Isle of Wight Council

Renewable Energy on the Isle of Wight

Anaerobic Digestion Review

6th August 2010

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GLOSSARY

Term / Acronym	Definition
Anaerobic Digestion (AD)	A series of processes in which microorganisms breakdown biodegradable material in the absence of oxygen to produce biogas and digestate.
Animal By-product Regulations (ABPR) 2005	The Animal By-products Regulation 1774/2002/EC lays down rules for the use and disposal of animal by-products not intended for human consumption.
Biogas	Can be produced by a number of processes including anaerobic digestion and is primarily composed of methane and carbon dioxide with small amounts of trace elements. Its energy content is dependent on its composition but is typically between 50% and 70% of that of natural gas.
Biodegradable Municipal Waste (BMW)	The fraction of municipal waste that will degrade anaerobically giving rise to biogas. It includes, amongst other materials, food waste, green waste, paper and cardboard
Climate Change Levy (CCL)	A tax on energy delivered to non-domestic users in the United Kingdom aimed at providing an incentive to increase energy efficiency and to reduce carbon emissions.
Combined Heat &Power (CHP)	The simultaneous production of electricity and useful heat.
Commercial & Industrial (C&I) Waste	Commercial and industrial waste is a broad category that includes business waste, construction and demolition waste, and waste from agriculture, fishing and forestry.
Composting	The breakdown of biodegradable material, such as food and garden waste aerobically (in the presence of oxygen) to produce compost.
Construction & Demolition (C&D) Waste	Construction and demolition waste consists of all waste originating from construction, renovation and demolition activities, such as rubble, bricks and tiles.
Digestate	The solid material remaining after anaerobic digestion of biodegradable material and is similar in nature to compost.
Environment Agency (EA)	UK government agency concerned mainly with rivers, flooding, and pollution.
Feedstock	Raw material supplied to a machine or processing plant.
Feed in Tariffs (FITs)	Payments to ordinary energy users for the renewable electricity they generate to give three financial benefits. These are a payment for the electricity produced even if used on site, additional bonus payments for electricity exported into the grid and a reduction on standard electricity bills for the generator.
Gasification	A process that converts carbonaceous materials, such as coal, petroleum, biofuel, or biomass, into carbon monoxide and hydrogen by reacting the feedstock at high temperatures with a controlled amount of oxygen and/or steam. The resulting gas mixture is called synthesis gas or syngas - itself a fuel. Gasification can be used as a method of extracting energy from many different types of organic materials.

Term / Acronym	Definition
Household, Industrial & Commercial Waste (HIC)	Household**,** industrial**,** commercial and clinical waste that requires a waste management permit for treatment, transfer and disposal.
Inert Waste	Waste which is neither chemically or biologically reactive and will not decompose.
Levy Exemption Certificates (LEC)	Electronic certificates issued monthly to accredited generating stations, for each Megawatt/hour (MWh) of CHP or renewable source electricity generated. These can then be sold to electricity suppliers so that they can claim CCL exemption on non-domestic supply.
Mesophilic	Temperature range typically between 15 and 40°C.
Ofgem	The Office of Gas and Electricity Markets (Ofgem), Regulates the electricity and gas markets in Great Britain
Recyclables	Products or materials that can be collected, separated and processed to be used as raw materials in the manufacture of new products.
Renewable Heat Incentive (RHI)	Tariffs payable to energy users generating their own heat from renewable sources.
Renewables Obligation (RO)	The RO is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK suppliers of electricity to source an increasing proportion of their electricity from renewable sources
Renewables Obligation Certificates (ROCs)	A electronic certificate issued to an accredited generator for eligible renewable electricity generated within the United Kingdom and supplied to customers within the United Kingdom by a licensed electricity supplier. One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated. ROCs can then be sold to suppliers, in order to fulfil their obligation
Residual Waste	Waste that is left over after recycling, composting and refuse activities have taken place.
Thermophilic	Temperature range between 45 and 80 °C.
Waste Incineration Directive (WID) 2000	The aim of the WID is to prevent or limit, as far as practicable, negative effects on the environment, in particular pollution by emissions into air, soil, surface and groundwater, and the resulting risks to human health, from the incineration and co-incineration of waste. The WID seeks to achieve this high level of environmental and human health protection by requiring the setting and maintaining of stringent operational conditions, technical requirements and emission limit values for plants incinerating and co-incinerating waste throughout the European Community
Windrow composting	The production of compost by piling organic matter or biodegradable waste, such as animal manure and crop residues, in long rows (*windrows*). The rows are generally turned to improve porosity and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile. This method is suited to producing large volumes of compost.

CONTENTS

1. EXECUTIVE SUMMARY

Grontmij are the 5th largest multi discipline engineering consultancy in Europe employing over 8,000 staff with an annual turnover of €846 million per year. Renewable energy is a major part of our business and expertise having been involved in numerous projects in Europe and Worldwide.

Through the Eco Island initiative, the Isle of Wight aspires to have the smallest carbon footprint in England by 2020. Anaerobic digestion of various waste streams to produce electricity and heat can contribute to this ambitious target. Grontmij have been commissioned to carry out a review of available waste, establish indicative system sizing, outputs and capital costs and determine relevant local, national and European regulations.

The review of waste arisings on the Island has estimated that the amount of biodegradable Household, Industrial & Commercial waste (HIC) suitable for processing by AD is currently 14,227 tonnes per annum. With optimised collection, separation and pre treatment this could rise to 81,878 tonnes per annum. In addition there is 20,803 tonnes of agricultural waste potentially available as feedstock for anaerobic digestion on an annual basis.

The combined biodegradable feedstock availability is therefore between 35,030 and 102,681 tonnes of waste per year.

The digester volumes required to treat the currently available biodegradable waste streams are 2,072 m^3 and 4,954 m^3 for the HIC and agricultural components respectively giving a total volume requirement of 7,026m^3. If all of the potentially available HIC becomes available the volume required for the biodegradable HIC component increases to 10,414m^3 and the total digester volume required for treatment of both the HIC and agricultural waste is 15,368m^3.

Biogas production is highly variable due to the heterogeneous nature of the feedstock. Total gas production is estimated between 4,025,450 m^3 at the lower end of the currently available waste quantity, and 18,999,243 m^3 per year if all potentially suitable waste is used in thermally efficient digesters. This gas could be used to provide heat only or in a CHP scheme where it would produce between 0.46 MW_e to 3.6 MW_e of renewable electricity and 0.52 MW_{th} to 4.1 MW_{th} of recoverable waste heat. Electricity produced from Anaerobic Digestion qualifies for incentive payments under the Renewables Obligation. Incentive payments for installations having an electrical output up to 5 MW_e are made either through Renewable Obligation Certificates or Feed In Tariffs at the option of the system operator. The selection of the incentive mechanism will depend on the balance between power exported and used on site. Any useful heat produced that is not used on site in the process may also be eligible for payments under the proposed Renewable Heat Incentive (RHI) currently under consideration. The structure of these incentives strongly favours installation of CHP over heat only schemes.

A single plant treating the combined available feedstock is estimated to cost in the region of £13 million for the total current available feedstock and £20 million for the total potential available feedstock. This gives an approximate specific capital cost of 200 - 450 $£.tonne^{-1}$ of annual treatment capacity depending on the system capacity.

Any AD plant built on the Island should ideally be located on a site which will facilitate the use of excess heat generated by the biogas utilisation plant. Strong candidate locations are those near new developments which would allow the heat to be distributed via a district heating scheme. Alternatively the AD plant could be located nearby an existing heat user such as the prisons or the Wight Salads operation at Arreton.

The digestion plant will be required to comply with applicable Local, National and European regulations depending on the technology and the feedstock being used. Applicable legislation includes the Animal By-product Regulations (ABPR) and Waste Incineration Directive (WID). A protocol defining the quality of digestate from AD plants is currently being developed. Digestate complying with this protocol will not be treated as waste and can be sold into other markets.

2. INTRODUCTION

Under Central Government policy[1,2] the Isle of Wight Council has a responsibility to ensure that any development on the Island is carried out in ways that protect and enhance the physical environment and optimise resource and energy use.

Central Government has declared targets of reducing the UK's carbon emission to 80% of the year 1990 levels by 2050 and for 20% of the UK's energy to be supplied from renewable sources by 2020.

The Council is actively committed to a sustainable energy policy under which measures are being taken to reduce the Island's carbon footprint in line with Government targets, including promotion of energy efficiency and the substitution of fossil fuels by low carbon alternatives.

Through the Eco Island initiative the Island Strategic Partnership (ISP) is promoting measures to sustainably reduce emissions of carbon dioxide while improving the quality of life on the Island. As part of this initiative the ISP has declared an ambition for the Island to have the smallest carbon footprint in England by 2020.

This plan should include a positive approach to harnessing the generating potential from renewable energy sources in an environmentally acceptable way. This report focuses on a review of the potential for anaerobic digestion (AD) on the Island.

AD is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen to produce a gaseous mixture of Methane and CO_2, known as biogas, and a digestate. Digestate is the solid material remaining after anaerobic digestion of biodegradable material and is similar in nature to compost. AD is commonly used to treat waste water, industrial effluent, agricultural waste and the biodegradable fraction of Household, Industrial & Commercial Waste (HIC). The biogas produced has an energy content between 50% and 70% of that of natural gas and can be utilised in much the same way.

Biogas produced by AD is currently commonly used for heating, power and combined heat and power (CHP) applications. The biogas can also be upgraded to natural gas quality and injected into the gas network or compressed for use as a transport fuel. These applications are not yet fully developed in the UK although within Europe, particularly Sweden, these are proven technologies with numerous plants in operation.

The stabilised digestate produced by the AD process can be used as a soil improver, subject to feedstock and regulations, or disposed of to landfill. Having been through the digestion process the biological content of the residual digestate is significantly reduced, therefore lowering the proportion of Biodegradable Municipal Waste (BMW) going to landfill.

This report will cover the following:

1. A review the volumes of waste available based on information provided by the Isle of Wight Council
2. Indicative system sizing exercise including gas, heat and electrical outputs
3. Indicative capital costing
4. Comment on appropriate locations based on information sent from the Isle of Wight Council
5. Determination of relevant local, national and European regulations

[1] Planning Policy Statement 1: Delivering Sustainable Development - Department for Communities and Local Government
[2] PPS: planning for a low carbon future in a changing climate: consultation - Department for Communities and Local Government

3. WASTE REVIEW

For the purpose of this report, the waste suitable for treatment by anaerobic digestion (AD) will be categorised into two main types:

- Household, Industrial & Commercial Waste (HIC)
- Agricultural Waste

Municipal sewage sludge has been omitted from this analysis as it is treated at existing Southern Water waste water treatment facilities.

Supermarket wastes are currently taken off the Island, as a result they do not appear in the published data. Generally supermarket wastes are returned to central depots operated by individual supermarkets. From these depots the waste is consolidated and sent to licensed disposal companies who will commercially tender a gate fee to take the material. Typically a medium sized UK supermarket will generate between 1-3 tonnes of waste per week per store.. However store operators are actively trying to reduce wastage, consequently the figure is likely to decrease in the future.

Security of this waste is a significant concern for the supermarkets given the potential damage to their reputation should, for example, out dated products find their way back onto the market. While diversion of the waste to local AD is attractive from the sustainability viewpoint there may be practical problems in achieving this.

3.1. HIC

HIC data has been obtained from the Environment Agencies Waste Data Interrogator 2008. More recent data is currently not available.

HIC suitable for treatment by AD can be broken down into the three subcategories as shown in table 3.1 below. Textile and wood waste does offer limited potential for treatment by anaerobic digestion but has been omitted from this analysis due to the significant digestion periods required and the technical difficulties associated with use of this type of feedstock.

Waste Category	Form	Basic Waste Category	SOC 3 Category	Tonnes Arising	Tonnes Currently Available for AD	Tonnes Potentially Available for AD
					Lower Bound	Upper Bound
Animal and vegetal wastes	Liquid	Hazardous	Mixed waste of food preparation and products	78	78	78
	Solid	Hhold/Ind/Com	Slurry and manure	371	0	194
	Solid	Hhold/Ind/Com	Animal waste of food preparation and products	799	641	641
	Solid	Hhold/Ind/Com	Mixed waste of food preparation and products	1,766	1,766	1,766
	Solid	Hhold/Ind/Com	Vegetal waste of food preparation and products	3,388	0	1,920
	Solid	Hhold/Ind/Com	Green wastes	25,710	43	10,703
			Category Total	**32,112**	**2,528**	**15,302**
Non-metallic wastes	Solid	Hhold/Ind/Com	Other paper and cardboard wastes	13,792	2,732	2,732
	Solid	Hhold/Ind/Com	Waste paper and cardboard packaging	221	215	215
			Category Total	**14,013**	**2,947**	**2,947**
Mixed ordinary wastes	Solid	Hhold/Ind/Com	Household wastes[3]	119,028	12,109	101,389
	Solid	Hhold/Ind/Com	Street cleaning wastes	5,065	1	281
	Solid	Hhold/Ind/Com	Other mixed and undifferentiated materials	690	286	690
	Solid	Hhold/Ind/Com	Other sorting residues	13,387	1,951	1,951
			Category Total	**138,170**	**14,347**	**104,310**
			Total Input	***184,295***	***19,822***	***122,560***

Table 3.1: Total HIC quantities on the Isle of Wight

The first, “Tonnes Arising” column lists the amount of waste generated on the Island in the individual categories detailed in the Waste Data Interrogator. Currently, not all of the waste arisings identified in this column would be available for use in an AD process. For example, approximately 2,299 tonnes per annum of animal & vegetal waste is treated by composting at the site where it is generated. In addition the windrow composting facility at Lynbottom Landfill treats approximately 14,043 tonnes per annum of garden waste. The Forest Road gasification plant owned and operated by Energos, uses approximately 30,000 tonnes per annum of residual HIC waste from the 60,000 tonnes per annum Island Waste Services resource recovery facility located on the same site. The remaining fraction of waste from the resource recovery facility is assumed to be recycled. Rejects from the gasification plant amount to approximately 9,000 tonnes per annum of fines.

[3] Includes mixed business waste

The 'Tonnes Currently Available for AD' column shows the volume of waste the IOW Council considers is currently available for AD given the existing collection and separation regimes. This is considered to be a conservative estimate consisting of household wastes, sorting residues and the rejects from the gasification plant. This is effect the lower bound of waste availability.

The 'Tonnes Potentially Available for AD' column shows the maximum volume of waste that could potentially be available for AD processing. This does assume that suitable collection facilities are in place and that separation and pre-treatment of the wastes is practical and economic. As such it represents the upper limit of waste availability on the Island.

For the purpose of this analysis, all of the wastes in the animal & vegetal and non metallic waste categories are considered to be biodegradable. The fraction of mixed ordinary wastes[4] assumed to biodegradable is 61%. This is a reasonable assumption based on current waste compositions in the UK given current recycling rates. Improvement in recycling, particularly of paper and card in the commercial waste sector, would reduce both the total waste quantity and biodegradable fraction.

On this basis the volume of biodegradable HIC currently available for AD is **14,227** tonnes per annum. Similarly the volume potentially available is **81,878** tonnes per annum.

Liquid animal and vegetal wastes arising from food preparation and products is classed as hazardous under the Animal By-product Regulations (ABPR). Food waste and animal wastes classified as ABPR Category 3 can be used as feedstock for AD plants following pasteurisation at 70°C for one hour. Fallen stock and Category 2 wastes must be rendered at high temperatures, the products of the rendering process can be then used as AD feedstock. Category 1 waste, generally high risk material or arising from diseased animals, cannot be used for AD even after rendering and must be incinerated.

3.2. Agricultural waste

Agricultural waste data for 2008 has been supplied by Natural Enterprise (formerly Isle of Wight Economic Partnership) for use in this analysis. More recent data is currently unavailable.

Waste Type	Total Quantity tonnes.yr^{-1}	Quantity Available for AD tonnes.yr^{-1}
Cattle manure	26,197	13,662
Wheaten straw	15,342	4,603
Barley straw	1,949	585
Oat Straw	941	282
Field bean straw	349	331
Oil seed rape straw	1,135	1,078
Linseed straw	154	146
Other cereal crop straw	388	116
Total	**46,455**	**20,803**

Table 3.2: Agricultural waste on the Isle of Wight

[4] Including mixed business waste

Table 3.2 shows different types and quantities of agricultural waste suitable for AD on the Isle of Wight. There is competition from alternative uses for some of these waste types such as use for animal bedding, fertiliser or fuel. The actual quantity of agricultural waste available for AD is therefore approximately 45% of the total.
Future competition from biomass fuel manufacturers on the Island may further reduce the availability as demand for biomass fuel increases.

As stated above direct disposal of fallen stock by means of anaerobic digestion is not permitted under the EU Animal By-products Regulation 1774/2002. This is because of the animal and public health risk associated with such means of disposal[5].

For the purpose of this analysis, the total agricultural waste available for AD is taken as **20,803** tonnes per annum.

3.3. Combined waste streams

Combining the figures for HIC and agricultural wastes the lower and upper bounds for the waste available for AD on the Island, based on the 2008 data, become **40,625** and **122,560** tonnes per annum respectively.

The associated quantities of biodegradable wastes are **35,030** and **102,681** tonnes per annum respectively.

4. INDICATIVE SYSTEM SIZING

For the purpose of this analysis the currently available – lower bound - and potentially available – upper bound - volumes will be modelled for the following configurations:

1. A single plant treating the available HIC stream only
2. A single plant treating the available agricultural waste stream only
3. A single plant treating the combined HIC and agricultural waste streams

4.1. Indicative AD plant size

Tables 4.1 and 4.2 show the digester volume requirement by waste type and total waste quantity. The digester volume was calculated assuming a hydraulic retention period of 26 days. It should be noted however that required hydraulic retention periods vary depending on the feedstock and the digestion technology employed. Specific applications will require further studies.

In sizing the digesters it has been assumed that the HIC waste streams will be subject to an appropriate collection, separation and pre-treatment regime so that only the biodegradable fraction will be fed to the digesters for processing.

[5] The Parliamentary Under-Secretary of State for Environment, Food and Rural Affairs, Dan Norris, House of Commons, 25th March 2010

Waste Category	Waste feed tonnes.day^{-1}	Waste feed m^3.day^{-1}	Required digester volume m^3
HIC			
Animal and vegetal wastes	7	20	545
Non-metallic wastes	8	24	636
Mixed ordinary wastes (Biodegradable Fraction)	24	34	891
Total HIC	*39*	*80*	2,072
Agricultural wastes			
Cattle manure	37	38	980
Wheaten straw	13	99	2,562
Barley Straw	2	13	326
Oat Straw	1	6	157
Field Beans	1	7	184
Oil seed rape straw	3	23	600
Linseed straw	>1	3	81
Other cereal crop straw	>1	2	65
Total Agricultural	*57*	*191*	*4,954*
Total	**96**	**270**	**7,026**

Table 4.1: Digester volume requirement by waste type for currently available waste volumes

Waste Category	Waste feed tonnes.day^{-1}	Waste feed m^3.day^{-1}	Required digester volume m^3
HIC			
Animal and vegetal wastes	42	127	3,303
Non-metallic wastes	8	24	636
Mixed ordinary wastes (Biodegradable Fraction)	174	249	6,475
Total HIC	*224*	*400*	*10,414*
Agricultural wastes			
Cattle manure	37	38	980
Wheaten straw	13	99	2,562
Barley Straw	2	13	326
Oat Straw	1	6	157
Field Beans	1	7	184
Oil seed rape straw	3	23	600
Linseed straw	>1	3	81
Other cereal crop straw	>1	2	65
Total Agricultural	*57*	*191*	*4,954*
Total	**281**	**591**	**15,368**

Table 4.2: Digester volume requirement by waste type for potentially available waste volumes

4.2. Potential gas and energy yield

Gas production from AD is critically dependent on the composition of the feedstock which is highly heterogeneous in nature. Thus the gas production and the resulting heat and electrical outputs from the gas utilisation plant are variable. For the purpose of this exercise three scenarios will be modelled. These are:

1. Base case: 29.5% of biogas produced required for parasitic load
2. Best case: Gas production +25% of base case, 12% of biogas produced required for parasitic load
3. Worst case: Gas production -25% of base case, 47% of biogas produced required for parasitic load

The parasitic load is principally the heat needed to maintain the digesters at operating temperature.

Waste Category	**Feed Rate Te. Day^{-1}**	**Gas yield $m^3.yr^{-1}$**			**Energy Content of Gas $GJ.yr^{-1}$**		
		Worst	**Base**	**Best**	**Worst**	**Base**	**Best**
HIC							
Animal and vegetal wastes	7	348,452	464,603	580,754	4,737	6,316	7,895
Non-metallic wastes	8	461,789	615,719	769,649	6,481	8,642	10,802
Mixed ordinary wastes (Biodegradable Fraction)	24	895,057	1,193,410	1,491,762	13,788	18,383	22,979
Total HIC	*39*	1,705,299	2,273,732	2,842,165	25,006	33,341	41,676
Agricultural wastes							
Cattle manure	37	491,576	655,434	819,293	11,126	14,834	18,543
Wheaten straw	13	1,242,810	1,657,080	2,071,350	15,822	21,096	26,370
Barley straw	2	123,974	165,299	206,624	1,526	2,035	2,544
Oat Straw	1	83,166	110,888	138,610	1,024	1,365	1,706
Field bean straw	1	76,603	102,137	127,671	1,327	1,770	2,212
Oil seed rape straw	3	241,180	321,573	401,966	2,969	3,959	4,948
Linseed straw	>1	32,664	43,553	54,441	402	536	670
Other cereal crop straw	>1	28,178	37,571	46,964	380	507	633
Total Agricultural	*57*	*2,320,151*	*3,093,535*	*3,866,919*	*34,575*	*46,101*	*57,626*
Total	**96**	**4,025,450**	**5,367,267**	**6,709,084**	**59,581**	**79,442**	**99,302**

Table 4.3: Gas production by waste type for currently available waste volumes

Waste Category	**Feed Rate Te. Day^{-1}**	**Gas yield $m^3.yr^{-1}$**			**Energy Content of Gas $GJ.yr^{-1}$**		
		Worst	**Base**	**Best**	**Worst**	**Base**	**Best**
HIC							
Animal and vegetal wastes	42	2,110,075	2,813,434	3,516,792	28,683	38,245	47,806
Non-metallic wastes	8	461,789	615,719	769,649	6,481	8,642	10,802
Mixed ordinary wastes	174	6,507,530	8,676,707	10,845,884	100,243	133,657	167,071
Total HIC	*224*	9,079,395	12,105,859	15,132,324	135,408	180,544	225,679
Agricultural wastes							
Cattle manure	37	491,576	655,434	819,293	11,126	14,834	18,543
Wheaten straw	13	1,242,810	1,657,080	2,071,350	15,822	21,096	26,370
Barley straw	2	123,974	165,299	206,624	1,526	2,035	2,544
Oat Straw	1	83,166	110,888	138,610	1,024	1,365	1,706
Field bean straw	1	76,603	102,137	127,671	1,327	1,770	2,212
Oil seed rape straw	3	241,180	321,573	401,966	2,969	3,959	4,948
Linseed straw	>1	32,664	43,553	54,441	402	536	670
Other cereal crop straw	>1	28,178	37,571	46,964	380	507	633
Total Agricultural	*57*	*2,320,151*	*3,093,535*	*3,866,919*	*34,575*	*46,101*	*57,626*
Total	**281**	**11,399,546**	**15,199,395**	**18,999,243**	**169,983**	**226,644**	**283,305**

Table 4.4: Gas production by waste type for potentially available waste volumes

Tables 4.3 and 4.4 illustrate the high degree of variability of gas production of anaerobic digestion plant utilising a mixed, heterogeneous feedstock. The amount of the produced biogas required to heat the digesters significantly impacts on the biogas gas available for utilisation, as can be seen from table 4.5 below.

The digester heating requirement is affected by the temperature of the area where the plant is located. For example, in colder, northern climates, gas requirement is significant as digesters need a high degree of heating. In warmer climates, AD plants can often operate without heating and therefore give a greater nett gas yield for a given waste quantity. For typical UK climatic conditions between 15 and 30% of the gas produced is used for heating. The exact figure is dependant on the details of the digester construction and the physical location of the plant.

The temperature at which the AD is carried out affects the heating requirement but also can affect gas yields. Mesophilic AD reactors operate between 35℃ and 40℃ whereas thermophilic AD reactors operate at around 55℃. Thermophilic reactors are much faster, yield more biogas and have a higher Volatile Suspended Solids (VSS) removal efficiency than mesosphilic reactors. However, the gas required to heat the digesters is significantly greater making the nett biogas available for utilisation generally lower.

	Current available			Potential available		
	Worst	Base	Best	Worst	Base	Best
HIC only						
Biogas required for AD heating ($GJ.yr^{-1}$)	11,753	9,836	5,001	63,642	53,260	27,082
Biogas available for Utilisation ($GJ.yr^{-1}$)	13,253	23,505	36,675	71,766	127,283	198,598
Agricultural waste only						
Biogas required for AD heating ($GJ.yr^{-1}$)	16,250	13,600	6,915	16,250	13,600	6,915
Biogas available for Utilisation ($GJ.yr^{-1}$)	18,325	32,501	50,711	18,325	32,501	50,711
Combined HIC and agricultural waste						
Biogas required for AD heating ($GJ.yr^{-1}$)	28,003	23,435	11,916	79,892	66,860	33,997
Biogas available for Utilisation ($GJ.yr^{-1}$)	31,578	56,006	87,386	90,091	159,784	249,309

Table 4.5: Gas Utilisation[6]

[6] Assuming Mesophilic Reactor Technology

4.3. Biogas utilisation plant

For the purpose of this study energy yields for heating only and CHP will be estimated. For a given gas quantity the output from electricity only plant will be the same as the electrical output from the CHP plant as the same prime mover technology would be utilised.

Tables 4.6 and 4.7 show the estimated energy yields and installed capacity for the heat only and CHP options detailing the base, best and worst case scenarios.

	Current available			Potential available		
	Worst	**Base**	**Best**	**Worst**	**Base**	**Best**
HIC only						
Heat output $GWh.yr^{-1}$	3.31	5.88	9.17	17.94	31.82	49.65
Estimated installed capacity MW_{th}	0.42	0.75	1.16	2.28	4.04	6.30
Agricultural waste only						
Heat output $GWh.yr^{-1}$	4.58	8.13	12.68	4.58	8.13	10.14
Estimated installed capacity MW_{th}	0.58	1.03	1.61	0.58	1.03	1.29
Combined HIC and agricultural waste						
Heat output $GWh.yr^{-1}$	7.89	14.00	21.85	22.52	39.95	62.33
Estimated installed capacity MW_{th}	1.00	1.78	2.77	2.86	5.07	7.91

Table 4.6: Estimated energy yield and installed capacity of Biogas boiler (heat only)[7]

[7] Based on an assumed thermal efficiency of biogas boiler of 90%

	Current available			Potential available		
	Worst	Base	Best	Worst	Base	Best
HIC only						
Heat output $GWh.yr^{-1}$	1.63	2.89	4.50	8.81	15.63	24.38
Electrical output $GWh.yr^{-1}$	1.44	2.55	3.98	7.79	13.82	21.57
Estimated available heat MW_{th}	0.22	0.39	0.60	1.18	2.10	3.27
Estimated installed generating capacity MW_e	0.19	0.34	0.53	1.05	1.86	2.90
Agricultural waste only						
Heat output $GWh.yr^{-1}$	2.25	3.99	6.23	2.25	3.99	6.23
Electrical output $GWh.yr^{-1}$	1.99	3.53	5.51	1.99	3.53	5.51
Estimated available heat MW_{th}	0.30	0.54	0.84	0.30	0.54	0.84
Estimated installed generating capacity MW_e	0.27	0.47	0.74	0.27	0.47	0.74
Combined HIC and agricultural waste						
Heat output $GWh.yr^{-1}$	3.88	6.88	10.73	11.06	19.62	30.61
Electrical output $GWh.yr^{-1}$	3.43	6.08	9.49	9.78	17.35	27.08
Estimated available heat MW_{th}	0.52	0.92	1.44	1.49	2.63	4.11
Estimated installed generating capacity MW_e	0.46	0.82	1.27	1.31	2.33	3.64

Table 4.7: Estimated energy yield and installed capacity of Gas engine CHP[8]

Heat Only Systems

The biogas produced by an AD plant is suitable for direct combustion in boilers producing steam or hot water for heating applications. There are two main options for this:

1. The gas is burnt in boilers on site and the energy distributed to users requiring low grade heat via a district heating system
2. The biogas is transferred via pipeline for use in offsite boilers producing steam or hot water for industrial processes, greenhouses or district heating.

The heat yields given in table 4.6 are based on a boiler thermal efficiency of 90% and an assumed capacity factor of modern gas fired boilers of 90%. For the combined waste streams the total biogas production can support between 1.0MW_{th} and 2.77MW_{th} of useable heat output for current available waste volumes rising to between 2.85MW_{th} and 7.88MW_{th} of useable heat output for the potential available waste volumes.

Heat produced from AD of biomass or waste and used outside the AD plant itself will qualify for payments under the proposed Renewable Heat Incentive (RHI). The RHI is intended to incentivise the use of heat from renewable sources in a similar manner to the existing systems used to promote renewable electrical generation. This is currently at the consultation stage with a target implementation date of April 2011. Currently the proposed RHI tariff level for heat generated from biogas schemes with an output <200 kW_{th} is 5.5p / kWh_{th}. Tariff levels for larger schemes have

[8] Based on assumed gas engine electrical and thermal efficiencies of 39.1% and 44.2% respectively

not yet been announced. These tariffs will be paid in addition to the commercial value of the heat energy and are intended to incentivise the use of heat from renewable sources.

CHP Schemes

CHP is usually the preferred option for biogas usage. Although the capital costs for CHP schemes are higher than for heat only applications the returns from generation and sale of renewable electricity significantly improve project payback.

Electricity generation from AD is classed by Ofgem as an Advanced Technology and as such qualifies for support under the renewables obligation at the highest rate. This allows generators to claim two Renewable Obligation Certificates (ROCs) per MW of electricity generated. These ROCs can be traded; currently the value of a ROC is approximately £35 / MWh_e.

Heat recovered from CHP schemes and used outside of the AD plant will qualify for the proposed RHI tariff payments in the same way as for heat only schemes.

CHP schemes that meet defined efficiency criteria can be accredited as “Good Quality CHP”. These schemes can claim Levy Exemption Certificates, (LECs). LECs are a system of incentivising efficient production of heat and electricity from both fossil and renewable fuels and can be used to offset tax liabilities on fuel purchases. LECs are also tradable with a current value of around £3.50 per MWh_e.

CHP schemes having an electrical output of less than 5 MW_e can opt to receive payments for the electricity generated via ROCs or through the Feed in Tariff (FITs). Currently FIT levels for electricity generated from AD are £90 / MWh for electricity used on the site and £30 / MWh for exported electricity. The choice between ROC and FIT based payment depends on the amount of on site power consumed, a system which exports the majority of its generated power would benefit more by opting for ROC payments while a scheme on, for example, an industrial site, where there is minimal export would benefit most from FIT payments.

Electricity generated from AD driven CHP on the Island can be fed into the Island’s existing distribution network, subject to a suitable grid connection being available.

In order to utilise the heat generated by the CHP units a suitable heat user must be available. There are three main options for this:

1. The biogas is burnt in CHP units on site and the heat recovered distributed to users requiring low grade heat via a low temperature district heating system. All of the heat generated and exported will qualify for RHI payments. The electricity generated will qualify for ROCs.
2. The biogas is transferred via pipeline for use in offsite CHP units located next to a heat user. The electricity generated and heat used will qualify for ROC and RHI payments.
3. The biogas is burnt in on site CHP units and the heat recovered used for digester heating displacing some or all of the gas used for this purpose. This increases the amount of gas available for power generation and therefore the income from this. However as the heat is being used within the AD process it will not qualify for RHI payments. Schemes of this type are most economic on relatively isolated sites where it is not practical to export the heat produced. The electricity generated will qualify for ROCs.

The thermal and electrical efficiency of the gas engine CHP units is assumed to be 44.2% and 39.1% respectively giving an overall efficiency of 83.3%. The capacity factor of the gas engine CHP units is assumed to be 85% allowing for maintenance and downtime. This is lower than the availability of natural gas fired gas engines due to the higher level of contaminants present in biogas. The installed electrical generating capacity of the gas engines ranges between 0.46 MW_e and 1.27 MW_e for the currently available waste volumes and 1.31 MW_e and 3.64 MW_e for the potentially available waste volumes.

Gas engine based CHP units for buildings and district heating schemes are optimally sized to suit heat demand. AD gas engine units differ in that they are sized to optimise electricity generation. The useful heat which can be recovered from the engines' exhaust gas and cooling system is considered a secondary benefit.

As gas production from the digesters is continuous it is necessary to provide a means of storing or disposing of the gas if there is no demand, due to planned or unplanned shutdowns of the gas utilisation units, or in case of emergency. Emergency disposal is normally done by flaring excess gas. To minimise the need for this it is normal to install multiple engines or boilers, often in parallel with gas storage vessels.

It is normal to install at least two engines on any one site. As biogas fired engines can typically only turn down to around 50% of full output these are often of different sizes to allow greater flexibility in energy generation. When demand or gas production is low, a unit can be shut down allowing the other units to run closer to full load.

This approach also allows one unit to taken out of service for maintenance, while the others remain in operation.

A further benefit from biogas utilisation is the potential to recover the CO_2 in the exhaust gas for other process uses, for example plant growth enhancement[9] in greenhouses. This would require the engine plant to be located adjacent to the greenhouses. Surplus heat produced could also be used for greenhouse heating.

5. INDICATIVE CAPITAL COSTS OF AD CHP PLANT

The capital costs of AD plants are very much dependent on their size. Larger plants will take advantage of economies of scale and thus have lower specific capital costs.

In terms of investment costs, small plants treating say 5,000 tonnes of pre sorted waste per year can cost up to £6 million whereas a large plant treating 100,000 tonnes of waste per year costs in the region of £20 million
.
A useful means of comparison is to convert these into relative figures as specific capital cost per tonne of waste treated. The specific capital costs for small plants are significant. A plant treating 5,000 tonnes of waste per year would typically cost between 500 and 1,200 £.tonne^{-1} of annual treatment capacity. In comparison, the costs for a large plant treating 100,000 tonne per year could fall to around 200 £.tonne^{-1} of annual treatment capacity. The CHP units contribute approximately 27.5% of total capital costs for small systems, decreasing to 20% for large systems.

Table 5.1 shows indicative capital costing for single plants treating the identified quantities of HIC only, agricultural waste only and combined HIC and agricultural wastes given in section 3. The costs are broken down into capital costs for the AD plant and CHP plant only. Further study work would be required to break down capital costs in more detail.

[9] Similarly to combustion of natural gas, biogas produces relatively clean emissions comprising mainly CO_2 and water. However biogas produced via AD of HIC can potentially contain a higher degree of contaminants. This would require the use additional exhaust gas cleaning technologies, such as NOx reduction. The specific treatment technology would depend on the source and composition of the biogas.

Assumptions:

- HIC only (currently available): Specific capital cost 450 £.tonne^{-1}, Break down of capital cost 73% AD plant, 27% CHP plant
- HIC only (potentially available): Specific capital cost 220 £.tonne^{-1}, Break down of capital cost 78% AD plant, 22% CHP plant
- Agricultural waste only: Specific capital cost 450 £.tonne^{-1}. Breakdown of capital cost 73% AD plant, 27% CHP plant
- Combined HIC and agricultural waste (currently available): Specific capital cost 320 £.tonne^{-1}.Breakdown of capital cost 75% AD plant, 25% CHP
- Combined HIC and agricultural waste (potentially available): Specific capital cost 200 £.tonne^{-1}.Breakdown of capital cost 80% AD plant, 20% CHP

Plant feedstock	AD plant capital cost	CHP capital cost	Total capital costs
HIC only (currently available)	£6.5million	£2.4million	£8.9million
HIC only (potentially available)	£14.0million	£4.0million	£18.0million
Agricultural waste only	£6.9million	£2.5million	£9.4million
Combined HIC and agricultural waste (currently available)	£9,8million	£3.2million	£13million
Combined HIC and agricultural waste (potentially available)	£16.4million	£4.1million	£20.5million

Table 5.1: Estimated capital costs for AD and CHP plant

6. POTENTIAL LOCATIONS FOR AD PLANT

As stated above, the biogas produced at an AD site can be used to provide both electrical power and heat. Subject to the grid capacity available the electricity generated can be fairly easily fed into the existing network. However finding a use for the heat produced is usually more difficult. One possible use would be as an energy source for district heating schemes; however this requires the AD plant to be located close enough to the consumers to make piping of heat practical and economic.

Plants without an external heat sink have to be used for power generation only. Although this is possible, and would generate electricity qualifying for ROCs at the highest banding, a large amount of potentially useful heat energy could be wasted.

A recent UK AD plant installation designed to treat 80,000 Te/year of food waste occupies an area of 1.25 Ha. This particular plant has four digester vessels each around 20m diameter and 19m high.

AD plants for specific waste streams will have different footprints and digester sizes however it is likely that a large AD plant will have a high visual impact. There may also be issues around odour control and lorry movements which would be unacceptable in urban environments.

The Entec study commissioned by the IoW Council [10] identified eleven sites as being potential locations for built waste treatment facilities as follows:

- IOW1: Parkhurst Forest Works: SZ 470 896
- IOW2: Nicholson Road, Oakfield: SZ 596 913
- IOW3: Stag Lane Depot: SZ 501 917
- IOW6: Whippingham Road: SZ 515 938
- IOW7: Land adjacent to Cowes Power Station: SZ504 943
- IOW8: Pan Lane: SZ 507 886
- IOW9: Standen Heath: SZ 531 882
- IOW11: Sewage Works, Fairlee: SZ 507 911
- IOW14: Lynnbottom: SZ 534 884
- IOW15: Lynn Plantation Landfill: SZ 537 882
- IOW16: North Fairlee Farm: SZ 510 912

The full methodology for the identification and assessment of the above sites can be found in the Entec document.

In identifying sites for waste management facilities Planning Policy Statement 10: Planning for Sustainable Waste Management leads Local Planning Authorities to consider the type of waste facility being promoted when looking for a specific location.

The search for sites for waste management has traditionally focussed on opportunities for landfill and/or on existing waste facilities. However waste management needs are changing and some waste management activities are now suitable for different types of sites.

Of these IOW16 is probably too small to contain a commercially viable AD development.

[10] Assessment Of Options For Waste Sites And Other Alternatives To Landfill On The Island – Sept 2009

Areas IOW9, IOW14 and IOW15 are wholly or partially within the existing Area of Outstanding Natural Beauty (AONB). Development of waste treatment facilities within the AONB is not prohibited as such, and these are existing waste treatment and disposal facilities. However it is possible that there may be some local resistance to further development of these facilities.

Area IOW1, Parkhurst Forest, has the advantage of already being a licensed waste management site, therefore making the permitting process easier. It is located some 2.5km from the prison complex which could give a significant and continuous heat load. The cost of transmission of the heat over this distance is likely to be around £1.5million, excluding local heat distribution systems at the end users. Long term income from heat sales and the RHI could make this attractive. There are however space restrictions at this site which currently make it unsuitable for further expansion. However should this situation change this could be attractive.

Site IOW2 is located within 500m of the potential new developments at Swanmoor and Oakfield. The new developments offer the Council an opportunity to specify the installation of community district heating infrastructure from the outset as part of the planning process. Consequently a heat load could be available relatively close to the site.

Site IOW3 is in itself too small to house a commercially viable AD plant, however there is additional land adjacent to the site which could potentially be made available. This site is located some 2 Km north of Newport in what is currently a relatively unpopulated area. However there is the potential for future employment and housing development in the area. An AD plant located on this site could supply heat to a community district heating network for any future development opportunities within the immediate area and could ultimately be extended further south to cover consumers in the north of Newport.

Site IOW6 is again located around 500m from a potential new development, and near to an existing factory site and a school, all of which could be heat consumers. The site is located adjacent to the AONB but not within it. It is however likely that there would be objections from local residents to locating a Waste to Energy (WtE) plant on this site, particularly given its proximity to IOW7 which may well be a better option.

Site IOW7 is close to IOW6 and even nearer to the potential development site at Kingston. Being close to the existing power station electricity grid connection is likely to be relatively straightforward. There may be some issues to be resolved regarding land ownership however if these can be overcome this would seem to be a strong candidate for an AD site. The presence of an energy centre could also increase the development potential of the remainder of this site.

IOW8 is located close to the ongoing Pan developments. These are planned to incorporate a district heating system. There may be the opportunity to heat this system using an AD plant although there may be local resistance to the installation of a WtE plant. However it is possible that there would be support for Pan to be a sustainable community generating its own heat and power by treating its own waste or to use an AD plant to supplement the biomass fired heating scheme currently proposed.

IOW11 is located remote from any significant heat consumers. A plant here would need to be designed primarily for electricity generation. There may also be difficulties with grid connection for relatively large generators on a remote site.

Other than the sites identified by Entec there may be commercial applications where an AD plant could provide heat to an existing user. One possibility for this would be the Wight Salads operation at Arreton. This is currently a gas fired CHP installation with heat being used for greenhouse heating. Installation of an AD plant local to the site, which could in part use organic wastes from the salad growing process as feedstock, would allow substitution of natural gas with biogas. This would generate increased revenue from the heat and electricity produced through RHI and ROC payments as well as displacing the cost of natural gas fuel.

7. LOCAL, NATIONAL AND EUROPEAN REGULATIONS

Any digestion plant on the Island will be required to comply with applicable Local, National and European regulations.

The overall European strategy is set out in the Waste Framework Directive[11]. UK Central Government policy on waste is set out in the Waste Strategy Documents[12]. These strategies outline in general terms objectives and targets for the ongoing reduction of waste together with the measures implemented to incentivise waste reduction.

A digester installation would need to be located on a site licensed for waste processing under the Waste Management Licensing Regulations[13]. The licensing process includes consideration of the environmental and social impacts of the proposed site and can be a fairly lengthy process. Existing waste site licences can be extended to include AD plants by agreement with the appropriate authorities.

Operators of sites licensed under the Waste Management Licensing Regulations are required to be individually licensed under the same regulations. This is intended to ensure that the operators will manage the site correctly and in a responsible manner.

The process used for waste treatment will need to comply with various legislation depending on the technology and the feedstock being used.

If the feedstock contains animal by-products, including kitchen wastes containing animal products, the plant will need to comply with the Animal By-product Regulations (ABPR).[14] These regulations define the treatment required to minimise the risk of transmission of pathogens potentially present in meat products back into the food chain. Typically they require the waste to be pasteurised by heating before being fed to the digesters.

If the proposed plant includes incineration, or other thermal treatment, of either solid or liquid waste streams the processes involved will need to comply with the requirements of the Waste Incineration Directive (WID)[15]. Combustion of biogas produced from AD plants is not currently subject to WID but the emissions from the combustion process will be controlled as part of the overall site Environmental Permit[16].

Electricity produced from Anaerobic Digestion qualifies for incentive payments under either the Renewables Obligation or Feed-in Tariff. Any useful heat produced that is not used in the process also qualifies for and Renewable Heat Incentive. The structure of these incentives strongly favours installation of CHP over heat only schemes.

A protocol defining the quality of digestate from AD plants is currently being developed[17]. Digestate complying with this protocol will not be treated as waste and can be sold into other markets as a recycled resource, for example as a soil improver. Digestate not complying with the protocol remains a waste and will need to be disposed of in accordance with the Waste Management Regulations. Feedstocks containing municipal waste which has not been source segregated will not produce “quality” digestate.

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[11] Directive 2008/98/Ec of The European Parliament 19 November 2008.

[12] Waste Strategy for England 2007 www.defra.gov.uk/environment/waste/strategy

[13] The Waste Management Licensing Regulations 1994 Statutory Instrument No. 1056 as amended by The Waste Management Licensing (England and Wales)(Amendments and Related Provisions)(No. 3) Regulations 2005 (WMLR) Statutory Instrument 2005 No. 1728.

[14] Animal By-Products Regulations 2005 (Statutory Instrument 2347/2005

[15] Directive 2000/76/EC Of The European Parliament 4 December 2000

[16] Environmental Permitting (England and Wales) Regulations 2007 (SI2007 No. 3538)

[17] WRAP (2008) The Quality Protocol for the production and use of quality outputs from anaerobic digestion from source-segregated biodegradable waste. Environment Agency.

Subject to the feedstock used digestate sludge can be used as a fertiliser, its use again being governed by regulation[18].

8. CONCLUSIONS AND RECOMMENDATIONS

- The review of waste arisings on the Island has estimated that between 14,227 and 81,878 tonnes of biodegradable municipal solid waste and 20,803 tonnes agricultural waste are available as feedstock for anaerobic digestion on an annual basis. The combined biodegradable feedstock availability is between 35,030 and 102,681 tonnes per year.
- The digester volume required for the HIC and agricultural wastes currently available is 2,072m^3 and 4,954m^3 respectively with a total volume requirement of 7,026 m^3. This requirement increases to 10,414m^3 for the biodegradable fraction of the HIC waste potentially available. The total digester volume required for treatment of all of the potential available volume of HIC and agricultural waste is 15,368m^3.
- Total usable gas production from the process is estimated to be between 4,025,450m^3 and 188,999,243m^3 per year depending on the waste quantity and digester heating requirements. This could support gas engine CHP units with a total generating capacity of between 0.46MW$_e$ and 3.64MW$_e$ with associated heat outputs of between 0.52MW$_{th}$ and 4.11MW$_{th}$
- The estimated capital costs for plants are:
    - HIC only (currently available): £8.9million
    - HIC only (potentially available): £18.0million
    - Agricultural waste only: £9.4million
    - Combined HIC and agricultural waste (currently available): £13million
    - Combined HIC and agricultural waste (potentially available): £20.5million

  This gives a approximate specific capital cost of between £200 –and £450 tonne^{-1} of annual treatment capacity depending on the system size.
- Any AD plant built on the Island should ideally be located on a site which will facilitate the use of excess heat generated by the biogas utilisation plant. Strong candidate locations are those near new developments or existing heat users.
- A digestion plant on the Island will be required to comply with applicable Local, National and European regulations depending on the technology and the feedstock being used. Applicable legislation could include the Animal By-product Regulations (ABPR) and Waste Incineration Directive (WID).
- Electricity produced from Anaerobic Digestion qualifies for incentive payments under either the Renewables Obligation (RO) or Feed-in Tariff (FITs). Any useful heat produced that is not used in the process will also be eligible for payments under the proposed Renewable Heat Incentive (RHI).
- A protocol defining the quality of digestate from AD plants is currently being developed. Digestate complying with this protocol is not treated as waste and can be sold into other markets.

[18] Sludge (Use in Agriculture) Regulations 1989 (SI 1989, No. 1263).