MENTER MÔN

"BACH A SYCH"

A REVIEW OF OPTIONS FOR ANAEROBIC DIGESTION ON SMALL SCALE FARMS IN GWYNEDD

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1.0 INTRODUCTION

The Severn Wye Energy Agency and the University of South Wales have been instructed by Menter Môn to undertake a review of potential options for the deployment of anaerobic digestion technologies to treat farm wastes and other available materials at small hill farms in Gwynedd. The primary aim of the potential deployment of anaerobic digestion is the improved management of farm wastes and nutrients, and the reduction of associated diffuse pollution. However, the associated benefit of energy production is also taken into account in the assessment of the technical and economic viability of the schemes considered.

1.0 Aims and Objectives

The overall aim of this study is therefore to consider the viability of deploying micro or small scale anaerobic digestion technologies on small hill farms in Gwynedd. These farms have low numbers of housed livestock, limited arable or pasture land and are dominated by upland topography and vegetation. Whilst a standard mechanism for assessing viability can therefore be employed, i.e. assessment of feedstock availability, likely biogas production and therefore income, the final consideration of whether the approach is 'viable' will require input from land owners, in particular the importance that they place on issues such as diffuse pollution management and ecological conservation and management.

Objectives of the study were:

1. To visit a number of representative farms in Gwynedd to gain an appropriate understanding of the site settings, agricultural activity and feedstock availability.
2. To consider feedstocks, available technology and operational configurations that would be most likely to deliver a 'viable' AD facility.
3. To present possible options within a written report for further consideration by the Client and landowners.

2.0 SITE DESCRIPTION

Information is based on the site visits undertaken by Dr Tim Patterson and Andy Bull on 13th July 2017 and on publically available on-line information. 3 No. farms were visited; Dolobran, Llyndy Isaf and Hafod y Llan.

2.0 Dolobran

2.1.1 Site Location

Dolobran farm is located approximately 1.8 km to the north west of Dinas Mawddy, Gwynedd at Ordnance Survey Grid Reference SH 843 162. The farm is accessed via an un-named track that leads directly to the north east of the A470 carriageway.

2.1.2 Site Description

The farm comprises a 364 acre (147.3 hectare) hill farm with approximately 233 acres (94.3 hectares) of the farm area located on the south western slopes of Foel Benddin mountain (Plate 1 & 2, Appendix A) where flora is dominated by bracken. Approximately 70-80 acres (approx. 30.3 heactares) on the lower slopes is dedicated to rough grazing with a further 50 acres (approx. 20.2 hectares) on the valley floor occupied by meadows and fields (Plate 3, Appendix A), primarily for grass production. Approximately 170 big bales / yr of silage are produced from a single cut.

Primary structures on the farm include a number of sheds of typical agricultural construction used for storage of equipment, storage of manure and the housing of animals. The stone and slate built farm house is located to the south east of the farm sheds. A second, currently derelict, stone and slate farm building is located approximately 40 m to the south of the farm sheds – it is understood that this building is listed. The stone ruins of a former mill building are also located approximately 60 m to the west of the farm sheds.

A small river (the Afon Cerist) flows from west to south east approximately 40 m to the south of the operational farm yard, and immediately to the south of the derelict building and mill ruins. It is likely that there are additional small streams and springs located on the farm, particularly in the valley between Foel Benddin and Y Gribin, the adjacent peak to the north west.

Livestock at the site includes approximately 500 ewes and 100 lamb replacements. Around 150 ewes are housed for 2 months of the year for lambing. The farm also rears 8-10 suckler cows for meat production. These are housed for approximately 7 months of the year. Whilst housed the animals are bedded on straw.

Manure produced on farm appeared to be managed in two streams, depending on whether it is wet or relatively dry (with high straw content). Approximately 10-20 t / year of dry manure / straw is produced and this material is stored outside on concrete hardstanding (Plate 4, Appendix A). Wet manure is scraped from bedded areas approximately once per week when animals are housed and stored under a roof on concrete hardstanding (Plate 5 & 6, Appendix A). It is estimated that over the course of the year a volume of approximately 6.5 x 9.0 x 1.5 m (58.5 m^3) of material is collected, approximated to correspond to 70 t / year. Total manure production for the farm is therefore estimated at 80-90 t / yr. Liquid that is released from the manure is collected via a slot drain in a 1,000 gallon underground tank located adjacent to the farm sheds. It is noted that at the time of visit the below ground tank was identified as never having been emptied. The integrity of this tank should therefore be investigated further. Manure is generally spread once per year at the end of May, although some spreading in February does take place if the weather allows.

Fertiliser use at the farm currently includes 3 t / yr of slow release fertiliser and 5 t / yr of grassland fertiliser (10:20:20), normally applied at the middle or end of May.

Energy use at the farm comprises approximately £1,200 / yr on electricity and £200 / year on oil. It is understood that a biomass boiler has relatively recently been installed. Approximately 30 t / yr of wood is utilised in the boiler, approximately 20 t / yr of which is bought in at a cost of around £35 / t (a total of £700 / year). The farm is eligible for RHI payments on the biomass used.

2.1 Llyndy Isaf

2.1.1 Site Location

Llyndy Isaf is located approximately 4 km to the north west of Blaenau Ffestiniog, Gwynedd at Ordnance Survey Grid Reference SH 625 498. The farm is accessed via an un-named road and track that leads to the south east from the A498 between the lakes of Llyn Dinas to the south west and Llyn Gwynant to the north east.

2.1.2 Site Description

Llyndy Isaf is a 614 acre (248.5 hectares) hill farm that stretches from the shores of Llyn Dinas and the A498 in the north east to the summit of Moel y Dyniewyd to the south / south east. The farm includes approximately 30-40 acres (12.1 – 16.2 hectares) of low lying meadow and 8 acres (3.2 hectares) of grass land primarily located to the north east of Llyn Dinas that is used to produce silage and for grazing (Plates 7 & 8, Appendix A). The remainder of the farm area is occupied by acidic heathland, bog, areas of soft-rush, woodland and upland grassland with very thin soils and frequent rock outcrops.

Large areas (estimated at 8-10 hectares) of flat land adjacent to Llyn Dinas are dominated by Soft Rush (Juncus effuses). This grass currently represents a conservation issue as it dominates wet low lying areas and prevents other species from gaining a foothold.

Surface watercourses at the farm are dominated by Llyn Dinas which occupies an area of approximately 180 hectares in the north of the farm (adjacent to the A498). The lake is fed by the Afon Glaslyn which bisects the area of meadow / grassland in the north east of the farm and flows from Llyn Gwynant to the north east. There are numerous small surface water streams and springs draining water from the upland areas of the farm towards Llyn Dinas in the north.

Primary structures at the site include a stone and slate built residential property. Approximately 20 m to the south of this is a stone and slate built double height barn that appeared to be used for storage of farm materials and equipment. Between these two structures are the stone ruins of a former property. It was noted that adjacent to this structure was what appeared to be an unbunded single skinned fuel tank. It is not known whether this was in use, however, as it in an area that is publically accessible the status of this should be reviewed. Approximately 110 m to the north west of the residential property is a metal framed timber and sheet metal clad shed with concrete hardstanding floor, used for the housing of animals and the storage of manure (Plate 10, Appendix A). The roof of this structure was fitted with PV panels. A small stone and slate roof barn is located approximately 50 m to the north west of the residential property. A small wooden structure housing a micro hydro turbine is located approximately 20 m to the west of the residential building.

Livestock at the site includes approximately 55 sheep. It is understood that during winter months ewes are moved from the farm to a location on the Llyn Peninsula. Whilst on farm over the summer months, sheep are permanently outdoors and there is no requirement for housing during lambing. The farm also rears 5-6 cows for meat production. The cows are housed for approximately 6 months of the year (Oct – Mar). Whilst housed the animals are bedded on straw.

The farm energy systems have recently been upgraded and include 2 No. 10 kW air source heat pumps, a 7.5 kW PV array and a 10.5 kW micro hydro-turbine was in the process of being commissioned at the time of visit (July 2017). Space heating at the property is powered by electricity. It is estimated that on site electricity use is approximately 20,000 kWh / yr.

2.2 Hafod Y Llan

2.2.1 Site Location

Hafod y Llan is located approximately 4.5 km to the north west of Blaenau Ffestiniog, Gwynedd at Ordnance Survey Grid Reference SH 267 512, and is located on the southern slopes of Snowdon, Lliwedd and Aran mountains. The farm is accessed via an un-named track that leads directly to the north of the A498 carriageway approximately half way between Llyn Dinas and Llyn Gwynant.

2.2.2 Site Description

Hafod y Llan is a 4,000 acre hill farm, the vast majority of which is occupied by the upland environments Snowdon, Lliwedd and Aran Mountains. An area of approximately 30 hectares to the south and east of the main farm buildings is dedicated to grassland and meadow.

Surface watercourses at the farm include Llyn Gwynant in the south east of the estate, and the Afon Glaslyn which flows in a south westerly direction to Llyn Dinas (via Llyndy Isaf). There are numerous streams, springs and lakes located in the upland areas of the farm area. The most significant of the streams is Afon Cwm Llan which flows in a broadly southerly direction from the Lliwed Mountain to join the Afon Glaslyn immediately to the north east of the farm building complex.

The primary structures at the farm comprise a complex of stone and slate single and double storey barns surrounding a concrete hardstanding yard. This area appeared to be predominantly utilised for parking of vehicles. Immediately to the west of this yard is another single storey open storage barn of stone pillar / slate roof construction used for the storage of farm equipment and materials. A small metal clad single storey 'garage' was located immediately adjacent to the barn. To the south west of these buildings was a modern metal frame, timber clad single storey double barn. This structure was used primarily for the housing of livestock and the storage of manures (Plate 11, Appendix A). The roof of the structure was fitted with PV panels. It is understood that there are early stage plans being made to extend this structure to the south west. Approximately 50 m to the south west of the main farm complex was a small group of single storey stone and slate structures that appear to be for residential / rental purposes along with a double height stone and slate barn. A large stone residential property was also located approximately 40 m to the north east of the farm complex. Camping facilities are also available in this area of the farm.

Livestock at the farm is understood to comprise approximately 1,550 ewes and sheep, fully located outdoors. It was noted that this is a significant reduction in flock size from the >4,000 sheep raised on the farm some 10-15 years ago, this being a reflection of the National Trust's focus on agriculture for conservation. As with Llyndy Isaf, ewes are moved to the Llyn Peninsula over winter and the number of sheep remaining on farm over the winter is low. The farm also rears approximately 70-80 cows for meat production. These are housed over the winter period and bedded on straw.

Manure is scraped and stored in a 6 month storage area (covered) with an area of approximately 30 ft x 25 ft (9.1 m x 7.6 m). Material is stacked to a height of approximately 1.8 m (Plate 12, Appendix A). As such when full this storage area contains approximately 125 m^3 of material, assumed to correspond to approximately 150 t. This storage area is located within the modern sheds located in the main farm complex and as such is fully covered to avoid diffuse pollution. Liquid waste and runoff from the store is contained within a below ground pit with a volume of 110,000 litres. Liquid material is spread to land, usually in August.

As with other National Trust farms, considerable effort has been placed on appropriate production of sustainable energy. Energy production technologies located at Hafod y Llan include:

- Ground Source Heat Pump (30 kW)
- Air Source Heat Pump (4 kW)
- Biomass Boiler (17 kW)
- Photovoltaic Power Generation – 10kW
- Micro hydro turbine – 17 kW (All electricity is exported)

- Micro hydro turbine – 10 kW
- Hydro turbine – 660 kW (All electricity is exported)

Electricity use at the farm is approximately 37,000 kWh / yr. The PV array provides approximately 8,000 kWh of this energy. The newly installed micro hydro turbine is likely to make a significant contribution to the remainder of the electricity requirement at the farm, although data was not available at the time of preparing this report. An additional significant energy bill incurred at the farm is associated with the utilisation of diesel fuel in farm vehicles. This has been estimated at a value of £10,000 / year.

3.0 SMALL SCALE ANAEROBIC DIGESTION

Small scale anaerobic digestion is generally considered to be AD plants with an electrical output potential of between 25 and 250 kWe. Micro scale AD would be those plants with a potential output of < 25 kWe (although electricity generation might not necessarily be part of the business model at this scale). The model for the deployment of small / micro scale AD plants is generally to deploy them at the feedstock source, or to digest materials sourced from an immediately local area, as opposed to transporting feedstock from multiple locations to a larger centralised facility. The economic viability of small scale AD plants has previously been considered as a barrier to widespread deployment, however, in the UK a number of companies have developed a range of small and micro scale technology offerings. These are summarised below. There is likely to be many more manufacturers and suppliers located outside of the UK, however these have not been considered as part of this review.

3.1 Marches Biogas

Marches Biogas has over 25 years of experience in anaerobic digestion and is based in the UK. They specialise in custom designed AD systems, for both commercial and on-farm uses. They claim that their digesters are robust, cost effective as well as being innovative. Along with designing, manufacturing, installing and commissioning AD plants, they offer alongside, training, maintenance, operational support and process research and analysis.

Marches Biogas offers a number of different designs, the Plug and Play Digester, The Continuously Stirred Tank Reactor (CSTR) and the AGRIDigestore. The CSTR approach generally has an output of 50 kW - 1,000 kW is therefore likely to be too large for the application being considered here and as such will not be considered further.

Plug and Play Digester

This digester is delivered on site completely ready for connection as a prefabricated modular unit. It is designed to work on predominantly low solids feedstock such as animal slurry and can be installed either above or below ground. Within the digester, a controller continuously records the level. Biogas is circulated throughout the digester through a series of nozzles fixed to the floor of the digester preventing stratification and temperature is maintained by the circulation of hot water through an internal heat exchanger. Digestate from the base of the digester is withdrawn by a dedicated pump whilst the slurry output is measured by a flow meter. The digester discharge can be adjusted. Electrical output of these digesters is up to 50 kWe.

AGRIDigestore

The concept of the AgriDigestore is to reduce the cost of on farm AD and to offer a product aimed at farms that may not necessarily have a consistent supply of animal slurry throughout the year by combining the function of a slurry storage facility with an anaerobic digester in the same vessel. The system can be purpose built or retrofitted to an existing slurry storage tank and can be deployed as a modular system allowing several vessels to be connected. The design of the AgriDigestore allows the use of digestate as and when is required with a minimum of 15% of digestate remaining in the vessel to maintain biological activity and allow periods with minimal feedstock addition. Electrical output for AGRIDigestore systems is in the order of 50 kWe.

Rainton Farm, Cream O'Galloway, Dumfries

An AgriDigestore has recently been constructed on a 340 hectare farm near Gatehouse of Fleet. It is a mixed livestock farm, with a dairy herd that supplies the Findlay's Cream O'Galloway ice cream company. The digester is fed on a mixture of cattle slurry and grass silage, with a power output of 25kWe. The AgriDigestore system has been fitted to the slurry store of a new state of the art dairy unit. The electricity produced will be used on the farm to generate hot water and for general usage.

3.2 Lutra Limited

The company is led by Dr Michael Chesshire who has a long history in developing, designing and constructing anaerobic digestion plants (Methanogen, Greenfinch, Evergreen Biogas). Lutra Limited was established in 2014 to focus on the task of developing small scale anaerobic digestion plants, primarily for community scale digestion of food wastes. Lutra Limited work with a partner company in Lincolnshire (GMT Biogas) which has more of a focus on small scale agricultural plants. As such, it is likely that Lutra would be in a position to provide services to develop, design and construct one or more micro / small scale anaerobic digestion plants for the purposes required.

3.3 SEAB Energy

SEAB Energy offer two containerised anaerobic digestion products, one designed to treat animal slurries and sceptic tank waste (Muckbuster®) and the second to treat food waste (Flexibuster™). Both platforms are fully containerised and modular. Since 2012 a Flexibuster has been operational at Southampton business park treating food waste from a manor house hotel as well as plant material from the park grounds. This unit is understood to be generating in the order of 70 MWh electricity per year. A Flexibuster unit is also understood to be operational at a commercial bakery.

3.4 QUBE Renewables

QUBE Renewables offer a range of micro / small scale anaerobic digestion products with electrical outputs ranging from 3kW – 50kW. Products include a modular system housed within a 20 ft shipping container (bioQUBE), a rapid deployment version of the bioQUBE designed to support military or emergency response activities (rapidQUBE), and a small scale CHP unit (powerQUBE) with outputs ranging from 3.2 – 30 kWe.

A product that is not included on the QUBE renewable web site is known as DryQUBE. The company has developed a system that was originally designed for SE Asia for the digestion of rice straw. Rather than trying to break down ligneous cell walls in order to facilitate digestion, the process relies upon a long retention time. The solid material (in our case this would be farmyard manure and rushes and/or bracken) would be loaded onto fabric that would then be wrapped around the resulting pile in order to form an airtight bag. Liquids would be drawn off the base of the pile, heated and recirculated onto the top. Gas would be drawn off as it is generated. The system is relatively inexpensive and with little day-to-day maintenance requirements - but the issues to be resolved are:

- Will it work with FYM and rush/bracken?
- How can the gas be utilised effectively when it will vary in quantity and quality across the life of the batch of feedstock?
- Can the timing of the different feedstock availability be matched?
- Can the removal of the fully digested material be matched to the spreading time for the digestate/fertiliser?
- Can leaks of methane into the atmosphere be avoided (otherwise the process may be counter-productive)

3.5 H2 Energy

H2 Energy promote a 'biorefining' concept to convert food waste and animal by-products to electricity and heat. Their core digestion technology is based around a modular, multi stage treatment process that can treat between 2-30 tonnes of material per day. The company combines this core digestion technology with a range of pre-treatment approaches such as thermal and pressure based processes, aerobic pre-treatment and enzyme pre-treatment. The company is known to be operating a 'research' unit treating predominantly poultry blood, and the company has also publicised that they will be manufacturing, installing and operating food waste treatment facilities in 40+ food factories across the UK on behalf of the Seven Sisters Food Group.

3.6 Natural Synergies Ltd.

Report authors know very little about this company and they appear to have no significant commercial track record in the UK anaerobic digestion market. However, between 2013 – 2015 the company was involved in a DECC funded Small Business Research Initiative (SBRI) project aimed at utilising wetland biomass (including soft rush) for biomass energy production. Anaerobic digestion was found to be a likely candidate technology and the project was primarily focussed on identifying / designing appropriate systems for the harvesting, storing and treatment of wetland biomass. The company is believed to be currently working on the commercialisation of a system to allow the treatment of wetland biomass including soft rush.

3.7 Methanogen Ltd

Methanogen has a small operating base in Knighton, Powys. The company is led by James Murcott and Angie Bywater who have a long track record of innovation – particularly at the micro-scale. The company does not have much in the way of current demonstration plants. There is no web site for the company.

4.1 Assessment of Anaerobic Digestion

4.2 Manure Present at Farms Visited

4.2.1 Energy Yield

The first step in evaluating the potential for AD in the farms visited is to consider the feedstocks that are immediately available i.e. manure and liquid effluent from manure storage / animal housing. The table below provides an estimate of the biogas and energy production that might be possible using these manure and liquid effluent feedstocks. Biogas yields are assumed and feedstocks should be tested prior to making any final decisions regarding deployment.

	Dolobran	**Llyndy Isaf**	**Hafod y Llan**
Biogas Production			
Manure (t)	80-90	20-30 (estimated)	150
Liquid Effluent (m3)	4.5	1 (estimated)	110
Gas Yield / t (manure)	20 - 35	20 – 35	20 – 35
Gas Yield / m3 (Liquid)	20 - 25	20 – 25	20 - 25
Gas Volume (Manure)	1600 – 3150	400 – 1050	3000 – 5250
Gas Volume (Liquid)	90 – 112.5	20 – 30	2200 – 2750
Total Biogas (m3)	1690 – 3262.5	420 – 1,080	5200 - 8000
% Methane	60	60	60
Methane Volume	1014 – 1957.5	252 – 648	3,120 – 4,800
Energy content of methane (kWh / m3)	9.95	9.95	9.95
Gross Energy Content (kWh)	10,089 – 19,477	2,515 – 6,448	31,044 – 47,760
Heat Only (Boiler)			
Max Heat Output (90% efficient boiler) (kWhth)	9,080 – 17,529	2,264 – 5,803	27,940 – 42,984
Approx. Value of Heat (3.5 p / kWh)	318 – 614 £ / yr	79 – 203	978 - 1503
RHI (2.88 p / kWh)	261 – 505 £ / yr	65 – 167	805 - 1238
Total Income from Heat	**579 – 1,119 £ / yr**	**144 – 370**	**1,783 – 2,741**
Heat & Power (CHP)			
Max Electrical Output (35% efficient CHP) (kWhe)	3,531 – 6,817	880 – 2,257	10,865 – 16,716
Approx Value of	212 – 409 £ / yr	53 - 135	652 – 1,003

Electricity (6 p / kWh)			
FIT (5.57 p / kWh)	201 – 389 £ / yr	49 – 126	605 - 931
Max Heat Output (40% efficient CHP) (kWhth)	4,036 – 7791	905 – 2,579	12,418 – 19,104
Approx. Value of Heat (3.5 p / kWh)	141 – 273 £ / yr	32 – 90	435 - 669
RHI (2.88 p / kWh)	116 – 224 £ / yr	26 – 74	358 - 550
Total Income from CHP	**670 – 1,295 £ / yr**	**160 – 425 £ / yr**	**2,050 – 3,153 £ / yr**

Estimated costs for a containerised micro AD system are £60,000 - £75,000. Clearly then, payback times based on energy production alone would be long. At Dolobran and Llyndy Isaf payback times are not likely to be viable even taking into account other potential benefits of the approach. Even the best case payback time at Hafod y Llan is 20 years based on energy production alone. These figures are potentially much lower for a dry, batch system but this is unproven technology.

From a practical perspective, the volumes of manures available at Dolobran and Llyndy Isaf are well below the approximate lower design limits of containerised micro scale AD units of around 0.5 t / day of feedstock input (Dolobran would average 0.26 t / day, Llyndy Isaf estimated at 0.08 t / day). Hafod y Llan would be above this with an average of 0.71 t / day average. Combining feedstock from farms that are in close proximity makes a great deal of sense and is easily possible at Llyndy Isaf / Hafod y Llan. However, movement of manures between farms is subject to there being no bio-security issues (e.g. TB outbreaks) and would therefore be 'at risk'. In addition, in order to comply with PAS110, movement of manure between farm would also then require a pasteurisation stage (if PAS110 compliance was a requirement), which would reduce the overall energy efficiency, and therefore income and payback time, of the system.

It is also noted that manure production is seasonal, the majority being generated during the winter housing of cows with Dolobran also producing manure during lambing in spring. As such, feedstock input, and hence gas generation, would not be evenly distributed over the year. This would therefore require either a larger AD facility to be specified to cope with the relatively rapid input of feedstock, which would then remain inactive for the rest of the year, or for a design change from the standard model of a plant that is fed regularly throughout the year to more of a 'digest and store' model.

The seasonal production of low volumes of biogas similarly presents practical challenges with the utilisation of the gas. CHP plants at these scales are not likely to be practicable, and the investment required to utilise the power generated is unlikely to be justifiable. Utilising the biogas for heat is therefore likely to be the favourable option, although again, justifying separate equipment specifically for the combustion of low volumes of biogas on a seasonal basis may be difficult.

As such, it is clear that the energetic benefits of digesting the manures and liquid effluents present on the farms visited is unlikely to be a primary driver for installing a micro AD system. It is also established that from a practical perspective, very low feedstock volumes at Dolobran and Llyndy Isaf, with seasonal availability is likely to result in practical issues with the design of the AD facility itself and the utilisation of biogas. Feedstock availability at Hafod y Llan is within the range that could be viable for micro scale AD processing, although again, seasonal availability of feedstock and biogas production would provide some practical and design challenges.

4.2.2 Reduction of Diffuse Pollution from Manures

Improved management of nutrients pollution associated with on farm manures was initially considered as a potential key benefit of deploying micro scale AD facilities to hill farms. However, all of the farms visited included facilities to store manures under cover, on hardstanding, under relatively well managed conditions. As such, the potential for the material to present a significant source of diffuse nutrient pollution through its *storage* on farm has already been reduced to a great extent, providing that the storage facilities are well maintained and that appropriate on farm manure management operations are employed. Installing an anaerobic digestion plant is unlikely to directly further reduce the pollution potential of the material as a result of its *storage* on site.

In terms of manure storage, it is likely to be just as beneficial and more cost effective to extend the deployment of covered manure storage bays with liquid collection systems, and ensuring that these systems are being used appropriately and are well maintained.

With regard to the spreading of manures, digested slurries / manure generally have higher ammonium: total nitrates ratios, decreased organic matter content, decreased total organic carbon, reduced biological oxygen demand, higher pH, smaller carbon : nitrogen ratios and reduced viscosities compared to undigested material. This leads to benefits associated with higher soil mineralisation of N and enhanced plant uptake leaving less N available for runoff to surface or groundwater.

However, the method of digestate to land application has a significant influence on the effectiveness of these benefits. Where digestate is fully incorporated into the soil matrix (e.g. soil injection methods) these benefits will be realised. Where digestate is spread using surface application methods the overall benefit may not be as significant. It is understood that the land owner of the farms visited (National Trust) is committed to direct injection of slurries and liquids, however, solid materials such as farm yard manures are generally surface spread. As such, whilst the digestion of the small volumes of manures available on the upland farms visited would provide some benefit in terms of nutrient utilisation post spreading (providing that liquids are injected to land), the spreading of digested solid material may provide relatively little benefit in terms of reduced nutrient runoff.

4.2.3 Anaerobic Digestion for Habitat Management / Conservation

The presence of invasive / dominating plant species such as bracken and soft rush is known to be creating a habitat management issue for the National Trust. As such, consideration should be given to the utilisation of these species as feedstocks for anaerobic digestion.

<u>Soft Rush (*Juncus effuses*) As A Feedstock</u>

The National Trust has expressed an interest in utilising Soft Rush as a potential feedstock for anaerobic digestion. As well as being present in low lying areas of Llyndy Isaf, it is estimated that approximately 100 acres of Soft Rush pasture is present in the area local to Llyndy Isaf and Hafod Y Llan. Limiting the dominance and preventing the spread of Soft Rush is becoming a conservation issue for the National Trust, and mechanisms to harvest and utilise the biomass are therefore of interest.

Soft Rush is a tough grass with stiff stems with a high lingo-cellulosic content, and as such it would not traditionally be considered as an ideal anaerobic digestion feedstock – the material is not easily digested. As such, some form of pre-treatment would normally be required to release readily digestible material – this could be a physical treatment, e.g. crushing / pressing, or a chemical or enzyme treatment.

A few projects have been undertaken in the UK to evaluate the potential for harvesting Soft Rush biomass and utilising the material in an anaerobic digestion process. These trials did not involve the AD Centre (USW) or the Severn Wye Energy Agency. Information relating to the trials has been located on-line and is therefore publically available. A summary of the major findings is provided below. Links to the full reports and contact details for those leading the trials are provided for completeness.

<u>Wetland Biomass to Bioenergy, Small Business Research Initiative (SBRI) Project – Natural Synergies Ltd</u>

<u>Report Link:</u>

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/497996/Phase_3_-_Milestone_4_Redacted_Final_Report_25March15_Rev1_11Nov2015.pdf

Harvesting of Soft Rush (and other wetland grasses) was found to be a significant problem, although progress was made throughout the course of the project. Two pieces of harvesting equipment were trialled; i) PistenBully supplied with a Kemper rotary crop header, and (ii) Softrak supplied with a Elho double chop forager. Neither piece of equipment appeared to reach the desired particle size of 12 mm maximum required for the anaerobic digestion plant. An alternative cutting head and lower operating speeds were suggested as a potential solution for the PistenBully, although this was not included within the harvesting trial. No alternative strategy was identified for the Softrack, although it is noted that both pieces of equipment were at the time being actively developed for wetland harvesting and were likely to need optimisation.

Ensiling of Soft Rush material harvested using the PistenBully appears to have been successful, despite the particle size of 20-30 mm an even up to 140 mm. Appropriate compaction of the ensiled material to avoid oxygen ingress was the most significant challenge. Due to the large particle size of material harvested by the Softrak (up to 300 mm) this material was not considered appropriate for ensiling.

Following ensiling, material was prepared for anaerobic digestion in a pre-treatment stage. This comprised of maceration of the ensiled material to reduce particle size to around 6 mm. This was to prevent physical blockages and also to provide larger surface areas for biological activity during the

AD process. Material was then pasteurised at >70 °C for 1 hour to ensure compliance with PAS110. It is likely that this would also act as a pre-treatment to begin the breakdown of lingo-cellulosic material. In initial trials, it is understood that no further pre-treatment was included prior to anaerobic digestion, however, gas yields achieved were low. Therefore, a further Ultrasound pre-treatment stage was included to disrupt cells and release available carbon.

The anaerobic digestion plant comprised of a custom built horizontal reactor that was operated at thermophilic temperatures (47-52 °C). The system appear to be based on a dry, plug flow type anaerobic digestion process. A number of retention times ranging from 28 days down to 15 days were trialled. Detailed performance data of the AD unit are not included in the report, however, a figures of Volatile Solids (VS) destruction of 37-40 % for fresh (not ensiled) biomass were reported without Ultrasound pre-treatment, and 80 % VS destruction for fresh (not ensiled) Soft Rush is reported.

The report also described a small trial undertaken to determine the effectiveness of enzymatic pre-treatment. Results were inconclusive, however, it is noted that the trial was limited in scope and that the approach requires additional research and development.

The report presents an initial business plan for the deployment of a wetland biomass AD system, however, given that this is one of the offerings being commercialised by Natural Synergies it is suggested that, whilst of interest, this may not necessarily be directly relevant to the applications being considered in this report.

Wetland Biomass to Bioenergy, Project Kade – AMW Arboreal Ltd in collaboration with Aberystwyth University and IBERS.

Report Link:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/497999/AMW-IBERS_Final_Redacted_Report.pdf

The report describes a project, again funded via the DECC Wetland Biomass to Bionenergy competition, that investigated the harvesting of wetland biomass and its conversion to bioenergy. The site location was a wetland in Scotland. In this case, the energy conversion process comprised the separation of the biomass to solid and liquid phases using a screw press. The solids (Press Cake) were then converted to a solid fuel briquette by combining part of the dried press cake with bio char derived from the slow pyrolysis of part of the dried Press Cake stream. The liquid fraction (Press Fluid) was treated using anaerobic digestion to produce biogas and a liquid digestate.

Harvesting techniques trialled a number of Softrak variations, Softrak cut and collect, Softrak chip and collect, and the Softrak reed cutter bundle and bail systems. This is a reflection of the various types of biomass considered in the trial; common reed, soft rush and willow / birch / alder. Overall, the combination of the various adaptations of the Softrak machine were concluded to be successful and achieved acceptable performance.

Details of the screw press utilised in the trial were not included in the report, however, the overall assessment concludes that the performance was below that expected, partially due to the difficulties in handling the particulate biomass matter. Adaptations to the system are suggested within the report.

Details of the anaerobic digestion element of the system are also not described in detail in this report, however, it is described as being supplied by QUBE Environmental, and is therefore likely to be one of their standard packages units. The performance of the AD element was described as straightforward and no significant technical problems are reported.

Material drying was achieved in low cost AgBags. Again, no significant technical problems were identified other than the long time necessary to achieve the required drying. Options to achieve this drying using excess heat from the AD plant or pyrolysis process are suggested to reduce drying times.

Performance of the biochar element of the process are again not described in detail in the report, however, it is know that this is an area of considerable research and development effort at IBERS / Aberystwyth University, and as such it is likely that the process is robust at the scales used.

Briquetting of the Press Cake or Press Cake combined with biochar was found to give mixed results. The briquetter itself was found to require relatively little supervision whilst the materials mixer proved more problematic, requiring constant supervision and small adjustments for continuous operation.

An initial life cycle assessment of the system indicated that the system delivered net primary energy savings of 83.1 % and that an overall reduction in carbon emissions is achieved. Particulate matter and Nitrogen Oxides emissions are less conclusive with some elements of the process potentially providing emission savings and others providing emissions increase.

Bracken (Pteridium aquilinum) As a Feedstock

The characteristics of bracken as far as the AD process is concerned are probably very similar to rush. The added complications lie around the harvesting of the material as it is generally growing on steep slopes – often with boulders protruding through the soil. There is a further complication around the suggestion that the spores of bracken are carcinogenic.

Summary Comments on Using AD for Habitat Management / Conservation

Significant trials for the use of both Bracken and Soft Rush as AD feedstocks have been undertaken and it is evident that both species can successfully be digested within an appropriately designed system. For optimum biogas production and low treatment times, pre-treatment of material is likely to be required which adds to the complexity and cost of the process. Commercial deployment of the systems has yet to occur, however, this is most likely because the business models are entirely based on energy production with no financial value attached to habitat management. Where Bracken and Soft Rush are proving to present a significant habitat management issue, every consideration should be given to deploying anaerobic digestion to treat the resulting biomass.

However, these are difficult feedstocks to digest. Trials have identified a number of approaches to improve biogas yields such as ultrasound and enzyme pre-treatment. Some further development of the approach is likely to be required before a robust and fully reliable system is finally available. Whilst the trials present real promise and there is not a requirement to return to ‘square 1’, some form of trial or demonstration of a candidate system with expected design improvements identified as a result of this work should be expected.

In the event that the digestion of biomass derived from species such as Bracken and Soft Rush is deemed appropriate, this also changes the dynamics of the utilisation of on-site manures. Where AD is deployed primarily for habitat management purposes, it would make sense (and most likely provide a more robust biological community) to co-digest farm manures and liquid effluents with harvested biomass.

The deployment of AD for the purposes of habitat management would present an issue that appears to be in contradiction to one of the primary reasons for considering the use of the technology in the first place – nutrient management. By harvesting areas of dominating species such as Bracken and Soft Rush and digesting them, the nutrients contained within them are centralised to the location of the AD facility. This therefore increases the local nutrient load. Care should therefore be taken that appropriate arrangements can be made for the spreading of the resulting digestate to land – and preferably ensure that the digestate is used primarily as a displacement of mineral fertlisers.

5. SUMMARY AND CONCLUSIONS

On the very small scale farms (<150 t / yr of feedstock), the practical challenges combined with the economics make it really difficult / impossible to justify “standard” AD models.

1. Diffuse pollution associated with the storage of manures can be, and is being, equally well addressed by providing covered storage areas with liquid collection facilities, maintaining these in good order, and using them properly.
2. Diffuse pollution associated with the spreading of manures, AD may provide some advantages here, but these advantages are only really realised with appropriate spreading techniques. If digestate is applied at the wrong time in the wrong way, advantages are limited.
3. Where possible, National Trust could consider combining feedstocks at a single treatment site – Hafod y Llan and Llyndy Isaf is a good example of where this could work, providing that bio-security advice allows it. The requirement to pasteurise will determine whether this is viable / desirable.
4. Probably the best justification for AD facilities is for habitat management purposes. Where this is a real concern, biomass including bracken and wetland grasses / reeds can be utilised by AD. It is challenging, but demonstrations suggest that it is possible. Energetically this may / may not be viable, but if it is combined with a conservation requirement to harvest the biomass in the first place, then energy isn’t the only driver. The material has to go somewhere. Where this is undertaken, it then makes sense to include whatever manure is available in the area.
5. The “dry digestion”, batch option (available from QUBE renewables but conceivably others) might be worth trialling but even here the cost is quite high compared to the economic benefits.

6. RECOMMENDATIONS

In view of the conclusions there are two options for consideration. They are not mutually exclusive and could both be implemented. If, however, option two was to be taken up, option one might be sensibly delayed:

1. National Trust undertake a desktop exercise to map out regional manure / slurry production. There are likely to be some obvious locations where AD at small scale can clearly play a role, and probably some locations where some aggregating of very local sites may make a lot of sense both practically and economically. Undertake a similar exercise for locations where bracken and soft rush are causing particular concerns. Again, some sites will stand out and some may need a little aggregation. Consider each of these locations on an individual basis in terms of conservation / habitat priority combined with the practicality and viability of locating an AD plant at the site and utilising the biogas.
2. Give consideration to the trialling of a dry, batch system at Hafod-y-Llan. Discussions have taken place with QUBE Renewables and they have suggested a trial of 50 tonnes of reasonably fresh farmyard manure with 10 tonnes of rush. They have said that a "60 tonne digester with irrigation system and extra fleecing to keep temperature as warm as possible would cost approxiamtely £25K, boiler would be £3k and some provision needed for pipe work and heat exchanger etc ". Some extra funding would be necessary for (preferably independent) monitoring and evaluation.

   The recommendation in respect of this option is not strong and further logistical discussions would be needed – as well as an assessment of value-for-money and the possible availability of grant funding. It would be very much a trial but the lessons learned would be valuable – and may lead to a cost effective solution being identified.

Credit and Disclaimer

This project has been funded with support from the European Commission. This publication (communication) reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

APPENDICES

APPENDIX A – SITE PHOTOGRAPHS

Plate 1 – View from Dolobran farm looking east towards the lower slopes of Foel Benddin

Plate 2 – View from Dolobran looking south east to the bracken covered Foel Benddin

Plate 3 – Looking south westerly across the lower meadow of Dolobran

Plate 4 – Dolobran, outside storage of dry manure on hardstanding

Plate 5 – Dolobran, internal storage of manure on hardstanding. Liquid is collected via slot drain.

Plate 6 – Dolobran, internal storage of manure

Plate 7 – Llyndy Isaf, View looking south east over lowland meadow towards Llyn Dinas

Plate 8 – Llyndy Isaf, View looking north west across meadow of white clover

Plate 9 – Llyndy Isaf, Old manure outside of storage area

Plate 10 - Llyndy Isaf, Internal storage of manure on hardstanding

Plate 11 – Hafod y Llan, looking north westerly over animal housing sheds and manure store to the upland areas of the farm

Plate 12 – Hafod y Llan, internal storage of manure. Liquid collected via slot drain