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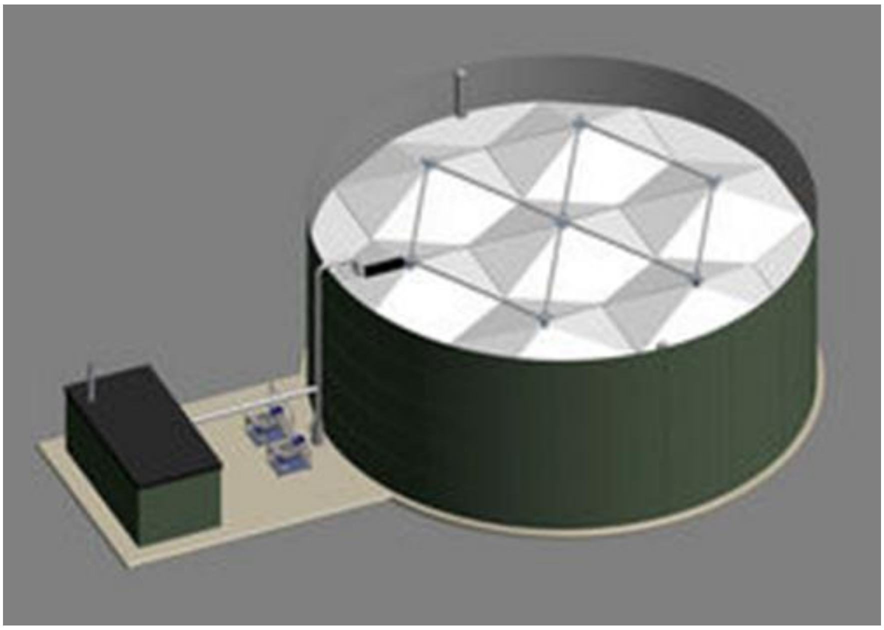
Anaerobic Digestion Feasibility Study – Final Report

Agri Digestore, small-scale AD – Marches Biogas Ltd



A feasibility report for the 'Driving Innovation in AD' programme. The study was undertaken by Marches Biogas, a private company in Ludlow, Shropshire which specialises in AD technology and has more than 20 years of experience in the design, construction and operation of digesters.

Project code: OIN001-512
Research date: February/ March 2012 **Date:** October 2013

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We work with businesses, individuals, and communities to help them reap the benefits of reducing waste, developing sustainable products and using resources in an efficient way.

Find out more at www.wrap.org.uk

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Front cover photography: Marches Biogas Agri-digestore

Executive summary

This report has been compiled to indicate the feasibility of the construction and operation of a Marches Biogas Agri Digestore at Hall Farm, Ludlow.

The primary aims for the project:

- income generation;
- business diversification;
- nutrient management;
- self sufficiency; and
- green credentials.

The following areas require consideration in the planning and feasibility process prior to progressing with an anaerobic digestion (AD) development:

- the cost of integrating the current slurry system with an AD plant proposal;
- the cost of upgrading and connecting to the local electricity grid for electricity export;
- the scope for use of heat on site, where gas is burned in a boiler and a CHP is not used;
- the cost of CHP purchase;
- maintenance costs against income while accounting for and comparing the above costs; and
- the land available for and the associated costs of growing and storing a quantity of energy/ forage crop for use to augment the slurry feed into the plant during the grazing season.

It is evident that for an AD plant on a small farm scale to be economically viable, the associated costs must be minimised and the income and benefits fully realised at all times, namely:

- the capital expenditure must be commensurate to the scale of plant income;
- the plant capacity must be employed fully throughout the year;
- any energy/ forage crops used as supplementary feed must be produced at minimal cost;
- the CHP/ boiler installation must allow for full use of both electricity and heat generation to be beneficially used;
- the digestate must be used to give best benefit in order to offset fertiliser costs; and
- the labour requirement cost must be internalised to the farm business.

The Agri Digestore complies with all of these issues. In this feasibility study we will demonstrate how we develop our technology specific to site, and how we ensure that our costs, construction, commissioning and delivery are carefully tailored to the client's specifications.

Contents

1.0 Foreword

WRAP awarded Marches Biogas funding to carry out a feasibility study for the design and installation of a Marches Biogas Agri Digestore at Hall Farm, Snitton near Ludlow.

Marches Biogas is a private company based in Ludlow, Shropshire that specialises in AD technology and has more than 20 years of experience in the design, construction and operation of digesters. Russell Mulliner of Marches Biogas was responsible through his role within Greenfinch Ltd for:

- The installation in 2004 of 7 on-farm AD plants for cattle manure in Southwest Scotland; this was a single contract awarded through competitive tender by the Scottish Executive as part of their investigation into diffuse pollution from agriculture. The contract was completed on time and within budget.
- The design and installation of the UK's first full-scale food waste digester which was commissioned in 2006 and is recycling 5,000 tonnes per year of source-separated kitchen waste from households in South Shropshire.
- The design and installation of on farm and industrial AD plants for animal slurry, energy crops, food wastes and other liquid wastes.
- The repair, maintenance, and upgrade of Water Company digestion assets throughout the UK.
- A number of government funded research projects into the anaerobic digestion of food waste and wet energy crops.

Recent contracts awarded to Marches Biogas Ltd include:

- Contract to design and build an on-farm anaerobic digestion facility at Cockle Park Farm for Newcastle University, which is now complete.
- Contract to design and build an anaerobic digestion research and training facility for Reaseheath College, Cheshire, which is now complete.
- Contracts to design and build three on-farm mixed feedstock plants in the West Midlands varying from 300kWe to 1MWe; all projects are in the build/commissioning phase.
- Contract to complete the process design and build an ABPR compliant plant for source separated food waste for Malaby Biogas, Wiltshire, which is now entering commissioning.

Carrying out maintenance and support for existing anaerobic digestion facilities, such as:

- The Agriculture, Food and Biosciences Institute in Hillsborough, Northern Ireland.
- Kemble Farm, Cirencester, Gloucestershire.
- Cannington Cold Stores, Bridgwater, Somerset.
- Copys Farm, Wighton, Norfolk.
- Many existing Greenfinch, Farm Gas and Waste Refinery AD plants.
- Kelda Water, United Utilities, Wessex Water, Yorkshire Water, Celtic Anglian Water.

2.0 Marches Biogas Agri Digestore

With many years' experience in the anaerobic digestion industry, the Marches Biogas team has recently developed a solution to the integration of AD with farm slurry storage and management. The Agri Digestore is in keeping with our philosophy of simple, robust engineering and aims to bring down the cost of establishing AD on farm.

Agri Digestore is the concept of integrating slurry and waste storage with AD technology in a single stage. This allows numerous benefits, including:

- may be purpose built or retrofitted to existing slurry storage;
- no need for additional storage/ process tanks;
- minimises the fugitive methane and nitrogen emissions from slurry storage;
- may be incorporated with Nitrate Vulnerable Zone (NVZ) compliance slurry store construction;
- modular design allows several Agri Digestores to be linked;
- increased material residence time to ensure complete digestion of substrates; and
- ease of operation and complete integration with slurry management.

The Agri Digestore components have been designed to allow slurry storage tanks of different capacity and construction to be transformed to anaerobic digesters. This design lends itself to new build tanks where the construction can incorporate some of the Agri Digestore design features or alternatively, an existing slurry store may be retrofitted with the process components.

By eliminating the need for separate process tanks and digestate storage, the Agri Digestore concept minimises capital expenditure, plant footprint and plant construction costs. Slurry and other feed stocks are transferred directly from the point of collection, slatted tanks for example, and fed to the Agri Digestore directly.

The retention of all stored slurry / digestate within the Agri Digestore, from the point of production to the point of application to land, means than not only are the methane losses normally incurred by slurry or digestate storage in an open tank both contained and used, the nitrate losses typically incurred in the same way are also prevented.

The threat of carbon accounting has hung over agriculture for some years, in the simplest terms, as a 'tax on cows'. The greenhouse effect of methane gas is 23 times that of carbon dioxide, almost a quarter of the methane produced by farming dairy cows is released from the slurry. The use of a complete storage and anaerobic digestion system effectively eliminates those emissions.

ADAS and DEFRA have estimated that in typical 6% dry matter cow slurry, 70% of the nitrogen content is lost or unavailable to plants. This is either through leaching unavailable nitrogen out of the soil before it becomes available to the plant or by losses of nitrogen to atmosphere in storage prior to application. By fully digesting fresh slurry and subsequently keeping it in a covered anaerobic state up to the point of land application, the amount of available nitrogen is increased, typically by 20% and the loss of volatile nitrogen in storage is prevented by as much as 25%, maximising its fertilising value when it is applied to the field.

The need to build slurry storage on farm is pressing, particularly for those farmers faced with NVZ regulations, dictating a prolonged closed period on spreading. The need to build new storage and the opportunity to make best use of that slurry while in enforced storage makes even more sense of incorporating the Agri Digestore into new slurry store plans.

On farms where several stores may have been built over time, the integration of the Agri Digestore system allows the benefits of AD with all the farm manures and slurries while stores may be managed individually as required.

The increased residence within the Agri Digestore when compared with a conventional one tank CSTR digester may be as much as 200%, this allows complete digestion, maximising the benefits of energy recovery and increased available nitrogen in the digestate. The prolonged residence time also increases the benefits of pathogen kill and weed seed suppression that AD offers.

Critical to the Agri Digestore design is the option of tank discharging in the same way that an open store operates, i.e. by allowing digestate use as and when required, this means that the digestate may be drawn directly from the tank without any process interruption. The only difference from normal slurry store management is that the Agri Digestore is typically only emptied to a level of 15% of the total store volume. This means that the process is continuous, no downtime or re-commissioning is required after digestate application.

3.0 Phase 1 - Feasibility

Between 90 and 100 million tonnes of slurry are produced on UK farms (plus other solid manure from beef and poultry farms), with attendant odour and greenhouse gas (GHG) emission problems, as well as the potential for run-off which in turn can pollute watercourses.

It is clear that few farmers have the resources or desire to invest in large scale AD plants, and many would prefer a solution that was more appropriate to the needs and scale of their farming operations. There is clearly a demand for small-scale farm based digestion.

Farm slurries can, with the appropriate technology, be digested in smaller scale AD plants on farms with other feed stocks that are available locally and can be included without excessive additional regulation. There is a perception that only large scale AD plants are viable, but the case studies and discussion with industry show that this need not be the case.

The UK has the expertise to continue to develop the technology for smaller scale AD applications and this would be helped further by a framework which ensures that this is a viable proposition.

Appendix 2 provides a comprehensive overview of AD, including some of the specifics which are applicable to the Agri Digestore project.

3.1 Background

The development of the Agri Digestore began through the desire to develop an anaerobic digester for installation on farms which tackles the preconceptions that AD has a very high capital cost and that it 'does not work' at smaller scales.

The concept of a single tank system was taken further with the retro-fit option that would allow the adoption of existing slurry storage for anaerobic digestion.

Further, the call for robust system design in terms of keeping operational restrictions to a minimum and complementing normal farm slurry management activities rather than limiting or restricting them, has influenced the operational and process design detail.

Key to the Agri Digestore design is the modular pre construction of the components, allowing faster plant build time and reduced costs. Marches Biogas manufactures its own mixing and heating systems, electrical installations and control panels as well as connecting pipework and gas system components, this gives complete control over the production of the separate component packages:

- Tank Package – Supplied and erected by preferred subcontractor to include preinstalled mixing and heating hardware.

- Feed /discharge equipment and pipework package – Factory built to site specification prior to installation prior to commissioning.

- Mixing equipment package – built into tank structure with unit constructed plant installed prior to commissioning.

- Water circuit equipment package – built in unit to be installed on site with the standby boiler prior to commissioning.

- Electrical equipment package – factory built for site installation prior to commissioning.

- Gas holder roof – Modular unit construction, factory built for site assembly and installation at the point of commissioning.

3.2 Farm survey

The feasibility study began with a site visit to Hall Farm Ludlow, to carry out a farm survey of the site on which the technology would be fitted for Phase 2. The survey was carried out by Russell Mulliner and Mike Phasey of Marches Biogas on 23rd February 2012, where Alan Watkins and his wife (Owners of Hall Farm) were interviewed with regards to their requirements for the project. They also provided an explanation of the farming operation and a walk around the dairy unit.

Hall Farm, Snitton, Nr Ludlow, Shropshire is owned by the Watkins family and the farm consists of 110 acres with a further 130 acres of rented ground nearby used primarily for growing cattle feed.
Hall Farm has a 240-head cross bred dairy herd comprising of Holstein, Jersey and Ayrshire cattle which are housed for 5 months of the year. For the remaining 7 months the majority of the herd graze on land near to the main farm site.

At present, the dairy cattle at Hall Farm are fed a mixture of maize, grass and brewers draff. The cows are bedded on a mixture of sawdust and sand and are milked twice per day.

Whilst cattle are housed on the farm, the slurry from the cubicles is scraped twice a day into an existing earth banked below ground slurry lagoon which has an approximate capacity of 450m^3. During 2011, the lagoon was emptied six times by a local agricultural contractor who applied the slurry using a splash plate system. All the slurry was applied to land owned or rented by H J Watkins to maximise beneficial nutrient use from the slurry. However due to the size of the existing lagoon this isn't always possible, leading to spreading outside the useful growing season. The farm currently imports 30 tonnes of mineral fertiliser per year. The wash water for the dairy is heated by electric immersion heaters and the resulting dirty water is fed to a separate tank and applied direct to land when the tank is full.

The electrical supply on the farm is 3 phase, preliminary investigations have been made concerning the export capacity of this site, at the time of this report presentation no response had been received from the local DNO. Our initial site investigation suggests that there is adequate capacity on the farm for the anticipated size of generator to be installed.

Several suitable positions for the location of the Agri Digestore were found one of which was adjacent to the site of the existing lagoon, the other behind the existing cattle feed clamps, the proximity of both positions to existing infrastructure simplifies slurry and digestate handling. Either position also lends itself well to use of heat from the biogas on site and electrical connection both for power supply and export.

The proximity of one position is adjacent to the property boundary and a metalled public highway means that Prior Notification (Permitted Development) cannot be accepted and planning consent will require to be granted, for the use of this report this position has currently been discounted[1].

Mr Watkins' intention for the operation of an anaerobic digester at Hall Farm is for a complementary plant to his existing farm operations. Of the outputs from the plant, digestate, for nutrient management maximisation and biogas for electrical and heat generation are key aims. The choice of gas consumer is therefore CHP with exhaust gas heat recovery, pending confirmation of costs.

In view of the seasonal grazing regime operating on the farm, Mr Watkins is aware that in order to maximise the potential of an anaerobic digester, supplementary feed stocks for summer use may be required. In this case, a small amount of energy crop can be grown to supplement summer slurry production and increase output if necessary.

3.3 Design Indications

From the farm survey, tank dimensions and capacity have been calculated as shown in the process calculations (10.0).

The system requirements are as follows:

- A reception pit for the collected slurry, with provision for additional feed stocks, with a macerator and feed pump make up the required front end.
- The discharge would be direct from the store to vacuum tanker, via double valves, no pump required.
- Heating would be by heat exchanger incorporated in the tank base and mixing by Marches Biogas gas recirculation.
- The combined tank roof and gas holder will be sized according to the required store dimensions.
- Ancillary equipment required includes motor control panel, standby boiler, CHP unit, water circuit pumps and gas/ fire detection equipment.

3.4 Process Calculations

A set of process calculations have been prepared using the information gathered from the interview, survey and subsequent visits.

Cattle slurry from 240 dairy cattle housed 120 days per year and milked twice a day.

[1] *Planning permission has now been granted for the Agri Digestore at Hall Farm*

The process calculations are arranged over several pages, and therefore are available in Appendix 1.

- **Feedstock** details the feedstock quantity, the dry matter, gas yields, feedstock cost and the anticipated energy output.
- **Treatment** details the daily feed rate, digester capacity and loading rates.
- **Energy** details the biogas output and therefore the energy produced by the plant, the plant heat and electrical requirements and the net outputs.
- **Economics** details the overall income and operating costs with a simple pay back for converting an existing slurry store into an Agri Digestore.
- **Mass Balance** details the overall inputs and outputs.

3.5 Process Calculation Variables

The process calculations above illustrate the scenarios detailed earlier, the indication of capital cost is for the anaerobic digestion plant only, this cost is based on conversations with technology providers of small-scale systems, no costs have been allowed for utility connections, ground works additional to the tank base, permitting, planning permission and CDM costs.

Hall Farm requires additional infrastructure improvements to accommodate an Agri Digestore, including slurry pit, pipework and pumping equipment to transfer the slurry from the slurry pit to the Agri Digestore and surplus heating pipework for the heat is to be utilised on the farm.

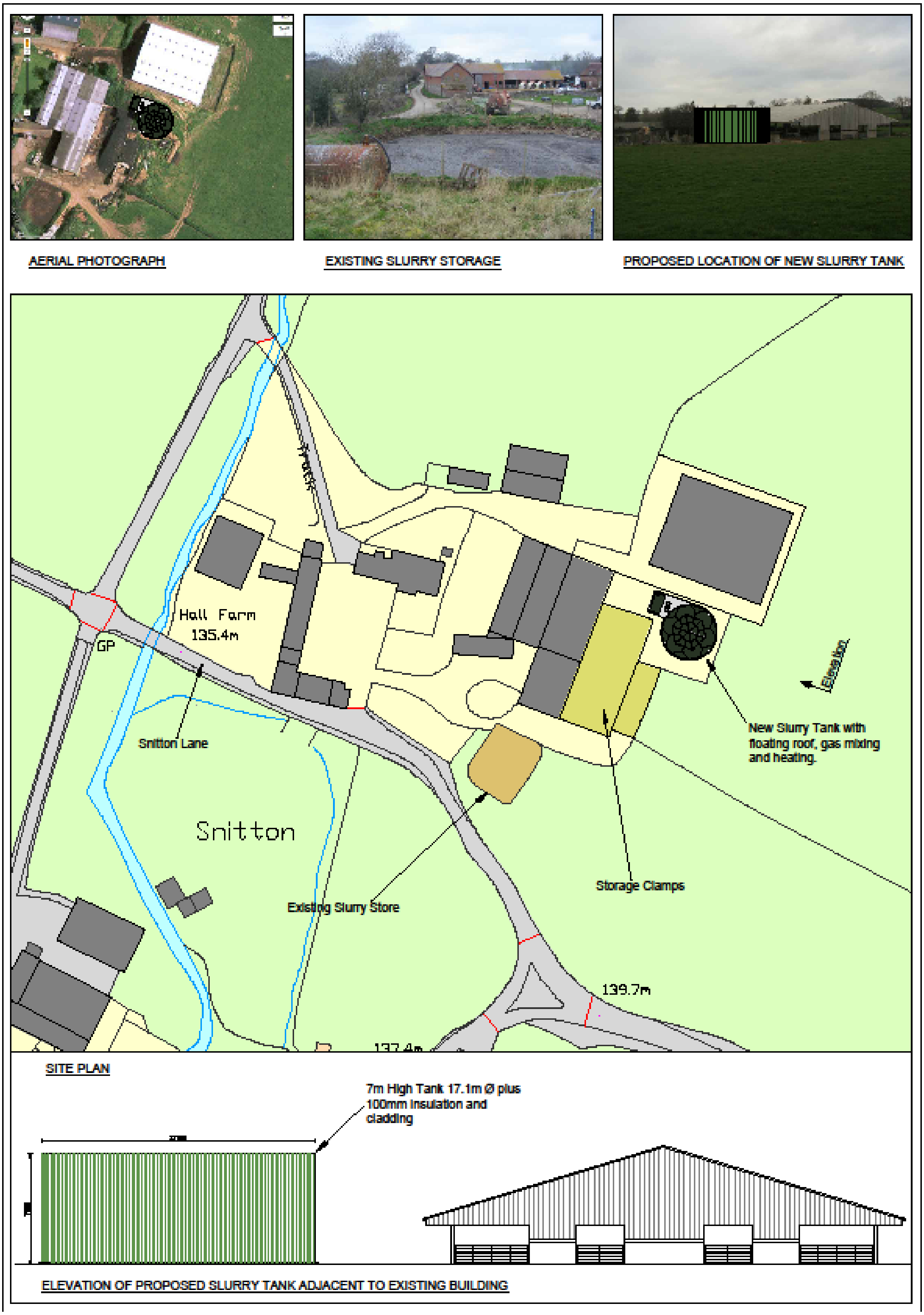
3.6 Operating Cost Variables

Within the process calculations, as illustrated on the feedstocks page, zero cost has been associated with the cattle slurry as these costs are variable depending on each installation. For example, chicken litter cost is £12 tonne but it has a value to the farm of £12 tonne as fertiliser, however allowance will have to be made for transport. Within the economics assessment page costs have been associated with labour charges to operate the plant. Some existing plants do not count these costs as the digester operation is seen as part of the daily routine.

3.7 Income Variables

Within the process calculations income has been associated with electricity generation which is generally a fixed income and income has been associated to a proportion of the surplus heat, the liquid and solid digestate.

Figure 1 Position of Agri Digestore at Hall Farm



4.0 Phase 2: Demonstration

4.1 Methodology

Marches Biogas is an engineering company, active in the anaerobic digestion technology market in the UK. Anaerobic digester feasibility, survey, design, build, commission and maintenance services are undertaken in house. As such we have a proven record of delivering projects from a green site to commissioned plant operating at full designed throughput.

The procurement and build process for the Agri Digestore at Hall Farm will be undertaken as business as usual, with the customer's requirements being the focus.

The following procurement and build process will need to be undertaken:

- Civil Engineering works; site preparation and groundwork including concrete pouring and finishing, tank foundations, ring beam and tank construction will be contracted to our preferred contractor, in this case; Reliant Installations.

- The Tank supplier will be Permastore via Reliant Installations.

- Ancillary equipment, not manufactured by Marches Biogas will be supplied by our existing suppliers of pumps, compressors, prefabricated building, boiler, CHP. All of these suppliers have an existing relationship with Marches Biogas for the provision of this equipment, or similar.

- Construction, commissioning, testing and evaluation of the demonstration plant will be conducted by Marches Biogas.

There are no additional stakeholders/ funders involved in the demonstration site besides Marches Biogas and Alan Watkins, owner of Hall Farm.

The site selected for demonstration has been chosen due to the owner's interest in both AD and particularly the Agri Digestore because of the advantages it offers and the reduced capital cost. In addition, the site owner has stated he has no desire for waste import / large scale energy crop anaerobic digestion but would prefer to employ a complementary system that will utilise on farm produced feedstocks i.e. slurry/ FYM. Furthermore it allows the farm's nutrient cycle to be maximised. The site location is within 10 miles of Marches Biogas' operating base and therefore is well placed to allow monitoring and reporting works to be conducted regularly.

4.2 Project Timescale

See Programme below for the full detail, key highlights of this are:

- Procurement
- Mechanical and Electrical Fabrication
- Tank Construction
- Site Installation
- Commissioning
- Monitoring

4.3 Financing

The Project will be financed in part by Phase 2 DIAD, in addition to the farms contribution a contribution in kind from Marches Biogas will allow the project to proceed. See cost and payment breakdown in 12.4.

4.4 Cost breakdown, milestones and equipment

Table 1 Project Payment Milestones

Project Payment Milestones				
Project name:	Driving Innovation in Anaerobic Digestion			
Project code:	MB420			
Document Ref:	MB420/266			
			Total Value	**Stage Value**
Design	Tanks Design		£1,297	£1,297
	Process Design		£1,297	£1,297
Procurement	1. Feeding and Pump Systems		£9,975	
	Stage Payment 1 Procurement	50%		£4,987.50
	Stage Payment 2 Delivery	30%		£2,992.50
	Stage Payment 3 Installation	20%		£1,995.00
	2. Mixing Systems		£18,900	
	Stage Payment 1 Procurement	50%		£9,450.00
	Stage Payment 2 Delivery	30%		£5,670.00
	Stage Payment 3 Installation	20%		£3,780.00
	3. Control Panel, Instrumentation and Cabling		£17,010	
	Stage Payment 1 Procurement	50%		£8,505.00
	Stage Payment 2 Delivery	30%		£5,103.00
	Stage Payment 3 Installation	20%		£3,402.00
	4. Boiler, Digester Heating and Gasholder		£64,890	
	Stage Payment 1 Procurement	50%		£32,445.00
	Stage Payment 2 Delivery	30%		£19,467.00
	Stage Payment 3 Installation	20%		£12,978.00
	5. Tank, Base, Erection and Insulation		£98,700	
	Stage Payment 1 Procurement	50%		£49,350.00
	Stage Payment 2 Delivery	30%		£29,610.00
	Stage Payment 3 Installation	20%		£19,740.00
	6.Pipework		£9,450	
	Stage Payment 1 Procurement	50%		£4,725.00
	Stage Payment 2 Delivery	30%		£2,835.00
	Stage Payment 3 Installation	20%		£1,890.00
Installation	1. Feeding and Pump Systems		£2,009	
	Stage Payment 1	40%		£803.55
	Stage Payment 2	40%		£803.55
	Stage Payment 3	20%		£401.77
	2. Mixing Systems		£3,806	
	Stage Payment 1	40%		£1,522.52
	Stage Payment 2	40%		£1,522.52

	Stage Payment 3	20%		£761.26
	3. Control Panel, Instrumentation and Cabling		£3,426	
	Stage Payment 1	40%		£1,370.26
	Stage Payment 2	40%		£1,370.26
	Stage Payment 3	20%		£685.13
	4. Boiler, Digester Heating and Gasholder		£13,068	
	Stage Payment 1	40%		£5,227.30
	Stage Payment 2	40%		£5,227.30
	Stage Payment 3	20%		£2,613.65
	5. Tank, Base, Erection and Insulation		£19,877	
	Stage Payment 1	40%		£7,950.91
	Stage Payment 2	40%		£7,950.91
	Stage Payment 3	20%		£3,975.46
	6.Pipework		£1,903	
	Stage Payment 1	40%		£761.26
	Stage Payment 2	40%		£761.26
	Stage Payment 3	20%		£380.63
Commissioning	Completion of Cold run & Rotation tests		£1,102	
	Completion of Slurry line pressure test		£1,102	
	Completion of gas line pressure test		£1,102	
	Completion of process guarantee period		£1,102	
Total			**£270,017**	

Table 2 Equipment Schedule

Equipment Schedule		
Project name:	Driving Innovation in Anaerobic Digestion	
Project code:	MB420	
Document Ref:	MB420/265	
Revision:		
Date:	28th March 2012	
		Qty
Feed Pump and Macerator		1
Agri Digestore Tank		1
Agri Digestore Tank Base		1
Agri Digestore Tank Erection		1
Agri Digestore Tank Insulation		1
Agri Digestore Tank Heat Exchanger		1
Agri Digestore Tank Heat Exchanger Water Pump		1
Agri Digestore Mixing System		2
Agri Digestore Gas Holder		1
CHP Unit		1
Biogas Boiler		1
PIPEWORK		
Slurry Pipework		1
Gas Pipework Tank Gas Outlet & Relief Valves		1
Gas Mixing Pipework		2
Water Circulation Pipework		1
Flue & Exhaust Pipework		1
INSTRUMENTS		
Slurry Tank Level Switch		1
Agri Digestore Tank Level		1
Agri Digestore Tank Temperature		1
Agri Digestore Gas Holder Level		1
Heating Water Temperature		1
Building Gas Detector		1
CONTROL PANEL & CABLING		
Control Panel Components		1
Cabling		1

5.0 Commercialisation of Technology

5.1 Intellectual Property

Marches Biogas has researched the options for protecting intellectual property on the Agri Digestore. It is our understanding that the plant when viewed in its component parts does not represent completely original concepts, as would be required for IP protection. As a whole concept, the Agri Digestore is unique in the market however; protecting an operational concept is not accepted for IP protection where the mechanisms for its operation are already in use within the industry. Marches Biogas will pursue an intellectual property protection of the design for the gas holder/ roof on the completion of its development, on the basis that the design features aspects that may be satisfactorily protected.

5.2 Markets

The target market for the Agri Digestore is the agricultural sectors that already have or require storage for cattle or pig slurry. This sector includes those farmers who may be unwilling to accept the additional investment required, both financial and agricultural (in the growing of energy crops to justify the higher capital cost of plant build). Because of the retrofit application of the Agri Digestore, we intend the product to target both those farmers who have existing storage, as well as the market for new build stores, particularly where NVZ regulations are being introduced.

The development of a number of demonstration plants, with Hall Farm being a key example, is recognised to be an important step in the marketing of the Agri Digestore product. We understand that an operational plant will always provide a better demonstration of a novel technology than the theory when selling to the target market, in this case livestock farmers. Our approach to market is by utilising the interest in the product that comes about at trade events, seminars and open days, achieving industry recognition, such as through the DIAD programme as well as by increasing awareness of the product through the farming press.

5.3 Permitting

We are currently in talks with the Environment Agency regarding the permitting of the Agri Digestore, it will either be covered by a T24 Exemption for Anaerobic Digestion on farm or a Standard Rules Permit; SR2010 No.16

5.4 Planning

Planning is required for the construction of a new Agri Digestore on that basis that the planners recognise that a 'Waste Treatment' process is being installed. For the same reason, the conversion of existing storage to Agri Digestore will normally require planning for the change of use.

5.5 Growth forecasts

As of 2009 there were over 8000 above ground circular slurry stores in use in England and Wales on both cattle and pig farms. These include bolted steel panel and concrete. With tightening NVZ regulations and an increase in the average size of dairy herds, new stores in build will also offer a market. We aim for a 10% market penetration, allowing for the growth in the conventional anaerobic digester market, so would expect there to be a potential for 900 Agri Digestores in the UK.

We project the likely uptake of the Agri Digestore in the first year to be 5 units with a growth in the second year to 18 units and 45 units in year three. By years 5 and 6 on the market we anticipate there to be a plateau in the growth of Agri Digestore installations at approximately 90 to 100 installations per year.

As a company well placed to deliver the design, engineering and build of the Agri Digestore, and capable of growing to deliver those installations, Marches Biogas anticipate retaining the UK Agri Digestore market.

5.6 Personnel

Marches Biogas has a dedicated team of engineers. The whole team works only on anaerobic digestion and their experience in this field is up to 25 years.
All design work is carried out on Autocad.

Procurement is partly through significant subcontracts, for example for tanks, pumps and for parts which Marches Biogas fabricates into completed assemblies.

The site manager will be from the Marches Biogas team and the installation team will comprise both Marches Biogas staff and subcontractors recruited for the purpose. Marches Biogas commissioning engineers will test the completed works and commission the anaerobic digester.

Table 3 Resources (excluding administration and finance personnel)

Name	Postion	Technical roles
Russell Mulliner	Director	Process design, control philosophy, plant configuration, mechanical and electrical design, plant installation & commissioning, project management, Health & Safety.
Jamie Gascoigne	Commissioning Engineer	Plant design, installation, **maintenance,** and commissioning.
Steve Cotterill	Autocad Designer	Plant layout design and configuration, production of all working drawings and plant installation.
Paul Owen	Electrical Design Engineer	Electrical, Instrumentation and Control design, plant **installation,** and commissioning.
Sean Owen	Electrical Engineer	Control panel manufacture and site electrical and instrumentation Installation.
Geraint Owen	Electrical Engineer	Control panel manufacture and site electrical and instrumentation Installation.
Justin Whittall	Mechanical Engineer	Mechanical design, fabrication and site installation.
Harvey Morgan	Mechanical Engineer	Fabrication and site installation
Mike Phasey	Site Engineer	Plant installation, ancillary civil work and commissioning.
Jimmy Ellis	Mechanical Engineer	Mechanical installation, plant commissioning and maintenance.

5.7 Evaluation and Monitoring for WRAP Reporting

Marches Biogas has in-house resources in place to carry out monitoring of Hall Farm Agri Digestore during and after commissioning. Full biological analysis of feed stocks and digestate will be carried out weekly as well as monthly analysis of performance from mass balance analysis to system efficiency for both mechanical and biological process. All the relevant information gathered from the mass balance analysis will be presented in a monthly report.

With experience in trouble shooting and process optimisation for a number of water companies in the UK including Kelda Water, United Utilities, Welsh Water, Celtic Anglian Water, Yorkshire Water and Wessex Water, Marches Biogas have a wealth of experience in understanding anaerobic digester performance and evaluating this through measurement and reporting.

6.0 Health and Safety

Safety is at the core of Marches Biogas designs and operations. Our approach is to examine safety from first principles and to make systems inherently safe, rather than depending on special equipment.

Gas collection, control, storage and utilisation systems will be designed in accordance with good engineering practice and, where appropriate, the technical and safety standards issued by the Institution of Gas Engineers and Managers (IGEM).

Exposed pipelines will be marked with in accordance with BS 1710. Gas will be marked Yellow Ochre (08 C 35), water pipes Green (12 D 45) and digestate Black. Buried pipes will be marked with a polythene warning tape 100mm above the pipe.

A Health & Safety Plan complying with the Construction Design & Management (CDM) Regulations will be prepared prior to the start of construction. A Health & Safety File will be prepared during the life of the project and handed over to the client on completion.

7.0 Conclusion

The abundance of digestible material created by the farming industry has prompted DEFRA and the NFU to encourage British farmers to adopt on-farm anaerobic digestion. However, the costs involved have prevented many farmers from engaging with the new technology.

The Marches Biogas Agri Digestore significantly reduces these costs, as digested material can be utilised in a conventional manner without disrupting the process, avoiding the need to build additional vessels. Existing slurry stores can simply be retrofitted with the process components. Almost a quarter of the methane produced by farming dairy cows is released from the slurry, in storage and on application. We believe we can drastically reduce those emissions with our product and utilise the methane to generate renewable energy. The widespread adoption of the Agri Digestore would also increase employment opportunities throughout the agricultural and renewable industries. The adoption of this concept by the agricultural sector will also increase the awareness and adoption of more conventional AD technologies.

Appendix 1 – Agri Digestore process calculations

FEEDSTOCK		Winter	Summer
Cattle Slurry			
Number of Cattle Housed		**240**	**240**
Average Slurry Production per Animal	**litres/animal/day**	**63**	**63**
Daily Production of Undiluted Slurry	**tonnes/day**	**15.1**	**15.1**
Slurry Dry Solids Concentration	**% DM**	**8**	**8**
Slurry Dry Solids	**tonnes/day**	**1.21**	**1.21**
Daily Production of Diluted Slurry		**15.1**	**15.1**
Winter Production	**days housed**	**120**	
Winter Production	**tonnes**	**1814**	
Summer Production	**days housed**		**245**
Summer Production	**tonnes**		**741**
Total Mass	**tonnes/year**	**1814**	**741**
% Dry Matter	**% DM**	**8.0**	**8.0**
% Organic Dry Matter	**% ODM**	**80**	**80**
Specific Methane Yield	**m3 CH4/tODM**	**180**	**180.0**
% Methane	**% CH4**	**58**	**58**
Dry Matter	**tonnes/day**	**1.21**	**0.24**
Organic Dry Matter	**tonnes/day**	**0.97**	**0.19**
Methane Production	**m3/day**	**174.2**	**34.8**
Biogas Production	**m3/day**	**300.3**	**60.1**
Electricity Production	**kWe**	**21.6**	**4.3**
Specific Biogas Production	**m3/tonne waste**	**60.4**	**29.6**
Total Feedstock			
% Feedstock of Slurry	**%**	**100**	**100**
Mass	**tonnes/year**	**1814**	**741**
% Dry Matter	**% DM**	**8.0**	**8.0**
% Organic Dry Matter	**% ODM**	**80**	**80**
Specific Methane Yield	**m3 CH4/tODM**	**180**	**180**
% Methane	**% CH4**	**58**	**58**
Dry Matter	**tonnes/day**	**1.21**	**0.24**
Organic Dry Matter	**tonnes/day**	**0.97**	**0.19**
Methane Production	**m3 CH4/day**	**174**	**35**
Biogas Production	**m3/day**	**300**	**60**
Electrical Efficiency of Generator	**%**	**30**	**30**
Electricity Production	**kWe**	**22**	**4**
Specific Biogas Production	**m3/tonne waste**	**19.9**	**19.9**

TREATMENT		Winter	Summer
Feedstock Conditioning			
Mass of Feedstock	**tonnes/day**	**15.12**	**3.02**
%DM	**%DM**	**8.0**	**8.0**
%ODM	**%ODM**	**80**	**80**
Dry Matter	**tonnes/day**	**1.2**	**0.2**
Organic Dry Matter	**tonnes/day**	**1.0**	**0.2**
Anaerobic Digestion			
Mass of Digester Feedstock	**tonnes/day**	**15.12**	**3.02**
Volume	**m3/day**	**15.12**	**3.02**
%DM	**%DM**	**8.0**	**8.0**
%ODM	**%ODM**	**80**	**80**
Dry Matter	**tonnes/day**	**1.2**	**0.2**
Organic Dry Matter	**tonnes/day**	**1.0**	**0.2**

Gross Capacity of Slurry Store	**m3**	**1,540**	**1,540**
Digestore Volume at 100% Capacity	**m3**	**1,475**	**1,475**
Digestore Volume at 15% Capacity	**m3**	**221**	**221**
Slurry Storage Capacity	**m3**	**1,254**	**1,254**
Methane Production	**m3 CH4/day**	**174**	**35**
% Methane	**% CH4**	**58**	**58**
Volume of Biogas	**m3/d**	**300**	**60**
Mass of Digester Output	**tonnes/day**	**14.7**	**2.9**
%DM	**%DM**	**5.7**	**5.7**
%ODM	**%ODM**	**71.1**	**71.1**
Dry Matter	**tonnes/day**	**0.8**	**0.2**
Average Hydraulic Retention Time	days	41.46	207.30
%DM of Digester Feed	%DM	8.00	8.00
Average Specific Loading Rate	kg/m3/day	1.14	0.23
Average Biogas : Digester Capacity	m3/d/m3	0.35	0.07

INCOME		Winter	Summer
Fuel Value of Biogas	**kWf**	**72**	**14**
Electrical Efficiency of Generator	**%**	**30.0**	**30.0**
Continuous Electricity Rating	**kWe**	**22**	**4**
Overall Generator Availibility	**%**	**90**	**90**
Gross Electricity Output	**MWh/year**	**56**	**23**
Plant Electricity Consumption	**MWh/year**	**5**	**5**
Net Electricity Production	**MWh/year**	**51**	**18**
Electricity Sale Price	**£/kWhr**	**0.065**	**0.065**
FIT	**£/kWhr**	**0.140**	**0.140**
LEC	**£/kWhr**	**0.004**	**0.004**
Value of Electricity	**£/kWhr**	**0.209**	**0.209**
Value of Electricity	**£/MWh**	**209**	**209**
Income from Electricity Sales	£/year	10,652	3,731
Gross Heat Output	**MWh/year**	**150**	**50**
Plant Heat Consumption	**MWh/year**	**90**	**40**
Surplus Heat Production	**MWh/year**	**60**	**10**
Value of Surplus Heat	**£/MWh**	**68**	**68**
Potential Value of Surplus Heat	**£/year**	**4,080**	**680**
% Utilisation of Surplus Heat	**%**	**100**	**100**
Income from Surplus Heat	£/year	4,080	680
Liquid Biofertiliser Production	**tonnes/year**	**1,770**	**723**
Value of Liquid Biofertiliser	**£/tonne**	**1.00**	**1.00**
Income from Liquid Biofertiliser	£/year	1,770	723
Total Income	£/year	16,501	5,134
OPERATING COST			
Digester Maintenance	**£/year**	**1,000**	**1,000**
CHP Maintenance	**£/year**	**784**	**320**
Total Operating Cost	£/year	1,784	1,320
ECONOMIC ASSESSMENT			
Capital Cost of Retrofit	**£**	**175,000**	**175,000**
Income	**£/year**	**16,501**	**5,134**
Operating Cost	**£/year**	**1,784**	**1,320**
Net Income	**£/year**	**14,718**	**3,814**

Simple Pay-Back	**years**	**9.4**

MASS BALANCE		Winter	Summer
Digester Inputs			
Organic Waste	**tonnes/yr**	**5,519**	**1,104**
Total	tonnes/yr	5,519	1,104
Digester Outputs			
Biogas	**tonnes/yr**	**136**	**27**
Digestate	**tonnes/yr**	**5,383**	**1,077**
Total	tonnes/yr	5,519	1,104
Digester Mass Balance		0.00	0.00

Appendix 2 – Anaerobic Digestion

Anaerobic digestion is a natural biological process which transforms organic waste into useful bio fertiliser. As such it is similar to composting, but it has two important differences; first, it is a fully-enclosed in-vessel process; and second, it also produces valuable renewable energy in the form of biogas, which typically comprises 60% methane and 40% carbon dioxide.

AD has been applied for nearly a century in the water industry as the favoured method for the stabilisation of sewage sludge, with the biogas being seen as a bonus. There are thousands of digesters in China, India and Nepal where village-scale plants are important for the recycling of nutrients in farm manure and night soil, as well as cooking and lighting.

The technology has been widely adopted across Europe. For example in Denmark there are a number of farm co-operative AD plants which produce electricity and district heating for local villages. In Sweden biogas plants have been built to produce vehicle fuel; fleets of town buses now operate on clean compressed biogas. In Germany and Austria, with their favourable government renewable energy policies, there are several thousand on-farm digesters treating mixtures of manure, energy crops and commercial food waste, with the biogas used to produce electricity.

Anaerobic digestion of manure, and hence the production of biogas, is currently perceived as the most promising way to tackle GHG emissions from agriculture and especially from animal and dairy production. AD has the potential to produce green energy as electrical power, heat or vehicle fuel. Additionally added organic wastes and energy crops can boost the gas yield and at the same time AD contributes to regional waste management schemes.

AD also facilitates the establishment of an environmentally sound manure management system on farm. It produces a digestate with an improved fertiliser value compared with the source material and thus has the potential to displace mineral fertilisers where the best use of this improved nutrient value can be realised.

A pollutant arising from manure spreading is nitrate. In raw animal manure, 30-50% of the nitrogen is in organic form with the rest as ammonia. Ammonia can be converted to nitrate for plant uptake, while some plants may use ammonia directly. In the organic form, nitrogen must be first mineralised before it is available to a plant's root system. The extent of nutrient uptake by plants depends on the time of application and there is always the possibility that nutrients will be leached from the soil when plants are unable to take them up. AD converts much of the organic N into ammonia, yielding a digestate with 60-80% of the total nitrogen content in the form of ammonia [Banks et al., 2007]. This makes it much more predictable, minimises leaching losses and is in line with the development of good agricultural practices.

In addition, odour emissions are significantly reduced through the anaerobic process. Biogas production in an AD plant makes use of a naturally occurring anaerobic biology and supplies a technically controlled environment that allows capture and utilisation of all the gases produced, offsetting the fugitive emissions arising from conventional slurry storage. Co-digestion of manure with other biomass can improve methane generation. Two main factors influence the result: a higher biogas potential of the additional biomass and beneficial effects on maintaining or establishing environmental conditions favourable for the microbial consortium. A strong reason for co-digestion of feedstocks is the adjustment of the carbon-to-nitrogen (C:N) ratio, which should be in a range of 25- 30:1 [Ward et al., 2008]. Different biomass types vary widely in their C:N ratios and co-digestion of a low C:N ratio feedstock with a high C:N ratio feedstock can adjust the resulting ratio closer to optimum.

Benefits of Anaerobic Digestion

While the obvious benefits of on-farm anaerobic digestion; the production of renewable electricity and/ or heat while retaining the nutrient value of the raw materials are widely recognised, as an integrated component within the slurry and waste management regime on farm, an AD plant has wider benefits. Industry experience and published case studies such as the RASE 2011 AD Report outline the fringe benefits which can, in combination, be of as much value as the energy recovery in an on-farm situation. Even now that the UK Government has embraced AD as a key technology, it still seems uncertain in which role to deploy it! If left to market forces, AD will certainly make money for those who invest in large centralised processing plants that accept high energy-value waste inputs, charge gate fees, and receive subsidy for the heat or power they produce.

This is not, however, a solution that will maximise the energy potential of the available waste biomass, as by far the largest tonnages of these materials are animal slurries and manures produced on farms. Although the energy potential of these per tonne is low, if they can be digested on farm, at source, the overall net energy yield is significant.

AD is a multi-faceted process and has a number of different benefits:

Waste Management

AD stabilises organic wastes, thereby preventing unwanted pollution. Uncontrolled methane emissions are avoided (CH_4 is 22 times more powerful than CO_2 as a greenhouse gas); the polluting power of waste is substantially reduced; foul odours are all but eliminated; pathogenic organics are killed (complete eradication is achieved by the inclusion of pasteurisation); and weed seeds are destroyed. Although not necessarily a selling point to the farmer at present, the reduction in greenhouse gas emissions from the storage of slurry and manure diverted to anaerobic digestion does have merit where carbon accounting is to be considered. While typically farming in the UK is at present not called to account for all emissions, there have been moves to call the dairy and beef cattle industry to account for the emission of methane gas arising from the rearing of livestock and the wastes associated with this.

Nutrient Management

Organic wastes, including chicken litter, contain valuable nutrients; however, a significant proportion of nitrogen in particular is locked up in unavailable forms. AD is an enclosed process that retains all the nutrients and, importantly, converts them into available forms. This enables a farm to better plan its nutrient management and to reduce its dependency on mineral fertilisers, which themselves require fossil fuels for their production. The combination of thorough maceration of incoming slurries and feed stocks mean that particle size is reduced for the AD process which then further reduces both the particle size and the organic solids content of the material so that, as whole digestate, the material is more uniform and consistent to pump and spread, therefore improving handling, ease of application to land and minimising the risks of ground water pollution. A well designed AD system, integrated into the farm's slurry infrastructure will not increase the need to handle slurry any more than traditional storage techniques.

The advanced decomposition of the organic nitrogen and other nutrients within whole digestate significantly increases the rate of root uptake by making more of the nutrient (N) value available to the plant and thus reducing losses to evaporation and leach-out after spreading. The reduced particle size in whole digestate mentioned above also reduces the amount of matting on top of the pasture when the digestate is spread, the solid material runs to root level and is incorporated into the soil more readily.

This also has the benefit of reducing the tainting of pasture for grazing or harvesting because less contamination adheres to the sward. Additionally, ground spread with digested material vs. raw stored slurry has a significantly reduced rejection 'value' to grazing beasts, at least halving the time before the grass on that ground becomes palatable again according to current on-farm AD operators. A significant reduction in the count for bacteria, virus and parasites including E.coli, salmonella, coliforms and gastrointestinal nematodes (various parasitic worms) in digestate when compared with raw stored slurry is also a significant benefit.

Renewable Energy

In addition to the benefits of waste and nutrient management, AD produces renewable energy in the form of biogas. Biogas can be used either in a conventional boiler, or as the fuel for a combined heat & power (CHP) unit, or as a vehicle fuel.

The prime interests behind the implementation of AD on farm vary with the scale of the operation and the farm business. Where the AD support mechanisms focus predominantly on the output of an anaerobic digestion facility, on or off farm, in terms of electrical and heat output, they largely ignore the benefits that may equal or exceed these measures in terms of value to the farmer when viewed as a package.
There stands at present, little external incentive to the farmer with a typical 200 cow milking herd to look into AD as a means to maximise their nutrient/ slurry management and farm energy recovery options. Using typical benchmark data, the waste produced on a 200 cow dairy farm would generate on average sufficient gas through AD to generate 20kWe and at this scale, a typical installation may look to use gas for direct heating if the costs of setting up electricity export are unviable.

With a Feed in Tariff water shed at 250kWe generation capacity and Renewable Heat Incentive effectively marginally less, a farmer will look to either diversify their operation into the growth of energy crops or importing non-agricultural wastes to supplement manures and slurries in order to make the tariff contribution viable. However, the latter option carries regulatory penalties and greatly increased costs and the former has been threatened with being dis-incentivised by legislation. With this contradictory message coming from the primary support mechanism offered by government, those farmers who look to capital grant support as a means to help set up an on-farm anaerobic digester will often then find that using a state capital grant disqualifies them from the FIT and RHI mechanism anyway.

When biogas is used to produce electricity in a CHP unit, this qualifies for either renewable obligation certificates (ROCs) if feed in tariff (FITs) under government legislation. A generator qualifies for ROCs or FITs whether the electricity is exported or is used on site.

The value of renewable electricity under ROCs is made up of three parts; first, the value of the electricity itself, currently worth about 4.5 pence per kWh (£45 per MWh) if it is exported or up to £80 per MWh if it is displacing existing demand; second, the electricity qualifies for levy exemption certificates (LECs) which are worth £4 per MWh; third, the current value of ROCs which depends on renewable targets, is about £40 per MWh. The electricity is thus worth between about £130 and £165 per MWh with double ROCs depending on whether it is exported or used on site. Small-scale renewable electricity is normally traded through specialist licensed electricity suppliers.

A generator may alternatively adopt the Feed in Tarriff (FITs) which are financial support measures introduced by the government to increase the uptake of small-scale renewable generation (<5MWe) and help deliver the UK's 2020 renewable energy targets. The mechanism provides renewable generators with a 20 year guaranteed per unit support payments (p/kWh) for electricity generation.

There are three ways that the Tariffs help you make money from generating your own energy:

1. **The Generation Tariff**

Earn a fixed income for every kilowatt hour of electricity you generate. Currently, this stands at 9p /kWh for greater than 500kwe, 13.7p /kWh for 250 - 499 kWe and 14.7p/kWh for less than 250kWe.

2. **The Export Tariff**

An additional fixed income for every kilowatt hour of electricity you generate and sell back to the grid. (Currently guaranteed at 3p /kWh)

Recently the Renewable Energy Association have conducted a specific consultation amongst the members of the REA UK Biogas Group and have built a model which details the commercial fundamentals of each proposed band and the necessary levels of support. The REA are in discussions concerning the details of the model with the Department for Energy & Climate Change (DECC). Many other renewable organisations have presented their own thoughts to DECC including more favourable tariffs for the on-farm anaerobic digestion of farm derived wastes (slurries) over energy crop systems.

Within the economic assessment we have used the Feed In Tariff (FITs) to demonstrate the simple pay back period. It is not intended that FIT financed plants will necessarily be more profitable from those using the ROC system, however for small-scale anaerobic digestion it will certainly make the economics much more attractive.

Total **FIT** Income (17.7p/kWh) = FIT (14.7p) + Export Tariff (3p)

3. **Renewable Heat Incentive**

A fixed income for every kilowatt hour (up to 200 kWh installed capacity) of heat you produce and use beneficially other than the parasitic demand of the process. This is likely to be used on your own property only, but if you are lucky enough to be connected to a heat network you could get an additional payment for 'exporting' surplus heat. (Currently 6.5p p/kWh).

Environmental

The environmental impacts of anaerobic digestion are positive and bring the following benefits:

- Renewable energy will be produced;
- The digestate will provide a valuable source of soil conditioning and biofertiliser, displacing mineral fertilisers;
- The pathogenic organisms and weed seeds in the manure will be significantly reduced leading to a reduced use of herbicides;
- The biological and chemical oxygen demand of the manure will be reduced;

- The odour of the manure will be effectively eliminated;
- Uncontrolled emissions of methane to atmosphere will be prevented;
- There are no significant emissions of noise;
- There are no significant emissions of dust; and
- There is typically no adverse visual impact arising from the development of on-farm AD.

In summary anaerobic digestion contributes to the low-carbon economy.

Feedstocks

In theory any form of organic material can be utilised within an AD system, particularly, any crop which has low levels of lignin. Wood cannot be easily digested through an AD process for this reason so should be avoided except where present in slurry because of its use as a bedding material. Straw presents similar issues though is recognised to be digestible in a correctly designed AD system, in large volumes however it is not a recommended feed material.

The more common crop inputs include maize, wheat, sugar beet and grass but manures, dairy washings and vegetable wastes can also be used. AD plants that use a combination of organic sources are the most common: typically, agricultural waste, crops and commercial food waste derived from food manufacturing and municipal food waste collection.

This study has as its focus the feasibility of AD systems fed only with material derived from farms. The rationale for this narrow focus is that for the majority of dairy farmers, the AD enterprise needs to be integrated into the general management of the farm and the demands of managing the movement of imported feed stocks onto the farm are likely to be too onerous on typical family run farms without significantly diversifying the business.

The availability of input material on any one farm will dictate the size and type of AD plant, the gas yield and the most suitable means of digestate use. In turn, this will depend on the existing farming system, its location, the number of livestock for producing input material and the available crop area. Larger volumes of feedstock need bigger plants, more storage and the ability to export more energy.

Table 4 Yields of biogas for particular feedstocks

Feedstock Yields Feedstock	DM %	Biogas Yield m3/tonne	Gross Value of Biogas £/tonnes
Cattle Slurry	8%	20-25	6.30-7.90
Pig Slurry	6%	15-25	4.70-7.90
Poultry manure	20%	30-100	9.50-31.70
Grass silage	20%	100-140	31.70-44.40
Maize silage	30%	180-210	57.40-66.60
Maize grain	80%	500	160
Whole crop wheat	33%	185	58

Regulations

Planning Permission

Planning permission is necessary for most anaerobic digestion installations. Small-scale digesters using only on-farm waste *may* only require Prior Notification as long as the relevant restrictions are met, but it is recommended you get planning advice before pursuing this. Any installation accepting third party waste will need full planning permission.

The Agri Digestore is no different to conventional on-farm AD build as far as planning requirements are concerned. In the event of a retrofit of Agri Digestore components to an existing slurry store, a change of use consent would be required as AD, on farm or otherwise is viewed as a 'treatment process' and requires planning notification where storage of slurries produced on the same farm does not.

Planning Policy Statement 22 states that a planning application for an anaerobic digestion plant could usefully include the following:

- Site plan and elevation drawings to determine visual impact;
- Photomontage of digester, plant building(s) and chimney stack with clear indication of building material;
- Information on grid connection works, including transformer and transmission lines;
- Details of emissions to air and an assessment of their impact;
- Details of vehicular access and vehicular movement;
- Landscaping provisions;
- Site management measures during the construction phase;
- Model of emissions dispersion; and
- Community consultation plans.

Permitting

Anaerobic digestion is considered to be a treatment process for organic substrates with only energy crops grown for the purpose of digestion, manures and slurries exempt from waste categorisation.

For the purpose of anaerobic digestion, substrates other than those above, sourced on site or imported for use in a digester are considered to be controlled wastes by the Environment Agency (EA).

In April 2010 the EA published a Standard Permit entitled SR2010No16 On-farm anaerobic digestion facility including use of the resultant biogas. The permit allows: "an operator to operate a facility for the anaerobic digestion of wastes and also use of the resultant biogas in compression and spark ignition engines, with an aggregate rated thermal input of up to 3 megawatts. The rules also allow use of standard commercial gas turbines, fuel cells or treatment followed by injection into the gas grid".

The main preconditions for the Standard Permit are as follows.

The activities shall not be within:

- 500 metres of a European Site, Ramsar site or a Site of Special Scientific Interest (SSSI);
- a specified Air Quality Management Area (AQMA);

- 200 metres away from any off-site building used by the public, including dwelling houses;
- stacks from the engine must not be located within 200 metres of any off site building used by the public, including dwelling houses;
- 10 metres of a watercourse;
- 50 metres of any spring or well, or of any borehole not used to supply water for domestic or food production purposes; and
- 250 metres of any borehole used to supply water for domestic or food production;
- a groundwater source protection zone 1.

If a site cannot meet one or more of these conditions it will have to apply for a bespoke permit. For the standard permit an application fee of £1590 is payable with an annual fee of £510.

The main limitations for an SR2010No16 permit are as follows:

- All activities must be carried out on premises used for Agriculture.
- Treatment of waste shall include shredding, sorting, screening, compaction, baling, mixing and maceration.
- Digestion of wastes including pasteurisation and chemical addition.
- Gas cleaning by biological or chemical scrubbing.
- Gas storage and drying.
- Treatment of digestate including screening to remove plastic residues, centrifuge or pressing, addition of thickening agents (polymers) or drying.
- Composting and maturation of digestate.
- The total quantity of waste accepted at the site shall be less than 75,000 tonnes a year.
- The use of combustible gases produced as a by-product of the anaerobic digestion process as fuel.
- Except for the auxiliary flare, the aggregate rated thermal input of all appliances used to burn biogas shall be less than 3 megawatts.
- Use of an auxiliary flare required only for short periods of breakdown or maintenance of the facility.

It is acceptable to import agricultural waste from one farm to another under the standard permit. It will not allow for the import of any non-farm waste.

The burning of biogas is also a permitable activity depending on the scale to which it is undertaken. Combined burner capacities rated over 3MW (3,000 kW) burning biogas on one site are classified as an installation requiring regulation under the Environmental Permitting Regulations 2007.

Agricultural AD systems that have a net rated thermal input of less than 0.4MW may fall under exemption T24 providing that they meet the necessary restrictions. Allowable activities include the following:

- Anaerobically digest manure and plant tissue waste in a dedicated AD plant to produce a digestate.
- Burn the biogas produced by the AD process to produce energy to provide power on your farm or export to the national grid.
- Sort, screen, cut, shred, pulverise and chip the waste to aid the AD process.

The main limitations include the following:

- The waste must remain in the AD plant for a minimum of 28 days.
- You can store and treat up to 1,250 cubic metres of waste at any one time.

This storage limit does not include on-farm manure and slurry pits used to store on site sourced products prior to treatment. Nor does it include the storage of digestate from manures, slurries and energy crops. If you import manure and slurry from other farms and store it before it is fed into your AD plant however, the storage of this material is included within the 1,250 cubic metre limit.

When manure and slurry is mixed with plant tissue *waste* the 1,250 cubic metre limit will include the storage of plant tissue waste, the digester and the storage of the resulting digestate.

Under most of the on farm circumstances anticipated, the exemption will allow for most situations although the technology may not.

While a 'light touch' approach has been adopted for the permitting of manures and slurries, there exist serious caveats within the regulations that, for example, preclude the use of rejected feed silage or excess forage crop from being digested within the remit of 'manures and slurries' by classifying them as a waste where in fact these same products would be added to the muck midden and spread to land by common consent in normal practice.

The Agri Digestore is most likely to fall under either the T24 Exemption or the SR2010 No.16 Standard Rules Permit, depending upon application.

Digestate Quality Protocol

WRAP has introduced a recognised quality protocol to give greater understanding and market trust to the use of digestate from anaerobic digestion. This standard is called PAS 110, derived from the similar standard for compost products; PAS 100. The protocol stipulates numerous hurdles for the digestate producer to cross before their digestate product can be accredited with the quality protocol (QP). Achieving the QP will also elevate the status of digestates that contain digested waste products beyond waste categorisation to become a 'product' for application to land without licences. While this is useful to the large scale/ ABP food waste digester operator without the necessary land bank to apply all the digestate products of their process, to the farmer, the costs associated may outweigh the advantages this offers unless buyers or market forces dictate that the QP is adopted. The typical cost to establish PAS 110 for digestate ranges from about £5000 with annual costs thereafter at about half that figure, enough to remove a significant incentive to adopt the QP on a small-scale plant.

With the adoption of a quality protocol for digestate, there come necessary costs but also ill-conceived additional requirements such as the wholesale pasteurisation of all feedstocks if not sourced on site. While the QP may not apply to the farmer intending to apply digestate to his own land alone, in the case of the farm cooperative where neighbouring farmers choose to combine efforts and investment on a centralised plant, this type of 'one size fits all' legislation either rules the project unviable or, again, pushes the economies of scale such that the project becomes grossly greater in capacity and investment for the required returns.

The PAS 110 QP is not anticipated to apply to the Agri Digestore where the intended user will be a producer of the slurry being digested, and where the resultant digestate will be used on the same farm. Where slurry, manure and energy crop is digested, these feed stocks are not considered as wastes on their site of origin so the requirement to achieve product categorisation for the digestate would be of no advantage.

Where PAS 110 is required, the Agri Digestore will comply and has the advantages of a significant retention and therefore through digestion of substrates.

Health and Safety

Anaerobic digestion is often regarded as similar to a chemical process with all the associated risks: flammable atmospheres, fire and explosion, toxic gases, confined spaces, asphyxiation, pressure systems, DSEAR, COSHH, etc. In addition, it also incorporates gas handling and gas storage. Therefore, it is essential that thorough hazard and risk assessments are carried out at each stage of a project from design to installation to commissioning to implementation and operation.

Increasing adoption of AD, even on the farm scale has led to a greater interest from regulatory bodies and associated industry such as insurance and the HSE, the risk from this increased regulatory involvement is that conflicting or incompatible regulations are drafted, rendering the adoption of small-scale AD more expensive to implement, if not to operate.

Animal By Product Regulations

Animal by-products (ABPs) are animal carcases, parts of carcases or products of animal origin that are not intended for human consumption including those products that may be intended for human consumption but have been discarded. The Animal By-Products Regulations (ABPR) permit the treatment in approved composting and biogas premises of low-risk (category 3) ABPs and catering waste which contains meat or which comes from a premises handling meat. High risk (Category 2) ABPs cannot be used as feedstock in biogas plants, except where they have first been rendered to the 133°C/3 bar/20 minute EU pressure-rendering standard.

Manure and digestive tract content are classified as a category 2 ABP, but they can be used without processing as raw material in a biogas plant. However, where manure or digestive tract content is sent to a biogas plant for treatment with other ABPs (including catering waste) the plant **must** be approved and the mixture treated to approved standards.

It is not intended that the Agri Digestore, as it is presented here, is used as the basis for an ABPR compliant AD plant. The regulations and necessary economies of scale that these bring about, render the use of ABPs as additional feedstock in on-farm AD most unlikely except on the largest scale.

Nitrate Vulnerable Zones

Defra has designated areas as NVZs, in accordance with the EC Nitrates Directive, in order to reduce nitrogen loss from agriculture to water. Farmers within NVZs are required to comply with measures in the Nitrates Action Programme. The NVZ rules affect the management of nitrogen fertiliser on farms. Nitrogen fertiliser includes all materials applied to land that contain nitrogen compounds. It includes manufactured nitrogen fertiliser, and all types of organic manure, including livestock manure. The Nitrate Pollution Prevention Regulations 2008, which provide the legal basis for the NVZ designations and rules, came into force from 1 January 2009.

AD has often been suggested as a means by which disposal of farm waste can be used to overcome NVZ obligations. This is not the case for a number of reasons.

- If energy crops are added the total available nitrogen will increase significantly compared to the original slurry based nitrogen.
- A digester cannot be used as a store throughout the closed periods because it will be full at the start and full at the end of the closed period.
- Storage in the closed period is necessary for the entire digestate –not just that from livestock manures.
- A farm that is within an NVZ has to implement an Action Programme with the following measures.

Limit inorganic nitrogen fertiliser application to current crop requirements, after taking into account the results of soil tests. The rules for NVZs set a limit for organic manure (nitrogen) loadings of 250 kg/(ha*a) of total N on grassland, and 210 kg/(ha*a) N on land in non-grass crops, averaged over all agricultural land within the NVZ. The loading limit for land in non-grass crops in NVZs reduces to 170 kg/(ha*a) N after the first four years of the Action Programme.

These limits *include* manure deposited by grazing animals and N in imported organic materials, and they are based on the period 19 Dec to 18 Dec in the following year. The amount of N produced as livestock excreta varies according to the number and type of livestock on the farm.

No individual field should receive organic manure applications (which *excludes* manure deposited by grazing animals) which supply more than 250 kg/ha of total N in any 12 month period, or supply available N in excess of the crop requirement.

On sandy or shallow soils the NVZ Action Programme imposes a closed period of 3 months (1 Aug to 1 Nov) when no slurry, poultry manures or liquid digested sewage sludge may be applied to land which is not in grass nor to be sown with an autumn sown crop. The closed period for land in grass or to be sown with an autumn sown crop is 1 Sept to 1 Nov. These closed periods do not apply to FYM (straw-based manures) or other forms of sewage sludge or other organic materials.

Farm records must be kept, including cropping, livestock numbers and the use of organic manures including digestates and nitrogen fertilisers.

The Action Programme under the Nitrates Directive is also a Statutory Management Requirement (SMR) for cross compliance under the Single Payment Scheme. This means that the farmers have to comply with the Action Programme measures to be entitled to their full subsidy payment; failure to comply could lead to deductions.

Manure cannot be applied in the following conditions: waterlogged or frozen or snow covered land, steeply sloping fields, within 10 m of watercourses, and during the closed autumn period (sufficient capacity for the cattle slurry to be stored must be provided).

The biogas plant operator should identify the actual land areas onto which the digestate is to be applied as part of the feasibility study and business plan. It must be determined if land is in an existing or new NVZ area. To determine the N content of the soil, soil tests should be conducted or obtained.

Moreover, the N content of animal slurries on the land less the amounts of slurry diverted to the biogas plant should be calculated. Based on the expected digestate nutrient content and the maximum allowed fertiliser application, the land area required for digestate spreading can be calculated. If there is not enough land for spreading the digestate on the own farm, nearby farms should be contacted which may be interested in taking the digestate.

Since digestate spreading is largely seasonal, there will have to be an adequate storage for the digestate to cover those times of the year when spreading is not allowed.

Other issues

Grid connection

An AD plant will normally be connected to the low or medium voltage distribution network. Contact with the Distribution Network Operator at an early stage is important to ensure that the desired connection date can be met. The DNO will carry out a feasibility study and will decide upon necessary grid reinforcement. Electricity generators must wait for grid reinforcement completion (if necessary) before they are connected.

Energy Supply Infrastructure

Depending on site location a major cost of setting up an AD plant will be the cost of supplying energy to the final end user. Grid connections for both electricity and gas to grid can be cost prohibitive. Costs of grid connection will be dependent on both distance and volume of supply. These can be as high as 10 to 15% of the overall capital cost of the project and on small scale or on remote farm applications may be considerably higher that the capital cost of the project.

For electricity the cost of connection depends on two factors, the setup of an electrical substation and the cabling. As a guide, the substation cost for an average size plant (500kW) is circa £50,000 plus cabling. This will vary depending on the maximum amount of electricity on the peak load. Depending on wattage the cable size may also need upgrading. This also assumes that a three phase supply is readily available.

In addition there may be other costs associated with wayleaves requirements and in sensitive locations cabling may need to be underground. There may be other physical issues such as road and river crossings.

The final major hurdle will be the capacity of the local grid to accommodate the additional load. This will be site specific and will require a survey to be undertaken by the District Network Operator (DNO) to establish the potential. There is usually a cost associated with the survey. Once this is completed the DNO will provide a quotation for connection.

Difficulties/Barriers

On-farm anaerobic digestion offers a significant step towards more sustainable farming. It is for these reasons that the UK Government and the agriculture industry see anaerobic digestion as the ideal way to treat slurry. As stated in DEFRA's Shared Vision for Anaerobic Digestion, the NFU would like to see 1000 on-farm digesters by 2020. Work done by the RASE and AEA Group indicates that for the greatest impact, low cost AD plant should be targeted at dairy farms, starting from about 100 cows and upwards.

If the Government and the regulators wish to employ the immense potential of AD to reduce GHG pollution from organic substrates and efficiently return nutrients back to the land whilst creating renewable biogas and reducing the carbon footprint of agriculture, it is necessary to ask if the current drivers and incentives for the technology are sufficient and appropriate to ensure the uptake of the technology at the scale where it is most needed.

In order to be appropriate to the drive for on-farm AD, in due course, the incentive system should be adjusted to be based on the net carbon reduction that is achieved, although it may still be necessary for some banding to promote smaller scale rural projects.

If UK farmers are to change the way they use and handle slurry, the primary incentive that is used must be addressed, based on the installation of an AD plant for all its benefits. The Feed-In Tariff (FIT), administered by DECC, does not encourage farmers to reduce pollution, but rather pays them to generate renewable electricity using a combined heat and power plant (CHP) which runs off biogas from the AD process.

However, combining AD with CHP to create electricity currently has a number of appreciable difficulties below 200kW output if compared with direct gas use (e.g. in a boiler). These include grid connection issues, significant extra capital/maintenance costs and plant complexity in terms of engineering a system which can continuously produce sufficient quantities of quality gas.

The average farmer's options to fully and economically utilise their slurries in an environmentally friendly manner are further compromised by the fact that:

- the primary feedstock (cattle slurry) is generally only available for 6 – 7 months when cows are housed indoors over the winter months;
- sufficient year-round on-farm organic substrates may be limited;
- there are significant regulatory & financial penalties imposed for digesting the off-farm substrates (which have to be returned to land, anyway), including those which can be fed to cows; and
- Some farmers may not have the option or desire to grow energy crops in order to boost biogas output to improve the economics of using AD with CHP, for what is primarily their

slurry treatment system, especially if the cost of bought in feed increases in line with fossil fuel costs, putting further pressure on farmers to grow their own crops to feed their cattle.

A further barrier is access to capital. Pollution control and other capital grants have largely been phased out. Banks are not prepared to lend money for a technology with which they are largely unfamiliar and suspicious of. In addition, the UK AD market has been slow to develop (compared to elsewhere in the EU), so technology suppliers of smaller plant, where margins are smaller, tend not to have a large working capital base themselves, further increasing investment wariness.

For many of the average sized farms in the UK, direct use of the biogas5 from the AD slurry treatment system might be a simpler and more cost effective option. This is because of the seasonal availability of much of the primary feedstock (slurry) and the cost, complexity and connection issues surrounding the use of CHP with AD.

However, the only incentive that direct gas use is likely to attract is the Renewable Heat Incentive (RHI), which is unlikely to provide sufficient income to make it economic for many and which is capped at present at $200kW_{th}$ installed capacity.

There are a number of factors that must be taken into account if farm scale AD is to take off:

- smaller AD projects which have the additional environmental benefit of treating 'the slurry problem' need a new, preferably incremental and unconditional FIT band with a higher rate to boost viability of AD with CHP, as well as sufficient Renewable Heat Incentive for direct gas use where CHP is not an option. The incentives for AD should make it at least as attractive as simply putting up a slurry storage tank which still has slurry handling, pollution and GHG emission problems;
- access to capital grants or rolling loans with preferential terms (for example, along the lines of student loans) need to be considered, possibly partly or wholly funded by relevant organisations (such as supermarkets) wishing to reduce the carbon footprint of their supply chain and who enjoy the cost benefits of farms which reduce GHG pollution as well as reliance on fossil fuels and fertiliser;
- access to a wide range of off-farm local organic feedstocks. Light touch regulatory controls on low-risk organic substrates including manures, slurries, crop waste and forage excess, as well as regulatory flexibility to allow for crop products which may have undergone pre-processing to be used as an AD feedstock on farm; and
- a desire by farmers for AD technology that is simple, robust and cheaper to install. Small-scale modular plants, similar to a number of those illustrated in the process technology options, will help reduce costs.

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