BIOMASS BIODIVERSITY FEASIBILITY STUDY

ABSTRACT

A scoping report, supported by Natural England and commissioned by the East Riding of Yorkshire Council, into the potential to harvest Low Input High Diversity Biomass from the Lower Derwent Valley Designated Sites and the Yorkshire Wolds National Character Area as a feedstock for the production of renewable energy.

Dr Nick Cheffins,
Peakhill Associates Ltd

January 25th 2019

Contents

Acknowledgements

1. Clare Langrick and colleagues at the North and East Yorkshire Ecological Data Centre for providing the core data and mapping services that underpin 1.2. Outline Description of the Study Areas
2. East Riding of Yorkshire Council Data Observatory for their analysis of road distribution within the study areas
3. NNR Staff from the Lower Derwent Valley for their data on biomass harvesting

Executive Summary

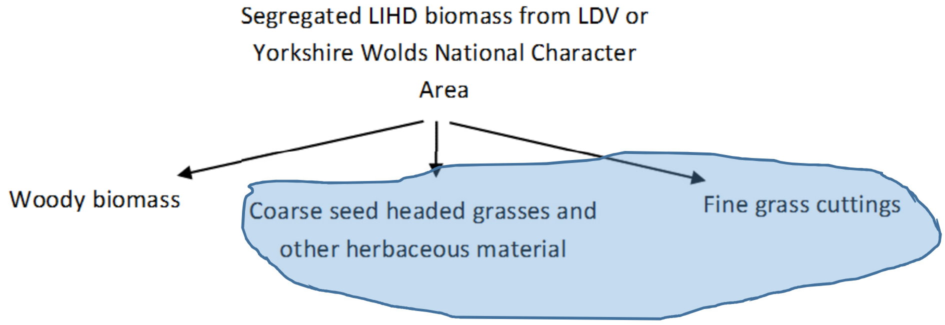
The East Riding of Yorkshire Council, as part of the Hull and East Yorkshire Local Nature Partnership (LNP), is working with Natural England to explore the potential to use biomass from a range of semi-natural habitats as a feedstock for producing renewable fuels.

This project, which is a predominately desk based feasibility study, focused on two study areas, the Yorkshire Wolds National Character Area (NCA No 27) and the Lower Derwent Valley Designated sites.

The study identified Anaerobic Digestion (AD) plants that were within 15 km of both study areas. The feedstock descriptors on the initial planning applications for the plants were used to screen for those that might have suitable engineering to accept the type of Low Input High Diversity (LIHD) Biomass that would be produced from the study areas. Of the plants listed from planning data, two possibilities were identified within 15 KM of the Lower Derwent Valley (LDV) and three for the Yorkshire Wolds NCA.

The study has attempted to categorise and produce a high level quantification of the LIHD Biomass that can be of potential use by the shortlisted AD plants. The result indicated that both could potentially produce meaningful quantities.

The study presents a brief overview of current research into the use of LIHD and confirmed the fractions of this material that would be useful to AD operators.



(Categories suitable for inclusion in conventional AD feedstocks)

This has been accompanied by the development of business case for the potential of LIHD as a feedstock. The results indicated that a case could be argued for the inclusion of LIHD biomass within the feedstock diet of AD plants.

From the viewpoint of the AD operator two financial benefits could flow. Firstly the case has been set out that LIHD biomass could be offered at a price that could reduce expenditure on current energy crops and secondly that there was a significant opportunity benefit gained from releasing farm land back into food crop production.

To set the opportunity for AD plants into context a section has been included that gives a background into the range of plant specification and business plans that may be encountered in bring the feasibility to the test. Within part of this it was recognised that very small scale AD plants would not provide a viable local or community option for utilising LIHD.

The business case for producers of LIHD biomass differed between the two study areas. In LDV producers regularly struggle to harvest all their hay crop due to wet ground conditions exacerbated by the high water tables of the meadows. A case was set out that suggests that they could consider developing a joint approach through a cooperative or a machinery ring to enable a centralised silage production that would aggregate sufficient LIHD biomass to supply the AD plant identified previously. It was noted that whist the profit margin to producers may be small they could benefit from a second management tool for their pasture land that may be useful in discharging their environmental management obligations.

The LIHD biomass from the NCA is dominated by verge mowing biomass and there is a reasonable amount of biomass potentially available However, the road network of the Wolds NCA is quite extensive and the logistics of collection could become an issue for the valorisation of the biomass on a standalone basis. The study therefore suggests that this could be pursued by operating it as a subcontract with the within the overall organisation of the Local Highways Agency management plan.

The biomass could be collected by the selected AD plants but they would also collect from beyond the NCA boundary; operating within a notional 10km radius of their plants. In this instance the valorisation of the biomass comes in part from the operation of a sub contract albeit there could be a recognition that the cutting payment was modified to take account of the fact that the operator was retaining the biomass and thus benefitting in a similar way to the business case developed in the LDV scenario.

An underlying issue across all the business case scenarios is the need to verify that there are AD plants in the study areas that can accept LIHD biomass without any additional modifications such as comminution or enhanced hydrolysis to improve the digestion of LIHD especially if it is harvested from August onwards.

The other underlying difference between the two study areas is the regulatory status of the LIHD produced.

The LDV biomass can be considered as a crop and therefore would be permissible into any suitable AD plant. The verge biomass is currently classified as a waste as it is a by-product of the maintenance of the highway verge. To answer this a ‘New’ and a ‘Future Option’ for using LIHD have also been presented.

The ‘New Option’ is Dry Anaerobic Digestion which could be described as a cross between aerobic composting as widely applied to green waste. It speeds up the standard aerobic process operated by green waste handlers and produces significant amounts on methane that will create an income. This has been taken up by several, local authorities and could provide an opportunity to consider localised AD utilisation of LIHD biomass to produce energy within their waste processing strategy.

The ‘Future Option’ is the entry of LIHD biomass into a Lignocellulosic Bio refinery process. The example outlined in this study is emerging from an industrial collaboration with the University of York and will be imminently proceeding to full pilot stage at a site within Yorkshire. This process will also produce bio methane together with bio ethanol and a lignin dominated solid fuel. Unlike the Dry AD option there is no significant low value compost residue stream requiring to be disposed.

1 Introduction

1.1. Project brief

The East Riding of Yorkshire Council, as part of the Hull and East Yorkshire Local Nature Partnership (LNP), is working with Natural England to explore the potential to use biomass from a range of semi natural habitats as a feedstock for producing renewable fuels. The principle route to be evaluated is its use within Anaerobic Digestion. The range of habitats include lowland meadows, calcareous grassland, wet grassland, rush pasture, reedbeds, tall ruderals (e.g. bramble, nettle and hogweed) and scrub.

The project, a predominately desk based feasibility study, focuses on two study areas, the Yorkshire Wolds National Character Area (NCA No 27) and the Lower Derwent Valley. The study has attempted to categorise and produce a high level quantification of the LIHD Biomass that can be of potential use for AD plants that are located in or near to the two study areas. This has been accompanied by the development of business analyses of the potential for LIHD as a feedstock. The study has also reviewed the business case for the development of logistics of a biomass supply chain.

1.2. Outline description of the study areas:

1.2.1. Lower Derwent Valley

The Lower Derwent Valley (LDV) is situated in the lower reaches of the River Derwent, immediately upstream of its confluence with the River Ouse Barmby Barrage, and forms the administrative boundary between the Unitary Authorities of the East Riding of Yorkshire and City of York and Selby District in North Yorkshire. It affords five different international and national designations, in many cases with slightly different boundaries (see Table 1).

Table 1: Lower Derwent Valley designations

Level	Designation
International	Ramsar site
International	Special Area of Conservation (SAC)
International	Special Protection Area (SPA)
National	Site of Special Scientific interest (SSSI)
National	National Nature Reserve (NNR)

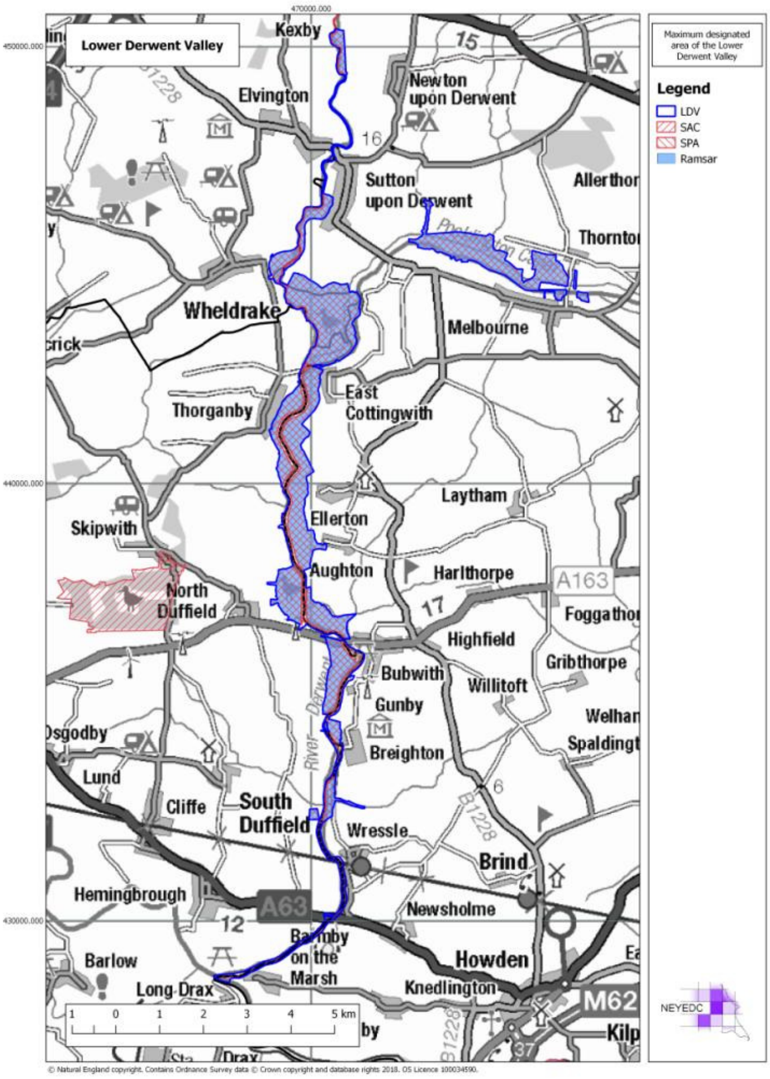
For the purposes of this project, NEYEDC combined the boundaries of these designations to create the 'maximum designated area', from Kexby in the north to the River Derwent's confluence with the River Ouse in the south.

A selection of habitats from the Priority Habitat Inventory (PHI) were mapped against the maximum designated area of the Lower Derwent Valley and their areas noted (Table).

Table 2: Priority habitats and their areas within the Lower Derwent Valley (North and East Yorkshire Ecological Data Centre)

Priority habitat	Area within LDV (ha)
Lowland meadows	527.79
Coastal and floodplain grazing marsh	370.25
Good quality semi-improved grassland	34.11
Lowland fen	21.85
Lowland deciduous woodland	16.70
Reedbeds	0.31
Total	971.00
Of which under SSSI management	Circa 350

Picture 1: Priority Habitats within the Lower Derwent Valley (North and East Yorkshire Ecological Data Centre)

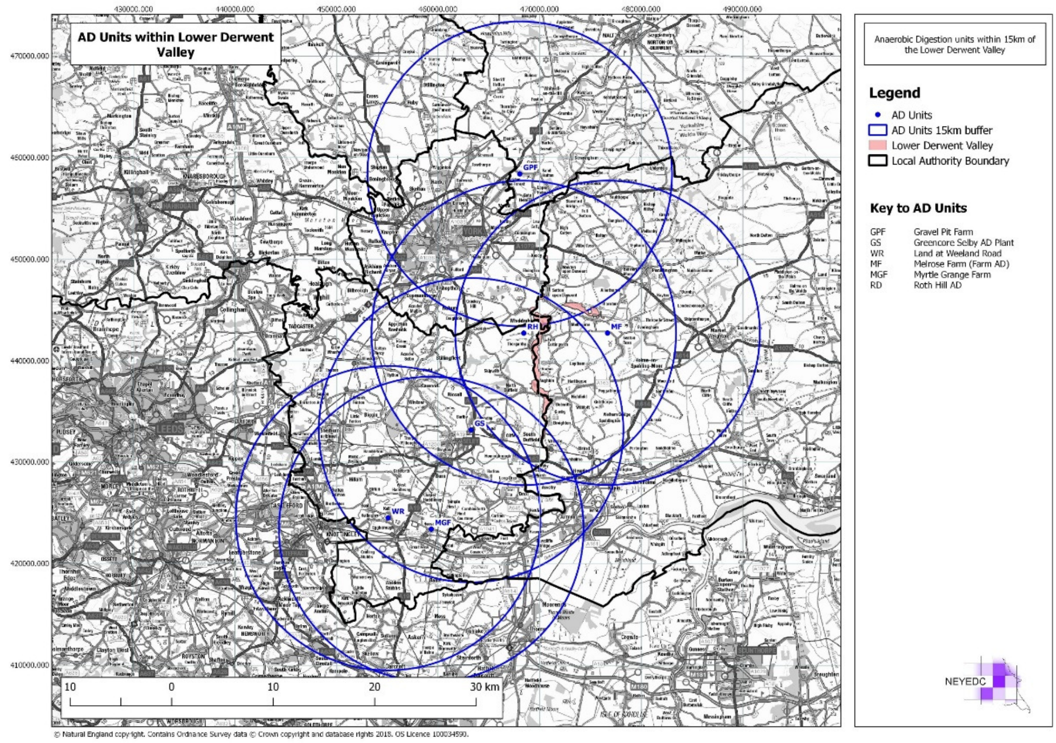


The list of Anaerobic Digestion (AD) units, with a 15km buffer was then mapped against the maximum designated area of the Lower Derwent Valley (Table 3 and Picture 2).

Table 3: List of Anaerobic Digestion units within 15km of the Lower Derwent Valley (North and East Yorkshire Ecological Data Centre)

AD Unit Name	AD Unit abbreviation	NGR
Gravel Pit Farm	GPF	SE 68037 58405
Greencore Selby AD Plant	GS	SE 63244 33159
Weeland Road	WR	SE 55066 24498
Melrose Farm (Farm AD)	MF	SE 76684 42739
Myrtle Grange Farm	MGF	SE 59321 23397
Roth Hill AD	RD	SE 68432 42733

Picture 2: All AD Units within 15 km of the Lower Derwent Valley NNR (North and East Yorkshire Ecological Data Centre)



1.2.2. The Yorkshire Wolds National Character Area

The second area of consideration are high quality verges within the Yorkshire Wolds National Character Area (NCA). As with the Lower Derwent Valley, Anaerobic Digestion (AD) plants, with a 15km buffer, were mapped against the Yorkshire Wolds (Picture 3 and Table 4).

Picture 3: AD units within or adjacent to the Yorkshire Wolds NCA (Shaded area) (North and East Yorkshire Ecological Data Centre)

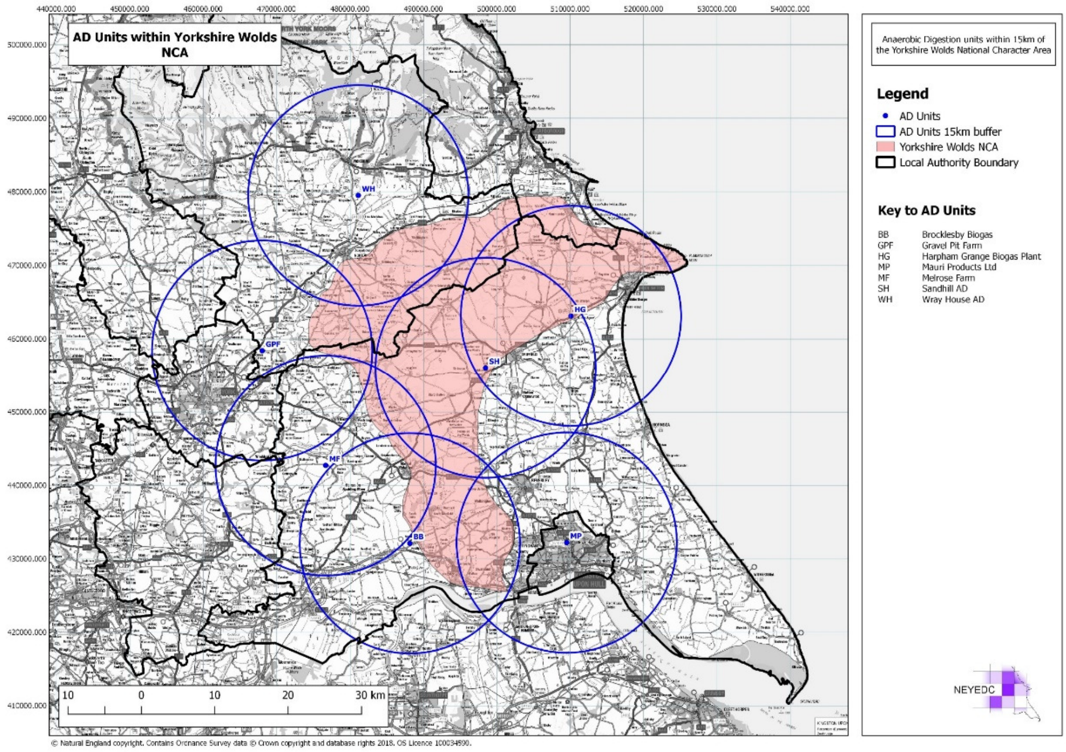
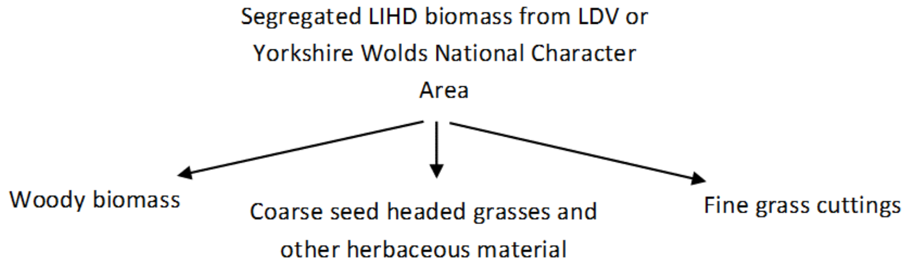


Table 4: List of Anaerobic Digestion units within 15km of the Yorkshire Wolds (North and East Yorkshire Ecological Data Centre)

AD Unit Name	AD Unit abbreviation	NGR
Brocklesby Biogas – Crosslands Lane	BB	SE 88154 32136
Gravel Pit Farm	GPF	SE 68037 58405
Harpham Grange Biogas Plant	HG	TA 10104 63127
Mauri Products Ltd	MP	TA 09529 32229
Melrose Farm (Farm AD)	MF	SE 76684 42739
Sandhill Anaerobic Digestion Plant	SH	SE 98472 56062
Wray House AD – farm waste	WH	SE 81133 79535

2. Summary of existing research into the use of Low Input High Diversity (LIHD) Biomass as a feedstock in Anaerobic Digestion (AD)

This project focuses on the co-mingled organic matter from two of the three fractions of Low Input High Diversity (LIHD) Biomass that exclude woody biomass.



Much of the existing research into the potential to use LIHD biomass as a source of renewable energy is quite recent. A recent review into the management of roadsides[1] identified a range of articles many of which are within the 'grey literature' authored by agencies or consultants in a drive to develop or refine policy for the management of linear infrastructure. Reporting is dominated by literature from North America and Europe.

A developing theme has been the recognition of the growing importance of linear infrastructure as both a refuge/reservoir of biodiversity and that management can influence this. Alongside this is the parallel issue of the management of conservation landscapes. Here it is common for the grazing activity of a range of agricultural or non-domesticated species to be supplemented or replaced by mechanical control of the vegetation resulting in a surplus of biomass of low agricultural value.

Recent research has confirmed that the biomass from the annual growth of herbaceous perennials has the potential to be high in materials that could provide a range of renewable bio-fuels[2] [3]. Coordinating the collection of such material from road verges and conservation landscapes creates a biomass stream that could offer opportunities to generate bio-fuel revenue.

It has been observed over several decades that management practices that reduced nutrient levels and introduced the required level of disturbance could, in many habitats, result in an improvement in biodiversity[4] [5]. Similarly preventing nutrient build up is vital for maintaining biodiversity. This is the principle behind the management regime employed on Roadside Nature Reserves (including both SSSIs and the most diverse roadside Local Wildlife Sites (LWSs)) where botanical diversity is maintained by removal of arisings from the full width of verges at the right time and frequency. This

[1] Bernes et al. Environmental evidence (2017) 6:24

[2] Heinsoo, K et al. 2012 The potential of Estonian semi-natural grasslands for bioenergy production. Agric. Ecosyst. Environ. 137, 86 – 92

[2] Jungers J.M. et al. 2013 Energy potential of Biomass from Conservation Grasslands in Minnesota, USA PLoS ONE 8(4): e61209. Doi:10.1371/journal.pone.0061209

[4] Parr T.W. and Way J.M. Management of roadside vegetation: The long term effects of cutting. The Journal of Applied ecology, 1988, 25, No 3, 1073-1087

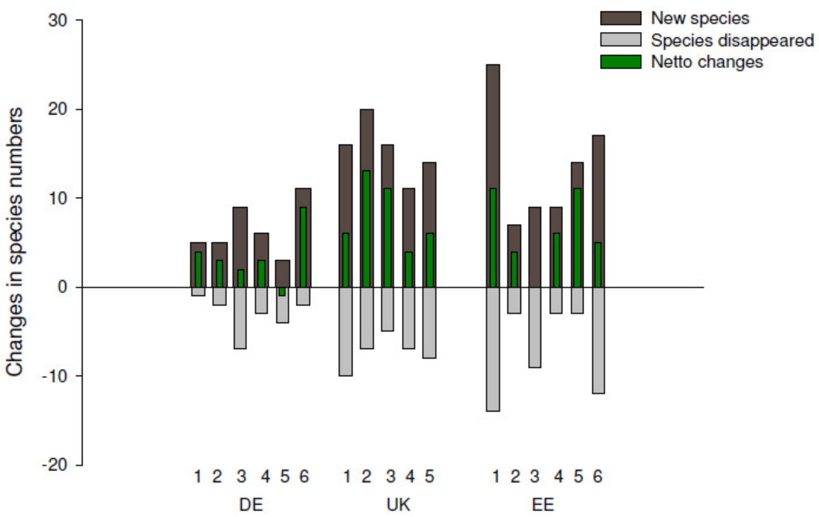
[5] Maron J.L. and Jeffries R.L. Restoring enriched grasslands: effects if mowing on species richness, productivity and nitrogen retention. Ecological Applications, 2001, 11, No 4 1088 – 1100

principle also guides the approach to restoring biodiversity to grass verges by reducing soil fertility: removal of cuttings prevents the build-up of nutrients.

A Trans European project called COMBINE[6] carried out a series of field harvesting trials which have clearly demonstrated the changes in species composition over three years but have also indicated changes in biomass yields as indicated in Figures 1 and 2 below.

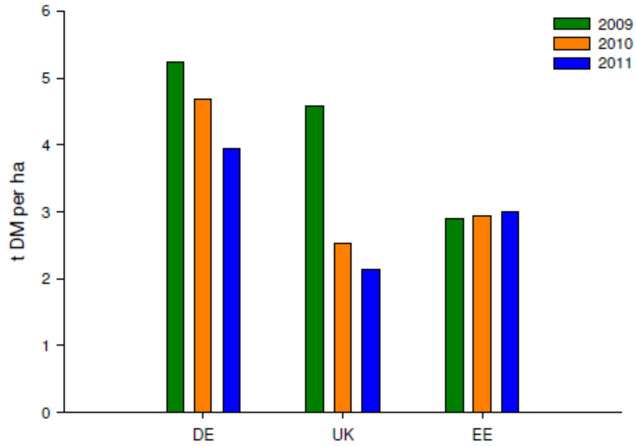
At first sight these results could indicate that there will be a long term issue with providing a stable supply of biomass given that the data from the UK site indicated significant reductions in biomass yields. The UK sites chosen for this research were wet degraded raised bogs in upland Wales dominated by invasive rush which was rapidly superseded under repeated mowing. However all the Estonian sites were described as 'unimproved grassland meadows' and showed no statistically significant reduction in biomass yield over the three years of harvesting. It is the contention of this report that the Estonian sites represent plant communities that may be much closer to the road verges within the Yorkshire Wolds NCA, but it may be that such effects could be observed within parts of the LDV wetlands study area. This may have implications for ongoing estimations of biomass supply within business plan assumptions and is discussed in later sections of this report.

Figure 1: Accumulated changes in species composition over three harvest years across trial sites in Germany (DE), The UK and Estonia (EE)[7].



[6] http://www.combine-nwe.eu/index.php?id=40 accessed 13/07/2018
[7] http://www.combine-nwe.eu/index.php?id=40 accessed 13/07/2018

Figure 2: Change in dry matter (DM) yields (tonnes DM per ha) of three years (DE= Germany Baden Baden trial sites, UK = Powys trial sites, EE = Estonian semi natural grassland sites)[8]



The COMBINE project developed a biomass treatment process termed IFBB which produced both a liquid feedstock for use in anaerobic digestion and a solid fuel for use in biomass that realised a positive energy mass balance of 45% after all process elements from harvest to combustion had been accounted for. The process treated biomass harvested from road verges or managed landscape across 12 sites within Europe with a warmed water extraction stage. The liquid was derived from a source of warmed water from a sewage treatment plant and the energy within the liquor was released by digestion within the water treatments system's own AD plant. Whilst exhibiting a positive energy balance the system requires a large scale water supply, ideally in a partnership with a water treatment works[8].

In 2006 Montgomeryshire Wildlife Trust[9] undertook the first large scale test of the potential for harvesting road verge biomass data which subsequently formed part of a study at Southampton University in 2017[10] which indicated the potential for a positive energy balance for a logistics strategy that involved the collection of verge biomass from up to 20km radii around selected AD plants. The study did not however consider the relative economic values of the energy forms used. This will be discussed in further sections of this report.

[8] Piepenschneider, M. et al (2016) Energy recovery from grass of urban roadside verges by anaerobic digestion and combustion after pre-processing Biomass & Bioenergy 85; 278-287

[9] Delafield M. A practical trial to investigate the feasibility of wide scale collection of cuttings from roadside verges in Powys, for use in biogas and compost production, Living Highways Project, Montgomeryshire Wildlife Trust. (2006) http://www.montwt.co.uk/what-we-do/projects/road-verge-nature-reserves - contact fillow up to be undertaken

[10] A. Salter, M. Delafield, S. Heaven, and Z. Gunton (2007). Anaerobic digestion of verge cuttings for transport fuel. Proceedings of the Institution of Civil Engineers Waste and Resource Management, 160, 105–112

2.1. Use of invasive and notifiable species within AD

A recent piece of European research[11] covering four species including Himalayan Balsam, Giant Hogweed and Japanese Knotweed has concluded that all could be processed through AD. The calculated energy outputs per ha for samples of the target species that were passed through the AD process were found to be equivalent to standard energy crops. The AD process was also successful in denaturing their propagules and could be considered as a possible control method for contaminated sites. Furthermore the use of a cut and suction lift system with covered transport would markedly reduce the potential for propagule dispersal compared to flail cutting and subsequent decomposition in situ.

It is therefore possible that realising the energy potential of invasive alien and vigorous notifiable weed species could offer an economic incentive for the habitat restoration of invaded sites.

---

[11] Biomass of invasive plant species as a potential feedstock for bioenergy production by Koenraad Van Meerbeek et al. Biofuels, Bio-products and Bio-refining (2015) Volume 9: 3, pp 273–282,

3. Analysis of the biomass potential of the semi–natural vegetation / habitat types in the pilot areas of the feasibility study

3.1. Lower Derwent Valley

The Lower Derwent Valley possesses a number of priority habitat classifications that can yield forage harvests. The norm for this activity is the production of baled hay timed to allow flowering of the Ings meadows before harvest. This is then followed by autumn grazing until the autumnal soil moisture content would lead to compaction damage of the biodiverse swards and their underlying soil structure. The harvested hay is of variable quality as influenced by the habitat type and species profile. Furthermore, in most years parts of the landscape become waterlogged earlier than when the hay crop can be taken. With the appropriate low ground pressure equipment (See 5.2) this could be harvested as a late silage and provide an ensiled crop.

Table 5: An estimation of the potential annual Fresh Weight (Fwt) production of ensiled LIHD biomass potential from the Lower Derwent Valley (LDV)

Priority habitats within the Lower Derwent LDV	Habitat area within LDV (ha)	Assume 75%of the area accessible to harvest	Total yield at 23.75 t Fwt /ha	Assume 15% of harvestable area available to AD	Yield assumptions Fwt t/ ha benchmarked against Unimproved Grassland[12]	
Lowland meadows	527.79	395.84	9,401.26	1,410.19		
Coastal and floodplain grazing marsh	370.25	277.69	6,595.08	989.26		
Good quality semi-improved grassland	34.11	25.58	607.58	91.14	23.75	fwt yield
Lowland fen	21.85	16.39	389.20	58.38	0.32	%DM
Totals	954.00	715.50	16,993.13	2,548.97	7.60	DM/ha

3.2. Yorkshire Wolds NCA

The Yorkshire Wolds has a relatively low density of road network at 1,592km within 111,446ha of predominantly arable land (i.e. 1.0 km of road / 70 ha of land). The implications of this degree of dispersal of LIHD Biomass are discussed in Section 5.

The yield data is calculated on the basis of data from the Lincolnshire County Council (LCC) trials carried out in 2016. Here the verges were assessed as having an average accessibility of 70% to mowing the standard 1.1m visibility. The verge in that trial were further estimated as 70% of their accessible length providing an opportunity to cut a second swath (i.e. 49% of the overall length).

[12] The 2018 Agricultural Budgeting and Costing Book 86th Edition, Agro Business Consultants Ltd www.abcbooks.co.uk

In 2016 the 1st swath produced an average of 1.412 t Fresh weight (fwt) / km of verge and 3.07 t fwt / km from the second swath where it was accessible. These values were used in Table 6. Below.

Table 6: An estimation of the potential annual production of LIHD biomass potential from mowing the accessible road verge within the Yorkshire Wolds NCA

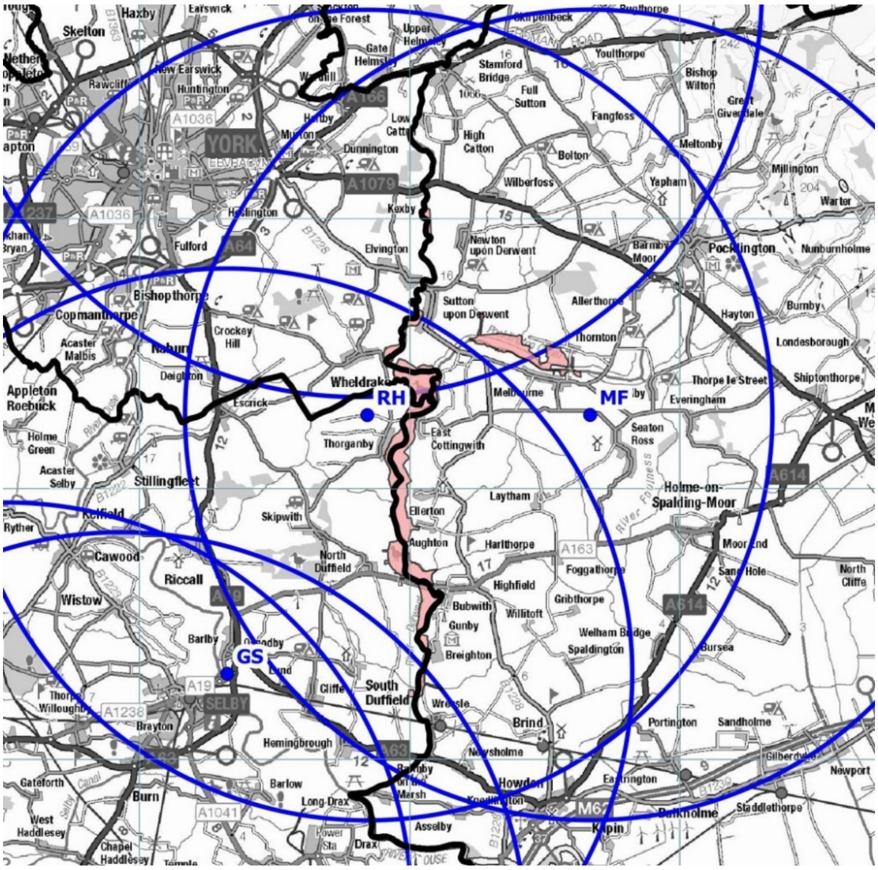
Road Type	Length (km)	total verge km 70% accessible for 1st swath	70% of 1st swath accessible for second swath cut	Yield from 1st swath tonnes fwt	Yield from 2nd swath tonnes fwt	Total yield tonnes fwt
A Road	245.9	172.1	120.5	243.0	369.9	612.9
B Road	295.1	206.6	144.6	291.7	444.0	735.7
Minor Road	1615.5	1130.9	791.6	1596.8	2430.2	4027.0
Local Street	236.8	165.8	116.0	234.0	356.2	590.2
Alley	2.0	1.4	1.0	2.0	3.0	5.0
Private Road - Publicly Accessible	6.5	4.5	3.2	6.4	9.8	16.2
Private Road - Restricted Access	784.0	548.8	384.2	774.9	1179.3	1954.2
Totals		**2230.1**	**1561.1**	**3148.9**	**4792.4**	**7941.3**

It was noted that both study areas but especially the Yorkshire Wolds NCA cross local authority boundaries. This could influence the integration of local biomass into the management of local waste to bioenergy supply chains as discussed in section 6. This would require further study.

4. Assessment of AD units in the feasibility study's pilot area

4.1. Lower Derwent Valley

Picture 4: Three optimally located AD units in relation to the Lower Derwent Valley and the details of two that may have suitable digestion technologies. AD outputs are shown as MWe (Electrical) and / or MWth (Heat) as appropriate



RH = Roth Hill AD

0.25 MWe
Commissioned 2014.

5,000 tpa* waste vegetables & grass silage; assume premixed and macerated; single stage digester tank.

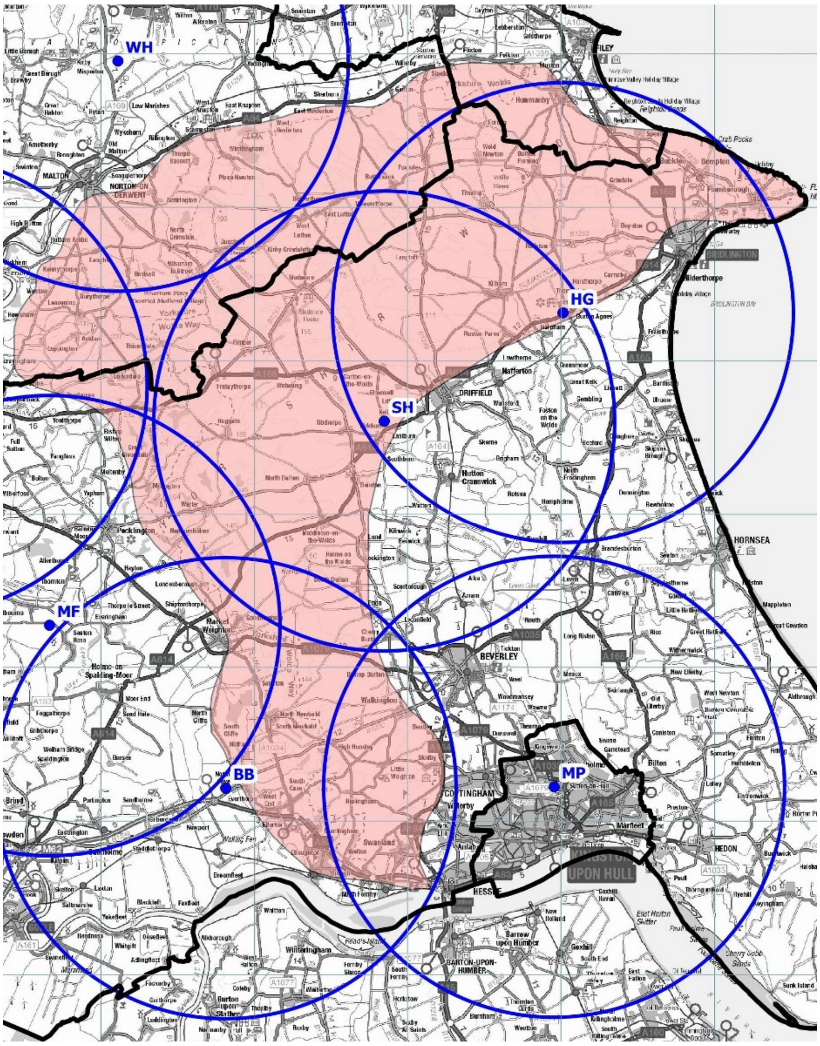
MF = Melrose Farm AD – British Crop Dryers

0.5MWe
Commissioned 2012; 16,450 tpa maize silage & pig slurry; single stage digester tank.

Both the AD plants selected as being of interest are well located to receive biomass arising from the LDV Designated sites but their technology would require further investigation.

4.2. Yorkshire Wolds NCA

Picture 5: Six optimally located AD units in relation to the Yorkshire Wolds NCA and the details of three that may have suitable digestion technologies AD outputs are shown as MWe (Electrical) and / or MWth (Heat) and / or BtG (biomethane to grid as appropriate



•HG = Harpham Grange Biogas

BtG 500 m^{3}/hr & 0.55MWe Commissioned 2016; 62,000 tpa silage maize and hybrid rye energy crops, straw, chicken & pig manure – engineering could be suitable.

•WH = Wray House AD

0.5MWe Commissioned 2015; 16,200 farm based energy crops and residues - engineering could be suitable.

•MF = Melrose Farm AD – British Crop Dryers

0.5MWe Commissioned 2012; 16,450 tpa maize silage & pig slurry; single stage digester tank.

As stated previously all the three selected plants would need to have their engineering reviewed. Also the Melrose Farm option could potentially select material from both/either study area.

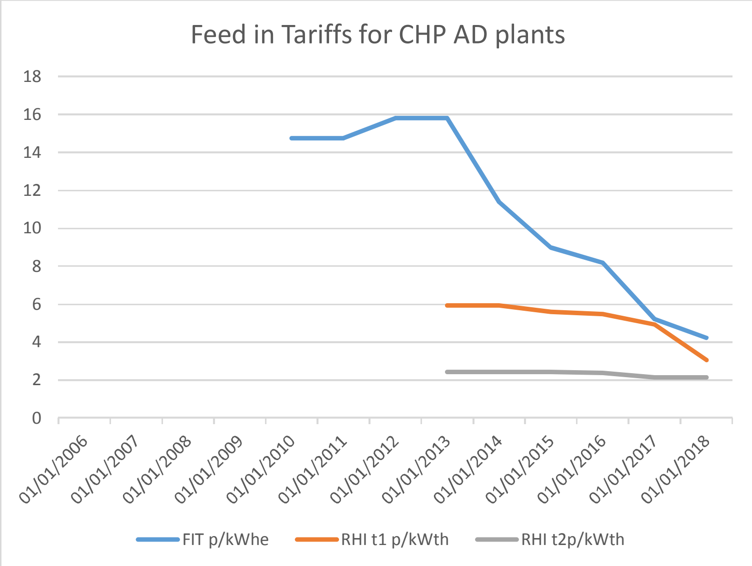
5. Business case for using LIHD Biomass from the pilot areas as a feedstock in existing AD plants

5.1. Background to the specifications for the selected AD plants

One of the challenges to this feasibility study comes from the recognition that each AD plant possesses unique characteristics that are the result of a number of factors, several of which interact significantly.

- Technology used in the AD plant:
  - Most established plants operate at mesophilic temperatures i.e. 37 – 43 ^{0}C
  - AD plants with two separate stages are the more efficient
    - 1st stage tanks perform a hydrolysis that breaks down the feedstock
    - 2nd stage tanks are larger and hold the liquidised feedstock whilst the biogas is produced
  - The newer AD plants that operate at thermophilic temperatures i.e. 50 – 53 ^{0}C are even more efficient (but tend to be more expensive)
  - LIHD may requires some physical pre-treatment to aid its management within AD plants. This would most commonly consist of increasing the surface are of the feedstock by cutting or grinding. Alternatively thermal and/or enzymatic treatments can reduce lignocellulose structures and speed the hydrolysis of the feedstock. However they have not yet proved to be economic options.
- However feedstock selection tend to influence both the technology and the ecology of the microbes operating within it:
  - AD plants that utilise silages made from grass, hybrid rye and manures with high straw content are more likely to possess the pre-treatment engineering that will cope with the high viscosity of grass-based feedstock. In addition longer term exposure to this set of feedstocks will select out the microbes with an emphasis on hydrolysis of the more recalcitrant elements of feedstock chemistry.
- Ownership models can make decision making more complex and conservative. Many on farm AD plants are, in fact, owned by investment companies or majority joint ventures that are distant from the farm company acting as the operator. Significant alterations to feedstock or operational processes may be adversely viewed purely from a risk management perspective without reference to on the ground opportunity.
- The date when the AD plant became operational also has a fundamental impact on the overall business strategy/profit generation potential. The first wave of plants commissioned between 2010 and 2013 were almost all designed to export electricity only, in response to the electrical Feed in Tariff (FiT). This was rapidly seen by central government as an overgenerous level of support and a degression mechanism was applied to later applications. In part mitigation of the impact of degression on electricity FiT support was offered under the Renewable Heat Incentive (RHI) for proposals for the use of the heat (Figure 3).

Figure 3: Changes in Feed in Tariff (FiT) in p /kWe and the onset values for the non-domestic Renewable Heat Incentive (RH)I payments for heat from a CHP as p / kWth

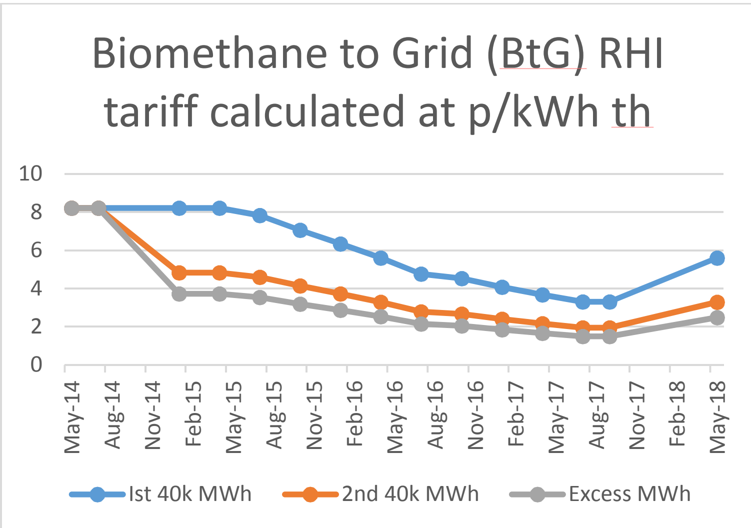


Note: t1 and t2 related to tier 1 and tier 2 payments triggered by the annual volumes of gas injected t2 is triggered for all gas after a fixed amount of gas has been supported at t1.

Alongside the Combined Heat and Power (CHP) energy conversion model the government introduced a revision to the RHI that supported the injection of biogas upgraded biomethane into the grid network (Figure 4). Although the level of support initially fell steeply under the same degression principle as for electrical FiT the rate has recently been revised upwards in response to the need to improve the carbon balance of heat consumption.

Alternatively compressed or liquefied Biomethane can be offered as a road fuel and attract support through the collection and trading of Renewable Transport Fuel Certificates (RTFC). This is a volatile market place but is a favoured tool as it is disconnected from taxpayer support as certificates have to be purchased by fuel blending companies if they choose not to utilise the bio methane. It is fair to say that the UK market place for this option is not large.

Figure 4: Changes in RHI support for Biomethane to Grid or compression for use as vehicle fuel



5.2. Case study for a farm based anaerobic digestion plant to accept LIHD Biomass

Picture 6; Medium scale farm based AD plant. The CHP is visible on the left with the digestate storage tank in the centre of the picture and aflat roofed hydrolysis tank half left. These plants are usually operated at mesophilic (37 -43C) temperatures.

Features of a typical medium scale farm based AD plant

This is a plant with 499kWe electrical output from CHP, designed to optimise FiT uptake probably commissioned in 2014/15. It uses 11,250 tonnes per annum (tpa) of a range of feedstocks as detailed in Table 7. Typical features include

1. The biogas produced contains 60:40 bio-methane:CO_2
2. The biogas is burnt in a CHP to yield heat and electricity and that either can be sold, or utilised in house. (There are also evolving local energy agreements that are making some AD plants much less support sensitive.)
3. Alternatively it is upgraded to Biomethane by removing the CO2 and any other trace contaminants and injected into the gas grid.
4. Alternatively the upgraded Biomethane is condensed and utilised on site or sold as a transport fuel, potentially attracting either RHI or RTFC support.
5. Total capital expenditure (CAPEX) on an AD plant of this type of will vary according to which of the energy sale assumptions is chosen:

5.1. Assumption 2 £3 – 3.5 million
5.2. Assumption 3 £3.5 – 4.0 million
5.3. Assumption 4 £4.1 – 4.25 million
5.4. CAPEX Exclusions
    5.4.1. Grid connection fees
    5.4.2. Site specific civil engineering.

Table 7 below outlines the biomass feedstock that a plant of this type might use. In this instance there is the assumption that a proportion of its feedstock is grass silage grown on farm. This would indicate that it has the necessary engineering to take in some LIHD biomass from an external supply.

Table 7: Indicative biogas outputs and feedstock costs based on benchmark budgeting figures[13]

Biomass feedstock	tpa fwt	Biogas / t	cum biogas pa	Cost[13]	Comments
Whole crop hybrid rye silage	800	140	112,000.00	£15,177.78	Grown on farm
Grass silage	2,500	120-215	393,750.00	£32,596.15	Grown on farm
Whole crop Maize silage	4,950	180-220	990,000.00	£102,256.58	Grown on farm
Straw	500	90	45000	£9,000.00	Grown on farm
Vegetable waste	1,500	50 - 80	105,000.00	-£37,500.00	Received via gate fee payment
Chicken manure	1,000	90 - 150	120,000.00	£15,000.00	Bought in
Total	**11250**		**1,765,750.00**	**£136,530.51**	
Average biogas output cu m / t Fwt		156.96			

Proposition to the AD plant operator

Scenarios in Section 3 indicated that approximately 2,500 t Fwt of LIHD biomass could be produced annually by the Lower Derwent Valley designated sites and up to 4,000 t Fwt is available across the Yorkshire Wolds NCA. Table 8 below has assumed that up to 2,500 tpa Fwt of LIHD Biomass could substitute for the main farm grown energy crops, Maize and Hybrid Rye, in the AD modelled in this case study. Substitution at 30% when feeding has been undertaken successfully within the Lincolnshire County Council 2016 study in a plant similar to the case study.

Table 8 below indicates that, when allowing for the substitution, there is both a saving in the cost of feedstock and the opportunity from releasing land back into food production. Taken together these amount to a modest reduction of £6,328 in costs to the AD plant and increase in gross margin of £48,426 to the associated farming business giving a net movement of £54,754. This assumes that there is no significant loss of biogas potential arising from the manipulation of the feedstock balance. In broad terms LIHD biomass performs within the grass silage output range shown in table 7 which overlaps the output values of maize and hybrid rye

[13] The 2018 Agricultural Budgeting and Costing Book 86th Edition, Agro Business Consultants Ltd www.abcbooks.co.uk

Table 8: Potential financial impact of including bought in LIHD Biomass within the model AD plant

Cost saving for AD plant of replacing a proportion of its feedstocks with LIHD Biomass			
Tonnage replacements	tonnage	cost / t	Total saving
Maize	2,000.00	20.92	£41,842.11
Hybrid Rye	500.00	18.97	£9,486.11
Purchase of LIHD	2,500.00	18.00	£45,000.00
Difference	0.00		£6,328.22
Income generation for farm business from replacing a proportion of the AD plant feedstocks with LIHD Biomass			
Ha of arable land released for winter wheat production - ha figures derived from above replaced tonnages divided by benchmark yields per ha	ha	gross margin produced	The cost saving is derived from bench gross margin / ha for winter wheat x the area of each energy crop released i.e. 52.6 + 13.9 x £728.00 / ha
From Maize /38)	52.6	£38,315.79	
From Hybrid Rye / 36	13.9	£10,111.11	
Extra net income		**£48,426.90**	

As indicated in paragraph 5.1 some ownership models can make the identification of who receives these savings less obvious but the overall financial value of this proposition would be unchanged.

Proposition to the producer of LIHD biomass silage

The key issue for farms and small holdings within the LDV, including its SSSI's is that their biomass needs to be harvested as silage rather than allowed to dry for baling as hay if it is to be offered for use in AD. The current situation, garnered from field records for the LDV SSSI is that the biomass is harvested for hay in late July and August and baled into a wide range of bale sizes and types. Converting the tonnage of hay to yield per ha gave approximately 4 – 5 t /ha. This assumed that all the area of each field record was harvested.

Harvest data also indicated that each year significant proportions of the available land was unable to provide a hay crop either because of unfavourable weather or ground conditions (i.e. flooding or wet ground making a cutting process unfeasible). Providing LIHD biomass as silage from this category of land could provide an additional income that is currently not being realised.

Table 9 gives an estimate of the benchmark variable costs for producing energy crops. Converting the approximate LIHD biomass yield from hay to silage by comparing dry matter moves the bulk yield from 4.5 t / ha hay to 12.5 t / ha of silage. On this basis silage from LIHD biomass may well have the lowest unit cost of production (Table 9). Informal discussions within the AD sector indicate that there may be an achievable price point around £15 – 18 /t Fwt for LIHD biomass silage delivered to the plant.

On the basis of the calculations in table 9 the LIHD silage does have the lowest costs and could return a small but positive gross margin at the farm gate if the market purchase price was around £15 - 18 / on reception at the AD plant.

Wholesale prices for meadow hay fluctuated between £65 and £90 within 2015 and 2018[14]. Higher returns are often achieved from direct retail sales of good quality hay in small bales at up to £3.00 into the equine market that values a tonne of small bale hay at around £150.

By comparison LIHD biomass converted from hay to silage produces a factor of 1: 2.79. Thus one tonne of 'hay' harvested as silage at £18.00 /tonne has a gross value of circa £50. This should therefore be viewed as addition income from a new biomass stream rather than substituting for hay production.

Table 9: Benchmark variable costs for energy crop production

Benchmark variable costs for energy crop production[14]					
Benchmark contracting charges / ha		£/ha			
Cultivation		**Maize**	**Permanent pasture**	**Hybrid rye**	**Low Input High Diversity Biomass**
Ploughing		55		55	0
Harrow		45		45	0
precision drill		42		42	0
rolling			12		0
spraying		28	14	28	0
Fertilizer		24	24	24	0
Total		194	50	194	0
Input (Seed, fertilizers & crop protection)Costs / ha					0
Maize inputs / ha		436			
Grass inputs / ha			154		
Hybrid rye inputs / ha				346	
Complete SILAGE harvesting costs /ha at specified tonnage	**T Fwt/ ha**				
maize	38	165			
grass	26		135		
hybrid rye	36			143.00	
LIHD Biomass (Estimated hay yield 4.5t at 89% DM converted to silage at 32% DM)	12.5				135
Cost / t Fwt at benchmark tonnages		**20.92**	**13.04**	**18.97**	**10.80**

5.3. Business case for producers of LIHD Biomass to establish a local supply chain and market

The two pilot areas of this feasibility study present divergent opportunities and challenges in charting the way forward for the managers/owners of the respective landscapes to develop supply chains and market opportunities.

[14] The 2018 Agricultural Budgeting and Costing Book 86th Edition, Agro Business Consultants Ltd www.abcbooks.co.uk

5.3.1. Lower Derwent Valley

The landscape of the Lower Derwent Valley is largely agricultural and thus any LIHD Biomass can be harvested as a crop. This will enable it to be traded with agricultural AD plants operating under a Standard Rules Environmental Permit and will most likely be recorded as Plant Tissue Waste (EWC 02-01-03).

In addition the target AD plants are sited within 5km of much of the Valley's designated sites. That means the logistics should be very simple for supplying LIHD into either plants. The reality would be that 1,000 tpa FWt might be the maximum for the Roth Hill plant due to its small size so the Melrose Farm option will need to be investigated as well. It is possible that Melrose could also become involved with the western side of the Yorkshire Wolds NCA.

The majority of the farms within the NNR are likely to have forage management equipment albeit for the production of baled hay. Management records indicate a wide range of bale types and sizes. The AD's feedstock will need to be ensiled and timed to be harvested such that the lignification of the plant stems is limited. If a clamped silage system is used the variation in bale types is removed making handling in bulk to a local AD simpler and achieved at a lower variable cost (Table 9).

This study has assumed that the reason there is a proportion each of the harvest that is not suitable for sale as hay is due to the wet conditions, difficulty of site accessibility and the presence of marshland species such as reed etc. This can however be harvested using specialist equipment such as the Log Logic Soft Track shown in picture 7.

Picture 7: Self-propelled Log Logic Soft Track[15] low ground pressure wetland biomass harvester

The output of a forage harvester of this type could be ensiled in a network of small farm based clamps until it is transported the relatively short distance to either of the target AD plants. Given the range of holdings and environmental management requirements this sort of operation may optimally be

[15] http://www.loglogic.co.uk/index.php/product-range/cut-and-collect-system accessed 04/09/2018

delivered through a cooperative activity such as a Machinery Ring or retained specialist contractor to maximise the use of the machine and spread the capital and finance costs.

Given the presence of fixed overhead labour within many smaller farming units there may be resource that can be diverted into managing the ensiling and transporting of ensiled feedstock to the AD plants at a marginal cost especially as a silage harvest is unlikely to coincide with hay production.

Thus if the LIHD is sold at £18 / t FWt and entails harvesting and ensiling costs of £10.80 then 2,500 tpa FWt would produce a gross margin of £18,000 to a cooperative minus costs of transport to the AD plant.

In addition however this operation may also produce a revenue stream from the necessary habitat management activities that many of the farms within the LDV designated sites have to undertake to maintain their enhanced environmental stewardship payments. No attempt has been made to factor that in at this stage.

5.3.2. Yorkshire Wolds NCA

The Yorkshire Wolds NCA presents different challenges for the valorisation of LIHD Biomass. There is a reasonable amount of biomass potentially available from the road verge. However the road network of the Wolds NCA is quite extensive (See 3.2) and the logistics of collection could become an issue for the valorisation of the biomass on a standalone basis. Other studies have shown that moving verge harvested biomass more than 10km raises costs that mitigate against a financially viable process in its own right. Given that all of the three target AD plants are at the edge of or outside the NCA this will occur to some extent.

The financial case for introducing LIHD biomass into an AD and the potential savings from release of land back into food production are very similar to the figures shown in Table 8 but the method for harvesting will dictate a different cut and ensiling cost and the options below may need to be investigated further.

Experience from the LCC trials indicate that a specialist machine can be fabricated and, working with two trailers, has the potential to harvest up to 60 tonnes / day in ideal conditions. The breakeven target for that experiment was 80 tonnes / day. Further machinery modifications and greater attention to driver and trailer management are expected to move performance closer to this KPI. Other opportunities are also under consideration as listed below.

Opportunities

- If the collection of verge biomass was incorporated into the mowing contracts for the NCA with the proviso that the contractor would retain the biomass for sale then the process may become viable especially if operated by the target AD plants.
- If the target AD plants are contracted to operate over the whole of a circle of road network surrounding their sites as shown in Picture 5 it is again possible that a sustainable cut and collect programme could be developed.
- Alternatively the Local Authorities that cover the NCA could develop an in house cut and collect LIHD Biomass project based on ensiling the biomass at their green waste centres/highways depots. The aggregated stockpile could then be used to develop an entry into the renewable energy feedstock market.
- Although the Environment Agency has not yet agreed a waste code that can be applied for the purposes of the 2016 LCC trials application to the EA it might be included under 20-02-01

in the Waste Classification List of Waste codes[16] (garden and parks waste – biodegradable). The food waste plants operate under standard rules permits designed for them to receive a wide range of bio wastes and it is possible that this bio waste will be included once its status has been resolved. This discussion is currently continuing with the EA's national policy unit.

Picture 8: Lincolnshire Verge Harvesting (LVH) Ltd self- designed 'wrap around cut and collect harvester.

Issues

- The subsidy changes shown in Figures 3 & 4 have coincided with an increased emphasis is on use of wastes as feedstock in AD. This has meant that the more recently commissioned, and best sited AD plants near to the Wolds NCA have been designed to utilise commercial food waste that is inherently low in the lignocellulosic fractions found in the tissues of LIHD Biomass. As a consequence their engineering would require adaptation to accept this waste stream.
- Unlike the LIHD Biomass from the farms and smallholdings of the Lower Derwent Valley LIHD Biomass arising from verge harvesting is classified as a waste as the landscape from which they are harvested does not have an Agricultural Holding Number. They cannot therefore be utilised under the SR 2012-10 environmental permit which is the commonest for farm based AD plants.
- Although some parts of verges, especially the wider examples found on the historic drove roads are legally part of adjacent farms it is likely that applying each individual RPA holding

[16] https://www.gov.uk/how-to-classify-different-types-of-waste

number would cause an unwieldy ledger of verge ownership that would cripple the organising of any cut and collect contracts without specific legal instruments being designed.

6. Outline of current and future options for the utilisation of LIHD Biomass

The chosen feasibility study areas present different opportunities and issues but both are capable of producing significant amounts of LIHD Biomass for use in energy conversion technologies including AD.

6.1. Policy drivers

There are two policy factors that could act as push and pull supports to the use of LIHD Biomass from a variety of sources.

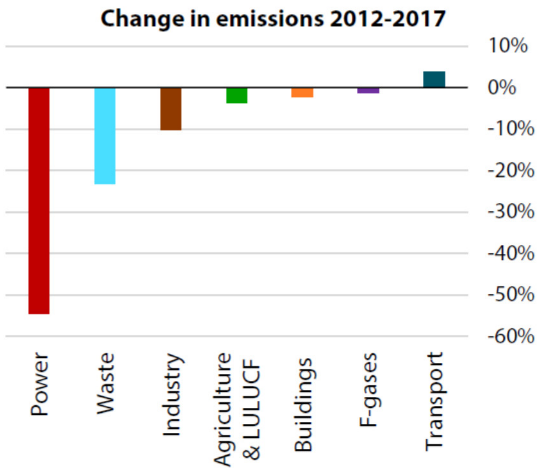
6.1.1. Stagnating recycling statistics

The government is currently on course to miss the recycling target for 2020. One part of the response is to support only new AD plants and other technologies that consume a minimum of 50% waste in their feedstock.

6.1.2. Carbon emissions from transport are still rising

The Committee on Climate Change's 2018 Progress Report to Parliament on Reducing UK emissions concluded that whilst reductions from sectors such as energy were on or exceeding targets the emissions caused by transport are continuing to rise. A relevant element of the response is to stimulate the use of biofuels for transport.

Figure 5: Changes in sectoral emissions between 2012 -2017[17]



The emissions from buildings, largely for heating are also significantly behind target but government policy on future support through a successor to the Renewable Heat Incentive has not yet been clarified and the current cut backs on support tariffs mitigate against further expansion of AD for this purpose.

[17] BEIS (2018) 2017 UK Greenhouse gas emissions – Committee on Climate Change 2018 Progress Report to Government, executive summary

6.2. Micro and community AD

The recent changes to levels and types of support have made it difficult for small scale community level projects to economically use LIHD Biomass. In theory it should be possible for community based projects to develop through cooperatives or community interest companies (CIC) type projects. There are small numbers of successful examples in the solar PV, hydro- electric and wind energy sectors. These three sectors share the advantage mass production of key components mean that scale and cost are quite closely linked so small installations can function economically. Also their operations do not generate by products that can require significant environmental risk management. Nonetheless reductions, or removal of subsidies have reduced the establishment of new examples.

Reducing the size of AD engineering, which tends to be more bespoke, to small / microscale does not tend to produce pro rata reductions in capital costs rather the capital cost per unit of energy output tends to edge upwards. The parasitic energy needed to maintain operating temperatures within the reaction tanks during the winter months can also significantly impact on the parasitic energy load in micro plants. In addition plants that process more than 100 tpa of biomass require full environmental permits to operate. There are however a number of micro AD units in existence, but these are mainly in the food processing sector where the business plan is to provide an effluent treatment process that reduces discharge fees whilst supplying heat and electricity directly to the parent operation through local energy agreements.

One possible option would be to consider some form of community engagement project to establish a CIC that contracted with its local authority waste strategy to accept (or even collect) some of its green waste stream topped up by the conservation biomass. There would be a gate fee income within the green waste element as well as from the use of the biogas. A CIC led by a charity may well be able to obtain capital grant assistance that is denied to standard commercial models. The other element of the model would be to maximise energy sales through local energy agreements especially for road fuel. A possible technology for this, called Dry Anaerobic Digestion is described in Section 6.4.1.

6.3. Adapting existing AD plants to accept LIHD Biomass

The main issue with LIHD biomass is the relatively larger proportion of lignocellulose found within its tissues than in specific energy crops and food wastes. This complex of cellulose, hemicellulose and lignin can prove difficult to physically move around in an AD plant and shows resistance to mesophilic bacterial digestion. Its proportion increases during flower formation and seed setting in the species common to both the study areas reducing its perceived value.

However recent developments provide two routes for improving digestibility are described below, including indicative capital costs for adapting the case study AD plant in Section 5.2. It should be emphasised that all costs and very significantly influenced by the design and operating circumstances of the existing AD plant.

- Firstly the inclusion of a comminution stage to reduce the particle size. This increases the surface area for enzymatic activity by the AD bacteria and makes the material pump and to stir within the AD tanks.
    - Costs £50 – 350k depending on the system chosen and the degree of comminution challenge
- Secondly strategies to enhance the enzymatic hydrolysis of the cellulose and hemicellulose components.

- This can be achieved by adding additional enzymes to the initial hydrolysis stage which brings an ongoing operational cost or:
- By incorporating / upgrading the initial hydrolysis tank to run as a thermophilic tank operating at 53C instead of 37-43C. The higher temperature conditions the bacterial population to select out different hydrolytic species
- Cost circa £450k

6.4. New and future options

Local authorities are required to manage large scale waste collections and then to be innovators in recycling the resulting waste streams (See 6.1). EYRC currently manages circa 44,000 t pa of mixed food waste and garden waste and 8000 t pa of Green waste from its Recycling sites.

6.4.1. Dry anaerobic digestion

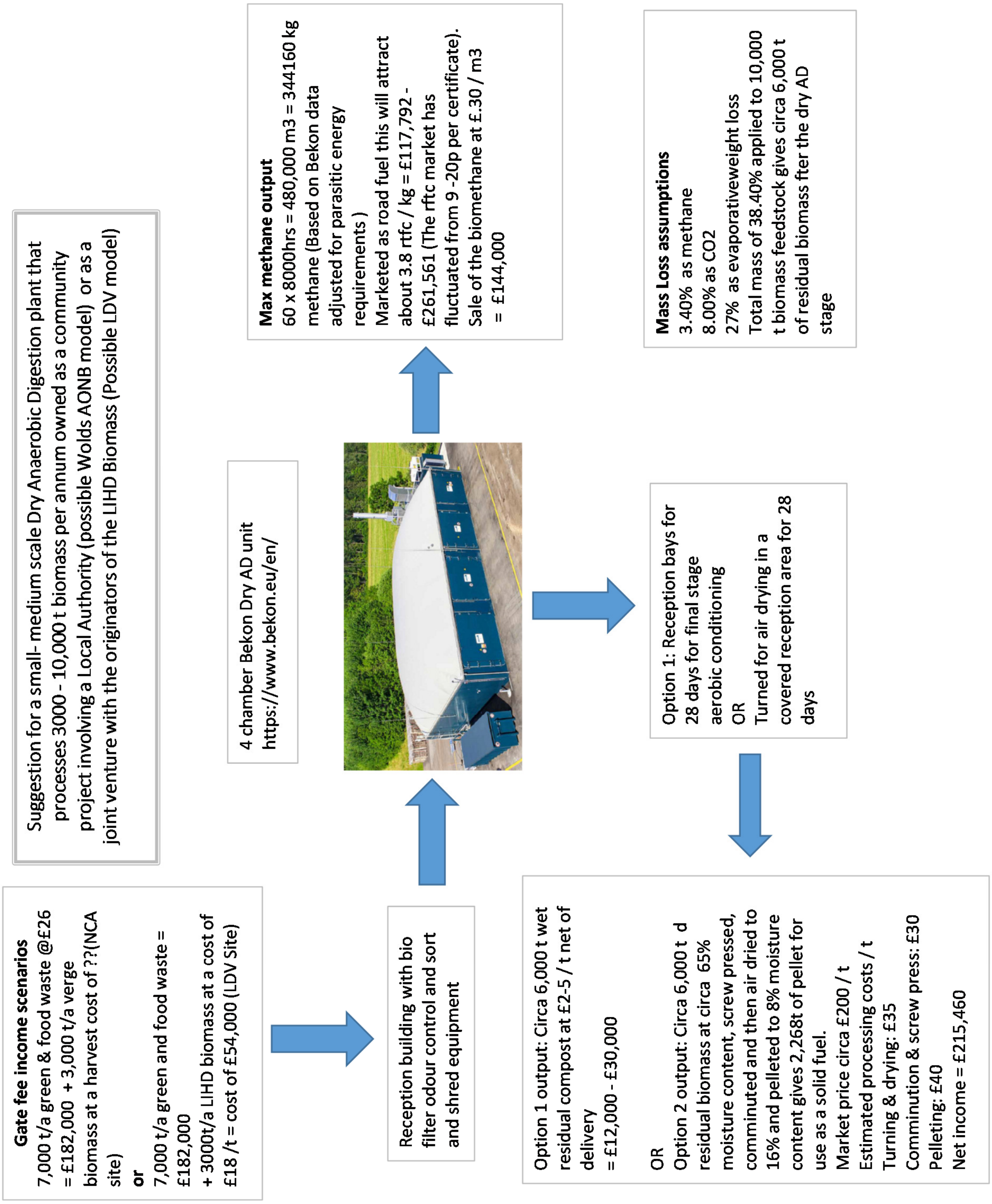
One anaerobic digestion option is **Dry Anaerobic Digestion** which is now being used by the waste management companies contracted to several local authorities.

Dry AD plants commonly consist of multiple concrete garage style fermenters that can be sealed gas-tight. Biomass is loaded into these chambers by a front-end loader and remains in the chamber for an average of 28 days. Heat is delivered to the fermenters through in-wall radiant heat and through the percolate, which is sprayed onto the biomass through over-head sprinklers. Percolate also acts as an inoculum source since it contains the appropriate anaerobic digestion bacteria. Biomass remains stationary but the percolate and water produced during the digestion process are continuously captured through floor drains and re-circulated. The biogas that is produced by the anaerobic digestion process is collected into a flexible gas storage bag from where it is continuously fed to the biogas utilization source. Biogas is either used in a combined heat power (CHP) unit or it can be upgraded to pipeline quality natural gas or vehicle fuel.

Picture 9: Mini scale dry AD facility by Bekon GmbH www.bekon.eu

The plant that is illustrated can handled between 3000 and 10,000 tpa of green waste. It is sized to produce 100 – 300 kWe and 100 – 300kW thermal from the CHP or between 60 -80 N m^3 / hr of biomethane. The residual biomass could be used either as agricultural soil conditioner or further processed into a pelleted fuel.

Figure 6: Cyclic One: Schematic of a Dry AD process that could combine of food and green wastes with LIHD Biomass and produce a biogas for CHP or biomethane and solid biomass residue



6.4.2. Dry AD as an option for community engagement

The concept in the third paragraph of 6.2 "Micro and Community AD" would see a plant such as this accepting the green waste of its local community who have successfully bid to accept a proportion of the local authority gate fee for disposal.

The cleaned bio methane would have a wholesale value of around 30p / m^3 adding a further £144,000 in revenue. This would increase if the gas was sold directly as a road fuel or consumed within the within LIHD biomass harvesting or green waste collection processes. The scenarios above indicate that, depending on the product output chosen a potential to generate income in the range of £402,000 to £803,000. As a guideline, an income generation performance at the upper end of the range could generate an operating margin and service a 10 year Equal Instalment Repayment of up to £5,000,000.

The provision of LIHD biomass as an ensiled product would be a useful and high quality product within the food and green wastes stream of a dry AD plant.

6.4.3. A lignocellulosic biorefinery (LB) plant

EYRC already has a food and garden waste collection into which verge biomass or LIHD biomass from the Lower Derwent Valley could be included. This could provide the scale and continuity of supply that would attract the necessary level of investment to develop a biorefinery approach to cyclic conversion of bio waste into useful products.

At present many local authorities will send this category of waste for aerobic composting. The waste management businesses carrying out this activity are largely dependent on the charging of gate fees and produce a low value land conditioner. Utilising Dry AD could go some way to improving the viability of the composting route by converting the most readily accessible 'volatile solids' into biogas. However this still produces considerable quantities of a composted end product that has minimal value. Recent developments in pre-processing lignocellulosic bio waste have begun to change this through improving the value and range of end products.

Some key technology is now available to utilise this style of waste stream including maceration/pasteurisation linked with thermophilic AD and the use of thermochemical and enzyme hydrolysis to release sugars for fermentation.

Local authorities have already moved rapidly to utilise Waste to Energy furnace technology and this will continue to be a better alternative than landfill for plastics and other non- digestible but combustible waste. However there is now the potential to separate out the bio waste element of their waste stream and add it to the urban green waste and LIHD Biomass. This releases capacity and can increase efficiency in the existing EFW plants.

The products of the Lignocellulosic Bio-refinery can include Bio-methane as described above, grid injection, district heating or road fuel, Bio-ethanol for EN5 and soon EN10 petroleum blends. The residual solid from the biorefinery is a lignin dominated fibre that can be processed by a CHP or to gasification to produce syngas and oils for a range of platform chemicals for the pharmacy and industrial chemical sectors.

The bio-refinery plant's commercial possibilities are in proof of concept at the pilot plant stage in an industrial partnership involving the University of York.

6.4.4. Cyclic usage of bioenergy within local energy use partnerships

ERYC is a major energy consumer and could become its own market consumer via an arms-length JV with the biorefinery or the dry AD technology.

- Condensed bio methane for its own fleet vehicles + sales to third parties (especially commercial transport) – Compared to diesel: CO_2 reductions - 84%. NOx - up to 75%.[18] Vehicle noise reductions up to 50% and reduces costs as fuel duty for Bio-methane fixed until 2032 at 18.6p /l equivalent. Diesel is currently 57.95p
- Biomethane to Grid injection for its own heating needs - circa 25% compared to natural gas
- Local fuel supply market for third parties – public sector housing – as above if natural displacement and larger if replacing LPG or heating oil

Central government recognises the potential of local energy partnership, especially in relation to integratingthe provisoin and use of lower carbon consuming heat, power and transport. Accordingly it recently initiated the following call.

"UK Research and Innovation (UKRI) will be launching the £**28m Detailed Designs of Smart, Local Energy Systems competition this summer as part of the Industrial Strategy Challenge Fund, Prospering from the Energy Revolution Programme.** UKRI, in collaboration with the Department of Business, Energy and Industrial Strategy (BEIS) and the Knowledge Transfer Network (KTN), would like to invite you to join a webinar on the 1st February to hear about the new funding programme and how you can get involved.

What is the opportunity? The "Prospering from the Energy Revolution" Challenge **Fund will support industry, academia, public bodies, and local communities** to develop a world-leading, smart local energy systems industry in the UK. We expect this industry to be worth billions of pounds by the early 2020s, supporting tens of thousands of new high-value jobs associated with design, testing, manufacture, financing, installation, and operation of new energy products and services across the wider low carbon energy economy.

This competition will fund the development of detailed designs for smart, local energy systems which integrate heat, power and transport in an intelligent way. Projects will be eligible to apply for up to £2m grant, with matched funding."

[18] EU data generated by EUCAR/Concawe/JRC in their report: "Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context – WTT APPENDIX 2 – Description and detailed energy and GHG balance of individual pathways – version 3c, July 2011"

Dr. Nick Cheffins, Peakhill Associates Ltd

M: 07812 096682

E: www.peakhill-associates.co.uk

Black Jumper Biofuels

"We did not weave the web of life, we are merely strands within it. Whatever we do to the web we do to ourselves." Chief Seattle 1854

“It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change.” Charles Darwin 1860

"There is a clear message from science: To avoid dangerous interference with the climate system, we need to move away from business as usual." Ottmar Edenhofer, Co Chair Working Group III; IPCC Climate Change 2014