Feasibility Study into Establishing an Anaerobic Digestion Plant using Substrates from Agriculture Sectors on Jersey

Prepared for: John Jackson

Rural Economy Manager
The Department of the Environment
Howard Davis Farm
Trinity
Jersey
JE3 5JP

Prepared by: ADAS UK Ltd

Tom Brassington & Alice Willett

Pendeford House
Pendeford Business Park
Wobaston Road
Pendeford
Wolverhampton
WV9 5AP

Date: 24 December 2013

Executive Summary

Introduction

The States of Jersey have identified that there is scope for the recycling of organic waste from agricultural, horticultural and food operations on Jersey. A consultation document, published by the States of Jersey, into the energy plan for 2050 concluded that a feasibility study ought to be conducted into the implementation of anaerobic digestion (AD) as a system of waste management of livestock slurries. This report assesses the feasibility of using wastes derived from the agricultural sector as a feedstock for AD.

The aim of the report is to determine whether it would be technically and economically feasible to install AD on Jersey using agricultural sourced feedstock. This was determined through analysis of the Agricultural Statistics for Jersey (States of Jersey, 2013[a]) and information gained through twenty stakeholder interviews, and reference to other relevant information sources on AD.

Agricultural land in Jersey totalled 37,004 vergées (14,975 hectares) in 2012. This equates to around 57% of the total land area in Jersey (64,612vergees / 26,165 hectares). There were around 529 holdings in 2012 with an average holding size of 70 vergées (States of Jersey, 2013[a]).

Two of the main agricultural outputs are Jersey Royal potatoes and dairy products produced from Jersey cows. Jersey Royal potatoes were grown over 49% (17,992 vergées) of the agricultural land area in 2012. There were 2,931 cows and heifers recorded in milk in 2012, with the average herd consisting of 113 cows. However, a high proportion of the cows are in herds over 100 cows, with 12 farms having an average 192 cows.

Key points from stakeholder survey

Positive feedback and support for developing AD was received from stakeholders. The agriculture, cropping, size and type of farm on the Island are unique, with strong reliance on the main sectors of dairy and potato growing. The need for them to work together is an essential consideration in the project. Economic viability was always mentioned, and farms are willing to support AD, and interested in the commercial opportunity that this could present for them, as they have very little other opportunity to enter the renewables market.

In order to assess the technical and economic feasibility of AD, a series of key questions were identified to ensure the research and analysis allowed conclusions to be drawn based on sound evidence.

Is there enough available feedstock for an AD plant on Jersey?

Based on livestock numbers and land use there is sufficient AD feedstock on Jersey to run a medium scale AD plant. The feedstock would be derived from a number of sources: cattle slurry, waste Jersey Royal potatoes, waste vegetables and purpose grown crops.

There is variability in the supply of feedstock through the year. This is mainly Jersey Royal potatoes during the 4 month main production period, and some seasonality of vegetable wastes. The inclusion of cow slurry and other crops, with associated storage, is an important requirement of the feedstock mix.

What is the best mix for maximum energy production?

Maximising energy production and sale value will produce the income to finance the AD. The waste potatoes provide a very good source of energy, as does the maize crop. The cow slurry has a lower contribution to gas yield. Maximising gas yield is important to maximise the income generated from energy, but a mix of feedstock is needed to balance the variation in feedstock supply quantities. A mix of slurry, potato waste, vegetable waste, and crop will be needed.

What is the impact on agriculture?

There will be an improved management of the vegetable and Royal Jersey potato waste, providing a more environmentally friendly alternative to the current situation of spreading these wastes back to land. There is an opportunity for some farmers to grow an additional crop as feedstock. There will be an improved management of the application of nutrients back onto land. Introducing AD provides the agricultural community to be more actively involved in the renewable energy market, and if the energy can be used in an agricultural process such as Jersey Dairy, provides an added value to product marketing.

Is there enough land bank to receive the AD derived digestate?

The annual digestate output of a medium scale AD plant would require 1,620 vergées, or 4.5% of agricultural land bank. From discussions with a limited number (10) of growers, it was felt that the area of land required, could be provided. Within the landbank there are environmental restrictions of non-spreading areas, non-spreading periods of the year and crop windows which will need to be managed within the available landbank.

Is there scope to utilise the energy generated from an AD plant?

The AD plant will produce biogas and this can be used to produce electricity and heat. In order to optimise the output of the AD plant, it is important that it is situated in close proximity to the main use of heat and electricity. There is an opportunity to export electricity, but at periods of peak demand only, to the grid. There is no financial support on Jersey for producing renewable energy, so the energy produced must be at a competitive price with electricity and heating costs and at a raised price for export to the grid.

The injection of biomethane into the gas grid is not considered viable. There are opportunities to produce and market bottled biomethane for commercial and domestic use or for vehicle fuel. The technology to clean the gas is currently high and higher than the cost of technology to generate electricity. The technology is in an early stage of development and requires further development.

Would an AD plant be economically viable on Jersey?

There is currently no system of financial support, either capital funding or renewable energy incentives, on Jersey. As a result an AD plant established on Jersey would need to optimise the financial return on the sales of energy, at competitive commercial prices. The scenario of a community medium scale digester could be economically viable. Within the assumptions used in the model, the financial return is very low for the capital investment required, and it would not be attractive to a financial investor. Support for an AD plant will be required from the States of Jersey, which could include provision of a site to locate the AD plant, a low interest finance loan, or a capital grant.

In conclusion

This project has established that there is adequate feedstock available to run a medium scale AD plant on the Island of Jersey established where the feedstock is sourced. There is sufficient land bank available to spread the resultant digestate. Financially the project could be viable assuming farmers do not charge for 'waste' feedstock, that inflation is included, the AD plant is situated next to an industrial/agricultural process that will purchase the energy and support is provided from the States of Jersey.

Further investigation required

1. Income from energy. Establish the actual supply quantity and price that an industrial process (milk processing plant, protected crop producer) and Jersey Electric will pay for the energy. This will require an energy audit for the industrial process and commercial price negotiation for the energy procurement.

2. Feedstock security. To establish actual feedstock quantities, a survey of the identified feed stocks is needed, followed by setting up and implementing a terms of supply agreement .

3. Review the project economics in light of the above points and then:

4. Secure a site. The use of the energy close to an industrial process will dictate the location. The actual site location, its ownership and cost, and implications on planning need to be determined.

5. AD equipment supply. Prepare a specification of equipment. Present the specification to three suppliers for them to provide the supply and build cost.

Additional associated research work

Investigate viability of prickly potato as a feedstock.

Contents

List of Tables

List of Figures

List of abbreviations

AD – Anaerobic digestion

ADQP – Anaerobic Digestion Quality Protocol

CHP – Combined heat and power

FIT – Feed-in Tariff

kW – Kilowatt

kWe – Kilowatt electricity

kWh/m^3 – Kilowatt hour per cubic metre

LPG – Liquid petroleum gas

N – Nitrogen

p/unit – Pence per unit

PCN – Potato cyst nematode

PGC – Purpose grown crop

Prickly potato – *Solanum sisymbriifolium*

QMP – Quality milk payment

SAP – Single area payment

tph – Tonnes per hour

1. Introduction

1.1 Background

The States of Jersey consider there to be scope for the recycling of organic waste from agricultural, horticultural and food operations on Jersey.

A consultation document published by the States of Jersey entitled '*Pathway 2050: An energy plan for Jersey'* (States of Jersey, 2012[a]) refers to using anaerobic digestion (AD) as a method of waste management for all livestock slurries by 2020. In the consultation document AD was mentioned as a method for abating the 41% of greenhouse gas (GHG) emissions from agriculture resulting from slurry.

AD is a process by which a culture of microbes in an air-excluded environment digests non-cellulosic substances in organic matter and in the process release carbon dioxide (CO_2) and methane (CH_4). A background to anaerobic technology can be found in Background to AD technology.8.1

The potential benefits of AD for Jersey were set out in the consultation document as:

- Recovery of energy from waste products – including livestock (especially dairy) slurries, waste dairy liquid etc.
- Plant disease management – by providing an alternative disposal route other than back to land for waste potatoes
- Methane capture
- Pollution control – with improved nutrient management and quality assurance
- Displace imported fertiliser – which has high embodied energy and GHG emissions

The challenges to implementing AD technology in Jersey were thought to be:

- The plant's energy yield and associated economic analysis
- Operation of the plant, including the provision of a homogeneous feedstock and storage issues
- Agreement from the industry to ensure the delivery of slurry and collection and approved return to land of the digestate
- Location of an AD plant(s)

The conclusion of the consultation document was that a feasibility study would be carried out into the implementation of AD as a system of waste management of livestock slurries.

This report seeks to provide a detailed assessment of the technical and economic feasibility of using waste derived from the agricultural sector as a feedstock for AD.

There are some unique features on Jersey that have been taken into account, which include:

- Public investment in waste recycling on Jersey has been made in two areas (not included in the scope of this project):
  - Waste water and sewage is treated by the publically-owned Bellozanne treatment works, which includes an AD plant
  - Green waste from municipal and domestic premises is processed at the La Collette composting site. Compost is either sold through garden centres or used on agricultural land
- States of Jersey do not have Feed in Tariff (FIT) system so the economics of energy production are different from the UK.

1.2 Aims and objectives

The aim of this study is to determine whether it would be technically and economically feasible to install AD technology on Jersey. This will be answered by addressing the following objectives:

1. Assess type, quantity and quality of AD feedstock (substrate) available from the agricultural, horticultural and food retail sector in Jersey.
2. Survey a sample of farmers, farming businesses, food processors and food retail outlets in Jersey to assess their interest in and commitment to using their waste streams in an AD plant(s) to produce biogas.
3. Estimate number, type, design and indicative costs of construction and possible locations (in discussion with representatives of States of Jersey) of AD plant(s) required to digest the above substrate, and the recommended feedstock mix to maximise biogas output whilst taking into account views expressed within the consultation process.
4. Examine options for the use of the biogas produced from the above AD facilities, (with the appropriate gas upgrading systems) that will provide the greatest economic benefit to the stakeholders committed to the biogas generation process.
5. Estimate quantity and describe likely analytical quality of the digestate produced.

1.3 Methodology

The analysis is based on information gathered from a range of sources including background information on Jersey agriculture taken from the agricultural statistics (States of Jersey, 2013[a]) and a stakeholder survey.

The survey was conducted with a range of stakeholders, including 10 farmers. The objective of the survey was to acquire a thorough understanding of farming practices on Jersey and to examine stakeholder views on AD. The survey was primarily conducted through face-to-face interviews using a standardised survey interview guide developed specifically for the project. Prior to farmer interviews, a pre-discussion document was sent out to capture quantitative data. Both the interview structure and pre-discussion document can be found in Appendix 8.2 and 8.3.

In total, twenty interviews were conducted between September 2013 and November 2013, with a range of stakeholders. The breakdown is given in Table 1 Breakdown of interviews by type. Of the 20 interviews, 18 were face to face and two were on the telephone. A further 3 stakeholders were contacted following interviews for further clarification. The interviews averaged an hour and a half in length and were mainly conducted with individual stakeholders, although 3 took the form of group discussions. The contacts were selected from a list of 27 stakeholders provided by John Jackson (Department for the Environment). Full interviews were selected, based upon an initial telephone discussion. In some cases the telephone conversation did not lead to a full interview.

As the interviews were conducted on a confidential basis, the names of the interviewees have not been included in this report and a detailed transcript of the individual discussions was not produced.

Ten interviews (including two group interviews) were conducted with stakeholders whose main business interest was farming. This sample size is not representative of the farming community of Jersey, however the survey was primarily to capture qualitative information to support the analysis of the Jersey agricultural statistics (States of Jersey, 2013[a]).

Table 1 Breakdown of interviews by type

Detailed interviews	**20**	**Telephone interviews**	**2**
Farmers	10	**Follow up conversations**	**3**
Supermarket	1		
Utility companies	2		
Government departments	3		
Transport	2		
Processing	2		

Two scenarios of AD plant were considered and analysed in a model using the Anaerobic Digestion Economic Tool (version 2.4) developed by The Andersons centre (http://www.biogas-info.co.uk/index.php/ad-calculator.html) to provide an understanding of how AD would fit into the agricultural practices on Jersey.

- Scenario 1- a medium sized digester requiring 29,000 tonnes of feedstock and producing electricity and heat from a combined heat and power (CHP) generator.
- Scenario 2 – taking scenario 1 and replacing CHP with technology producing biomethane to be bottled and sold for domestic and commercial use.

Scenario 1 - medium sized digester was selected as the stakeholder interviews indicated that around 25,000 tonnes of feedstock could be available on Jersey. This volume best matches a digester with a capacity for 29,000 tonnes of feedstock and accommodates the seasonal feedstock variation. The energy output from this size of digester would be sufficient to supply an identified industrial process (milk processing plant etc.) and sell electricity to Jersey Electric at their peak demand times.

A second scenario investigates the option of taking scenario 1 and replacing the CHP with gas clean up technology and gas compression. This would allow for an alternative use of the biogas.

2. Summary of information gathered and analysis

2.1 Summary of agricultural activity on Jersey

The following data are taken from Agricultural Statistics 2012 (States of Jersey, 2013[a]).

Agricultural land in Jersey totalled 37,004 vergées (14,975 hectares) in 2012 (States of Jersey, 2013[a]). Agricultural land makes up around 57% of the total land area in Jersey (64,612 vergées / 26,165 hectares). Of this, 9,034 vergées are owned and farmed and 27,970 vergées are rented. Within the agricultural land, the main crop types in 2012 are shown below in Table 2. This indicates that grassland and potatoes were the main land using crop type, with maize and cereals only accounting for 5% each of the total agricultural land area. There were 529 holdings in Jersey in 2012, ranging in size from five holdings which were above 1000 vergées and 268 holdings (50%) which were between one to ten vergées. The average holding size was 70 vergées (States of Jersey, 2013[a]) and farm enterprises are generally specialised to potatoes and/or vegetables or a dairy herd .

Table 2 Main crop types on Jersey

Crop	Percentage of agricultural land (%)
Grassland	51
Potatoes	50
Maize	5
Cereals	5

Total will not equal 100% due to the effect of double cropping within a year.

Two of the main agricultural outputs are Jersey Royal potatoes and dairy products produced from Jersey cows. Jersey Royal potatoes were grown over 49% (17,992 vergées) of the agricultural land area in 2012. The Jersey Royal potatoes are mainly grown and retailed by two companies; The Jersey Royal Potato Company and Albert Bartlett.

There were 2,931 cows and heifers recorded in milk in 2012, with the average herd consisting of 113 cows. The majority of the Island's herd (2,300 cows or 78.5%) were owned within 12 herds. Milk from all except one of the herds in Jersey is processed and retailed by Jersey Dairy.

A full breakdown of the livestock numbers and cropping areas in Jersey are given in Appendix 8.4, 8.5 and 8.6. It should be noted that the total cropped areas will not reconcile with the total agricultural land area because of the effect of double cropping. Within Jersey a system of double cropping and land sharing is practiced to provide enough land and resource for each enterprise (stakeholder interview) or as a result of the requirements of the Single Area Payment (SAP).

2.2 Anaerobic digester feedstock supply

The findings from the Agricultural Statistics 2012 (States of Jersey, 2013[a]) were analysed alongside the stakeholder interviews, to determine the volume of anaerobic digester feedstock that may be available.

2.2.1 Horticultural, arable and other cropping waste as anaerobic digester feedstock

Stakeholder interviews included a discussion as to whether the enterprise would be prepared to deliver their waste, free of charge, to the anaerobic digester (AD) plant. The total estimated volume of waste that could be available following discussions with stakeholders is summarised in Table 3, with the full breakdown given in Appendix 8.7.

Table 3 Estimate of potential horticultural, arable and other crop feedstock for the AD plant (tonnes)

Farm	Waste potatoes (Jersey Royal)	Waste potatoes (Main Crop)	Vegetable waste	Maize	Other waste (grass, prickly potato)
Sub total	5,350 – 10,050	650	1,730	6,670 – 8,900	2,770 – 3,990
Grand total	**17,170 – 25,320 tonnes**				

The volume of **waste potatoes** comprises of waste taken from two points during the harvesting process (secondary on-farm grading line and washing line), along with the small volume of waste produced when the primary chit is removed. The waste does not include undersized potatoes that are not harvested from the field, as this would involve additional harvesting or grading. An explanation of the planting to packing cycle for Jersey Royal potatoes in Jersey can be found in Appendix 8.8. The volumes of waste Jersey Royal potatoes take into account the existing requirement of the two Vodka producing industries on Jersey (stakeholder interviews).

From discussion with two of the major vegetable growers with pack houses who would produce high volume of waste, it is estimated that approximately 2,380 tonnes of **vegetable waste** (see Table 3) is generated annually from vegetable (1,730 tonnes) and main crop potato (650 tonnes) processing and packing. This figure is based upon: out of specification items, trimmings and processing (washing and peeling) waste. (This was not a detailed survey and on Jersey there will be additional sources of vegetable waste).

Maize would be grown as a 'purpose grown crop' (PGC). During the stakeholder interviews, the consensus view was that it would be possible to grow maize as a second crop, following the harvest of Jersey Royal potatoes from March through to June. The maize volume shown in Table 3 is an estimate by one stakeholder of what that stakeholder could feasibly grow as a second crop following Jersey Royal potatoes. In practice the maize for feedstock would be sourced from a number of individual farmers growing the crop. This is based upon committing around 900 vergées of land to maize, which represents 5% of Jersey Royal planted land, with an expected yield of around seven tonnes per vergée. The yield quoted is from traditional varieties of maize and so there may be potential to increase the yield through appropriate variety selection.

There were comments made from two stakeholders that they thought it unlikely that the dairy industry would support an increase in the area of maize grown as it may reduce the availability of grazing or cutting grass - especially if there was financial income for growing maize. A further concern was related to the belief that an herbicide used during the growing of maize could have a negative impact upon potatoes. Some of the herbicide label recommendations include advice on following crops which should be used when making herbicide selection.

Other wastes include: grass, bio fumigant 'hot' mustard, prickly potato, ornamental waste and fruit pulp. Grass is often planted as a second crop after Jersey Royal potatoes, however this is not always completely utilised by the dairy industry and so it is flail mowed and incorporated into the soil as a green manure, prior to planting potatoes.

Hot mustard and prickly potatoes are grown for the control of potato cyst nematode (PCN) (stakeholder interview). Bio-fumigant 'hot' mustard is required to be incorporated into the soil for the isothiocyanates to have an effect. Prickly potato has a 'trap crop' action and does not require incorporation in order to have a beneficial effect, and there is the potential to flail mow the tops from the plant and ensile them. It is estimated that prickly potato yields between 6.5 and 10 tonnes per vergée (40-60 tonnes/hectare) and there is currently 365 vergées (60 hectares) grown in Jersey (stakeholder interview). As there is no evidence on the feasibility of ensiling prickly potato or its viability as a feedstock for an AD plant, this area requires further investigation.

The volumes of **ornamental waste and fruit pulp** are limited, and seasonal, so they have not been considered as a potential reliable feedstock. However as they could be used in an AD plant, more detailed discussions with stakeholders are warranted.

2.2.2 Livestock derived waste as anaerobic digester feedstock

The livestock numbers for Jersey are given in Table 13, found in Appendix 8.4. The figures indicate that only low numbers of pigs, beef cattle, goats and sheep are kept on Jersey and so their manure/slurry output has not been included in the calculation as a potential feedstock. Similarly, the output from Jersey's laying hen flock has not been included.

The main source of slurry produced in Jersey is from dairy cattle and this has been taken as the main source of animal-derived AD feedstock.

Dairy Industry

The majority of dairy farms in Jersey are based upon cubicle systems, bedded on sawdust or chopped straw. Cows are generally housed over the winter months and are out at grass for the remaining half of the year (States of Jersey, 2009). Whilst the main volume of slurry is produced when cows are housed, slurry is also produced when cows are brought in for milking.

The slurry is collected and stored in on-farm slurry stores. The Water Pollution Order (States of Jersey, 2009) states that "the Countryside Renewal Scheme provided financial assistance to help fund the construction of slurry stores, to contain 4 months production of slurry and dirty water, prior to the introduction of the closed period for spreading slurries". The closed period on Jersey covers the period of the year when the risk of nitrogen leaching into water courses is at its highest, (1st October to 31st December inclusive) and the spreading of slurry, organic matter and digestate to land is not permitted.

The total slurry produced per year from the Island's dairy herds is estimated to be 34,720m^3, the calculations can be found in Appendix 8.9 (Table 17). The parlour washings (values in Appendix 8.9, Table 18) generally drain to the slurry system. When taking 8,915m^3 of parlour washings into account, the total volume of slurry produced per year equals 43,630m^3, or an average of 1,605m^3 per farm. There is considerable variation in individual herd size on Jersey, but 78% of cows are kept in 12 herds of over 100 cows. The 12 farms average 192 cows per herd, and would be the main source of supply to the AD. A dairy farm with 192 cows produces estimated 2,950m^3 slurry (excreta and parlour wash) per year, producing more in the winter months (359m^3/month) compared to summer months (165m^3) .

A small amount of out of specification milk products (yoghurt etc.) is currently sent to the municipal incinerator at La Collette for disposal. This does not currently incur a charge. The low volume of waste dairy product results in it not being considered as a major source of feedstock for AD. However the dairy processing plant is currently experimenting with a sludge separator for the wash water. The separated matter could be included within an AD system; however it would only contribute a small proportion of the feedstock (stakeholder interview).

2.2.3 Retail store derived waste as anaerobic digester feedstock

Food waste from retail stores is currently collected by the waste collection systems determined by area. The waste is disposed of through the island's municipal incinerator at La Collette.

Stakeholder interviews were conducted with two retailers based on Jersey. A telephone conversation was conducted with retailer A and a meeting was held with retailer B. Retailer A was not interested in further discussions or in sending waste vegetables to an AD plant. Retailer B would be interested in disposing of waste fruit and vegetables through an AD plant if one were to be introduced onto Jersey. However Retailer B said that the quantities are generally small as they operate policy to minimise waste, and there would not be a constant or known volume. Therefore this element has not been factored in as an AD feedstock in the scenarios examined. If an AD plant were to be constructed, further detailed conversations with Retailer B would be useful to determine whether their vegetable waste could be used as potential feedstock.

2.2.4 Feedstock mix

Feedstock planning. Knowledge of the feedstock supply and seasonal variation will be essential to the running of the AD plant. Therefore a small amount of buffer storage adjacent to the digester, which could hold a few days of buffer volume, would be required. The feedstock must be managed so that the digester operates consistently, and provides a consistent yield of biogas. This is illustrated in Figure 18 Scenario 1: Breakdown of feedstock and biogas yield (Anderson model).

Jersey Royal waste potatoes will be mainly produced from April to July. Currently the waste potatoes are loaded into a trailer from the grading line to be returned, by the grower, to their fields. The waste potatoes could be diverted from being returned to fields to go to a digester. The supply would therefore be daily during the grading period. To allow for some fluctuations in the quantities that cannot be stored at the packing line, storage capacity for approximately 100 tonnes of waste potatoes would be required at the digester. The front of the silage clamp could be utilised.

Vegetable wastes are produced all around the year, with some seasonal variation. This would be delivered daily to the plant, by the producer, for direct mixing into the digester. Under this system, storage is not required. The monthly volumes of vegetable waste are shown in Figure 18. Vegetable waste is a small proportion of the feedstock and so any daily variations could be accommodated in the digester vessel. Storage for long periods should be avoided as that would be a potential source of odours.

The Maize or other PGC would be harvested and placed in storage in clamps at or near to the digester. Part of the purpose of the maize feedstock is to balance the feedstock supply, and to provide feedstock in the months when potatoes would not be available. The location of the maize crop clamp would be adjacent or very close to the digester to allow easy access to draw feedstock. The clamps will be loaded by the farmers producing the crop, and then the clamp will be accessed by the AD operators.

Animal slurry is produced on a continual basis and is currently collected daily on the farms. Part of the function of the animal slurry is to provide a balance of feedstock in the months when potatoes are not available. The digester site would not require storage capacity, but rely on the existing storage capacity on the dairy farms (4 months capacity is installed on farms) and the farmers to deliver the slurry on a regular basis. However it would be diligent to provide buffer storage at the digester site to accommodate the varied work load of farmers. A $100m^3$ store would provide a number of days storage at the site. For example in scenario 1 the daily requirement ranges between $25m^3$ and 55 m^3 of slurry.

Feedstock variability. The AD Plant is not dissimilar to an animal's digestion system and will perform best with regular and consistent feed supply. The variation in the feedstock, mainly from the potatoes, will affect the bacteria mix. In operation, the AD plant will have the technology supplier's continual monitoring system to ensure that the digester runs smoothly with the changes in feedstock. The sizing of the AD vessel provides the buffer effect, as potatoes would supply up to 55% of the feedstock. The feedstock plan can be predicted, as illustrated in Figure 18, and the technology supplier will have analysis of each of the feedstocks at the pre-construction stage. Therefore the feedstock variations can be successfully managed.

Feedstock agreements. The regular and reliable supply of feedstock is essential to the operation of the AD plant, and supply agreements will need to be set up. Ideally these should be established as long-term agreements, as the feedstock must be planned ahead. The waste industry experience extreme difficulty in establishing long-term feedstock agreements, particularly where a value is perceived. However for an agricultural community digester with partner involvement short-term agreements with annual reviews should be established. A key point is to establish feedstock agreements early in the project planning stage, to mitigate against the risk of failure in supply.

3. Use of outputs from an AD plant

3.1 Biogas

The biogas produced from the AD plant has a methane content of between 55% and 60%. The remainder of the gas is mainly carbon dioxide and water, together with smaller traces of contaminants, dependant on the feedstock that is used in the digester.

The energy value of methane is $11.2kWh/m^3$ which means that each m^3 of biogas produced will contain $6.72kWh/m^3$ energy. On this basis, $1m^3$ of biogas has the equivalent energy content of 0.55 litres of fuel oil and can be used to replace both oil and electric heating systems.

Biogas can potentially be used in many applications, including the most common:

- Electricity generation in a combined heat and power (CHP), plant also producing heat;

- Fuelling biogas boilers for heating buildings, applications in buildings and for raising the temperature of the vessel digester;
- Transport and commercial and domestic use after conversion to biomethane; and,
- Injection into a national circulation grid after clean up.

The biogas can be used to generate electricity, with some limited treatment to remove moisture and sulphur. The Jersey Electric company will purchase energy from private generators on the Island, at a published price of 6.15/4.59p/kWh (2013) Table 8 Energy costs published by energy suppliers. During the stakeholder interviews, it was indicated that a higher price could be discussed for supplying electricity at peak demand times. This is where the flexibility of an AD plant could be used to provide energy on demand, provided that the gas can be stored short term (in the gas holders) to balance the supply and demand.

Combined heat and power (CHP) units driven by piston engines are available and can be designed to run specifically on biogas quality fuel. These CHP units are easily installed on an AD site. The CHP unit will produce electricity and heat in near equal proportions and the heat generated can be used for building and other site process heating whilst the electricity can be used to either supply an adjacent site, or to feed electricity into the national grid network.

Figure 1 CHP package unit supplied for operation with biogas

Figure 2 CHP generator and heat exchangers

The generation of heat alone may be a viable option - there is the potential to use this heat on commercial operations including the milk processing plant or protected cropping (stakeholder Interviews). However as generating electricity is generally considered to be the most economically advantageous option this has been used in the economic appraisal.

Biomethane for vehicles

Vehicles can be converted to run on biomethane at three levels:

- Dedicated – runs on 100% compressed biomethane or natural gas
- Bi-fuel – runs on 100% compressed biomethane or natural gas but also has a petrol tank if required
- Dual fuel – runs on a mixture of diesel and compressed biomethane or natural gas. Typical ratio – 60:40, gas: diesel.

The energy density of biomethane is such that it requires comparatively large fuel tanks. This means that where tank space is limited vehicle range will be restricted. As a result, biomethane may be best suited to short range vehicles such as buses and local delivery or collection vehicles. Another possibility would be to power those vehicles used to transport feedstock and digestate between farms and the AD plant. More detail is given on running vehicles on biogas in Appendix 8.10.

The current feasibility study is based upon a plant using agricultural wastes and so it might be logical to consider the use of biomethane as a tractor fuel. The use of biomethane in agricultural tractors is currently in the early stages. The Swedish government has actively supported the use of biomethane in vehicles, and possibly leads the development of this area. The Swedish company, Valtra, have developed a biogas fuelled tractor and there was small scale production of a few machines in 2013. The 80kW tractor carries 4 cylinders (168 litres) of biomethane compressed at 200 bar. This is equivalent to 30 litres of diesel or 4 working hours.

An alternative market for biomethane would be as a road transport fuel within fleet operations, such as Jersey's bus company, or a distribution company such as Ferryspeed. Whilst either would have the advantage of providing a single large outlet point, continuity and consistency of biomethane supply would be critically important.

- The Technical and Transport Services who run the bus fleet of 43 regular buses (84 at peak times) estimate that the service uses around 1 million litres of diesel fuel per year (Stakeholder interview), which reconciles exactly with the potential output from Scenario 2 – medium scale AD plant with bottled biogas.
- Ferryspeed provide the main goods transport service for the island. They run a fleet of 65 vehicles, half being lorries (with refrigeration running on diesel) and the remainder light vans (Stakeholder interview).

Either of these operations could theoretically convert part of the fleet to operate on biomethane, and would be interested if there was a price advantage over current fuels (stakeholder interview). The cost of converting vehicles to run on biomethane is in the region of £2,000 for a light van and £25,000 for a lorry or bus. Because of the technical and financial complexity of these particular options a detailed review on the feasibility of biomethane is beyond the scope of this current study and has not been undertaken.

Biomethane grid injection

Jersey Gas import propane to mix with air for distribution around the island to domestic and commercial properties, and the company has stated that this system would not be suitable for biomethane injection (reference stakeholder interview). The Jersey Gas Company also supplies propane gas, and there is a bottling plant in the centre of the island. The plant, which bottles 1,000 tonnes a year (20 tonnes a week), is due to relocate when the lease on the site expires (stakeholder interview). Relocation and reconstruction could open an opportunity for bottling biomethane that would be produced from AD.

LPG

Biomethane has an energy value of 55.53Mj/kg, which is 10% greater than that of propane at 50.35Mj/kg. Biomethane could be compressed and distributed in either bulk tanks or high pressure bottles. The biomethane could be marketed beside propane, which is currently sold on Jersey through in bulk tanks or high pressure bottles.

Digestate

The nutrient content of digestate depends on the specific feedstock entering the AD system. The ratio of total nutrients in the digestate will be similar to that of the feedstock, adjusted proportionately. However the readily available proportion of the nutrients (particularly the ammonium-N) in the digestate may increase compared to the feedstock. Two examples of nitrogen, phosphate and potash analysis from different cattle slurry feedstock and the resultant digestate are shown below in Table 4.

Table 4 Nitrogen, phosphate and potash content of cattle slurry feedstock and resultant digestate (ADAS/SAC, 2006)

	Example 1		Example 2	
	Feedstock	**Digestate**	**Feedstock**	**Digestate**
Dry Matter %	8.10	6.23	7.66	6.76
pH	7.68	7.84	7.35	7.58
	kg/m^3 in fresh sample			
Total N	2.35	1.81	2.23	2.03
Ammonium-N	0.89 (38% of total N)	0.81 (45% of total N)	0.84 (38% of total N)	0.81 (40% of total N)
Phosphate (P_2O_5)	0.90	0.67	0.77	0.74
Potash (K_2O)	3.48	2.62	1.76	1.55
Ratio $N:P_2O_5:K_2O$	1:0.38:1.48	1:0.37:1.45	1:0.38:0.79	1:0.36:0.76

In the examples in Table 4 the increase in the proportion of readily available N (ammonium-N) is relatively small. In a wider literature search carried out for the SEERAD (ADAS/SAC, 2006) report the average increase in the ammonium-N of livestock slurries following digestion was around 26% and the average rise in pH of around 0.4 pH units. The rise in ammonium-N content will be responsible for the rise in pH. The lower increase in pH in the examples is likely to be due to the lower rise in ammonium-N content.

Digestion can also slightly increase the proportion of total phosphate present as water soluble phosphate (readily available phosphate).

AD will typically reduce the dry matter content of slurry by around 25% (slurry dry matter converted to biomethane, a mix of methane and carbon dioxide).

Examples of the nitrogen, phosphate and potash contents of digestate are compared to the standard contents of 6% dry matter cattle slurry and are given below in Table 5.

Table 5 Example of digestate nitrogen, phosphate and potash contents compared to cattle slurry (15th European Biosoilds and Organic Resources Conference & Defra, 2010)

	Dry Matter	Total Nitrogen	Ammonium-N	Total Phosphate (P_2O_5)	Total Potash (K_2O)
	%	kg/m³ in 'fresh' material			
Example digestate from maize feedstock	7.4	4.2	3.0 (71[a])	1.6	4.2
UK digestate derived from:					
Food-based	4.3	7.4	5.9 (80[a])	0.5	1.8
Manure-based	7.5	4.4	2.6 (59[a])	1.4	3.5
Cattle slurry	6	2.6	1.2 (46[a])	1.2	3.2

a) Mean figures % total N

Constraints to spreading digestate to land

Digestates are organic manures with high available nitrogen (ammonium-N resulting from the degradation of proteins) and thus should be subject to closed periods for application, at times of the year when the nitrate leaching risk is highest. The closed period for application on Jersey is 1st October to 31st December inclusive.

Under the 'Environmental Permitting (England and Wales) Regulations 2010, digestate is classed as waste unless it is solely derived from livestock manures and/or energy crops (e.g. maize) or produced in accordance with the requirements of Defra/Environment Agency Anaerobic Digestion Quality Protocol (ADQP). The ADQP requires digestion facilities to go through procedures to show compliance with (and on-going monitoring) for 'PAS110:2010 – *'Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials'*.

In England and Wales if the digestate does not meet PAS110/ADQP requirements the person responsible for application requires a permit for land spreading. This requires the Environment Agency to be notified of the spreading activity on deployment form LPD 1 and an agricultural benefit statement produced by a FACTS qualified person. Fees are applicable. These same rules should be used in the Island of Jersey. Achieving PAS110 status takes a period of actual operational time therefore the AD plant would initially be required to use the deployment form. Digestate spreading could occur under the deployment form, with agronomy support and therefore should not be a barrier to the project.

In the UK the Biofertiliser Matrix (Figure 15 Biofertiliser Matrixhas been proposed to ensure safe use of digestate in agriculture and field horticulture. It applies to PAS110/ADQP feedstock materials. The matrix shown in Figure 15 (Appendix 8.16) is however in draft form and yet to be agreed.

3.2 Impacts of using the outputs on Jersey

3.1.1 Biogas

Biogas storage

The biogas collected from the digester is at a low pressure. The storage capacity required will depend upon the end use of the biogas. A CHP unit with a constant feed of electricity into the grid would have enough capacity to provide a biogas buffer for CHP equipment failure. The storage would be provided in the void space above the digester vessel, as shown in Figure 11Figure 11 Gas Holder Constructed on the Top of Digester Vessel. Stakeholder discussions indicated that the electricity and heat demands for some industrial processes on Jersey (milk processing plant and protected cropping) were irregular. Therefore additional storage would be required in the form of a gas holder dome. One days worth of storage capacity on a typical digester size (illustrated in scenario 1) would be 2,500m^3.

The gas storage construction must comply with Gas Storage Regulations, and associated Health and Safety Regulations. The operator will need to undergo appropriate training; such training is now well established in the UK.

AD sites are required to have a gas flare installed for emergency situations. The flair is to avoid gas emissions to the atmosphere in the event of a prolonged equipment failure. An example of a gas flair is given in Figure 12.

Sale of biogas

Electricity generated from the CHP unit could be sold for industrial use, so the price must be competitive with that of Jersey Electric (14.29p/kwh). A breakdown of energy prices are given in Table 8. An industrial user would have purchasing power to buy electricity at a lower cost from Jersey Electric, which is generally commercially confidential. A 10% saving would make an electric price of around 13p/kWh, which is used in the scenarios.

A CHP plant also produces heat. Both the milk processing plant and protected cropping industry have a considerable use for heat and this could be supplied from the AD plant, replacing the gas that is currently purchased.

Jersey Electric will purchase electricity from private generators at 6.15p/kWh during the day and 4.59p/kWh at night. Stakeholder interviews with Jersey Electric indicate that the company would be interested in buying electricity at a raised price, if it could be produced at peak demand times (the evening). The price is not known, but a figure of 8p/kWh is proposed by the project team to enable analysis of the scenarios.

The biogas could be burned directly in a boiler to provide heat, for a facility or process that requires heat all year around. Initial discussions with stakeholders did not identify a definitive user for the heat. There was interest from protected crop growers, but that would involve a seasonal demand. The price of mains gas in 2013 was 13.04p/kWh to 14p/kWh, depending on usage. The price of gas is given in Table 8.

Gas can be injected into the grid for distribution, following suitable clean up. The main gas system on Jersey is an LPG gas air mix system and Jersey Gas stated that it would not be suitable to introduce biomethane.

Jersey Gas have a plant where they bottle LPG. The plant is to relocate in the near future, which may provide an opportunity to develop biomethane bottling. Jersey Gas could retail compressed biomethane if it was possible to produce the gas at an equivalent price to that of LPG (currently 96.95p/litre).

Vehicle fuel

Biomethane can be used in vehicles. The opportunity would be with fleet vehicles rather than private vehicles. Discussion with the Transport and Technical Services revealed that a new long-term lease had recently been agreed for the bus fleet and so they would not be interested in the additional expenditure associated with converting the fleet to run using biomethane. The main private transport fleet is Ferryspeed. They also operate vehicles which are purchased on lease. However they would be interested in purchasing alternative fuels at a competitive price.

Tractors could be powered on biomethane. Although they are being developed by one tractor manufacturer, they are generally not commercially available. Powering tractors by biomethane is a developing technology and the capital cost of cleaning and compressing gas is very high. Therefore this area would require support from the States of Jersey in order to develop.

3.1.2 Digestate

Digestate storage

With the constraints of non-spreading periods, and the cropping patterns on Jersey, 6 months storage capacity for digestate is advised. The digestate could be transferred from the AD plant to an on-site holding store, as it is produced. All of the dairy farms have stores which are used for slurry. An arrangement could be made, whereby dairy farmers deliver slurry direct to the AD plant; on a daily basis in exchange for the storage of digestate in their existing on-farm slurry store. This would be arranged on an individual case basis and would need further study, as a temporary slurry collecting vessel would be required. In the scenarios, it is assumed that the AD plant enterprise would undertake the transport and spreading back to land of the digestate, at a price of £2/m^3 for transport and £2/m^3 for spreading.

Competition with livestock manures

The nutrient value of digestate is slightly different to undigested livestock manures. Digestate has a higher ammonium-N content, compared to undigested livestock slurry, which, will give the digested slurry a slightly higher manufactured nitrogen fertiliser replacement value. However in the long-term there may be little difference between them in replacement value as there may be a higher residual nitrogen effect from the undigested slurry. The digestate has similar levels of phosphorus to cattle slurry. This is likely to be of negligible significance on Jersey as the soil phosphorus indices are generally high.

Overall there is unlikely to be competition between digestate and livestock manures as the nutrient analysis indicates that they are similar in composition. However swapping slurry for digestate has added benefits in that the digestate is likely to be a more consistent product with a lower dry matter. For example, it should be easier to inject digestate output than undigested slurry. It may also infiltrate the soil faster following surface application.

Land bank requirement for spreading

The process cattle slurry undergoes in an AD plant does not increase the total nutrient content. Therefore if cattle slurry is the only feedstock, the land bank required for the resultant digestate would not increase from the current requirement for cattle slurry. Digestion would only result in an increased land bank being required if:-

- Energy crops (e.g. maize) are grown for co-digestion with cattle slurry. Each 100 tonnes of maize digested would add around 13.3 vergées (2.4 hectares) to the land bank required for spreading organic manures on the island. Assuming an annual permitted total organic manure nitrogen loading of 30kg/vergée (167kg/ha) on arable land of organic manures and that fresh maize contains about 4kg/t of total N.

- Waste potatoes and vegetables are co-digested with cattle slurry. Digesting 100 tonnes of waste potatoes or vegetables would add respectively about 9 vergées (1.6 hectares) or 15 vergées (2.7 hectares) to the land bank required for spreading organic manures on the island. Assuming that waste potatoes and vegetables respectively contain about 2.7kg/t and 4.5kg/t of total N on a fresh basis.

The two examples given above are further detailed in Table 28 in Appendix 8.16. and shows that the estimated additional land bank required for organic manures on the island would be 1,620 vergées (290ha) for scenario 1 - Medium AD plant with CHP. The increased requirement for land bank in scenario 1 - Medium AD plant with CHP represents about 4.5% of the island's farmed area of 37,004 vergées (States of Jersey, 2013[a]). The other wastes that are returned to land are the separated solids from the sewage sludge treatment works which require 1,200 vergées (215ha) and the green waste compost requiring 800 vergées (144ha) (Stakeholder interview).

During the stakeholder interviews, some anecdotal evidence was collated from ten farms as to the land available for spreading digestate. This does not take into account other wastes (excluding slurry) that could be spread to land and could therefore require land bank. The results of the discussions are shown below in Table 6. The interviews indicated that eight out of the ten farms would be prepared to receive digestate and spread it to their land. An estimated total of 25,800 tonnes of digestate could be received by five farms. This represents around 90% of the total digestate output from the medium scale AD plant.

Table 6 Available land bank (derived from farmer interviews)

Farm	1	2	3	4	5	6	7	8	9	10	Total
Amount of digestate that could be taken[1] (tonnes/yr)	10,000	2,500	9,500	600	Interested but area not known	Interested but area not known	0	0	3,200 – 3,700	Interested but area not known	25,800 – 26,300

1 - Assuming 30 tonnes/hectare

Constraints to spreading digestate

The same constraints on spreading slurry to land apply to spreading digestate during the closed periods. This can be addressed by installing storage to hold the digestate until land is available to spread and therefore a risk map for non-spreading areas around boreholes, watercourse etc. should be consulted before the decision to spread is made. Digestate could therefore be considered in the same way as slurry.

The cropping pattern on Jersey limits the application of digestate to two main periods:

- after harvest of the Jersey Royal potatoes and other crops; and,
- pre-planting of crops.

This will be in the spring and autumn months, but before the commencement of the non-spreading date. This is a similar spreading constraint that applies to other organic manures. However, there is an increased opportunity to apply digestate to a growing crop, such as between silage cuts on grass.

Cropping protocols for the Jersey Royal potato could constrain the timing of the application of digestate to fields being planted with Jersey Royals. During discussions with stakeholders some referred to the policy sections in their growing protocols for the spreading of organic manures and composts. None directly specify any restrictions to the spreading of digestate to land going into vegetable production. The growers adopt a documented risk assessment, and do not see any reasons for not applying digestate to land prior to or following a potato crop. The proposed (draft) Matrix for digestate (shown in Figure 15), may be adopted and would limit the spreading of digestate to12 months prior to the harvest interval, unless it is pasteurised.

Benefits to Jersey of spreading digestate

The benefits of spreading digestate to land are:

- The addition of organic nutrients that can be used to replace bagged fertiliser;
- A potential reduction in odour. Digestate is thought to be less odorous than cattle slurry; and,
- A greater window of opportunity for spreading digestate. The digestate is more flowable and can be injected into the soil and thus can be applied to growing crops, such as grass.

4. Economic analysis of anaerobic digester scenarios

The economics of AD plant is dependent on a number of factors including the size of plant and its efficiency, its location, costs of feedstock and value of energy output. This section examines the costs and income from two AD plant scenarios.

4.1.1 Summary of key financial components

Capital costs

Capital cost of a system will be quite site specific, and dependant on a number of factors, but the budgeted capital costs include:

- Planning and license requirements;
- Concrete access road and handling yard;
- The control equipment and a separate building to house controls;
- The feedstock preparation tank and equipment, possibly short term storage (generally a straightforward mixing tank and mixer for small scale farm applications);
- A digester vessel with gas holder positioned in the roof, or as a separate structure;
- A matched combined heat and power (CHP) electricity generator, biogas boiler, or gas clean up and amendment for grid injection or alternative use of gas;
- Provision of storage for energy crops where these are included in the feedstock; and,
- Storage capacity for half the annual digestate volume produced (equivalent to 182 days storage).

Table 7 Average cost of on-farm anaerobic digesters including CHP*

Digester		Capital cost per £/m^3 digester	Capital cost per £/kW installed CHP
1	Average cost of digester with slurry and silage crop for small tonnage less than 4000 t/yr	**£683**	**£6,264**
2	Average cost of digester with slurry and silage crop	**£330**	**£4,048**
3	Average cost of digester with small amount of slurry and mostly crop silage crop with after digester	**£469**	**£4,083**
4	Average cost of digester with slurry and silage crop and food waste with hygienisation	**£636**	**£7,5901**
*based upon eleven UK case studies (Cornwall Agri-food Council, 2009)			

The capital cost of the AD plant, used in the scenarios, have been budgeted using reference to the case studies in table 7 and taking example 3 as the closest match to a suitable system for Jersey. The budgeted costs allow for inflation and have been "sense checked" through discussions with colleagues and trade. A summary of budget costs of capital items can be found in Table 20 (Appendix 8.13).

It should be noted that budgeted costs can vary between suppliers. For example, seven project developers were asked to provide indicative capital expenditure costs for a plant similar to BiogenGreenfinch's plant near Bedford. The developers gave a range of figures between £2 million and £4.4 million, depending on their assumptions.

Energy prices on Jersey

The published energy prices in Jersey for electricity, gas, LPG and road fuel are shown below, in Table 8. These prices are referenced within the economic analysis of the scenarios.

Table 8 Energy costs published by energy suppliers

Energy type	Energy supplier	Description	Energy price
			p/kWh
Electricity	Jersey electric	General domestic and commercial	14.29
	Jersey electric	Economy 7 domestic/commercial	14.99 /7.52
	Jersey electric	Buy back	6.15 – day 4.59 - night
Gas (Propane/air)	Jersey gas	Below 1643 units	14.0
		Above 4,931 units	13.04
			p/litre
LPG	Jersey gas	Liquid Petroleum Gas	96.95
Road Fuel (diesel)	Various	Road Fuel (diesel including fuel duty and GST)	117p/litre
(Goods and Services Tax (GST) 5% applies. Road Fuel tax 46p/litre 2013) High energy users may have a negotiated tariff, related to their demand profile.			

Electricity: Electricity is purchased from EDF in France and imported through one of three undersea cables to Jersey. A ten year agreement between Jersey Electric and EDF was established in 2010.

There is also the capacity on Jersey to generate 7 mega watts of electricity from the energy from waste plant at La Collette (stakeholder interview).

Gas: The gas used on Jersey is a manufactured liquid petroleum gas and air mixture (LPG/air). The St Helier area is supplied via a mains gas system services whilst the remainder of Jersey is supplied via bottled or bulk tank distribution systems.

Vehicle fuel: The 118,838 vehicles on Jersey (States of Jersey, 2012[b]) run primarily on either petrol or diesel with an estimated 150 vehicles running on propane (stakeholder interview). The promotion of electric vehicles is ongoing (November 2013).

4.1.2 Outline of the scenarios

Two scenarios that could be used on Jersey were considered, based on current technology, available feedstock and experience in mainland UK. Detailed assumptions and analysis are given in Appendix 0, and 8.15.

Scenario 1 - Medium AD plant with CHP

- A 3,740m^3 digester vessel;
- Approximately 29,000 tonnes of agricultural feedstock required;
- Biogas used in a variable output 700kWe CHP;
- Providing electricity and heat to an industrial process; and,
- Excess electricity sold to the grid at island peak demand times

Scenario 2 – Medium AD plant with bottled biomethane

- Digester as scenario 1;
- Biogas cleaned and compressed into bottled biomethane; and,
- Biomethane used for domestic and/or commercial heating or transport

4.1.3 Analysis of the scenarios

Scenario 1 – Medium AD plant with CHP

The energy (electricity and gas) would be supplied to a commercial consumer, which could be the milk processing plant, or a protected cropping company (glasshouse or polytunnels). This would potentially replace all of their current purchased electricity and part of the quantity of purchased gas. Energy generated from the AD plant would be charged at a price just below their current energy cost.

To assess the viability of Scenario 1, four economic models have been examined; this is shown in full in Appendix 0. The models show the effects of differing rates of inflation and interest on the financial outcomes of scenario 1.

Scenario 1 is viable and produces a positive cashflow of £327,819 during the 20 year lifespan of the project, or £16,390/year. The figures are accurate, providing that money is borrowed at a low interest rate of 5.5% and allowing for inflation of prices over the project life. Whist the AD plant is viable in that it shows a return, this level of return on a capital expenditure of £2.9m is small, and is unlikely that investors would be interested in the project.

As the location of the site is not known, and ownership of the land cannot be determined, this cost has not been included. The income also relies on the price of energy used in the analysis being achieved, and the waste arriving on site at no cost.

To attract investors to the project, there will need to be support from the States of Jersey, to develop the project with stakeholders. Additional support from the State of Jersey may be required with financing the AD plant which could be through a finance loan at a lower rate, or capital grant support.

Scenario 2 – Medium AD plant with bottling of biomethane

Scenario 2 looked at converting biogas (55-60% methane) into biomethane for use as a transport fuel. As 1m^3 of biomethane is the equivalent of 1 litre diesel, and so the output in this scenario would be equivalent to around 1,000,000 litres of diesel.

After taking into account offsetting the cost of vehicle conversion and the purchase of specialist fuelling equipment the income from scenario 2 is £625,000.

Scenario 2 has a lower income than scenario 1 and higher capital costs; therefore is not an attractive proposition.

5. Conclusions

In order to assess the technical and economic feasibility of AD, a series of key questions were identified to direct the analysis and draw conclusions based on the evidence from the research.

5.1 Is there enough available feedstock for an AD plant on Jersey?

Feedstock is available from a number of sources; slurry produced by the Jersey dairy herd; waste from Jersey Royal potato production; vegetable trimmings and purpose grown maize. Based on the consultations conducted during this feasibility study it was concluded that there was sufficient feedstock to run a medium scale AD plant.

Assumptions

- AD plant with a nominal vessel volume of 3,740m^3;
- This would require 29,000 tonnes of feed stock; 50% slurry: 30% vegetable and potato waste: 20% purpose grown maize (ensilaged);
- This would consume one third of the available slurry and all available vegetable waste, excluding that used for vodka production; and,
- Maize is considered to be the best purpose grown feed stock, although grass and prickly potato would also provide potential alternatives, given further research.

Benefits to Jersey

Disposal of waste Jersey Royal potatoes and vegetable trimmings as feedstock to an AD plant would provide an environmentally friendly alternative to the current practice of spreading back to land and will help the dairy industry by providing an improved liquid manure (digestate) to spread back to land.

The use of a purpose grown crop (i.e. maize) for part of the feedstock could provide an opportunity for an additional income on a number of farms. If the decision of offering a monetary return exchange for the PGC were made by the AD plant enterprise.

Considerations

The supply of slurry to a medium sized AD plant relies on the cooperation of the dairy farmers. In the two scenarios the slurry is to be delivered at no cost to the AD plant. The benefit to the farmer will be the return of beneficial nutrients to land, which would be managed and spread by the AD plant enterprise. Delivery of the potato and vegetable waste will also be carried out by the farmer at no cost to the AD plant. Provided that the location of the AD plant is convenient, will be a benefit to the farmer over the current practice of returning potatoes to land.

5.2 Is there scope to utilise the energy generated from an AD plant?

Biogas use

The energy produced must be generated at a competitive price to the price of other forms of energy available on Jersey.

The AD plant will produce biogas that is used to produce electricity and heat. To optimise the output from the AD plant it is important that it is positioned in close proximity to a main user of the heat, and also power.

The electricity and heat generated by the AD plant would need to be sold at a lower price, to the industrial or agricultural process, than the retail price set by Jersey Electric or Jersey Gas. Whilst remaining economically viable for the plant. A sale price of 13p/kWh for electricity and 5.5p/kWh for heat is used in the analysis.

Additionally, the electricity generated could be exported to grid. There is a published buy back price of 6.5p/kWh day and 4.59p/kWh night and Jersey Electric have indicated that a higher price could be paid if supplied on demand at peak times. This figure would not be disclosed but 8p/kWh is used to generate a budget.

Potential users of the biogas include;

- The milk processing plant – due to the requirement for both heat and power.

Future developments

There is also an opportunity to produce the biogas in a compressed and bottled form that can be distributed and used in a wider market for domestic or commercial use, or for transport. Whilst this technology is available, it is in early stages of development, is relatively expensive, and will require further research and development in the marketing and use of the compressed gas.

Other considerations

The use of biogas for powering vehicles is not currently deemed economically viable where there is a requirement to convert existing vehicle fleets to run on biogas. However, where conversion is not required, this is a market which is attracting interest and could be developed on Jersey with government support.

5.3 Is there enough land bank to receive the AD derived digestate?

There were 37,004 vergées of agricultural land on Jersey in 2012. Based upon the 27,500 tonnes of digestate produced annually by a medium sized AD plant, the land bank area required is calculated at 1,620 vergées, or just over 4% of Jersey's total agricultural area.

Digestate must also be spread within the environmental constraints (e.g. not close to boreholes or watercourses, not exceeding crop nutrient requirements or allowable application rates and within cropping plans and growing protocols of the food markets). Within these constraints and from discussions with a limited number of growers, it was felt that growers on Jersey could provide the required area of land. However if the supermarkets were to insist upon a break period (of around 12 months) between spreading digestate and harvesting Jersey Royal potatoes, the land area may not be as easily guaranteed. If this situation were to arise, pasteurisation of the digestate would surmount the requirement of a break period.

For consideration

- Digestate applications must not compete for land with other wastes that go to land e.g. water treatment works digestate and green waste compost;
- The digestate will provide a very useful source of plant nutrients, with similar values to cow slurry, but with more availability of the nutrients, and so will enable growers to make better use of the nutrients in their annual cropping calculations; and,
- There is also an opportunity with digestate to separate out some of the solids to produce a separate solid product, amounting to about 10% of the digestate quantity, which could have different application, and would be easier to transport further distances from the AD plant.

5.4 Would an AD plant be economically viable in Jersey?

There is no financial support either in capital funding, or renewable energy incentives. Therefore any AD plant established on Jersey would need to optimise the financial return on the sales of energy at competitive commercial prices. The economics of the AD plant are affected by the cost of generating the feedstock supply to a digester. Therefore it is anticipated that the feedstock of waste from agriculture will be delivered to the plant at no cost in exchange for the beneficial return of the digested product to land as a liquid fertiliser. The purpose grown crop (e.g. maize) for the AD plant would be purchased from the farmer at the cost of production (£25/tonne).

The AD plant from scenario 1 (medium scale with CHP) be would be marginally viable based on the following (further economic details are given in the appendix 0):

- Medium size AD plant - 3,740m^3 digester vessel volume;
- Approximately 29,000 tonnes of agricultural feedstock required and provided free of charge in exchange for digestate delivered to farmers door;
- Farmers paid £25/tonne for purpose grown maize delivered to AD plant;
- Biogas used in a variable output 700kWe CHP;
- AD plant needs to be situated in a location where it provides electricity and heat directly to an industrial process. The price for the electricity sold to the industrial

process would need to be less than the commercial price for heat (5.5p kWh) and electricity (13p kWh) in order to be competitive; and,

- Excess electricity sold to the grid at peak demand times on Jersey (8p/unit).

Scenario 1 (medium scale plant with CHP) is more viable and produces a positive cashflow of £327,819 during the 20 year lifespan of the project, compared to scenario 2 (medium scale plant with bottled biogas)

Due to the low level of return shown in scenario 1 the States of Jersey will need to support the development of an AD plant. Support will be required in terms of:

Developing the project by engaging and managing stakeholders; and,

Financing the AD plant which through a finance loan at a lower rate, or capital grant support.

5.5 Summary

There is adequate feedstock available to run an AD plant on the Island of Jersey and sufficient land bank available to spread the resultant digestate. Financially the project could be viable, although at low returns. To attract an investor who would look for higher returns, support from the States of Jersey will be required. The assumptions used for the energy prices expected for the AD plant must be further investigated.

6. Recommendations

This study has established that there is a positive level of support coming from the agricultural community on Jersey. There is adequate feedstock to supply a medium scale (29,000 tonnes) AD plant on Jersey, along with adequate land bank to return the digestate back to land. The location of an AD plant is yet to be determined (and was beyond the scope of this project), but should be close to an industrial heat or energy user. From the discussions with stakeholders a few potential users were identified. In order for AD plant to be viable the user should have a central location on Jersey, which is convenient for the movement of feedstock and digestate.

A medium scale AD plant with CHP is economically viable, although returns are considered too low to attract a commercial investor. Support from the States of Jersey will be needed to progress the project.

The next steps for the States of Jersey to make further investigation into are:

1. Income from energy. Establish the actual supply quantity and price that an industrial process (Jersey Dairy) and Jersey electric will pay for the energy. This will require an energy audit for the industrial process, and commercial price negotiation for energy process;

2. Feedstock security. To establish actual feedstock quantities, a survey of the identified feed stocks is needed, followed by setting up the terms of supply agreement, and then implementing agreements;

3. Review the project economics, based on the refined information (from 1 & 2 above);
4. Secure site. The use of the energy close to an industrial process will dictate a location. Actual site location, its ownership and cost, and implications on planning needs to be determined; and,
5. AD equipment supply. Prepare a specification of equipment. Present to three suppliers to provide build cost.

Additional associated research work that is required is to investigate the viability of prickly potato as a feedstock.

7. References

15th European Biosolids and Organic Resources Conference

ADAS/SAC (2006) report for the Scottish Executive Environment and Rural Affairs Department (SEERAD) on the Nutrient Value of Digestate from Farm-Based Biogas Plants in Scotland (CR/2006/17)

Cornwall Agri-food Council report (): Economic Modeling of Anaerobic Digestion/ Biogas Installations in a Range of Rural Scenarios In Cornwall

Defra (2010). Fertiliser Manual – RB209. 8th Edition

Stakeholder Interview (20 in total – breakdown Table 1)

States of Jersey (2009) Water Pollution (Code of Good Agricultural Practice) Order

States of Jersey (2012a) Pathway 2050: An energy plan for Jersey

States of Jersey (2012b) Jersey in Figures, 2012

States of Jersey (2013a). Agricultural Statistics 2012.

States of Jersey (2013b) SAP3 Cross Compliance

8. Appendix

8.1 Background to AD technology

The following section describes types of digesters that are in use and their characteristics. It also describes the components that make up an installation that is able to utilise feedstock from farm and external origins, but excluding commercial and industrial wastes.

History

The chemical and biological degradation of organic material is a natural process. Historical records indicate that the industrialisation and exploitation of AD started in Bombay in India in the mid C19, and appeared in the UK in 1895 when biogas from a sewage works was recovered and used to run street lights in Exeter.

The relative cost of coal and petroleum products have made biogas production less attractive in developed countries. More recently the technologies have developed and the main drivers behind the development in European countries are:

- Energy production - the increasing price of energy, and
- Waste treatment - increasingly stringent environmental regulations.
- Fertiliser value – increasing cost of fertiliser, and benefits of organic matter
- Greenhouse Gas – production of energy from AD treatment of waste contributes to a reduction in GHG

The chemical process of anaerobic digestion

AD is a process which uses a culture of microbes in an air excluded environment to digest non-cellulosic substances in organic matter and in the process releasing carbon dioxide (CO_2) and methane (CH_4). The equipment that is used to control and enclose this process is very varied. The chemical process is described below and the equipment packages are discussed in section 5.3.

The four biochemical phases are:

- 1. **Hydrolysis** is the process that breaks down the long chain carbohydrates into simpler soluble organic compounds (such as glycerol). This is the step in AD that takes longest so determines the retention time to be held in the digester vessel.
- 2. **Acid Fermentation**. Bacteria then break the compounds down directly into Acetic acid
- 3. **Acetogenesis.** If not broken down directly to acetic acid, it is first broken down to propionic butyric acid and long chain Volatile Fatty Acids.
- 4. **Methanogenesis**. The hydrogen then binds with carbon molecules released from the acid digestion to make methane.

The speed of the chemical process, and the efficiency of converting to gas, is dependent firstly on the composition of the feedstock mixture, and secondly on the temperatures, and conditions within the vessel which is a function of the design. The time over which the material is held in the digester is termed the ‘retention period’

The products of anaerobic digestion

The processed material is termed digestate. It should be understood that the total reduction of feedstock volume can be small, especially for wet systems where the water remains, but the amount of organic matter will fall having been converted into methane and carbon dioxide which forms the gas mixture termed the ‘Biogas’.

The Biogas product is primarily 55%-65% methane (CH4) with the balance carbon dioxide (CO_2) together with some minor gases such as hydrogen sulphide and ammonia and some moisture. Pre cleaning can make this gas suitable for use in combustion engines used to generate electricity, or in a thermal boiler. With further and more expensive treatment this can be further upgraded to be added to gas supplies.

Anaerobic Digester classification

There is a range of types of anaerobic digester available commercially which enables an operator to select the most appropriate system to meet specific conditions and objectives. These variables are:

- Variations of different feedstock – moisture content, chemical composition
- Space available – vertical and horizontal space
- Existing infrastructure – storage and preparation facilities, grid and heat connection.
- Throughput required – affected by the retention time needed by the process.
- Value of respective outputs - gate fee of feedstock, electricity and heat output, digestate value.

The digester could operate either in a ‘Mesophilic’ or ‘thermophilic’ temperature range. For agricultural situations, the mesophilic system is most commonly used, operating at 25 to 45^{o}C, using mesophilic bacteria and requires a longer period in the digester and releasing gas at a slower rate. A thermophilic digester operates at 50 to 60^{o}c and requires less time in the digester and releases gas at a higher rate. Comparison of the two is given in Table 9.

Table 9 Comparison of mesophilic and thermophilic anaerobic digestion systems

	Mesophilic	Thermophilic
Temperature	25-45°C	50-60°C
Digestion(retention) period	20-60 days	12-18 days
Gas production /unit feedstock	Lower	Higher
Space required	Higher footprint, or taller	Lower footprint
Pathogen Kill	Good	Better
Management requirement	Lower	Higher
Capital Cost and operating cost	Cheaper	Dearer
On Farm	Most common	Less likely

Single stage and multi stage digester

As the complete digestion process has four biochemical stages, there is an advantage in providing separate conditions (pH temperature etc) for each stage by providing digester vessels in sequence.

In the acetogenesis stage the formation of acetic, lactic and proprionic acid lowers the pH of the digestate. A pH below 6.4 can be toxic to methane forming bacteria which have an optimum pH of between 6.6 and 7.0. The pH should thus be maintained between 6.5 and 7.0. The minimum stages in a multi stage digester therefore is two, with the first stage for Hydrolysis and acetogenisis and the second for parthenogenesis, and some systems will have further stages to improve efficiency.

Consequently higher gas per m^3 feedstock can be achieved in multiple vessel processes, but this has to be balanced with higher operating and management costs as well as a greater set-up capital requirement. Most UK farm systems will be single or double stage digesters.

Table 10 Comparison of single and multi stage digestion

	Single	Multiple
Gas production /unit feedstock	Lower	Higher
Space required	Less	More for multiple digester

Maintenance	Lower	More
Management requirement	Lower	Higher
Operating cost	Lower	Higher for more pumping and heating
Capital cost	Cheaper	Dearer for more digester vessels, controls and pumping equipment

Farm Digester Systems

Digester principles and associated machinery increase in their complexity and capital cost according to requirements for feedstock, processing and recycling and marketing options for the biogas. For farm based systems, simple and proven designs are recommended.

The characteristics of the digesters have been described above. The farm based digester selection is influenced by the typical materials and feedstock that are available on farm. The availability of slurry will mean that there is a considerable volume of liquid that can be digested. Also the dry matter of farm grown energy crops is in the range 25-30%. Therefore a combination of slurry and energy crop will result in the need for a low solids digester.

This also fits with the current practice for managing slurry on the farm so that it is compatible with the existing storage system tanks and lagoons.

System simplicity has much to commend it so processing of slurry and energy crop feedstock types will be much easier than in systems that import feedstock with no need for pasteurisation of imported material. The permitting of the process, planning and general management will be much simpler in a farm based system.

Components of a farm feedstock Anaerobic Digestion system

The digester vessel is at the heart of an anaerobic digester system, but each system is made up of a combination of components, with the digester vessel at the centre.

Figure 3 Illustration of a typical farm scale (wet) AD process

The type of equipment, the scale, and number of individual components is very dependent on the objectives to be achieved. The five stages of the process are illustrated in Table 11.

Farm waste exclusive digester systems generally require the main components set out in Table 11and essential pre treatment and post digestion facilities (first row in Table 11). If the Site wishes to import other materials then those components may require additional treatment in order to comply with planning and environmental permitting. There is also a need to record the volumes processed for revenue quantification and regulatory dictates. The marketing benefits of complying with accreditation will also have an administrative requirement.

Table 11 The five stages of the anaerobic digestion process

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	
	Feedstock preparation / treatment	**Digestion of feedstock**	**Digestate storage and use**	**Gas storage and use**	**Gas use**	**Administration**
For on farm wastes (slurry and silage crops)	• Storage tanks (liquids) • Bunkers (solids/silage) • Mixer tank (liquids) • Mixer pump • Feed mechanism / pump to digester • Weight / volume measurement Additionally for silage • Mixer wagon (solids)	• Digester vessel • Insulation • Agitators in the digester • Gas relief valves • Heat exchangers • Monitor equipment • Controllers	• 6 months covered liquid storage • Store agitation • Solids separator • Solids storage • Pumping system • Land spreading equipment Or • Solids separator • Liquid treatment for sewer discharge	• Gas holder • Gas scrubber (dependant on use) • Biogas filter • Gas flare	• CHP unit • Electricity grid connection • Cables Or • Boiler • Heat exchanger • Piping Or • Gas treatment • Compress and bottle / Grid injection	• Office • Laboratory facility • Metering and recording
Additional components for imported waste	• Weighbridge • Enclosed reception hall • Air extraction and biofilter • De- packaging • Shredder/mixer • Sterilisation / pasteurisation • Hydrolysis					• Gate fees processing • license and permit • PAS 110 • AD protocol

Anaerobic Digestion stage 1 feedstock preparation

Feedstock storage

The AD process will operate most efficiently with an even flow of feedstock.

Liquid feedstock storage

If using cow slurry there will be a difference between the daily productions of slurry when livestock are housed in the winter compared to the summer when just parlour and collecting yard slurry accumulates. Consideration should be given to providing buffer storage.

Existing farm storage of an earth lagoon or concrete/steel above ground storage will be suitable, and if installing new storage, a covered store specification is recommended to minimise gaseous emissions.

If importing liquid waste the delivery load volume is likely to exceed the daily loading of the digester and short term storage of several days to one week capacity may be appropriate.

Solid feedstock storage

If growing crop as feedstock, storage will be required to hold the crop out of season. Grass and maize crop can be placed directly into the digester during the growing months, but 11 months storage will be required for ensiling maize, and 8 months for grass. In the UK, silage clamps must be constructed to SAFFOS standard (Silage slurry and agricultural fuel oil Regulations).

If importing solid waste such as vegetables and potatoes then some short turn storage bunker will be required to buffer the delivery volume against the digester demand.

Feedstock mixer

Animal slurry can be deposited in a below ground tank and mixed with a high capacity chopper pump to also be used to transfer into the digester.

Dry waste such as silage can also be introduced into the pit with animal slurries to decrease the dry matter (to around 12%DM) and once mixed and homogenised can be transferred to the anaerobic digester.

An alternative with energy crops is to use a feed wagon which will chop and deliver the feedstock such as silage directly into the digester. This will be a lower cost than using a mixer tank, but may affect digester efficiency if the material does not break apart and mix completely in the vessel.

Figure 4 Fixed feedstock mixer for small scale on farm AD

Weighing equipment

Knowledge of the quantities of feedstock and feed rate into the digester will provide the operator with greater information on which to base management decisions for the digester. A stamped weighbridge to customs and excise standards is recommended to keep a register in input materials arriving from different sources.

Figure 5 Full size vehicle weighbridge, with reception hall

Reception hall

Where waste is imported to the site additional facilities, mainly associated with environmental and health risk control, are necessary. It is unlikely that either planning permissions or an operator's permit will be obtained without them. Imported waste which could be in a state of decomposition on arrival may present odour issues. For imported wastes a reception building which is large enough to receive a delivery vehicle with doors closed, and tall enough to allow tipping would be ideal. This should therefore be a minimum 10m span 15m long with 6m eaves. For agricultural materials, an enclosure would be adequate, but if odorous materials are imported the reception hall will require positive air movement to create a negative air pressure within the building, and to pass the exhaust air through a bio filter.

Sterilisation / Sanitisation

Waste imported and classified as category 2 or 3 waste under the Animal By Products Regulation must be sterilised. These wastes are not considered in the agricultural waste digester.

Anaerobic Digestion stage 2. Digestion equipment

Fermentor vessel

The primary structure for the AD process is the digester vessel used to hold the feedstock during the digestion period.

Wet AD digester vessel

The most common process for farm feedstock digesters is the wet system. The primary feed stocks will generally include animal manure in slurry form which will have high moisture content with solids content of between 6% and 10% which is most suited to wet AD. The vessels are constructed above ground, and are usually circular structures constructed of concrete panels, or coated steel / corrosion resistant steel panels with integral roof. A continuous insulation layer is installed on the outer surface to help to retain the raised temperature of the digestate with minimal heat loss. The vessel usually has some heating pipes installed on the floor of the vessel to maintain the design operating temperature of the digestate and optimise digestion rate.

The digestate must be agitated to optimise the mixing of feedstock as it is introduced into the vessel, and to maintain consistency of digestion. Electric driven impellor agitators fixed to the structure walls are used on programmable cycle to provide periodic operation. Using a compressor to inject gas, usually the biogas produced from the process, through pipes in the base of the vessel is an alternative method of agitation favoured for the low energy requirement and low moving parts.

Figure 6 Wet AD Digester Vessel

Anaerobic Digestion stage 3. Digestate storage and utilisation

Digestate storage structures

In almost all AD installations on farms the digestate will be used as an organic fertiliser to be applied to crop on land owned by the farm, or on neighbour's farm land. Storage of the digestate will be required to allow application of digestate to crops outside of the non spread period of Nitrate Regulations, and also to allow application at the optimum window for the crop. The volume to be stored will generally be a minimum 6 months capacity.

A great benefit of the AD process is the stabilisation of the organic matter in the digestate matrix, and resultant reduction in odour emissions. It should not be assumed that the digestate will be totally odourless. There is an economic limit to the retention period in the digester when gas yields decline, and the total digestion may not be complete. This needs to be considered in the type and location of storage.

Liquid digestate storage

The storage for liquid digestate should preferably be covered to control emissions. On farms with suitable soil types to provide an impermeable lining, an earth lagoon provides a very economic solution. A more secure solution is to construct a circular or rectangular above ground store with steel or concrete panels, and incorporate a cover on the store.

Figure 7 Covered and uncovered circular store for digestate storage

Dry digestate storage

The separated solids fraction from wet digestate process will be a stackable product. The material should be stored on an area where it can mature by natural compost process. Provided the area is located away from drains and ditches, with no risk of runoff, then temporary field clamp storage can be used. These must be in a different location for each 12 month production. A lower risk solution would be a store on an impermeable concrete base with drainage to collect the free liquid and rainfall on the area.

Figure 8 Solid digestate maturing in windrows on a secure concrete storage area

Solids and liquids separators

Management of liquid digestate can be improved with separation of the solids from the liquids. Liquid digestate with the solids separated out will be easier to handle in store reducing the need to agitate to mix when emptying the structure and removal of solids will reduce the risk of odour. The separated solids are easier to store on the farm, and could be transported to areas where access for liquid spreading would be more difficult. Slurry separators can typically remove up to 10% of the volume of liquid digestate thus reducing the liquid storage capacity.

Figure 9 Solids and liquid separator for digestate

Digestate applicators for land spreading

Digestate can be spread to land through standard agricultural manure and slurry spreading equipment. Experience indicates that whilst odour emission from digestate is much reduced compared to farm wastes, there may be some odour when spreading to land. Broadcasting equipment will be acceptable in low risk odour areas. Surface application using dribble bars, or injection into the soil is the preferred method to not only improve accuracy of placement for the fertiliser value, but also for reduced risk of odour emissions. This equipment requires high capital investment and will normally be carried out by a contractor who will spread the digestate to land once or twice per year dependant on cropping.

Figure 10 Surface Applicator for Digestate Application to Crops

Anaerobic Digestion stage 4. Biogas collection, storage and treatment

Biogas holders

Depending on the use of the biogas generated from the AD process, a store for the biogas will provide a reservoir and buffer to even the supply and the demand. Small on farm AD installations will have a flexible container secured on the top of the digester vessel which will provide an economic store with minimal ground footprint.

Larger installations that may require more flexibility for the gas use can have a separate gas holder mounted on the ground on a separate base.

Figure 11 Gas Holder Constructed on the Top of Digester Vessel

Biogas flare

When there is excess gas production or at early stages of operation the quality of the biogas produced is not good enough for the use (CHP or boiler). Release of the biogas into the atmosphere is to be avoided from a safety and global warning aspect. It is necessary to combust the gas in a process flare. These must be located away from enclosed structures and be securely fenced

Figure 12 Flare system alongside the gas storage

Technology providers

The AD project can be approached by building the individual components supplied from a number of different specialist equipment suppliers to match the exact requirements of the site and the feed stocks to be digested. This requires a considerable level of engineering, microbiological and project management experience.

In the past 30 years there has been a considerable development in companies which specialise in manufacture and installation of AD in the UK , and in the continental European countries where the economic climate has encouraged the development of AD.

8.2 Pre-discussion document and survey

Feasibility Study of Anaerobic Digestion in Jersey

Data Collection prior to discussion meetings

There is considered to be scope for recycling of organic waste from agricultural, horticultural and food operations on Jersey, and this project seeks to provide detailed assessment of the feasibility of using these wastes, together with possible crop supply as feedstock for anaerobic digestion (AD).

The aim of the project is to:

- quantify the volumes of feedstock that would be available
- quantify the available area of land to spread digestate to
- highlight potential sites for an AD plant
- determine whether there is stakeholder interest in running an AD plant

Prior to our meeting, I would appreciate it if you were able to take the time to answer the below questions. The answers to the questions will structure the discussions with you, along with saving you time when we meet.

Any answers are given in confidence and will be kept in confidence. No information will be used without your consent. The volumes of digestate and land area will be used as an indication and are in no way a commitment.

If you have any questions, please feel free to contact me.

Alice Willett	or	Tom Brassington
01954 268229		01234 826343
07785 278833		07836532562
Alice.willett@adas.co.uk		Tom.brassington@adas.co.uk

Name:	
Business name:	
Address:	
Telephone no:	
Mobile no:	

Email address:		
		Please tick
Main business interests:	Farming - Arable	
	Farming - Dairy	
	Farming - Horticulture	
	Retail	
	Waste management	
	Energy production	
	Processing/distribution	
	Other – Please state:	
Land area?	Please state the units (vergées, acres or hectares)	
Owned:	Rented:	

1. **Feedstock**

a) Do you have feedstock that could feed an AD plant?

	Type	Please tick	Description	Quantity (tonnes or vergées etc)
	Manure			
	Potato waste			
	Vegetable waste			
	Other waste			
	2nd crop			
	Cereal crops			
	Energy crop (e.g. maize)			

	Other			

b) Would you consider providing feedstock to an AD plant?

Yes ☐ No ☐

If yes, what do you perceive the benefits to be?

If no, what are the barriers?

We are interested in the production/supply costs and would like to discuss this when we meet. Any comments here will be helpful

2. Location of an AD plant

a) Is there a location that you think would be good for sighting an AD plant? Possibly in relation to your business

b) Would you be interested in having an AD plant at your business?

Yes ☐ No ☐

c) Please give your reasons below:

d) If you are interested in having an AD plant, what (if any) would be your barriers to sighting it? (e.g. planning issues, perceived odour, access, visual impact, land availability, finance, neighbours etc)

e) Would you be interested in providing labour and skills to run an AD plant if it was located with/near you?

Yes ☐ No ☐

Please give your reasons below:

3. Digestate recycling

a) Would you consider taking digestate to spread to land?

Yes ☐ No ☐

Please give your reasons below, including any barriers (e.g. housing nearby, disease, sloping land, cropping, difficult access to land etc):

b) What do you perceive as the benefits of digestate to you (nutrients, organic matter, sustainability policy etc)?

c) Do you currently spread or bring in any other organic manure/material on to your land (e.g. sewage sludge, other wastes etc)?

Yes ☐ No ☐

If yes, what?

If no, what are your reasons?

d) Do you have an estimation of the quantity of digestate you could use? Assume 30 t / ha

e) Do you have any concerns about spreading digestate to land (nutrient planning, machinery availability etc)?

4. Energy use

a) Do you have a use for energy at your business?

Yes ☐ No ☐

What kind of energy use do you have (heat, electricity, transport etc)?

b) Do you envisage having a need for energy in the future (e.g. new business area)?

c) What quantity of energy do you use?

5. Any other relevant comments?

8.3 Interview structure

DATE:

LOCATION:

PEOPLE INVOLVED:

Tom Brassington ADAS UK Ltd

Alice Willett ADAS UK Ltd

Company name

Main business interests:

Table 12 shows the breakdown of owned and rented land.

Table 12 Land Area

Total land area:			
Owned:			
Rented			

Feedstock

Feedstock Type	**Description**	**Volume**

Confirm feedstock with pre-discussion questionnaire

Digestate recycling

Energy Use

Location for AD Plant

8.4 Livestock numbers for Jersey

Table 13 Livestock numbers for Jersey

Sector		Number
Dairy	Total cattle	5,152
	Cows & heifers in milk	2,931
Beef	Under 12 months	170
	Over 12 months	139
Other cattle		50
Pigs	Total pigs	452
	Breeding sows	73
Poultry	Laying hens	25,418
	Broilers	5
	Other table fowl	823
Sheep	Total sheep	1,074
Goats	Total goats	20

8.5 Field crop areas for Jersey

Table 14 Field crop areas for Jersey

	Total Area (Vergées)
Grassland	19,004
Hay (1st, 2nd & 3rd cut)	1,439
Silage (1st, 2nd & 3rd cut)	5,699
Haylage (1st, 2nd & 3rd cut)	776
Forage maize	1,891
Other livestock feed	316
Cover crops/green manures	5,483
Total cereal cropping	1,770
Barley	1,021
Oats	12
Wheat	260
Cereal crops only for straw	477
Total outdoor fruit/vegetables (including potatoes)	20,766
Total potatoes	18,670
Jersey royal potatoes	17,992
Autumn earlies	51
Other potatoes (including main crop)	627
Total outdoor fruit/vegetables (excluding potatoes)	2,096
Cabbage	397
Spring courgette	256
Leeks	188
Carrots	110
Tomatoes	0
Top fruit	192

8.6 Glasshouse and polythene crop areas for Jersey

Table 15 Glasshouse and polythene crop areas for Jersey

	Total area (m^2)
Total glasshouse area	291,506
Over 15 yrs old	217,655
Not cropped in 2012	41,875
Fruit and vegetables	173,932
Tomatoes	28,495
Ornamentals (including bedding plants)	105,345
Bedding plants	97,844
Polythene production	223,808
Heated	33,859
Not cropped in 2012	19,484
Polythene production	223,808
Fruit and vegetables	72,405
Potatoes	120,061
Ornamentals	31,342
Outdoor flowers	1,005

8.7 Total estimated anaerobic digester feedstock

Table 16 Estimated anaerobic digester feedstock from stakeholder interviews

Farm	Waste potatoes (Jersey Royal)	Waste potatoes (Main Crop)	Vegetable waste	Maize	Other waste (grass, prickly potato)
	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes
1	3,000 – 7,000			6,670 – 8,900[1]	2,400 – 3,600[2]
2	250				200
3	1,300 – 2,000				
4	700		1,000		10
5	Unknown	Unknown	Unknown	Unknown	Unknown
6	100				
7					5 – 10[3]
8					55 – 70[4]
9		50[5]	50[5] – courgette		
10		600	680[6]		100
Total	5,350 – 10,050	650	1,730	6,670 – 8,900	2770 – 3990

1 - Based on 7.3 tonnes/vergée

2 - Prickly potato 60 hectares grown at 40 – 60 tonnes/ha

3 - End of crop waste and pruning

4 - Grape & apple pulp

5 - Total of 100 tonnes from main crop potatoes and courgettes – assumption made of a 50/50 split

6 - Waste vegetable peelings 0.5 tonnes/day x 360 days. Cabbage waste – 500 tonnes/year

8.8 Jersey Royal planting to packing cycle

The planting to packing cycle for Jersey Royal potatoes is as follows:

- Jersey Royals planted (by hand) – 1st week of January
- Harvest begins (by hand) – late February to June
- Small and diseased potatoes discarded in the field at grading
- Potatoes taken to on-farm grading lines (out-sized discarded and hauled back to fields for disposal)
- Taken to pack house for washing and grading (further potatoes and washing discarded)
- Animal manure, compost/sewage sludge/slurry/seaweed etc spread (if desired)
- Second crop planted

8.9 Assumptions for the calculation of estimated dairy slurry

The assumptions used to calculate the values given in Table 17 and Table 18.

- The number of dairy cows in 2012 was 2,931 (Jersey States a, 2013)
- The standard figure for excreta from cattle using the NVZ leaflet 3 reference is used to calculate the quantity of slurry
- Cows are housed in buildings for 5 months
- Cows are out to grass for 7 months, but a 40% proportion of excreta is collected when milked.
- Young cattle may be on straw bedded yards rather than slurry but the excreta volume is included

Table 17 Estimate – Dairy slurry 2012

Livestock type on slurry based system or part slurry system	Number of stock on slurry or part-slurry based system	Volume per livestock type (or place) per month (m3)	Daily volume	Volume produced each winter month (m3)	Volume produced each summer month	Volume produced each 5 month winter period (m3)	Volume produced each 12 month
Dairy cow after first calf (less than 6,000 litres milk yield)	2931	1.26	121.4	3,693	1,477	18,465	28,806
1 beef cow or steer from 13 months and less than25 months	1004	0.78	25.7	783	-	3,916	3,916
1 beef cow or steer (castrated male) from 3 months and less than 13 months *	597	0.6	11.8	358	-	1,791	1,791
1 calf (all categories) up to 3 months *	199	0.21	1.4	42	-	209	209
			160.3	**4,876**	**1,477**	**24,381**	**34,721**

Table 18 Estimate - Dairy parlour wash water 2012

Wash water	Number of cows	Wash water per day	Wash water per month	Wash water in 5 month
Litre per cow per day		litre	m3/month	m3
20	2,931	58,620	1,783	8,915

8.10 Biomethane for vehicles

The experience of cleaning and distributing biogas for biomethane use in vehicles, or remote locations where compressed bottled gas is used, is varied. Certain countries, such as Sweden, have invested in the infrastructure. In other countries, including the UK, the biogas industry is at the early stages of development, and the infrastructure for cleaning and distributing biomethane for vehicles has not been invested in.

However, this is developing and in the UK the government has provided £88 million in grant aid through the Green Bus scheme. In the previous year Reading Transport and Stagecoach North East invested in 54 single decker buses running on Biomethane. There has been greater development in Compressed Natural Gas (CNG) vehicles, where natural gas from the Gas Grid is used.

There has also been an increased interest in cleaning biogas for injection into the National Grid. There are existing operational sites in Dorchester (Poundbury) and Suffolk (Southwold). Further sites are under development in Merseyside (AD site taking food waste) and Suffolk (AD site using energy crops).

Valtra are currently working in collaboration with the Swedish Government on a joint project (MEKA) to develop the use of biogas in agriculture. The associated legislation is also being considered within the scope of the MEKA project.

Figure 13 Preparing biogas for use in vehicles

In the spring of 2010 a trial of a mobile gas filling station, to fuel commercial vehicles began with some of Sheffield Council's light vehicles. The gas was supplied under high pressure in a special multi-cylinder road trailer (conforming to bulk gas transport regulations) show in Figure 14. This was established at one of the Council's vehicle depots where it was linked to a refueling module, to partially decompress the gas and dispense at a pressure of 3 bar through a pump to the vehicles. Accurate records were kept of fuel use and the emission levels were closely monitored. Vehicles operating on gas included VW Caddy light vans. These were converted for dual fuel operation but, increasingly, vehicle manufacturers around the world are producing models designed from the outset to run on gas.

Figure 14 Multi-cylinder road trailer

8.11 Draft Digestate Matrix

DRAFT: Biofertiliser Matrix (PAS110/ADQP input materials) – agriculture and field horticulture

Crop type		Pasteurised+	Not pasteurised
Ready to eat	Salad and soft fruit	✓ before drilling/planting	✗ 12 month harvest and 6 month no drilling interval applies
	Top fruit	✓ before drilling/planting	✗ 12 month harvest and 6 month no drilling interval applies
Vegetables		✓	✓
Grassland and forage		✓[a] 3 weeks no grazing period and harvest interval applies	✓ 3 weeks no grazing period and harvest interval applies
Combinable and animal feed crops		✓	✓[b]

+ Pasteurisation process compliant with animal by products regulations (SI 2347 – 2005; SRNI 495 – 2003; SSI 411 – 2003; WSI 1293 - 2006)

Notes: a) 2 months no grazing period for pigs

b) If feedstocks contain maize, biofertiliser applications should be ploughed into the soil before cereal crops

Figure 15 Biofertiliser Matrix

Ready to eat		**Vegetables**	**Combinable and animal feed crops**	**Grassland and forage**
Salad and soft fruit	**Top fruit**			
Soft fruit (currants and berries etc.)	Apples/pears etc.	Potatoes	Wheat	Grass
Lettuce and leafy salads	Plums/cherries etc.	Leeks	Barley	Maize
Radish	Vines	Sweetcorn	Oats	Hay
Onions	Hops	Brussels sprouts	Rye	Haylage
Beans	Nuts	Parsnips	Triticale	Swedes/ turnips
Vining peas	*Etc.*	Swedes/ turnips	Field peas	Fodder mangolds/beet/kale
Mangetout		Marrows	Field beans	Forage rye and triticale
Cabbage		Pumpkins	Linseed/ flax	Herbage seeds
Cauliflower		Squashes	Oilseed rape	Turf production
Calabrese/ broccoli/kale		Rhubarb	Sugar beet	*Etc.*
Courgettes		Artichokes	Sunflower	
Celery		*Etc.*	Borage	
Red beet			Nursery stock	
Carrots			Bulbs	
Herbs			*Etc.*	
Asparagus				
Garlic				
Shallots				
Spinach				
Chicory				
Celeriac				
Fennel				
Tomatoes/ cucumbers/peppers				
Etc.				

Figure 16 Categories for Biofertiliser Matrix

8.12 Assumptions made in the calculation of the AD scenarios

Assumptions made in the calculation of AD scenarios:

- The cow slurry delivered to the AD site by the dairy farms. No gate entry cost, in exchange for the digestate returned to land for the benefit of the nutrients
- Digestate will be delivered to the farms and spread by the AD plant. The AD plant will provide agronomy advice for optimum utilisation of nutrients
- The farms will benefit from the nutrients of digestate, and the AD plant will not receive this income
- The potato outgrades from the grading lines are delivered to the AD site by the potato growers. No gate entry cost, instead of returning waste to fields
- The vegetable trimmings from the grading lines are delivered to the AD site by the growers. No gate entry cost, instead of returning waste to fields
- The Purpose Grown Crop (PGC) is grown and supplied at market value of £25/tonne. There is opportunity to use prickly potato green crop at the lower cost of covering transport and harvesting (£7 -£10/tonne)
- Silage clamp will be required and constructed as a cost to the AD plant
- The AD site is close enough to an energy user to utilise both electricity and heat
- The energy sale price stated can be achieved in 2013
    a. Electricity @ 13p/kWh (a commercial rate used just less than published rate)
    b. Heat @ 5.5p/kWh (a commercial rate used just less than published rate)
    c. Electricity sold to the grid @ 8p/kWh at peak demand times (a rate selected as a possible rate the Jersey electric might pay)
- Energy prices will increase at a rate greater than inflation, which will increase the return in future years
- The capital is borrowed at an interest rate of 7.5% or 5.5% (as illustrated in the financial summary and is repaid over 20 years
- All the capital expenditure is depreciated over 20 years
- No tax has been included

Also possible:

- The AD plant will have a separator installed which will generate a solid fraction (10%) and a liquid (90%) A market could be developed for the solid product for an additional income stream which has not been included at this stage
- The dairy farms delivering slurry to the AD plant may have redundant slurry store capacity for digestate. This will reduce the storage requirement of digestate at the site

- Other organic wastes may be available to add to the feedstock at a future date

Table 19 Reference data

Assumption	Value
Biogas methane content	55 – 60%
Energy value of methane	11.2 kWh/m^3
AD losses and inefficiencies	10%
Electric parasitic load	15%
Parasitic heat load	33% (depending on feedstock temperature)
CHP electric efficiency	39%
CHP heat efficiency	42%

8.13 Capital cost items required for the installation of an AD plant

Table 20 Typical costs of capital items

Item	Capital cost
Planning application and consultant fees	£20,000 to £30,000
Consultancy fees technical	£2,000 to £20,000
Consultancy fees financial –grants etc	£2,000 to £4,000
Solid feedstock storage - Silage clamp	£90/t stored * (0ften less @60/t)
Weigh bridge / weigh equipment	£5,000 to £20,000
Liquid feedstock storage (circular above ground)	£45/m^3 stored*
Feedstock shredder/mixer	7tph £15,000, 14tph £35,000
Digester tank (including pipes and fittings)	£160 - £200/m^3
Pumps	£2,000 to £3,000 each
Biogas storage	£100,000 - £150,000
Digestate separator	£20,000 - £25,000
Digestate(solid) storage including structure	£90/t stored*(0ften less @60/t)
Digestate (liquid) storage(circular above ground)	£45/m^3 stored*
Digestate (liquid) storage(earth lagoon)	£25/m^3 stored
Access road improvements (Hardcore road)	£27 / m length*
Access road improvements (Tarmac road)	£77/m length*
(*Nix, J., Farm Management Pocket book)	

Table 21 Budgeted on-farm CHP cost

Installed CHP kWe	Budget cost £/kWe
0 - 150kW	**£940**
400kW	**£750**
500kW	**£700**
600kW	**£580**
1mW	**£450**
2mW	**£400**

Table 22 Example Agricultural Anaerobic Digester sites in the UK

	Site	Feedstock	Energy output	Installation date	Cost
1	Copys Green Farm, Wighton, Wells Next the Sea, Norfolk	5,000 tonnes cow slurry, maize	140kWe CHP	2010	£0.75m
2	Cockle Park, Morpeth Northumberland	8,000 tonnes cow slurry, manure, vegetable waste, maize	75kWe CHP	2010	£1.85m (£860k RDPE grant)
3	Farmgen Dryholme Farm, Siloth, Cumbria	32,000 tonnes (slurry), maize, Grass	1200kWe CHP	2011	£4m
4	Farmgen Carr Farm, Warton, Preston	16,000 tonnes maize, Grass	800kWe CHP	2010	£3m
5	Langage Farm, Plympton, Plymouth	20,000 tonnes food waste, slurry, dairy water	500kWe CHP	2010	£3.4m
6	H and Q Homleaze Farm, Haterop, Cirencester, Gloucester	21,000 tonnes slurry, maize, grass.	360kWe CHP	2010	£1.1m self build
7	Barfoots of Botley Sefter Farm, Bognor Regis West Sussex	28,000 tonnes vegetable waste, maize	1100kWe CHP	2010	£3.5m (£750,000 SEEDA grant
8	Crouchland Farm, Billinghurst West Sussex	25,000 tonnes cow slurry, maize, grass	1000kWe CHP	2010	£2m
9	Staples Vegetables, Boston, Lincolnshire	51,000 tonnes vegetable waste	3000kWe CHP	2010	£6.3m
10	Severn Trent Water Bulcote Farm, Stoke Bardolf, Nottingham	37,000 tonnes maize only	2000kWe CHP	2010	£15m

Source: Biogas information portal. http://www.biogas-info.co.uk/maps/index2.htm

8.14 Scenario 1: Anaerobic digestion with CHP

Scenario 1 features a medium scale Digester (3,740m^3 digester), with 29,000 tonnes feedstock, and biogas utilised in CHP generating electricity and heat.

Table 23 Scenario 1: Data

Feedstock:		
Cow slurry	15,000	m ^{3} /year (approx. 52%)
Potatoes	6,000	T / year (approx. 20%)
Vegetables	2,500	T / year (approx. 8%)
Maize	5,300	T / year (approx. 18%)
Dairy process	156	T or m ^{3} / year
Total	28,956	T / year
Residence time	40	Days
Digester size	3,740	m ^{3}
Biogas output	1,850,000	m ^{3} /year
Biomethane to use	1,017,000	m ^{3} /year
Energy from Biogas	12,430,000	kWh
CHP	500	kWe **
** Install 1x 700KW with capability to ‘turn down’ to minimum 200kW when required		

Scenario 1: Feedstock supply

Figure 17 shows a dashboard graphic of feedstock proportions related to biogas production levels. The diagram shows the proportions of the feedstock, volumes, and importantly the relative proportions of gas which is produced for the energy output to generate energy sale. The slurry has a low contribution to gas production compared to the wastes and maize crop.

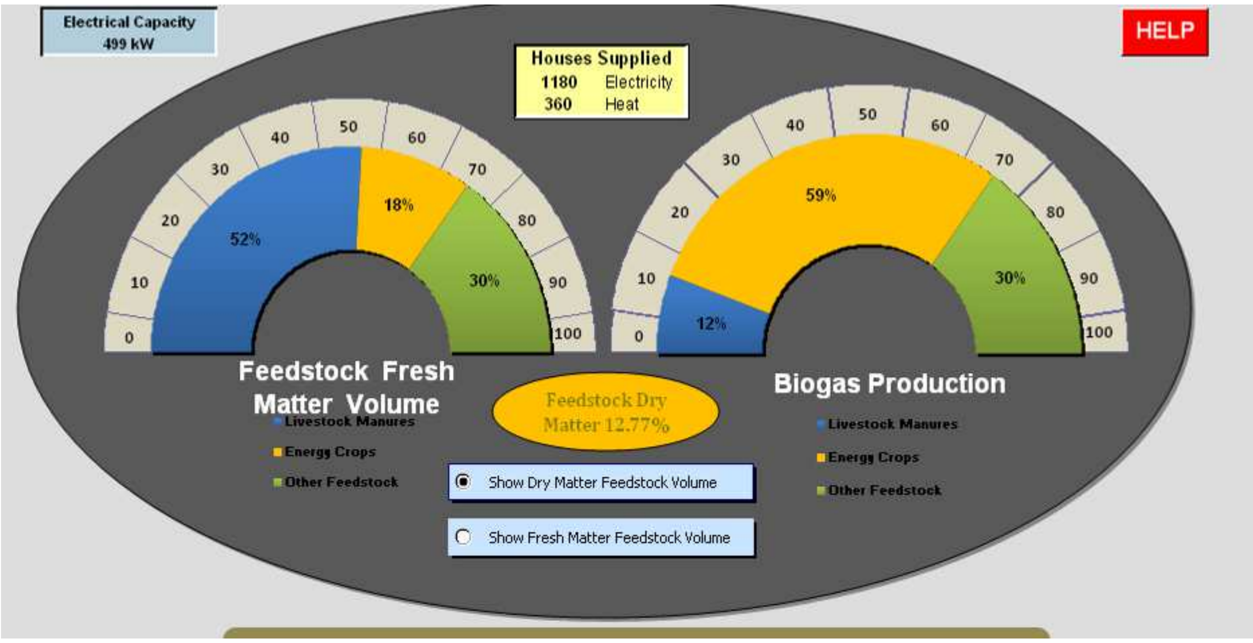

Figure 17 Scenario 1: Dashboard of feedstock and biogas production (Anderson model)

Cattle slurry

- 15,000 tonnes, approximately 35% of total produced (estimated c43,000m$^{3)}$
- Up to 55 tonnes per day in winter months (5 tractor deliveries); 25 tonnes a day in spring months
- Supplied free with no delivery charge

Milk processing plant waste

- Estimated at 3 tonnes per week, 156 tonnes per year. Separated sludge (assuming 10% separation) –
- Occasionally a few tonnes of out of specification product would be available

Jersey Royal potato waste

- 6,000 tonnes from the Jersey Royal Company (~4,000 tonnes) and Albert Bartlett (~1,200 tonnes) with the balance from primary farm grading lines
- Jersey Royal Potatoes are produced for 5 months only: March to July
- Supplied free of charge, diverted from being spread back to the field

Vegetable waste

- Estimated to be 2,500 tonnes per year
- 1,700 tonnes per year from 1 grower/packer. (3t per day - peelings, 500t – cabbage waste for 6 months December to June, and 600t – potato waste for 5 months March to July) Balance from other growers
- Waste produced all the year – but slight seasonal variation

Purpose grown crop (PGC) or other e.g. waste prickly potato

- 5,300 tonnes required per year
- Used from July to February, to balance the seasonality of Jersey Royal potato waste and ensure a level production of biogas
- Crop is ensiled and stored in a silage clamp
- Budgeted on the basis farmers would grow the crop at the cost price (£27/tonne)

Feedstock	Feedstock Tonnage	Gas Yield	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dairy cow slurry	15000	14	1200	1200	800	800	800	800	900	1700	1700	1700	1700	1700
None	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0												
	0	0												
Maize silage	5,300	205	610	600	600	80	80	80	200	610	610	610	610	610
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0												
	0	0												
Potato peeling wastes	6,000	68	0	0	0	1600	1600	1600	1200	0	0	0	0	0
Vegetable wastes	2,500	57	200	200	300	300	300	350	350	100	100	100	100	100
Skimmed milk fresh	156	30	14	13	13	13	12	12	12	12	13	14	14	14
None	0	0												
	0	0												
Water	0	0												
Feedstock Tonnes			2,024	2,013	1,713	2,793	2,792	2,842	2,662	2,422	2,423	2,424	2,424	2,424
Biogas Production m³			154,006	151,926	151,914	153,595	153,565	156,415	155,373	155,386	155,416	155,446	155,446	155,446
edstock Yield m³/t feedstock			76	75	89	55	55	55	58	64	64	64	64	64

Figure 18 Scenario 1: Breakdown of feedstock and biogas yield (Anderson model)

Scenario 1: Budgeted Capital Expenditure

The table below (Table 24) lists the financial cost of the required capital components of the AD plant for scenario 1

Table 24 Scenario 1: Cost of capital items

Item	£
maize/grass silage pit (5,000 tonne)	325,000
Digester infrastructure (3,740 m^3 vessel)	1,575,000
Digestate (12,000 $m^{3)}$	480,000
Digestate separator	20,000
CHP Generator	500,000
Total budget cost	**2,900,000**

(The budgeted cost is based upon work completed in England and so there may be a higher purchase cost in Jersey, e.g. cost of land).

Scenario 1: Energy output

The output from scenario 1 is 1,850,000m^3 of Biogas. The intention is to supply energy to:

- An adjacent industrial process (milk processing plant) to displace the purchased electric and gas energy with renewable electricity and heat
- Surplus electricity to Jersey Electric at the peak demand at a raised value

The model is for a 500kW continuous running CHP generator, but operated with variable output. Installing a 700kw CHP could provide flexibility to supply all of the milk processing plant's electric and some heat energy. Storage of energy (gas) will be needed to provide a buffer for the uneven daily and weekly energy cycles. The AD has potential of producing approximately: (kWh in brackets available after parasitic load removed)

- 4,375,000 kWh output of electric energy (4,231,000 kWh saleable)
- 4,653,000 kWh output of heat energy. (3,490,000 kWh saleable)

Scenario 1: Income

The projected annual income from the AD plant installed in scenario 1 is given in Table 25.

Table 25 Scenario 1: Projected annual income

Source	£ (GBP)
Electricity	458,000
Heat	179,000
Total	**637,000**

Scenario 1 - Financial assessment of the project

AD plants in the UK have become only viable due to the Feed in Tariffs or ROC applied in the UK. The state of Jersey does not have either of these systems currently in place to provide income to any potential owner of an AD plant. The financial appraisal carried out has excluded support of this type.

Assumptions

In order to carry out the financial assessment a set of basic assumptions were required, these were split into three separate categories:-

1. Assumptions which involved the quantity of feed stocks and the outputs in terms of quantities of energy, heat and digestate that these would produce
2. Assumptions which involved how feedstock would be acquired and how digestate would be disposed of
3. Assumptions around the financial aspects of the project which ranged from cost of feedstock through to interest rates.

The assumptions are detailed in section 8.12

Interest Rates

Although base interest rates in the UK are 0.5% the cost of long term borrowing is around 5% but most lend institutions like to use an interest rate of 7.5 % when assessing the viability of long term projects. Therefore this rate has been used.

Inflation

The increasing shortage of Carbon based fuels and requirement for green energy sources has for some time been driving up energy prices. The long term estimate for inflation in the UK is 2-3 % /annum and this has been used to estimate the effect of inflation on the viability of the project. The heat and electricity generated together with feedstock, repairs and maintenance, and other overheads except for interest and depreciation costs were increased by 2% / year to show the effect of rising energy costs on the viability of the project.

Repayment of Loan capital

It assumed that all the capital for the project is borrowed and this is repaid over the projects 20 year lifespan.

Site

No capital cost has been included for the purchase of the site for the AD plant but £20.000 has been included for rates to be paid on the site

The full financial assumptions used for an Anaerobic Digester, 29,000 tonnes feedstock, £2,900,000 budget capital costs are shown below Table 26.

Table 26 Costs

		Assumption used
Feedstock cost	Slurry	No charge
	Vegetable	No Charge
	Potato	No charge
	Maize	**£25/tonne**
Energy output	Electricity to user	£13p/kWh
	Heat to user	£5.5p/kWh
	Electricity to grid	**8p/kWh**
Running cost	Labour	£10,000
	Management	£20,000
	Maintenance AD Plant	£48,000 (2%)
	Maintenance CPH plant	£43,753
	Insurance	£20,000
	Transport (digestate) back to farm	£55,000
	Testing fees	£2000
	EA Fees	£3,600
	Professional Agronomy	£8000
	Spreading Digestate	**£55,000**
	Office overheads	£6,500
	Rent and Rates	£20,000
	Interest rates on loan	**7.5%**
	Depreciation – straight line	20 years
	Inflation rate	2-3%

Financial Appraisal of the project

Four different financial models were examined. They were as follows

1. AD project with all capital borrowed at an interest rate of 7.5 %
2. AD project with all capital borrowed at an interest rate of 7.5 % and 2% inflation through out the 20 year life of the project.
3. AD project with all capital borrowed at an interest rate of 5.5 %
4. AD project with all capital borrowed at an interest rate of 5.5% and 2% inflation through out the 20 year life of the project.

Full details of these models are shown at appendices 8.17, 8.18, 8.19, 8.20.

Models 1, 2 and 3 all had negative cashflows until very late in the 20 year project and build up significant level of debt £590,000 to £1.4m without overdraft interest being added to this debt each year. They are therefore considered to none viable.

Model 4 produced a positive cashflow of £327, 819 during the 20 year lifespan of the project or £16,390/year. Thus this model showed that the project could be viable. This is such a small return on a capital expense of £2.9m and commercial investors would not be interested in the project.

As the location of the site is not known, and ownership of the land is not known this cost has not been included. The income also relies on the price of energy used in the analysis being achieved, and the waste arriving on site at no cost.

To attract investors to the project, there will need to be States of Jersey support, to develop the project with stakeholders, and with finance which could be a finance loan at a lower rate, or capital grant support.

8.15 Scenario 2: Anaerobic Digester with bottling plant

This scenario uses the same medium scale digester as scenario 1 and with biogas utilised as compressed biomethane, sold for domestic and commercial use

Scenario 2: Feedstock

This has a feedstock requirement of around 29,000 tonnes, as given in scenario 1

Scenario 3: Budgeted Capital Expenditure

The table below (Table 27) lists the financial cost in Pounds Sterling (£) of the required capital components of the AD plant.

Table 27 Scenario 2: Cost of capital items

Item	£
maize/grass silage pit (5,000tonne)	325,000
Digester infrastructure (3740m^3)	1,575,000
Digestate 12,000 m^3	480,000
Digestate separator	20,000
Clean up and compression	1,050,000
Boiler for AD	40,000
Total capital cost	**3,490,000**

Scenario 2: Energy output

The output from scenario 2 is 1,850,000m^3 of Biogas.

Energy use

The biomethane that is produced from the biogas would displace diesel fuel to be used in vehicles, or could displace propane used in vehicles or for a variety of domestic and commercial applications.

Fuel	**Unit**	**Cost**	**Energy**	**Cost**	**Cost**
		p/litre	Mj	P/Mj	P/kWh
Diesel (Forecourt)	Litre	117	38	3.08	11.1
Diesel (net of fuel duty and GST)	*Litre*	*65*	*38*	*1.71*	*6.2*
Propane (commercial rate)	Litre	49	25	1.91	6.9

Scenario 2: Financial assessment of the project

Diesel road fuel: 1m^3 of biomethane is the equivalent of 1 litre diesel, and so the output in this scenario would be the equivalent of around 1million litres diesel.

The garage forecourt cost of diesel in Jersey is currently 117p/litre, which would be the equivalent of £1,170,000 income to the AD. (£1,111,000 if GST taken off)

There will be a cost involved in converting vehicles to run on biomethane as a fuel, which would be in the region of £2,000 for a light van and £25,000 for a lorry or bus. The cost of biomethane as a road fuel must offset the additional cost vehicle conversion by the fleet operator, and the infrastructure for refuelling vehicles. If the biomethane is produced at a diesel price equivalent of 65p/litre, which is a comparable cost of diesel net of Fuel Duty and GST, this would give a sales **of £607,000**.

LPG: The biomethane could be marketed beside propane which is used on the island either in bulk tanks or high pressure bottle. (Methane 55.53Mj/kg compared Propane 50.35Mj/kg so similar energy value). Larger commercial users such as protected cropping glasshouses, factory process, and large establishments such as hospitals and Hotels, would use LPG delivered in bulk storage, and purchase LPG at competitive market price.

The cost of propane as published in Jersey gas tariff is currently 96p/litre, or equivalent of 192p/kg. Propane purchased in cylinders is slightly higher which would account for the included cost of handling (298p to 434p/kg). The price paid for bulk propane delivered to a customer would be comparable to the cost of oil.

The average price paid for heating fuel oil is 73p/litre (DECC quarterly energy prices, commercial sites Quarter 2 2013). Using this as a comparative cost of energy this would be 6.9p/kWh, and LPG sold at 49p/litre (This could be slightly higher than the price paid by an industrial operator using large amounts).

The AD plant producing biomethane energy for sale at 6.9p/kWh would give an annual sales of £677,000.

In this scenario 2, if the budget capital cost rises to £3,490,000, compared to £2,900,000 capital budget expenditure for AD with CHP. The return from the CHP scenario 1 showed an income of £637,000 per year.

A more detailed economic appraisal has not been undertaken on this scenario, which with lower income and higher capital cost will be less viable.

The experience of the clean up technology is developing in the UK, mainly (only) in the market of biomethane injection into the grid, but as the experience and market matures, the cost of technology will come down. At the present time the increased capital cost of the clean up and compressing plant, together with a relatively low competitive fuel price, make this option less attractive at this point in time unless States of Jersey supports the project.

Use of biomethane

The ideal target user for biomethane for road transport would be fleet operations, such as the Island bus company, or a distribution company such as Ferryspeed.

The Technical and Transport Services who run the bus fleet of 43 regular buses (84 at peak times), but TTS has just entered a lease agreement for a new bus fleet running on diesel in 2013, which has a long term agreement (10 years). And so developing the use of biomethane as an alternative fuel would not be of immediate interest, but of interest in the future if the biomethane is produced at very competitive price.

Ferryspeed are the main goods transport company running a similar size fleet of 65 vehicles, half being lorries, all with refrigeration running on diesel, and the remainder light vans. The company also operates in the UK and it is understood that it has not yet developed a programme of alternative fuels in vehicles, but as with the bus company would be interested in the development. Either of these operations would be key partners and could theoretically convert part of the fleet to operate on biomethane if there would be a price advantage.

The development of a tractor running on biomethane is being taken very seriously by a Swedish tractor manufacturer which has worked for a number of years developing an 80Kw tractor. The machine carries 4 cylinders of compressed biomethane at 200bar carrying 168 litres, equivalent of 30 litres of diesel, and is equivalent to working for 4 hours. This development has not reached production but could be produced in small scale this year, and worthy of following.

8.16 Example of the additional land bank required

Table 28 Estimate of the additional land bank required for spreading organic manures on the island if cattle slurry is co-digested with waste potatoes and vegetables, maize and dairy process waste under Scenario 1 or 2 (Defra, 2010)

Waste or energy crop co-digested with cattle slurry	Scenario 1	
	tonnes or m^3/year	Additional land bank required for spreading vergées (ha)
Potatoes	6,000	540 (97.1)
Vegetables	2,500	375 (67.4)
Maize	5,300	705 (126.8)
Dairy process waste	156	5 (0.8)*
Total	13,956	1,620 (291)

* Based on the dairy process waste containing 1kg/m^3 total N

8.17 Financial summary – Scenario 1 (7.5%interest, no inflation)

7.5%Interest No inflation

Year	1	2	3	4	5	6	7	8	9	10
Profit and Loss										
Income										
Electricity	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440
Heat	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155
Revenue	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**
Costs										
Feedstocks	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500
Labour	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Depreciation										
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Pow er Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Maintenance & veh	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753
General Overheads	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100
Land & buildings	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Loan Interest	217,500	212,477	207,078	201,274	195,035	188,327	181,117	173,365	165,033	156,075
Trading Costs	**786,853**	**781,830**	**776,431**	**770,627**	**764,388**	**757,680**	**750,470**	**742,718**	**734,386**	**725,428**
P&L	**-149,258**	**-144,235**	**-138,836**	**-133,032**	**-126,793**	**-120,085**	**-112,875**	**-105,123**	**-96,791**	**-87,833**
Return on all Capit	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*
Supply of Funds										
Profit / Loss	-149,258	-144,235	-138,836	-133,032	-126,793	-120,085	-112,875	-105,123	-96,791	-87,833
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000
Loan	2,900,000									
Total Source of F	**2,895,742**	**765**	**6,164**	**11,968**	**18,207**	**24,915**	**32,125**	**39,877**	**48,209**	**57,167**
Disposition of Funds										
Capital Purchase	2,900,000	0	0	0	0	0	0	0	0	0
Loan Repayments	66,967	71,990	77,389	83,193	89,433	96,140	103,351	111,102	119,435	128,392
Annual Draw ings and Tax		0	0	0	0	0	0	0	0	0
Total Disposition	**2,966,967**	**71,990**	**77,389**	**83,193**	**89,433**	**96,140**	**103,351**	**111,102**	**119,435**	**128,392**
Opening Bank	0									
Bank Change	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225
Closing Bank Positior	-£71225	-£142,451	-£213,676	-£284,901	-£356,127	-£427,352	-£498,577	-£569,803	-£641028	-£712,254
Balance Sheet										
Assets										
Capital Value of Pla	2,755,000	2,610,000	2,465,000	2,320,000	2,175,000	2,030,000	1,885,000	1,740,000	1,595,000	1,450,000
Cash at BankBank	0	0	0	0	0	0	0	0	0	0
Total Assets	**2,755,000**	**2,610,000**	**2,465,000**	**2,320,000**	**2,175,000**	**2,030,000**	**1,885,000**	**1,740,000**	**1,595,000**	**1,450,000**
Liabilities										
Loan Outstanding	2,833,033	2,761,043	2,683,654	2,600,460	2,511,027	2,414,887	2,311,536	2,200,434	2,080,999	1,952,607
Overdraft	71,225	142,451	213,676	284,901	356,127	427,352	498,577	569,803	641,028	712,254
Total Liabilities	**2,904,258**	**2,903,493**	**2,897,330**	**2,885,362**	**2,867,154**	**2,842,239**	**2,810,114**	**2,770,237**	**2,722,028**	**2,664,861**
Net Assets	**-149,258**	**-293,493**	**-432,330**	**-565,362**	**-692,154**	**-812,239**	**-925,114**	**-1,030,237**	**-1,127,028**	**-1,214,861**

Year	11	12	13	14	15	16	17	18	19	20
Profit and Loss										
Income										
Electricity	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440
Heat	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155
Revenue	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**
Costs										
Feedstocks	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500
Labour	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Depreciation										
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Pow er Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Maintenance & veh	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753
General Overheads	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100
Land & buildings	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Loan Interest	146,446	136,094	124,966	113,003	100,143	86,319	71,458	55,482	38,308	19847
Trading Costs	**715,799**	**705,447**	**694,319**	**682,356**	**669,496**	**655,672**	**640,811**	**624,835**	**607,661**	**589,200**
P&L	**-78,204**	**-67,852**	**-56,724**	**-44,761**	**-31,901**	**-18,077**	**-3,216**	**12,760**	**29,934**	**48,395**
Return on all Capit	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*
Supply of Funds										
Profit / Loss	-78,204	-67,852	-56,724	-44,761	-31,901	-18,077	-3,216	12,760	29,934	48,395
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000
Loan										
Total Source of F	**66,796**	**77,148**	**88,276**	**100,239**	**113,099**	**126,923**	**141,784**	**157,760**	**174,934**	**193,395**
Disposition of Funds										
Capital Purchase	0	0	0	0	0	0	0	0	0	
Loan Repayments	138,022	148,373	159,501	171,464	184,324	198,148	213,009	228,985	246,159	264,621
Annual Draw ings and Tax	0	0	0	0	0	0	0	0	0	0
Total Disposition	**138,022**	**148,373**	**159,501**	**171,464**	**184,324**	**198,148**	**213,009**	**228,985**	**246,159**	**264,621**
Opening Bank										
Bank Change	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,225	-£71,226
Closing Bank Positior	-£783,479	-£854,704	-£925,930	-£997,155	-£1068,380	-£1139,606	-£1210,831	-£1282,056	-£1353,282	-£1424,508
Balance Sheet										
Assets										
Capital Value of Pla	1,305,000	1,160,000	1,015,000	870,000	725,000	580,000	435,000	290,000	145,000	0
Cash at BankBank	0	0	0	0	0	0	0	0	0	0
Total Assets	**1,305,000**	**1,160,000**	**1,015,000**	**870,000**	**725,000**	**580,000**	**435,000**	**290,000**	**145,000**	**0**
Liabilities										
Loan Outstanding	1,814,585	1,666,212	1,506,710	1,335,246	1,150,922	952,774	739,765	510,780	264,621	0
Overdraft	783,479	854,704	925,930	997,155	1,068,380	1,139,606	1,210,831	1,282,056	1,353,282	1,424,508
Total Liabilities	**2,598,064**	**2,520,916**	**2,432,640**	**2,332,401**	**2,219,303**	**2,092,380**	**1,950,596**	**1,792,836**	**1,617,903**	**1,424,508**
Net Assets	**-1,293,064**	**-1,360,916**	**-1,417,640**	**-1,462,401**	**-1,494,303**	**-1,512,380**	**-1,515,596**	**-1,502,836**	**-1,472,903**	**-1,424,508**

8.18 Financial summary – Scenario 1 (7.5%interest, 2% inflation)

7.5% Inflation, 2%interest

Year	1	2	3	4	5	6	7	8	9	10
Profit and Loss										
Income										
Electricity	458,440	467,609	476,961	486,500	496,230	506,155	516,278	526,603	537,136	547,878
Heat	179,155	182,738	186,393	190,121	193,923	197,802	201,758	205,793	209,909	214,107
Revenue	**637,595**	**650,347**	**663,354**	**676,621**	**690,153**	**703,956**	**718,036**	**732,396**	**747,044**	**761,985**
Costs										
Feedstocks	132,500	135,150	137,853	140,610	143,422	146,291	149,217	152,201	155,245	158,350
Labour	30,000	30,600	31,212	31,836	32,473	33,122	33,785	34,461	35,150	35,853
Depreciation										
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Pow er Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Maintenance & veh	91,753	93,588	95,460	97,369	99,316	101,303	103,329	105,395	107,503	109,653
General Overheads	150,100	153,102	156,164	159,287	162,473	165,723	169,037	172,418	175,866	179,383
Land & buildings	20,000	20,400	20,808	21,224	21,649	22,082	22,523	22,974	23,433	23,902
Loan Interest	217,500	212,477	207,078	201,274	195,035	188,327	181,117	173,365	165,033	156,075
Overdraft interest										
Trading Costs	**786,853**	**790,318**	**793,575**	**796,601**	**799,368**	**801,847**	**804,007**	**805,813**	**807,230**	**808,216**
P&L	**-149,258**	**-139,971**	**-130,221**	**-119,980**	**-109,215**	**-97,891**	**-85,971**	**-73,417**	**-60,186**	**-46,231**
Return on all Capit	*2.4%*	*2.5%*	*2.7%*	*2.8%*	*3.0%*	*3.1%*	*3.3%*	*3.4%*	*3.6%*	*3.8%*
Supply of Funds										
Profit / Loss	-149,258	-139,971	-130,221	-119,980	-109,215	-97,891	-85,971	-73,417	-60,186	-46,231
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000
Loan	2,900,000									
Total Source of F	**2,895,742**	**5,029**	**14,779**	**25,020**	**35,785**	**47,109**	**59,029**	**71,583**	**84,814**	**98,769**
Disposition of Funds										
Capital Purchase	2,900,000	0	0	0	0	0	0	0	0	0
Loan Repayments	66,967	71,990	77,389	83,193	89,433	96,140	103,351	111,102	119,435	128,392
Annual Draw ings and Tax		0	0	0	0	0	0	0	0	0
Total Disposition	**2,966,967**	**71,990**	**77,389**	**83,193**	**89,433**	**96,140**	**103,351**	**111,102**	**119,435**	**128,392**
Opening Bank	0									
Bank Change	-£71,225	-£66,961	-£62,610	-£58,173	-£53,647	-£49,031	-£44,322	-£39,519	-£34,620	-£29,623
Closing Bank Positior	-£71,225	-£138,186	-£200,796	-£258,969	-£312,617	-£361,648	-£405,970	-£445,489	-£480,110	-£509,733
Balance Sheet										
Assets										
Capital Value of Pla	2,755,000	2,610,000	2,465,000	2,320,000	2,175,000	2,030,000	1,885,000	1,740,000	1,595,000	1,450,000
Cash at BankBank	0	0	0	0	0	0	0	0	0	0
Total Assets	**2,755,000**	**2,610,000**	**2,465,000**	**2,320,000**	**2,175,000**	**2,030,000**	**1,885,000**	**1,740,000**	**1,595,000**	**1,450,000**
Liabilities										
Loan Outstanding	2,833,033	2,761,043	2,683,654	2,600,460	2,511,027	2,414,887	2,311,536	2,200,434	2,080,999	1,952,607
Overdraft	71,225	138,186	200,796	258,969	312,617	361,648	405,970	445,489	480,110	509,733
Total Liabilities	**2,904,258**	**2,899,229**	**2,884,450**	**2,859,430**	**2,823,644**	**2,776,535**	**2,717,506**	**2,645,924**	**2,561,109**	**2,462,340**
Net Assets	**-149,258**	**-289,229**	**-419,450**	**-539,430**	**-648,644**	**-746,535**	**-832,506**	**-905,924**	**-966,109**	**-1,012,340**

Year	11	12	13	14	15	16	17	18	19	2
Profit and Loss										
Income										
Electricity	558,836	570,013	581,413	593,041	604,902	617,000	629,340	641,927	654,765	66
Heat	218,389	222,757	227,212	231,756	236,391	241,119	245,941	250,860	255,877	26
Revenue	**777,225**	**792,769**	**808,625**	**824,797**	**841,293**	**858,119**	**875,281**	**892,787**	**910,643**	**92**
Costs										
Feedstocks	161,517	164,747	168,042	171,403	174,831	178,328	181,894	185,532	189,243	19
Labour	36,570	37,301	38,047	38,808	39,584	40,376	41,184	42,007	42,847	4
Depreciation										
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	12
Pow er Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	2
Maintenance & veh	111,846	114,083	116,365	118,692	121,066	123,487	125,957	128,476	131,046	13
General Overheads	182,971	186,630	190,363	194,170	198,054	202,015	206,055	210,176	214,380	21
Land & buildings	24,380	24,867	25,365	25,872	26,390	26,917	27,456	28,005	28,565	2
Loan Interest	146,446	136,094	124,966	113,003	100,143	86,319	71,458	55,482	38,308	
Overdraft interest										
Trading Costs	**808,729**	**808,724**	**808,148**	**806,949**	**805,068**	**802,442**	**799,004**	**794,679**	**789,389**	**78**
P&L	**-31,505**	**-15,954**	**477**	**17,848**	**36,225**	**55,676**	**76,278**	**98,108**	**121,254**	**14**
Return on all Capit	*4.0%*	*4.1%*	*4.3%*	*4.5%*	*4.7%*	*4.9%*	*5.1%*	*5.3%*	*5.5%*	
Supply of Funds										
Profit / Loss	-31,505	-15,954	477	17,848	36,225	55,676	76,278	98,108	121,254	14
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	14
Loan										
Total Source of F	**113,495**	**129,046**	**145,477**	**162,848**	**181,225**	**200,676**	**221,278**	**243,108**	**266,254**	**29**
Disposition of Funds										
Capital Purchase	0	0	0	0	0	0	0	0	0	
Loan Repayments	138,022	148,373	159,501	171,464	184,324	198,148	213,009	228,985	246,159	26
Annual Draw ings and Tax	0	0	0	0	0	0	0	0	0	
Total Disposition	**138,022**	**148,373**	**159,501**	**171,464**	**184,324**	**198,148**	**213,009**	**228,985**	**246,159**	**26**
Opening Bank										
Bank Change	-£24,527	-£19,328	-£14,025	-£8,616	-£3,099	£2,528	£8,268	£14,123	£20,095	£2
Closing Bank Positior	-£534,260	-£553,587	-£567,612	-£576,228	-£579,328	-£576,799	-£568,531	-£554,408	-£534,313	-£5
Balance Sheet										
Assets										
Capital Value of Pla	1,305,000	1,160,000	1,015,000	870,000	725,000	580,000	435,000	290,000	145,000	
Cash at BankBank	0	0	0	0	0	0	0	0	0	
Total Assets	**1,305,000**	**1,160,000**	**1,015,000**	**870,000**	**725,000**	**580,000**	**435,000**	**290,000**	**145,000**	
Liabilities										
Loan Outstanding	1,814,585	1,666,212	1,506,710	1,335,246	1,150,922	952,774	739,765	510,780	264,621	
Overdraft	534,260	553,587	567,612	576,228	579,328	576,799	568,531	554,408	534,313	50
Total Liabilities	**2,348,845**	**2,219,799**	**2,074,323**	**1,911,475**	**1,730,250**	**1,529,573**	**1,308,296**	**1,065,188**	**798,934**	**50**
Net Assets	**-1,043,845**	**-1,059,799**	**-1,059,323**	**-1,041,475**	**-1,005,250**	**-949,573**	**-873,296**	**-775,188**	**-653,934**	**-50**

8.19 Financial summary – Scenario 1 (5.5%interest, 0% inflation)

5.5% interest No inflation																				
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Profit and Loss																				
Income																				
Electricity	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440	458,440
Heat	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155	179,155
Revenue	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**	**637,595**
Costs																				
Feedstocks	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500	132,500
Labour	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Depreciation																				
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Pow er Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Maintenance & veh	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753	91,753
General Overheads	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100	150,100
Land & buildings	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Loan Interest	159,500	154,926	150,100	145,008	139,637	133,970	127,992	121,684	115,030	108,010	100,604	92,790	84,547	75,850	66,675	56,995	46,783	36,009	24,643	12,651
Trading Costs	**728,853**	**724,279**	**719,453**	**714,361**	**708,990**	**703,323**	**697,345**	**691,037**	**684,383**	**677,363**	**669,957**	**662,143**	**653,900**	**645,203**	**636,028**	**626,348**	**616,136**	**605,362**	**593,996**	**582,004**
P&L	**-91,258**	**-86,684**	**-81,858**	**-76,766**	**-71,395**	**-65,728**	**-59,750**	**-53,442**	**-46,788**	**-39,768**	**-32,362**	**-24,548**	**-16,305**	**-7,608**	**1,567**	**11,247**	**21,459**	**32,233**	**43,599**	**55,591**
Return on all Capit	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*	*2.4%*
Supply of Funds																				
Profit / Loss	-91,258	-86,684	-81,858	-76,766	-71,395	-65,728	-59,750	-53,442	-46,788	-39,768	-32,362	-24,548	-16,305	-7,608	1,567	11,247	21,459	32,233	43,599	55,591
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000
Loan	2,900,000																			
Total Source of F	**2,953,742**	**58,316**	**63,142**	**68,234**	**73,605**	**79,272**	**85,250**	**91,558**	**98,212**	**105,232**	**112,638**	**120,452**	**128,695**	**137,392**	**146,567**	**156,247**	**166,459**	**177,233**	**188,599**	**200,591**
Disposition of Funds																				
Capital Purchase	2,900,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Loan Repayments	66,967	71,990	77,389	83,193	89,433	96,140	103,351	111,102	119,435	128,392	138,022	148,373	159,501	171,464	184,324	198,148	213,009	228,985	246,159	264,621
Annual Draw ings and Tax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Disposition	**2,966,967**	**71,990**	**77,389**	**83,193**	**89,433**	**96,140**	**103,351**	**111,102**	**119,435**	**128,392**	**138,022**	**148,373**	**159,501**	**171,464**	**184,324**	**198,148**	**213,009**	**228,985**	**246,159**	**264,621**
Opening Bank	0																			
Bank Change	-£13,225	-£13,674	-£14,247	-£14,960	-£15,828	-£16,868	-£18,100	-£19,544	-£21,223	-£23,160	-£25,383	-£27,921	-£30,806	-£34,072	-£37,757	-£41,901	-£46,550	-£51,752	-£57,559	-£64,030
Closing Bank Positior	-£13,225	-£26,899	-£41,146	-£56,105	-£71,933	-£88,802	-£106,902	-£126,447	-£147,669	-£170,830	-£196,213	-£224,135	-£254,941	-£289,012	-£326,769	-£368,670	-£415,220	-£466,972	-£524,531	-£588,561
Balance Sheet																				
Assets																				
Capital Value of Pla	2,755,000	2,610,000	2,465,000	2,320,000	2,175,000	2,030,000	1,885,000	1,740,000	1,595,000	1,450,000	1,305,000	1,160,000	1,015,000	870,000	725,000	580,000	435,000	290,000	145,000	0
Cash at BankBank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Assets	**2,755,000**	**2,610,000**	**2,465,000**	**2,320,000**	**2,175,000**	**2,030,000**	**1,885,000**	**1,740,000**	**1,595,000**	**1,450,000**	**1,305,000**	**1,160,000**	**1,015,000**	**870,000**	**725,000**	**580,000**	**435,000**	**290,000**	**145,000**	**0**
Liabilities																				
Loan Outstanding	2,833,033	2,761,043	2,683,654	2,600,460	2,511,027	2,414,887	2,311,536	2,200,434	2,080,999	1,952,607	1,814,585	1,666,212	1,506,710	1,335,246	1,150,922	952,774	739,765	510,780	264,621	0
Overdraft	13,225	26,899	41,146	56,105	71,933	88,802	106,902	126,447	147,669	170,830	196,213	224,135	254,941	289,012	326,769	368,670	415,220	466,972	524,531	588,561
Total Liabilities	**2,846,258**	**2,787,942**	**2,724,799**	**2,656,566**	**2,582,961**	**2,503,689**	**2,418,438**	**2,326,881**	**2,228,669**	**2,123,437**	**2,010,798**	**1,890,346**	**1,761,651**	**1,624,258**	**1,477,691**	**1,321,444**	**1,154,985**	**977,752**	**789,152**	**588,561**
Net Assets	**-91,258**	**-177,942**	**-259,799**	**-336,566**	**-407,961**	**-473,689**	**-533,438**	**-586,881**	**-633,669**	**-673,437**	**-705,798**	**-730,346**	**-746,651**	**-754,258**	**-752,691**	**-741,444**	**-719,985**	**-687,752**	**-644,152**	**-588,561**

8.20 Financial summary - Scenario 2 – (5.5% interest 2% inflation)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Profit and Loss																				
Income																				
Electricity	458,440	467,609	476,961	486,500	496,230	506,155	516,278	526,603	537,136	547,878	558,836	570,013	581,413	593,041	604,902	617,000	629,340	641,927	654,765	667,861
Heat	179,155	182,738	186,393	190,121	193,923	197,802	201,758	205,793	209,909	214,107	218,389	222,757	227,212	231,756	236,391	241,119	245,941	250,860	255,877	260,995
ROCs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertiliser Saving	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gate Fees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenue	**637,595**	**650,347**	**663,354**	**676,621**	**690,153**	**703,956**	**718,036**	**732,396**	**747,044**	**761,985**	**777,225**	**792,769**	**808,625**	**824,797**	**841,293**	**858,119**	**875,281**	**892,787**	**910,643**	**928,856**
Costs																				
Feedstocks	132,500	135,150	137,853	140,610	143,422	146,291	149,217	152,201	155,245	158,350	161,517	164,747	168,042	171,403	174,831	178,328	181,894	185,532	189,243	193,027
Labour	30,000	30,600	31,212	31,836	32,473	33,122	33,785	34,461	35,150	35,853	36,570	37,301	38,047	38,808	39,584	40,376	41,184	42,007	42,847	43,704
Depreciation																				
Digestion	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Power Unit	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Maintenance & vehi	91,753	93,588	95,460	97,369	99,316	101,303	103,329	105,395	107,503	109,653	111,846	114,083	116,365	118,692	121,066	123,487	125,957	128,476	131,046	133,667
General Overheads	150,100	153,102	156,164	159,287	162,473	165,723	169,037	172,418	175,866	179,383	182,971	186,630	190,363	194,170	198,054	202,015	206,055	210,176	214,380	218,667
Land & buildings	20,000	20,400	20,808	21,224	21,649	22,082	22,523	22,974	23,433	23,902	24,380	24,867	25,365	25,872	26,390	26,917	27,456	28,005	28,565	29,136
Loan Interest	159,500	154,926	150,100	145,008	139,637	133,970	127,992	121,684	115,030	108,010	100,604	92,790	84,547	75,850	66,675	56,995	46,783	36,009	24,643	12,651
Trading Costs	**728,853**	**732,766**	**736,597**	**740,335**	**743,970**	**747,490**	**750,882**	**754,133**	**757,227**	**760,151**	**762,888**	**765,420**	**767,729**	**769,796**	**771,599**	**773,118**	**774,328**	**775,206**	**775,723**	**775,853**
P&L	**-91,258**	**-82,419**	**-73,243**	**-63,714**	**-53,817**	**-43,534**	**-32,846**	**-21,736**	**-10,183**	**1,834**	**14,337**	**27,350**	**40,896**	**55,002**	**69,694**	**85,001**	**100,953**	**117,581**	**134,920**	**153,002**
Return on all Capit	*2.4%*	*2.5%*	*2.7%*	*2.8%*	*3.0%*	*3.1%*	*3.3%*	*3.4%*	*3.6%*	*3.8%*	*4.0%*	*4.1%*	*4.3%*	*4.5%*	*4.7%*	*4.9%*	*5.1%*	*5.3%*	*5.5%*	*5.7%*
Supply of Funds																				
Profit / Loss	-91,258	-82,419	-73,243	-63,714	-53,817	-43,534	-32,846	-21,736	-10,183	1,834	14,337	27,350	40,896	55,002	69,694	85,001	100,953	117,581	134,920	153,002
Depreciation	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000	145,000
Loan	2,900,000																			
Total Source o	**2,953,742**	**62,581**	**71,757**	**81,286**	**91,183**	**101,466**	**112,154**	**123,264**	**134,817**	**146,834**	**159,337**	**172,350**	**185,896**	**200,002**	**214,694**	**230,001**	**245,953**	**262,581**	**279,920**	**298,002**
Disposition of Funds																				
Capital Purchase	2,900,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Loan Repayments	66,967	71,990	77,389	83,193	89,433	96,140	103,351	111,102	119,435	128,392	138,022	148,373	159,501	171,464	184,324	198,148	213,009	228,985	246,159	264,621
Annual Drawings and Tax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Dispositi	**2,966,967**	**71,990**	**77,389**	**83,193**	**89,433**	**96,140**	**103,351**	**111,102**	**119,435**	**128,392**	**138,022**	**148,373**	**159,501**	**171,464**	**184,324**	**198,148**	**213,009**	**228,985**	**246,159**	**264,621**
Opening Bank	0																			
Bank Change	-£13,225	-£9,409	-£5,632	-£1,908	£1,750	£5,326	£8,803	£12,162	£15,382	£18,442	£21,315	£23,976	£26,394	£28,537	£30,370	£31,853	£32,944	£33,596	£33,761	£33,381
Closing Bank Position	-£13,225	-£22,634	-£28,266	-£30,174	-£28,423	-£23,097	-£14,295	-£2,133	£13,249	£31,691	£53,006	£76,982	£103,377	£131,914	£162,284	£194,137	£227,080	£260,676	£294,437	£327,818
Balance Sheet																				
Assets																				
Capital Value of Pl	2,755,000	2,610,000	2,465,000	2,320,000	2,175,000	2,030,000	1,885,000	1,740,000	1,595,000	1,450,000	1,305,000	1,160,000	1,015,000	870,000	725,000	580,000	435,000	290,000	145,000	0
Cash at BankBank	0	0	0	0	0	0	0	0	13,249	31,691	53,006	76,982	103,377	131,914	162,284	194,137	227,080	260,676	294,437	327,818
Total Assets	**2,755,000**	**2,610,000**	**2,465,000**	**2,320,000**	**2,175,000**	**2,030,000**	**1,885,000**	**1,740,000**	**1,608,249**	**1,481,691**	**1,358,006**	**1,236,982**	**1,118,377**	**1,001,914**	**887,284**	**774,137**	**662,080**	**550,676**	**439,437**	**327,818**
Liabilities																				
Loan Outstanding	2,833,033	2,761,043	2,683,654	2,600,460	2,511,027	2,414,887	2,311,536	2,200,434	2,080,999	1,952,607	1,814,585	1,666,212	1,506,710	1,335,246	1,150,922	952,774	739,765	510,780	264,621	0
Overdraft	13,225	22,634	28,266	30,174	28,423	23,097	14,295	2,133	0	0	0	0	0	0	0	0	0	0	0	0
Total Liabilitie	**2,846,258**	**2,783,677**	**2,711,920**	**2,630,634**	**2,539,451**	**2,437,984**	**2,325,831**	**2,202,567**	**2,080,999**	**1,952,607**	**1,814,585**	**1,666,212**	**1,506,710**	**1,335,246**	**1,150,922**	**952,774**	**739,765**	**510,780**	**264,621**	**0**
Net Assets	**-91,258**	**-173,677**	**-246,920**	**-310,634**	**-364,451**	**-407,984**	**-440,831**	**-462,567**	**-472,750**	**-470,916**	**-456,579**	**-429,229**	**-388,333**	**-333,332**	**-263,638**	**-178,637**	**-77,685**	**39,897**	**174,816**	**327,819**