provided that the private organisation is not the lead applicant / beneficiary and the project itself is non-profit distributing.

Technical grants

Technical assistance funding of up to 100% is available to support non-capital projects, such as feasibility or scoping studies. The maximum grant is £10,000 and applicants are required to outline contributions from other sources (public or private).

Capital grants

Capital grants pay for a contribution to the capital costs of projects, with funding of up to 100% of project costs. The maximum grant is £100,000.

Funding is available for:

- ? Capital costs of installing renewable energy generation plant
- ? Capital costs for supporting infrastructure, such as roads

- ? Project management costs associated with the development and installation of generating equipment
- ? The costs of the community establishing a partnership with a third party such as a developer, or setting up a new company or purchasing an equity share in an existing company
- ? The costs of implementing regulatory or fiscal regulations designed to encourage renewable energy generation or use. These may include metering equipment, licences or costs of accessing Renewable Obligation Certificates

6.3.4 EU/International Funding

There may be an opportunity to source funding from EU renewable support schemes. The 6th Framework Programme, which has several programmes, aimed to support renewable technologies at different stages of development. There is a current call for proposals for projects aiming to demonstrate “innovative approaches to improving the yield of medium to large scale biogas plants”. This programme requires participation with 2 other member or linked EU states to acquire funding, and submissions are due in by Dec 8th 2004.

Through this project a link has been established with a project in New Zealand, which is looking at various ways to improve the efficiency of farm based biogas systems. The New Zealand project Developer is keen to link with a UK based project and has shown an interest in the project on Mull. The funding from the 6th framework programme would suit such collaboration well, but would also require collaboration with two other EU or European states. At present there are no collaborations with EU projects of this type and the project on Mull. The deadline of December 8^{th} may be a little close to try to establish such a link. However, in the absence of EU funding from other international sources should be looked into, as there could be benefits to working with the New Zealand project in terms of technology transfer, community interest and publicity.

7 Conclusion and Recommendations

This chapter will conclude this study, detail the status of the project at present, and make recommendations for future work that would benefit the project.

7.1 Conclusion

This project has attempted to investigate the feasibility of a community driven Energy from Waste project on the Isle of Mull. The desire to install a facility that would help deal with organic waste on the island in a sustainable manner has been a key factor in this assignment. In line with community interests in Renewable Energy it has created much discussion on the island, and has drawn spotlight on the sewage sludge issue.

The data that was collected during this report preparation has shown that there is a significant quantity of organic waste on the island that could be used as feedstock for an AD plant. The derogation that applies to the island in respect of treatment of animal by-product waste is an issue that will undoubtedly face greater scrutiny over the coming years, as more stringent waste management directives are forecast from the EU. It is clear from the work done for this report that if there were no derogation for the island, there would be a much greater need for treatment of animal derived waste. The extra costs involved in the pressure treatment equipment that would be needed for treating Category 2 type wastes may be prohibitive to an island AD plant at present. As discussed previously there is a question over the availability of extra funding that would be required to establish source segregation or on site sorting of the biowaste content of MSW collections. In the short term it may not be feasible to include biowaste and Category 2 animal derived wastes in the proposals for an AD plant.

There is still however a very strong case for AD on Mull, waste management on the island is a financial issue as well as an environmental one. The existence of a plant that could offer an alternative to landfill disposal at a slightly cheaper cost if possible would be welcomed by many of the industries on the island. The potential for a farm based AD plant is also very strong. The calculations detailed earlier have shown the energy resource available from the farm wastes. If this energy were captured by an AD process, diesel and conventional energy use at the farm would decrease, a nutrient rich natural fertiliser resource would become available, offensive odour problems would be reduced, the farms methane emissions would decrease and the farm's economics improve considerably.

Through the investigations for the potential of sewage sludge integration in AD, the area of future sewage treatment plans for the island became a key focus of this project. Over the last few months the proposals suggested by Scottish Water have been investigated and questioned. It became clear that the proposals they had did not take account of tourist figures and, in an attempt to make the case for AD treatment of sewage sludge even stronger, the urgent need to account for large visitor numbers was highlighted to Scottish Water. Although they have only very recently given firm commitment to their plans for facultative lagoons, they were appreciative of the relevant information and have spent some time reassessing their calculations and proposals accordingly. Therefore it is hoped that although the possibility of using sewage treatment sludge in an AD plant is now low, the sewage treatment system designed for the island is a more robust one than originally proposed

The project is now at a stage where dissemination of these results will be used to move the case for AD on Mull even further. Through the contacts made as result of this project, links have been forged with many of the key players in AD in Scotland in present. It is hoped to hold dissemination events with key stakeholders that would be involved in the development of an AD plant on Mull. It was also identified that there is a growing interest in AD technology in remote and island locations across Scotland. Already there are projects under investigation on Westray, Bute and the Western Isles. An inter-island information and collaboration event is to be organised in the next few weeks. This will enable communities to share information and resources to help integrate AD into the waste management of remote communities across Scotland.

7.2 Recommendations

The proposals for an AD project on Mull are ongoing and the following recommendations are made with this in mind.

- Further information on all the heat loads and energy demands at the farm is needed to properly assess the potential for AD integration.

- An assessment of the capacity to integrate heat exchangers in the existing network on farm would prove beneficial as there is already significant engineering work in use-much of it new or recently installed.
- An investigation into the possible collaboration with the New Zealand project may prove beneficial in terms of funding potential.
- There is a need for more accurate costing of AD plant and installation costs to truly assess the viability of such a plant.

Appendix A
Energy calculations

2 pages

Anaerobic Digestion	
Digester Feedstock Volume	13.75 m3 per day
Digester Hydraulic Retention Time	21 days
Digester Volume	300 m3
Digester Specific Loading Rate	4.0 kg VS per m3 per day
Volatile Solids Reduction	59.8 %
Volatile Solids Destroyed	717.6 kg VS per day
Specific Biogas Production	1.0 m3 per kg VS Destroyed
Biogas Production	717.6 m3 per day Biogas Production
Biogas Production: Digester Capacity	2.3 m3 per day per m3
Digester Heat Requirement	
Digester Feedstock Volume	13.75 m3 per day
Digester Feedstock	Temperature 10 oC
Digester Temperature	38 oC
Ambient Temperature	5 oC
Heat to Digester Feedstock	1608 MJ per day
Diameter of Digester Tank	6 m
Height of Digester Tank	8 m
Thickness of Insulation	50 mm
Average Thermal Conductivity of Insulation	0.030 W/m°C
Digester Heat Loss	304.3 MJ per day
Total Digester Heat Requirement	1912.68MJ per day
Pasteurisation Heat Requirement	
Pasteurisation Feedstock Volume	13.75 m3 per day
Pasteurisation Feedstock Temperature	38 oC
Pasteurisation Temperature	71 oC
Ambient Temperature	20 oC
Heat to Pasteurisation Feedstock	1835.82 MJ per day
Diameter of Pasteurisation Tank	2m
Height of Pasteurisation Tank	1.4m
Thickness of Insulation	50 mm
Average Thermal Conductivity of Insulation	0.030 W/m.^{o}C
Pasteurisation Heat Loss	40 MJ per day
Total Pasteurisation Heat Requirement	1876.14 MJ per d
Total Process Heat Requirements	3788.82
Energy Production	
Biogas Production	717.6 m3 per day
	29.9 m3 per hour

Biogas % Methane	60.0 %
Energy @ 11.04kwhr per m3 methane	4753.3kWhrs/day
Combined Heat & Power	
Biogas Fuel Value	4753.3 kWhrs/day
Efficiency of Electricity Generation	35 %
Electricity Production	1663.65kW hours per day
Efficiency of Heat Generation	50 %
Heat Production	2376.5 kW hours per day 8555.4 MJ
Number of Days Maintenance/Downtime	20 days per year
CHP Availability	95 %
Annual Electricity Production	545.2 MW hours per year
Surplus Heat	
Heat from CHP Unit	8555.4 MJ per day
Total Process Heat Requirement	3788.82 MJ per day
Surplus Heat (without heat recovery)	4766.58 MJ per day
Process Electricity Requirement	
Average Process Electricity Requirement	181 kW hours per day
Total Electricity Output from CHP Unit	1663.65 kW hours per day
Value of Energy	
Gross Electricity Output	545.2 MWhrs/yr
Process Electricity Consumption	66 MWhrs/yr
Surplus Electricity Production	479.2 MWhrs/yr
Unit Value of Renewable Electricity	52 £ per MWhr
Value of Electricity	£24918 per year
Surplus Heat Production	4766 MJ day 1324 kW day 483MWhr/year

Appendix B - Abbreviations

1 page

MW – Mega Watt

kW – Kilowatt

kWhr – Kilowatt hour

MWhr – Megawatt hour

J – Joule

MJ- Mega Joule

ABP- Animal By Product

SRO –Scottish Renewable Obligation

BMW- biodegradable source segregated fraction of municipal waste

MSW- municipal solid waste

Mtpa Megatonne per annum

BPEO- best practicable environmental option

TSE- transmissible spongiform encephalopathy

ppm – parts per million

RPM- revolutions per minute

SEPA –Scottish Environment Protection Agency

SEERAD- Scottish Executive Environment and Rural Affairs Dept.

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4 pages

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