Verge Biomass

A Feasibility Study into the utilization of Anaerobic Digestion to sustain the harvesting of Low Input High Diversity road verge biomass

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Executive Summary

In Lincolnshire there are approximately 8,750 km (5,500 miles) of highway of which 6,173 km are termed 'rural' and largely bounded by grass verges. The majority of road verges are within the public highway and Lincolnshire County Council as the Local Highways Authority is required to keep them in a safe and unobstructed condition. The annual cost for the discharge of this responsibility utilises a significant proportion of the £800,000 Roadside (Environmental) Maintenance budget (http://www.lincolnshire.gov.uk/upload/public/attachments/524/10.pdf No 10 Assets protection

Current practice is to flail mow a 1.1m strip of the verge, and wider swaths around visibility zones at road junctions, three times over the summer and leave the mown vegetation in situ. With the majority of the verge width left uncut and the visibility strip being regularly mulched, the result has been a gradual increase in nutrients, encouragement of growth of vigorous tall grass and weeds and suppression of the overall biodiversity potential of the road verges.

In recognition of the issues posed by current practice Lincolnshire County Council's Highways Authority works in partnership with the Lincolnshire Wildlife Trust to manage a selection of the most bio-diverse verges as Roadside Nature Reserves. On these special verges, a late cut of vegetation across the entire verge and the removal of the cut material maintains low nutrient levels. This management ensures survival of the rich assemblage of wild flowers and invertebrates, some species of which are nationally rare.

The challenge for this study has been to propose possibilities for cost effective approaches to extending this modification in the management of road verges with the realisation of additional economic, environmental and social benefits.

Using data from research trials in the UK and across Europe a model has been developed that suggests several significant opportunities could arise from a new and innovative road verge management strategy including:

[1] To be able to develop a new feedstock for renewable energy generation that does not take agricultural land out of production and does not require fertilisers or other inputs with a high carbon footprint.

[2] To be able to replicate the experience of pilot projects where the harvesting of Low Input High Diversity (LIHD) verge biomass has positively benefited biodiversity, thus contributing to Biodiversity 2020 objectives, the County Council's responsibilities under the NERC Act 2006, the proportion of Local Wildlife Sites in positive conservation management and providing benefits for pollinating insects in accordance with The National Pollinator Strategy 2014.

[3] Specifically in the context of Lincolnshire, to be able to use this technique to cost effectively extend the range and connectivity of roadside verges of wildlife value and achieve the strategic objective of providing a network of biodiverse corridors supporting sustainable populations of wild flowers, wild pollinators and other wildlife across the county and reducing the potential vulnerability of isolated pockets of biodiversity to local extinction events. This is in line with the LCC Natural Environment Strategy.

[4] To be able to provide an additional source of income and employment from the rural landscape by the production and use of a new renewable energy feed stock.

[5] To reduce the net carbon emissions resulting from the management of the soft landscape around Lincolnshire road network

The crucial next stages of this investigation include

[1] To evaluate current cut and lift systems to critically compare their performance with the key performance indicators that inform current road verge mowing contracts.

[2] To carry out a field study to assess the range of fresh weight yields, methane gas potential and contaminant levels of road verge biomass over a harvest season.

[3] Establish without prejudice discussions with existing AD operators on the relevance of LIHD biomass to their business models

[4] Carry out an assessment of verge mowing machinery and logistics development in relation to modified mowing strategy

[5] Seek to resolve any relevant regulatory issues

Contents

Introduction

The management of rural road verges are a significant issue for all Local highway Authorities. In Lincolnshire there are approximately 8,750 km (5,500 miles) of highway. As shown in Table 1 below the majority of the network is rural and usually bounded by grass dominated verges. The majority of these verges are within the public highway and the County Council as the Highways Authority is required to keep them in a safe and unobstructed condition. There is a significant annual cost to the discharge of this responsibility.

Table 1:

Road classification	Rural km	Urban km	Total km
A Class	903	171	1,074
B Class	629	158	787
C Class	2,447	470	2,917
Unclassified	2,194	1,786	3,980
Grand total	6,173	2,585	8,758
Total length of verge	12,346	5,170	17,516

The Lincolnshire Local Highways Authority (LLHA) lets contracts to mow a total of 13,135 km of the total length of road verge. The minimum management requirement is for a 1.1m wide strip of road verge to be mowed by tractor mounted flails three times a year with wider swaths mown at highway junctions. In operational terms that presents a total mown area of approximately 1,445ha to be covered three times per year. Custom and practice is for all the grass residues to be left in situ. In addition a further 118ha of amenity grassland (usually within the urban areas) is cut seven times by pedestrian mowers or strimmers and again all the grass residues remain on site.

The challenge for this study is to propose opportunities for cost effective approaches to modifying the management of the road and amenity verges with the realisation of additional economic, public and environmental benefits.

Literature review

There is an increasing body of evidence that the practice of mowing and allowing the residues to compost in situ results in a suppression of biodiversity through a build-up of nutrients and the suffocation of less robust plants.

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[1] [2]. Removal of the grass cuttings from road verges creates a biomass stream that could offer opportunities to generate bio-fuel revenue.

Lincolnshire County Council has a history of proactively investigating differing approaches to the management of road verges. In 1960, the then Lindsey District Council and the Lincolnshire Wildlife Trust (LWT), set up the first “Protected Roadside Verge” (PRV). Now known as Roadside Nature Reserves (RNRs), these now number 65 covering approximately 80km of rural road . Some are SSSIs but most are designated as Local Wildlife Sites (LWS) currently managed by LWT with funding from

[1] 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

LLHA. A further 233 km of road have so far been identified as being of high conservation value. Most have been identified through the Life on the Verge project[3].

Biodiversity is under continuous pressure and overall there is evidence of steadily increasing nutrient levels in ecosystems across the UK leading to successful competition by an increasingly narrow range of vigorous tall growing herbaceous plant species[4]. Lincolnshire itself is not immune from this effect. The most recent County Biodiversity Action Plan notes that although some aspects of biodiversity were improving the "… overall decline in habitats and species and degradation of landscapes has not yet been arrested"[5]. The point was also emphasised that isolated wildlife sites are the most prone to local catastrophic species loss and that strategies that could provide corridors and pathways for the movement of species would provide the best return for effort invested. The network of road verges, if correctly managed, could contribute significantly in this regard.

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[6] [7]. Similarly preventing nutrient build up is vital for maintaining biodiversity. This is the principle behind the management regime employed on RNRs (including both SSSIs and the most diverse roadside LWSs) where botanical diversity is maintained by removal of arisings from the full width of verges at the right time and frequency. This 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[8] 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 signification 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 selected for this project 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 Lincolnshire than the Welsh upland sites considered by COMBINE.

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.

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[3] www.lifeontheverge.org.uk

[4] Hains-Young R.H. et al. Countryside Survey (2000) Accounting for Nature: Assessing Habitats in the UK Countryside. Department of the Environment, Transport and the Regions (2000)

[5] Lincolnshire Biodiversity Action Plan 2011 – 2020 (3rd Edition) pp 10

[6] 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

[7] 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

[8] http://www.combine-nwe.eu/index.php?id=40

Figure 1: Accumulated changes in species composition over three harvest years across trial sites in Germany (DE), The UK and Estonia (EE)[8].

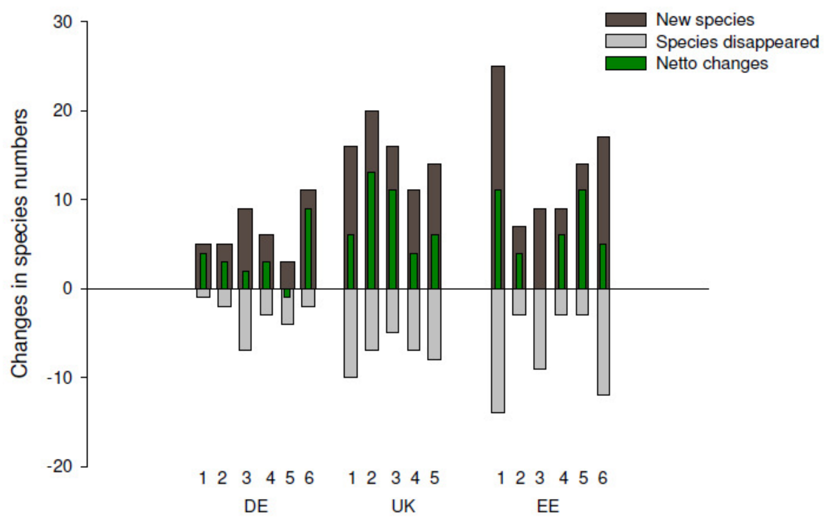
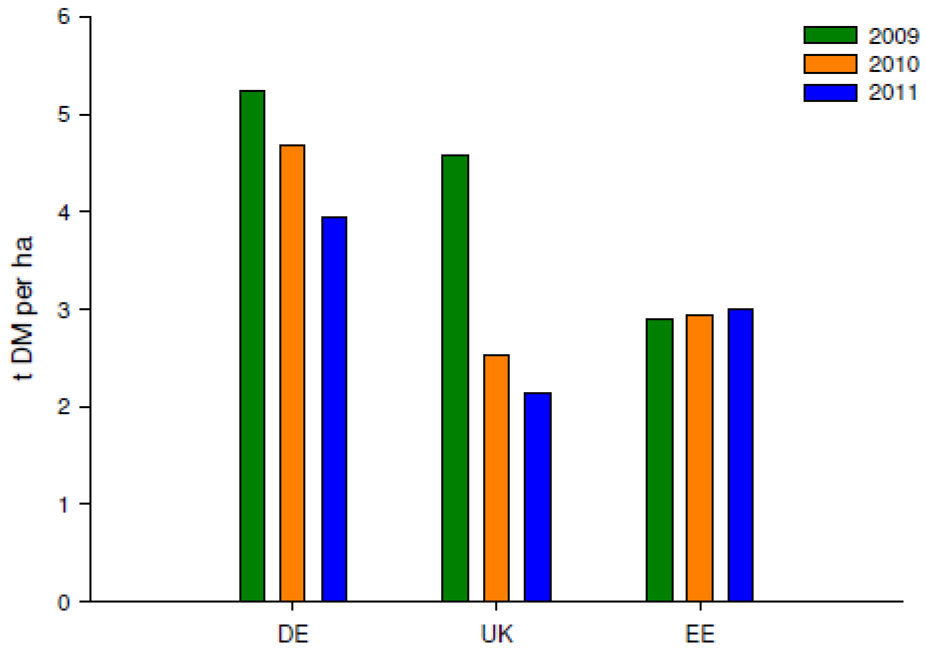


Figure 2: Change in dry matter (DM) yields (tonnes DM per ha) of three years (DE= Germany Baden Baden trial sites, UK = Powys trial sites, EE = Estonian semi natural grassland sites)[8]



Energy potential of Biomass

Road verge clippings are also sometimes described as Low Input High Diversity (LIHD) biomass to emphasise their origins as being from land that is not under agricultural monoculture and without any deliberate addition of fertiliser or agrochemicals.

The energy potential of LIHD biomass can be realised in a number of ways:

1. The production of methane by anaerobic digestion (AD) (See below)
2. The production of liquid biofuels – ethanol[7]
3. The production of fibre that may be:
   3.1. Burned directly in a RHI compliant biomass burner[8]
   3.2. Stored as solid biofuel for combustion on site as required (e.g. summer stockpiled for winter heating campaign) in a RHI compliant biomass burner
   3.3. Sold on to third parties as energy-dense briquettes for use in domestic wood fuel and multi-fuel stoves (see below) (May also be domestic RHI compliant)
   3.4. Utilised in the production of biochar and syngas[9] [10]

Anaerobic digestion

Anaerobic digestion (AD) involves the breaking down of biodegradable material in the absence of oxygen by micro-organisms. There are three clear steps to the process. Digestion begins with bacterial hydrolysis of the biomass feedstock. Compounds, such as carbohydrates and fats, are broken down into simpler, soluble chemicals (sugars, amino acids etc.) that become available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. These bacteria convert the resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The resulting 'biogas' contains up to 60% methane together with carbon dioxide and some water vapour. There can be other impurities at lower concentrations depending on the feedstock.

Most AD plants work on wet feedstock. After being pre-treated by shredding or maceration to reduce particle sizes within the dry matter of the feedstock, the input material is mixed with liquid (often recirculated AD liquor and water) to give a slurry of about 10 – 15% dry matter and then fed into the AD plant's digester tanks in small regular amounts.

The rate of digestion and quantities of biogas produced per unit of feedstock can vary considerably depending on the composition of the feedstock and how it is prepared before entering the AD plant as a pumped fluid. This rate of digestion, sometimes called the 'hydraulic retention' or 'dwell' time of the digestate has a major effect on the design of the AD plant. The slower the rate of gas release the larger the volume of the reactor vessels have to be for a given amount of energy release. An alternative is to utilise the material in a sludge-like form where the dry matter content is around 10 - 20%. This is sometimes termed a plug flow digester. Whereas the wet form often employs a two tank system the plug flow will use a larger single tank. Although the relative size and construction of the tank in this method can contribute to its higher capital costs there is a claimed benefit from simpler and cheaper operation. Figure 3 below illustrates a typical small scale wet digester.

[9] http://www.carbongold.com/kilns-biochar-production/kiln-tech-information/

[10] http://blushfulearth.co.uk/wp-content/uploads/2014/09/Performance-of-10-kW-Power-Pallet-Gasifier-and-its-Potential-for-Small-scale-Off-grid-Electricity-from-Biomass.pdf

Figure 3: A wet digestion system of approximately 200kWe output

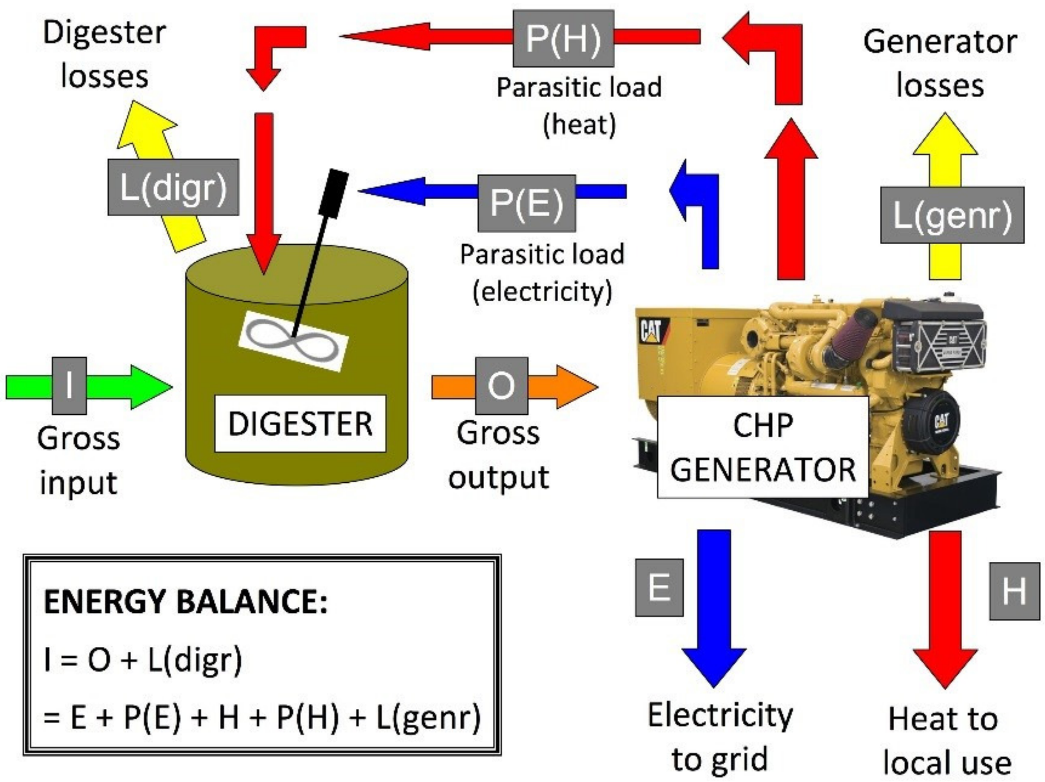
Digester tanks are maintained at a constant temperature to optimise efficiency. Most systems are operated at around 30 – 40^{0}C (mesophyllic). Some can be operated at higher temperatures (thermophyllic up to 60^{0}C). Themophyllic systems tend to be technically complicated and are more suited to short hydraulic retention, high output feed stocks such as abattoir and food wastes.

All anaerobic digesters require energy to operate and this is termed the parasitic load of the AD plant and will vary according to design and feedstock. It is commonly equivalent to about 15% of the total energy produced. Efficiency losses will account for a further 5% (See Yield calculations and Financial Assumptions below.)

The energy ratings of AD plants are most usually described in terms of kWh of electricity from the combustion of the biogas. This is the more common business model. The Biogas can also be cleaned and refined to 100% methane for use in vehicle fuel or grid injection. However when electricity is produced on site there is also a proportionately larger output of heat that is commonly underused.

The slurry that exits the digester after the bio-methane has been extracted is termed 'Digestate'. The AD digestate can be separated into a liquor and fibre faction through a number of processes such as a screw press (See below). The digestate contains a useful range of plant nutrients in a form that can act as organic fertilizer although the costs of transportation and application can mitigate against any significant financial contribution to the business model.

Figure 4: An illustration of the energy pathways within an AD plant.



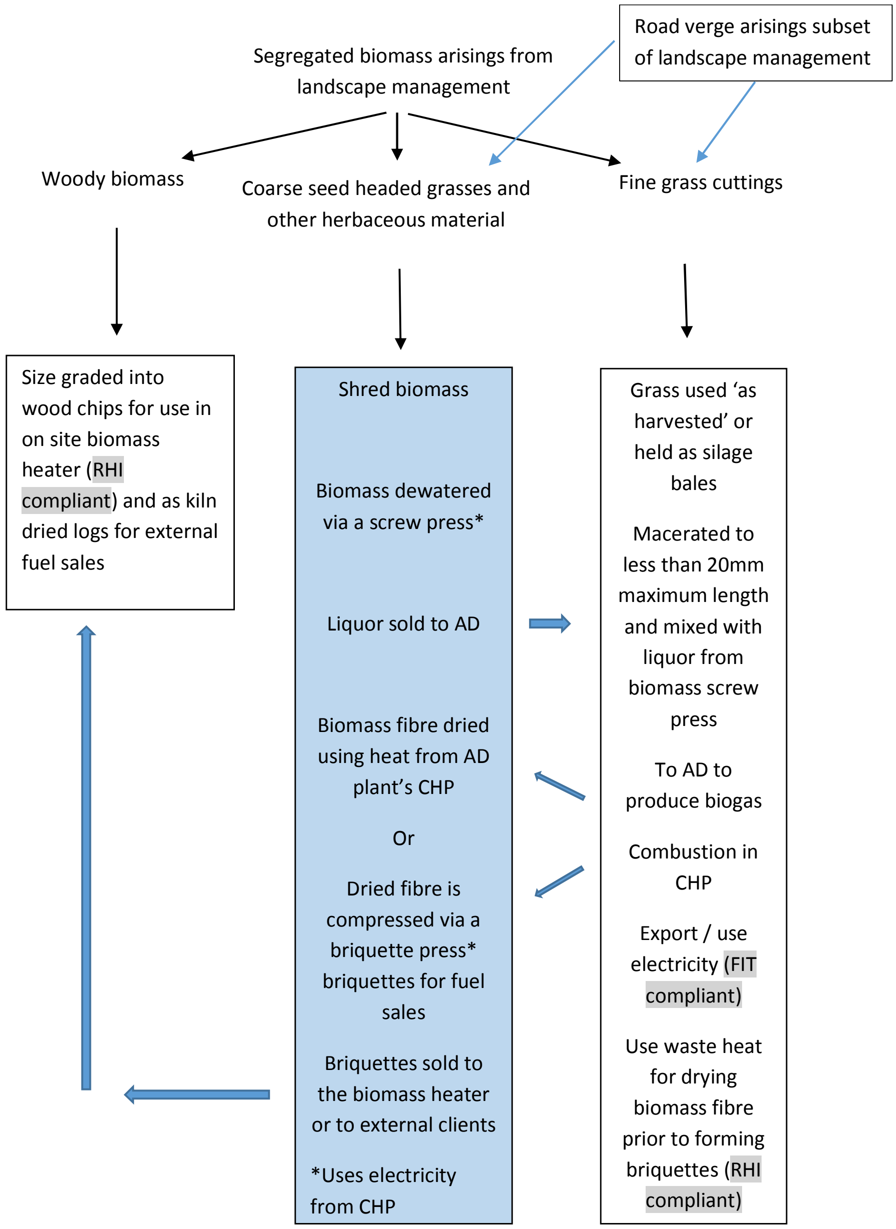
Fibre production

Verge biomass will yield a source of fibre at the end of the AD process that can be used as listed above.

The harvesting process and the timing of that harvest will affect the yield of fibre from verge harvests. RNR harvesting is usually carried out after flowering to allow for seed dispersal. As a result the feed stocks that will arise from RNR verge harvests will tend to have higher ligno-cellulosic contents. This is a common feature of the desired management of conservation landscapes[8]. The common practice has been to use the harvest to provide coarse hay for livestock. However the nutrient value is lower than from ensiled grass harvested earlier in the season and its use for animal feed has declined.

High ligno-cellulosic feed stocks are also not ideal for anaerobic digestion as they will often give lower bio gas yields due to digestibility issues. However they do yield a fibre that can be utilised for a range of uses as listed above. A proposal for integrating this fibre with the feed stock inputs for AD and utilisation of the energy outputs is shown in Figure 5 below.

Figure 5: Integrated biomass feedstock management producing a range of renewable energy products



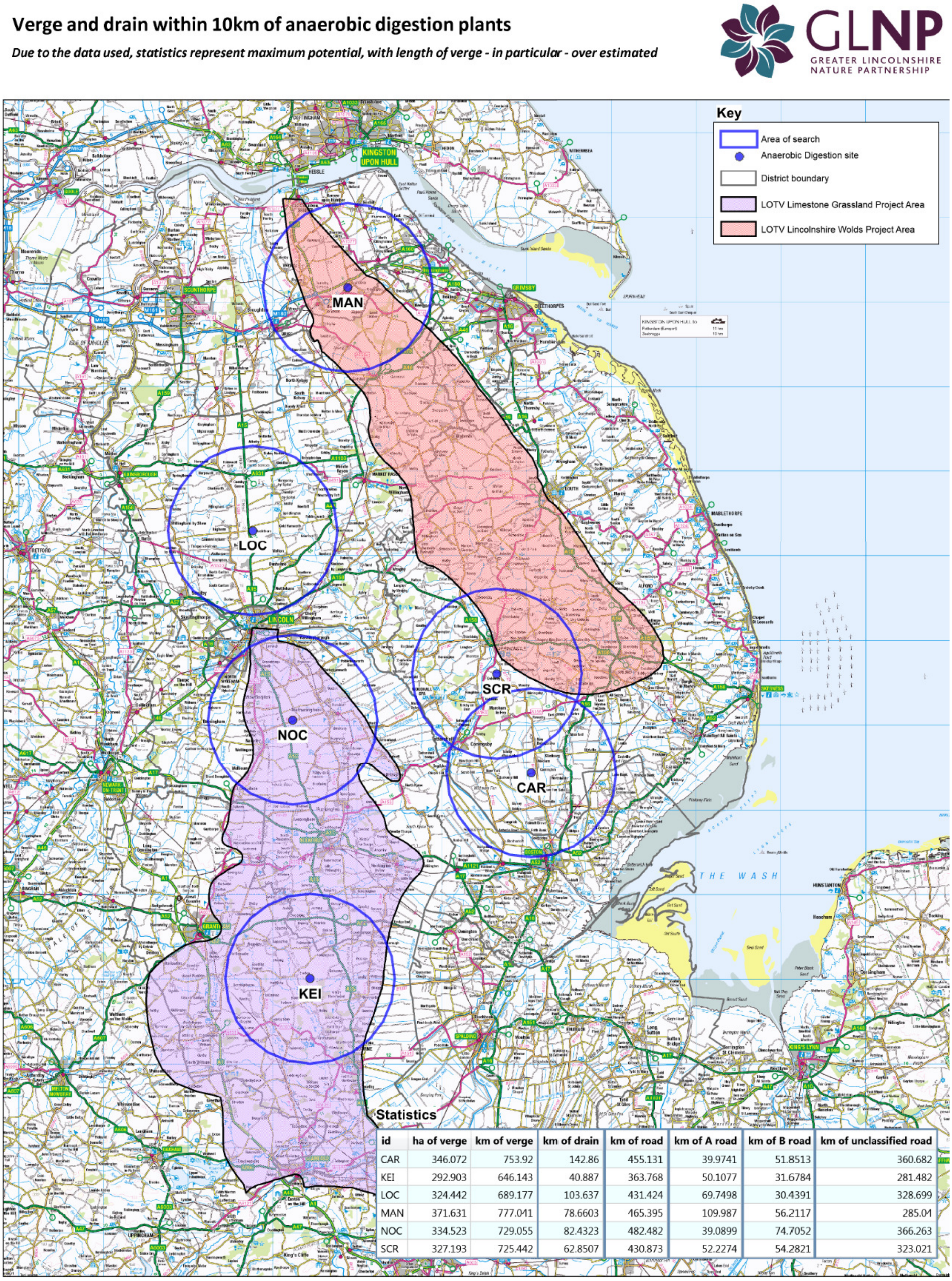
The Financial Models section includes the assumption that significant value can be realised from the digestate fibre by using it as part of the feed stock for briquette production and that the AD plant's energy output will support the electrical and heat energy requirements of this process.

Scoping distribution and supply of biomass

The spatial distribution of road verge biomass presents specific challenges in attempting to quantify the location and amounts of material that may be available. Variations in road density and classification, irregularities in the width and profile of a verge, soil type, soil depth and fertility, its orientation/shading by buildings or trees and the ingress of scrub and saplings will all impact on assumptions about yield. These are further complicated by the plant communities that are present, and previous management practices.

Mapping

Figure 6: Road verge distribution within Lincolnshire with six potential AD reception sites surrounded by 20km diameter hinterlands. The figure includes dike embankments into the hinterland for each AD plant.



id	ha of verge	km of verge	km of drain	km of road	km of A road	km of B road	km of unclassified road
CAR	346.072	753.92	142.86	455.131	39.9741	51.8513	360.682
KEI	292.903	646.143	40.887	363.768	50.1077	31.6784	281.482
LOC	324.442	689.177	103.637	431.424	69.7498	30.4391	328.699
MAN	371.631	777.041	78.6603	465.395	109.987	56.2117	285.04
NOC	334.523	729.055	82.4323	482.482	39.0899	74.7052	366.263
SCR	327.193	725.442	62.8507	430.873	52.2274	54.2821	323.021

Following reference to the model developed by Salter et al[12] which calculated theoretical energy requirements for the collection and transport of verge-harvested biomass, the Greater Lincolnshire Nature Partnership kindly provided a series of maps derived from data sets contained within MapInfo GIS software. Salter et al [12] defined the optimum transport distance to between 10km and 22.5 km from an AD site. Thus circles with a diameter of 20k or 45km were chosen to surround six sites centred on anaerobic digesters selected on the basis that their planning applications indicated they could utilise a significant proportion of ensiled grass within their feed stock (See Figures 6 and 7). It was therefore considered possible that they might be able to utilise ensiled verge biomass as part of their feedstock mix.

The mapping software allows estimates of road length and notional verge widths to be assembled within each of the 20 or 45km diameter circles. However there is a danger that, at this level of resolution, rounding errors can lead to an overestimate potentially harvestable area. For the purposes of the financial modelling below the area of potentially harvestable verge has therefore been reduced by 20% as indicated in tables 3a and 3b below.

Yield assumptions

There have been few verge harvesting trials in the UK but a detailed study by Montgomeryshire Wildlife Trust (MWT)[11] reported in 2006 and a follow up study by Southampton University[12] in 2007 have provided the principal data that are used in the calculations below.

Yields of dry matter will vary considerably depending on the environmental factors influencing specific sites. These are numerous but would include plant communities present, previous management (e.g. when last cut took place), soil type and fertility, climate etc.

The range of values for the MWT trial is shown below. They represent two harvests from 1.2 m wide swaths reflecting the LHA contract requirements at the time of the trial. The harvests were carried out over a range of sites chosen to reflect the verge habitats common to Powys highways. Material was harvested between June and the end of August.

Table 2: Yields of vegetation cut from Powys verges[12]

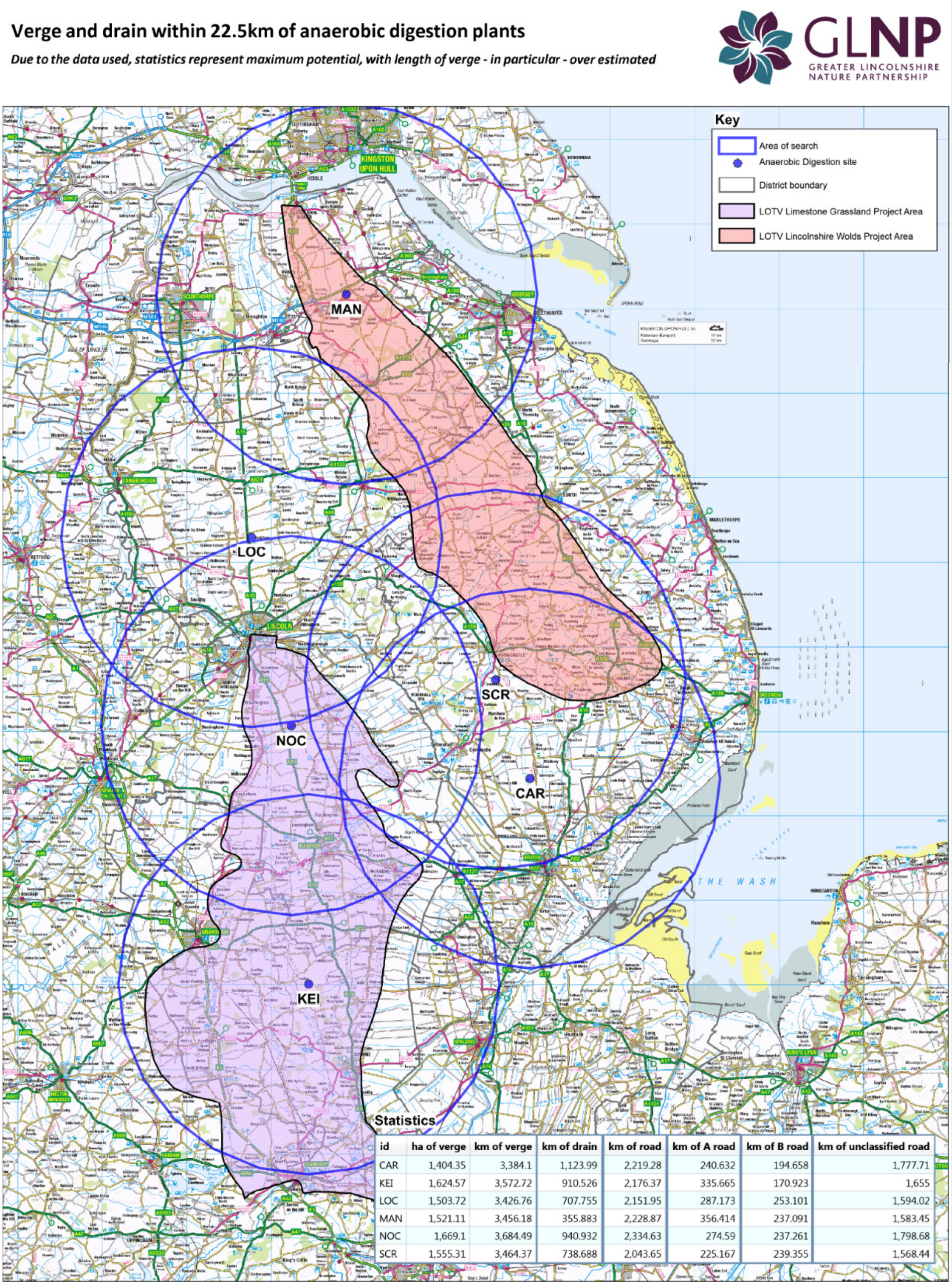
Dry weight harvested: kg/km	Minimum	Maximum	Mean +/- SD
First cut	89	267	177 +/- 58.8
Second cut	89	297	201 +/- 76
Total harvest	178	564	378

The average dry matter content (total solids) was 29%[12] giving a total harvest fresh weight of 1,303kg/km. The collection process employed in the trial achieved a bulk density of 400kg fwt / m^3, or 3.25 m^3 of harvested fresh material / km travelled.

[11] 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

[12] 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

Figure 7: Road verge distribution within Lincolnshire with six potential AD reception sites surrounded by 45km diameter hinterlands. The figure includes dike embankments into the hinterland for each AD plant.



id	ha of verge	km of verge	km of drain	km of road	km of A road	km of B road	km of unclassified road
CAR	1,404.35	3,384.1	1,123.99	2,219.28	240.632	194.658	1,777.71
KEI	1,624.57	3,572.72	910.526	2,176.37	335.665	170.923	1,655
LOC	1,503.72	3,426.76	707.755	2,151.95	287.173	253.101	1,594.02
MAN	1,521.11	3,456.18	355.883	2,228.87	356.414	237.091	1,583.45
NOC	1,669.1	3,684.49	940.932	2,334.63	274.59	237.261	1,798.68
SCR	1,555.31	3,464.37	738.688	2,043.65	225.167	239.355	1,568.44

The growth stages of the verge material varied over the harvests. Figure 8 shows a June harvest site in Powys where foliage of up to 40cm in height was harvested compared to an RNR in Lincolnshire where the foliage is clearly shorter and sparser. Thus whilst there is a significant range of foliage species and growth stages that will be encountered it seems reasonable to accept the above assumptions on indicative yields and these have been factored into the Yield Calculations below.

Figure 8: Comparison of cut and uncut road verge from Lincolnshire and Wales indicating the potential range of variations in foliage height and density that may encountered

Powys verge detail

Lincolnshire Ponton RNR with 1.1m flail cut completed

Yield Calculations

Table 3a: Yield calculations using data from the MWT Living Highways project[11] linked to the 20 km diameter circle mapping data for Lincolnshire shown in Figure 6 above. The length is adjusted down to 80%

AD site codes	km of verge	km adjusted to 80%	Assumed annual harvest yield* in tonnes Fwt from standard LLHA harvest swath x three cuts
CAR	754	603.2	786.0
KEI	646	516.8	673.4
LOC	689	551.2	718.2
MAN	777	621.6	809.9
NOC	729	583.2	759.9
SCR	725	580	755.7
Average yield			**750.5**

Based on:

* The average dry matter content from the MWT trial was 378kg / km travelled. The harvest material had a total solids of 29% giving a total harvest fresh weight of 1.303t/km (i.e. 378 x 100/29) of verge travelled at 1.2m swath width. In agricultural terms the yield was therefore 1.303 x (1/0.12) = 10.85 tonnes fwt/ha.

Table 3b: Yield calculations using data from the MWT Living Highways project[11] linked to the 45 km diameter circle mapping data for Lincolnshire shown in Figure 7 above. The length is adjusted down to 80%

AD site codes	km of verge	km adjusted to 80%	Assumed annual harvest yield* in tonnes Fwt from standard LLHA harvest swath x three cuts
CAR	3384	2707.2	3527.5
KEI	3572	2857.6	3723.5
LOC	3426	2740.8	3571.3
MAN	3457	2765.6	3603.6
NOC	3684	2947.2	3840.2
SCR	3464	2771.2	3610.9
Average yield			**3646.1**

The collection process employed in the MWT trial achieved a bulk density of 400kg Fwt / m^3, which is equivalent to 3.25 m^3 of harvested fresh material / km travelled. This becomes important when considering the logistics of the harvesting process and will increase if the 2.0 m swath width is chosen for harvest.

The total hectare data for either the 20 or 45 km diameter circles as shown in the map legends of Figures 6 and 7 is based around integration of varied boundaries and widths for the verges within the respective catchments. If the harvesting procedures were able to run in fixed swath widths but follow the same road edges as for the LLHA contracts they will achieve more efficient work rates.

Discussion with two contractors with experience of road verge harvesting suggest that a 2 m wide harvest width might work whilst achieving work rates within reach of current values if an efficient pick up system can be devised. This would, theoretically, yield a larger amount of biomass than is being used in the financial models below which are based around the 1.2 m swath. This agreed with results arrived at from a Google Street View survey of verge widths undertaken during a student project at the University of Lincoln which investigated the influence variability of road verge dimensions on yield projections.

Table 4: Assumed harvest tonnages adjusted to provide a proportion of the 6,000 tonne capacity of the AD plant modelled in Options 1 a and 1b below

Harvest areas	Assumed tonnes FWt from 1.2 LLHA harvest swath x three cuts	Adjusted to 2.0m width	Tonnage utilised in Options 1a and 1b respectively
20km diameter circle Fig 6	750.5	1,250	1,250
45 km diameter circle Fig 7	3,646	6,076	4,500*

- A proportion of a co-digestible feedstock to mix with grass based feedstock is required by twin tank and plug flow digesters to maintain performance as described below.

The financial model assumes that the verge grass is not allowed to wilt on the roadside as contractors have stated a preference for the cut and lift stage to be completed in one pass or two stages completed within a few hours. If the biomass is wilted after collection to lower the volume of water stored and transported to the AD plant then the costs in baling and wrapping in table 5 may be mitigated. The lost water is returned during the AD feedstock preparation stage. However any benefit from lowered logistic costs may have to be set against the possibility of respiration during wilting reducing subsequent gas yield.

Consideration of the business case

Having established that, in principle (Ref. Salter et al[12]) there is sufficient biomass within the 20 or 45km diameter the circles in Figures 6 and 7 to provide a viable source of feedstock to the AD plants at their centres the study was asked to look at what high level business cases existed

Two main options have been considered:

1. A cost benefit analysis comparing the costs of collecting/transporting plus capital and revenue costs of appropriate AD plants versus the benefits through income from energy and fuel production (See Options 1a, 1b and 1c below)
2. The implications or opportunities arising from valuing the biomass as a component of a verge management contract to supply verge biomass to third parties and the potential for restructuring future verge management arrangements to achieve this (See Option 2, Scenarios a, b and c below)

In Option 1a and 1b the 200 kWe (Electrical output) represents the small scale farm unit that may be able to manage the verge harvest from within a 20 or 45 km diameter circle. In both cases the verge biomass is co-digested with energy crop maize but other co-digestions can be equally suitable. The effect of the capital costs of a twin tank wet flow and a single tank plug flow digester have been assessed.

Option 1c evaluates a micro-scale, possibly community integrated, AD plant that might collect from a more localised area within one of the 20km diameter circles. Again a co-digestion process combining some energy crop maize has been evaluated.

Option 1a: 200 kWe farm scale AD processing 4,500 tonnes or 1,000 tonnes Fwt LIHD Verge Biomass within an overall capacity of 6,000 tonnes

The calculations in Table 6a or 6b below have assumed that 1000 - 4,500 tonnes of verge biomass can be harvested from each of the 20 – 45 km diameter circles.

It also assumes that a significant proportion of a second feedstock material of ensiled energy crop maize silage has to be included to maintain the Carbon:Nitrogen ratio of the feedstock above 20:1 to balance the performance of the digester.

A digester size based around a small scale farm based unit has been chosen. In Option 1a the verge biomass is a minor component (22.5%) of the feedstock mix and in Option 1b it is the dominant (75%) component.

Tables 5 indicates the estimates for the costs of harvesting or purchasing feedstock based on benchmark data from Nix Farm Pocket Management Book 2015[13]. The Nix data comprises figures for

[13] Nix J. (2015) Farm Management Pocketbook ISBN 978 – 0 – 9576939 – 1 – 3 www.thepocketbook.co.uk

mowing and readying grass for baling, baling and wrapping and also the market costs for buying in clamp stored maize silage. These have been incorporated in tables 6&6a, 7b, 8a and 8b.

Table 5: Annual cost of sourcing feed stock based on Nix benchmarks

Costs Option	Unit costs	Annual Subtotal
Cutting grass 420 ha = 1,250 tonnes	140ha x £62	£8,860
Baling and wrapping verge biomass	1,250 tonnes x £11.67/t	£14,587
Purchase of bought in Energy Crop Maize	4,750 tonnes x £36.00/t	£171,000
Total		**£194,447**
Cutting grass 420 ha = 4,500 tonnea	420ha x £62	£26,040
Baling and wrapping verge biomass	4,500 tonnes x £11.67/t	£52,500
Purchase of bought in Energy Crop Maize	1,500 tonnes x £36.00/t	£54,000
Total		**£132,540**

The calculations below indicate the financial sensitivities of the conversion process. They are based on the following:

A. A wet process twin tank AD plant of less than 200 kWh electrical (Circa 500 kWh total energy) output being constructed for around £950,000.
B. A single tank plug flow unit costing around £1,300,000
C. In both cases the additional cost for a briquetting line at £75,000 and a maceration pre-treatment stage at £75,000 giving construction values of £1,100,000 and £1,450,000 respectively
D. The costs of the feed stocks are included with no allowance for service payments from the LLHA budget for Roadside (Environmental) Maintenance.
E. Both options are financed over 10 years at 3.5% on an equal instalments repayment model
F. The following CAPEX and OPEX costs have been excluded
    a. Planning and other legal services
    b. Site specific civil engineering costs
    c. Grid connection fee (Grid side connection)
    d. Grid connection engineering
    e. Digestate liquor storage and disposal
    f. O & M annual costs
    g. Capital depreciation

Table 6a: Indicative operational budget for a 6,000 tonne capacity AD plant receiving 22.5% of its feedstock as verge biomass from with a 20 km diameter harvesting circle.

Perfomance data for a 12 month cycle	units			Comments
Feedstock total - tonnes	6,000			Assumes 1,250 of fresh / rehydrated verge grass silage + 4,750 tonnes of maize silage to balance the performance of digester
Biogas yield cu m /tonne fwt	172			Assumes a bio gas potential across grass at 140 and maize at 180 cu m / tonne fwt
Specific energy in kWh per cu m at 60% Methane	6			
Total theoretical annual energy output MWh	5,573			The reality is that good operation would still be at about 90% of maximum for servicing This presupposes a plant rated around 450kW electrical output
CHP Energy Split - 42% electrical : 58%				
Electrical energy yield - MWh	2,224			
Heat energy yield - MWh	3,071			
				Parasitic energy requirement of the AD plant both heat and electricity - 15% of CHP output
Net total electricity output - MWh	1,890			
Average daily electricity output - kWh		5,178		
Net total heat energy output - MWh	2,610			
Average daily heat output - kWh		7,151		
Total support payments				
Electricity Feed in Tariff at 10.13p / kWh			£191,458.53	
RHI Payments at 5.9p / kWh*			£153,991.23	
Assume 75% electricity exported at			£57,321.83	
Assume 25% consumed at			£42,460.61	
Total putative AD plant income			£445,232.21	
Total AD plant Income Net of RHI (If no use found for the heat)			£291,240.97	This is the reality for most farm based AD as there is frequently little use for the heat component.
Briquettes at £200 / tonne wholesale			£120,000	Briquette production assume 10% of feedstock results in usable fibre for screw press and drying treatment once dried to 25% provides 600 tonnes of briquettes for external sale
Assume 25% of the CHP heat is transferred to briquette fibre drying process			£38,498	Becomes an RHI eligible process
Total annual income			£449,738.78	

Table 6b: Indicative operational budget for a 6000 tonne capacity AD plant receiving 75% of its feedstock as verge biomass from within a 45 km diameter harvesting circle.

Perfomance data for a 12 month cycle	units			Comments
Feedstock total - tonnes	6,000			Assumes 4,500 of fresh / rehydrated verge grass silage + 1500 tonnes of maize silage to balance the performance of digester
Biogas yield cu m /tonne fwt	150			Assumes an average gas yield across grass at 140 and maize at 180 cu m / tonne fwt
Specific energy in kWh per cu m at 60% Methane	6			
Total theoretical annual energy output MWh	4,860			The reality is that good operation would still be at about 90% of maximum for servicing This presupposes a plant rated around 450kW electrical output
CHP Energy Split - 42% electrical : 58% heat energy and adjusted for efficiency System Losses during generation - 5%				
Electrical energy yield - MWh	1,939			
Heat energy yield - MWh	2,678			
				Parasitic energy requirement of the AD plant both heat and electricity 15% of CHP output
Net total electricity output - MWh	1,648			
Average daily electricity output - kWh		4,516		
Net total heat energy output - MWh	2,276			
Average daily heat output - kWh		6,236		
Total support payments				
Electricity Feed in Tariff at 10.13p / kWh			£166,969.65	
RHI Payments at 5.9p / kWh* *dependant on Ofgem approval of use eligibility			£134,294.68	
Assume 75% electricity exported at 4.55p / unit			£49,989.97	
Assume 25% consumed at displacement value of 10p / unit			£37,029.60	
Total putative AD plant income			£388,283.90	
Total AD plant Income Net of RHI (If no use found for the heat)			£253,989.22	This is the reality for most farm based AD as there is frequently little use for the heat component.
Briquettes at £200 / tonne wholesale			£120,000	Briquette production assume 10% of feedstock results in usable fibre for screw press and drying treatment once dried to 25% provides 600 tonnes of briquettes for external sale
Assume 25% of the CHP heat is transferred to briquette fibre drying process			£33,574	Becomes an RHI eligible process
Total annual income			£407,562.89	

Table 7a: Twin tank wet digester + briquetting line estimated capital cost £1,100,000 (Outline data supplied by Hallmark power http://www.hallmarkpower.co.uk/anaerobic-digesters/) incorporating 22.5% verge biomass in its feedstock showing annual margin and capital payed off over ten years

	Total annual income inflated at 2%	Total annual debt repayment	Annual cost of feedstock inflated at 2%	Annual operating margin	Cumulative Margin
	449,739				
Yr1	458,734	147,538	194,447	116,749	116,749
Yr2	467,908	143,688	198,336	125,885	242,634
Yr3	477,266	139,838	202,303	135,126	377,760
Yr4	486,812	135,988	206,349	144,476	522,236
Yr5	496,548	132,138	210,476	153,935	676,170
Yr6	506,479	128,288	214,685	163,506	839,677
Yr7	516,608	124,438	218,979	173,192	1,012,869
Yr8	526,941	120,588	223,358	182,995	1,195,863
Yr9	537,479	116,738	227,826	192,916	1,388,780
Yr10	548,229	112,888	232,382	202,959	1,591,739
	5,023,004	1,302,125	2,129,140	1,591,739	

Table 7b: Twin tank wet digester + briquetting line estimated capital cost £1,100,000 (Outline data supplied by Hallmark power http://www.hallmarkpower.co.uk/anaerobic-digesters/) incorporating 75% verge biomass in its feedstock showing annual margin and capital payed off over ten years

	Total annual income inflated at 2%	Total annual debt repayment	Annual cost of feedstock inflated at 2%	Annual operating margin	Cumulative Margin
	407,563				
Yr1	415,714	147,538	132,540	135,637	135,637
Yr2	424,028	143,688	135,191	145,150	280,787
Yr3	432,509	139,838	137,895	154,777	435,564
Yr4	441,159	135,988	140,653	164,519	600,083
Yr5	449,982	132,138	143,466	174,379	774,462
Yr6	458,982	128,288	146,335	184,360	958,822
Yr7	468,162	124,438	149,262	194,463	1,153,284
Yr8	477,525	120,588	152,247	204,691	1,357,975
Yr9	487,075	116,738	155,292	215,046	1,573,021
Yr10	496,817	112,888	158,398	225,532	1,798,553
	4,551,954	1,302,125	1,451,276	1,798,553	

Table 8a: Single tank plug flow digester + briquetting line estimated capital cost £1,450,000 (Outline data supplied by Evergreen Gas Ltd http://www.evergreengas.co.uk/) incorporating 22.5% verge biomass in its feedstock showing annual margin and capital payed off over ten years.

	Total annual income inflated at 2%	Total annual debt repayment	Annual cost of feedstock inflated at 2%	Annual operating margin	Cumulative Margin
	449,739				
Yr1	458,734	194,481	194,447	69,805	69,805
Yr2	467,908	189,406	198,336	80,166	149,971
Yr3	477,266	184,331	202,303	90,632	240,604
Yr4	486,812	179,256	206,349	101,207	341,811
Yr5	496,548	174,181	210,476	111,891	453,702
Yr6	506,479	169,106	214,685	122,687	576,389
Yr7	516,608	164,031	218,979	133,598	709,987
Yr8	526,941	158,956	223,358	144,626	854,613
Yr9	537,479	153,881	227,826	155,773	1,010,386
Yr10	548,229	148,806	232,382	167,041	1,177,427
Total	5,023,004	1,716,438	2,129,140	1,177,427	

Table 8b: Single tank plug flow digester + briquetting line estimated capital cost £1,450,000 (Outline data supplied by Evergreen Gas Ltd http://www.evergreengas.co.uk/) incorporating 75% verge biomass in its feedstock showing annual margin and capital payed off over ten years

	Total annual income inflated at 2%	Total annual debt repayment	Annual cost of feedstock inflated at 2%	Annual operating margin	Cumulative Margin
	407,563				
Yr1	415,714	194,481	132,540	88,693	88,693
Yr2	424,028	189,406	135,191	99,431	188,124
Yr3	432,509	184,331	137,895	110,283	298,407
Yr4	441,159	179,256	140,653	121,250	419,658
Yr5	449,982	174,181	143,466	132,336	551,993
Yr6	458,982	169,106	146,335	143,541	695,534
Yr7	468,162	164,031	149,262	154,869	850,403
Yr8	477,525	158,956	152,247	166,322	1,016,725
Yr9	487,075	153,881	155,292	177,902	1,194,627
Yr10	496,817	148,806	158,398	189,613	1,384,240
Total	4,551,954	1,716,438	1,451,276	1,384,240	

On the above standalone finance basis biogas yield is crucial and sampling tests need to be undertaken to verify the theoretical methane potential of road verge biomass. In each model the accumulated operating margin could be used to pay off outstanding debt within the 10 year debt period. It should also be noted that increasing the proportion of verge biomass from 22.5% to75%gave larger overall operating margins due to the lower costs of the feedstock.

To achieve improved viability the AD plant needs to optimise the value of the energy products it produces by:

1. Increasing the proportion of the electricity sold locally through local Energy Supply Agreements or through on site consumption
2. Increasing the proportion of the heat output that can be utilised on RHI compliant distribution systems
3. Integrate the operation of the fibre drying and briquette manufacturing within the processing of other more lingo-cellulosic landscape management biomass (See Figure 3 above)
4. Maximise the value of fibre briquettes through a retail rather than a wholesale marketing strategy

Figure 5 above illustrates the potential to integrate the collected verge material within a process that is being developed from the concepts within the COMBINE project.

In this system the process can be sized to utilise all of the CHP heat output and also a significant proportion of the electrical energy to operate the middle biomass stream within Figure 5.

Option 1b: 30 kWe micro AD processing 500 tonnes Fwt LIHD Verge Biomass within a 750 tonne capacity

An alternative option may be to consider a containerised micro AD unit that could be moved to different sited or incorporated into a rural community energy project. There are several designs now coming to market that incorporate AD units within standard 20 or 40 foot shipping containers. They are modular with central controls operating across serval container units. The example below is based on the quickQUBE unit assembled within a 20 x 20m floor area by 3.5 – 5.0m high.

The option being evaluated below is based on a unit supplying 30kWe and 38 kWth. The assumption is that this could process about 750 tonnes Fwt of biomass utilising 250 tonnes of maize and 500 tonnes grass. Capital costs is estimated at £345,950 for the Micro AD unit plus a small scale briquetting line at £45,000.

Table 9: Feedstock costs

Feed stock costs	
harvest 28 ha at £62 /ha	£2,852
Bale and wrap 300 tonnes at £11.67/t	£5,835
150 tonnes of Maize silage at £36/t	£9,000
Total	£17,687

The financial models are shown below. Several key revenue assumptions have been changed compared to the larger plants as highlighted in the coloured cells. For example the unit tariff for electricity saved is assumed to be closer to a domestic single phase rather than a commercial tariff. At this scale the impact of capital cost per unit of energy producing capacity becomes apparent. The two designs in option 1 provide total energy output costs in the range of £1,900 -2,600 / kWh whilst the micro unit is nearer to £5,800. There is a similar range of exclusions for this option as in Option 1. In order to be viable it wold be essential for this option to secure either significant support for the cost of feed stock or a significant capital grant as part of a community or charitable project. There is encouragement in that the project would become debt free within the ten period even without these provisos but this is an unattractive term over which to secure external finance.

Table 10a: Indicative operational budget including capex budget for a 750 tonne capacity AD plant

Perfomance data for a 12 month cycle	units			Comments
Feedstock total - tonnes	750			Assumes 500 tonnes of fresh / rehydrated verge grass silage + 250 tonnes of maize silage to balance the performance of digester
Biogas yield cu m /tonne fwt	167			Assumes an average theoretical biogas potential across grass at 140 and maize at 180 cu m / tonne fwt
Specific energy in kWh per cu m at 60% Methane	6			
Total theoretical annual energy output MWh	676			The reality is that good operation would still be at about 90% of maximum for servicing This presupposes a plant rated around 15kW electrical output
CHP Energy Split - 42% electrical : 58% heat energy and adjusted for efficiency System Losses during generation - 5%				
Electrical energy yield - MWh	270			
Heat energy yield - MWh	373			
Parasitic energy requirement of the AD plant both heat and electricity - 15% of CHP output				
Net total electricity output - MWh	229			
Average daily electricity output - kWh		628		
Net total heat energy output - MWh	317			
Average daily heat output - kWh		868		
Total support payments				
Electricity Feed in Tariff at 11.52p / kWh			£23,236.61	
RHI Payments at 5.9p / kWh* *dependant on Ofgem approval of use eligibility			£18,689.34	
Assume 25% electricity exported at 4.55p / unit			£2,318.98	
Assume 75% consumed at displacement value of 14p / unit			£21,643.80	
Total putative AD plant income			£65,888.74	Assumes that all of the heat can easily be transferred to community use e.g.to heat a primary school and / or drying fibre for briquetes and becomes an RHI eligible process
Briquettes at £400 / tonne via a mixture of retail and local wholesale			£18,000	Briquette production assume 10% of feedstock results in usable fibre for screw press and drying treatment once dried to 25% provides 45 tonnes of briquettes for external sale
Assume 25% of the CHP heat is transferred to briquette fibre drying process			£4,672	
Total annual income			£88,561.07	

Table 10b: 30KWe micro AD plant housed within 2 x 20 foot shipping containers+ briquetting line, with an estimated capital cost of £345,000 outline data supplied by 'Qube Renewables'. (http://www.quberenewables.co.uk/bioqube)

	Total annual income inflated at 2%	Total annual debt repayment	Annual cost of feedstock	Annual operating margin	Cumulative Margin
	88,561				
Yr1	90,332	52,402	17,687	20,243	20,243
Yr2	92,139	51,034	18,041	23,064	43,307
Yr3	93,982	49,667	18,402	25,913	69,220
Yr4	95,861	48,300	18,770	28,792	98,013
Yr5	97,779	46,932	19,145	31,701	129,714
Yr6	99,734	45,565	19,528	34,642	164,356
Yr7	101,729	44,197	19,918	37,613	201,969
Yr8	103,763	42,830	20,317	40,617	242,586
Yr9	105,839	41,462	20,723	43,653	286,239
Yr10	107,955	40,095	21,138	46,723	332,962
	989,113	462,484	193,668	332,962	

Qube Renewables have also supplied information on a non-containerised version of their system, entitled the "Quickqube" that allows significant savings in equipment capex but requires more site preparation and the provision of a building to house the system.

Option 2: Implications arising from incorporating a value for verge biomass within a Local Highways Agency verge mowing contract

Three scenarios are presented below that allow the possible value of the verge biomass to be set against the costs of three different cut and lift regimes. The ownership of the biomass is discussed within the context of different approaches to the delivery partnerships.

Scenario 1

Based on the yield assumptions described above, the average total biomass arising from the three cut programme is estimated to be 1.303 tonnes Fwt / km annually. This equates to 10.85 tonnes Fwt / ha / yr.

This is now benchmarked against low input meadow grass silage harvesting costs from the Nix Farm Pocketbook[14]. Utilizing the Nix benchmarks for mowing of £62 / ha this would convert to a cost of (£62 x 0.11ha) x 3 = £22.32 /km/yr.

Given that harvesting in a field is faster and uses swath widths of at least 2.2 m the reality check is: 50% reduction in forward speed and 50% reduction in swath width to 1.1 m, the cost/ km/yr would be 20.46/ 0.25 = £81.84/ km / yr + costs of moving up to 20 km to the AD may mean that a cost of £95/km/yr is more realistic and carries the further assumption that delivery will be in bulk for clamping at the AD site rather than in bales.

The optimum open market value of the biomass as an AD feedstock would not exceed £45 / km /yr (dependent on a gas yield equivalent to ensiled meadow grass traded at £36/tonne[14]).

Under this scenario the LLHA contract for mowing the verge would still need to offer up to £50/km/yr to cover the costs of a lift and cut regime contract.

Scenario 2

The LLHA could consider reducing the frequency of cut on B, C and unclassified roads to twice. This could reduce the cut, collect andtransport costs to around £65 / km /yr. Assuming a similar overall volume and quality of biomass is produced for each cut, the £45 / km /yr revenue for 3 cuts adjusted to £30/km/yr for 2 cuts would mean the cost is reduced to £35/km/yr.

Scenario 3

Alternatively the LLHA would be mandated to license the cutting of a 2m swath twice on selected B, C and unclassified roads. This would increase the value of the biomass harvest to £75 / km / yr potentially allowing an operating profit on those verges where this regime were to be put in place.

Potential harvesting systems

Given that the above financial models indicate that there is the potential to operate AD plants on LIHD biomass there are probably three main options for the collection of verge biomass.

A. Collect loose via a cut and suck system and aggregate into a conventional silage or an AG BAG at the AD plant
B. Treat as field silage; mowing, baling and bagging on the roadside and then transporting the finished bales
C. A hybrid of the two with a static site to bale and wrap verge grass brought into a temporary collection point

The standard against which harvesting efficiencies could be measured are the values for mixed grassland harvesting and ensiling and also the costs of the production of energy crops[14]. This formed the basis for estimating the cost of feedstock in the financial models.

As indicated above conversations with mowing contractors indicate a clear preference to complete the cut and lift in one operation. There are no UK based machinery manufacturers. Although one importer based in Boston, Mastenbroek, has exhibited the Dutch manufactured Herder KDM 150 (below) which is the current continental standard where verge biomass must be picked up. A prototype similar to this unit was used in the MWT[15] trial in 2005. Mastenbroek imported a demonstrator from Herder in 2010 but subsequently returned the unit for lack of sales. The main issues with this unit are said to be the amount of soil contamination picked up in the grass, its ability to manoeuvre and overall work rate.

[14] Nix J. (2015) Farm Management Pocketbook ISBN 978 – 0 – 9576939 – 1 – 3 www.thepocketbook.co.uk
[15] 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

Figure 9: Flail mower with vacuum pick up

Herder have recently introduced an experimental unit (Shown in Figure 10) which is claimed to have lower power requirement as the flails have been replaced with twin rotary heads. The contra rotating action of the two heads 'feeds' the grass cuttings into the suction chamber and reduces the level of fine soil particle contamination that could be an issue for AD plant operation. The same power unit is claimed to service a 2.0 m wide cutter and suction system compared to a 1.5m unit with larger power requirement on the current model.

Figure 10a: Herder 'Eco' Rotary Mower with vacuum pick up – a flail mower version is in common use across parts of France, Holland and Belgium. The unit can have a collection trailer attached.

Figure 10b: Herder Eco model details

In discussion with harvesting contractors the issue of the unevenness of verge surfaces and the consequent level of biomass contamination with soil as well as damage to the cutting head emerged as a common theme. The spring of 2015 has seen a very high incidence of molehills which will contribute significantly to the levels of soil contamination. The presence of poorly maintained slot drainage channels or grips on C and unclassified rural roads was also seen as an issue that would increase the uptake of soil and wear to the cutting head.

The common denominator across three separate conversations that discussed potential verge harvester solutions was to develop an adaptation of a Unimog 4 WD tool carrier based on the unit shown in Figure 11 below. The axis could be lengthened, a cage-style forage collection box with a compacter would be added to the back and the vacuum collection unit mounted to the front of the cab utilising the hydraulic/PTO facilities at the front of the chassis. Being wheel driven the maintenance of an adequate forward speed was seen as achievable. Also this would be a shorter and more manoeuvrable unit.

Setting a target width of 2.0m was also seen as achievable either via the Unimog approach or using a two vehicle system with a tractor unit with front and rear mounted flails and a rubber finger spinner to spin the two swaths into one for picking up either into a bulk carrier or via a round baler for producing wrapped silage

Figure 11: The Unimog is being investigated as a possible tool carrier to mount the twin chop forage harvester or a flail plus vacuum lift such as in figure 9.

Figure 12: The Loglogic 120hp ‘Softrak’

This Loglogic unit is also being investigated to assess whether its tracks could be replaced by wheels to improve speed for road based work. The front mounted double chopper is 1.7m wide and has the advantage of being able to maintain the swath width on areas where there has been shrub encroachment. In order to be used on the road the harvesting head would need to be offset and on a floating arm to cope with the uneven surface of most UK verges.

Figure 13: Conventional side mounted grass cutter leaving a swath behind for picking up or baling in position as exhibited at a verge management demonstration in Belgium. This may be the most cost effective on the widest verges or where the RNR requires full harvesting.

Figure 14: Conventional mid-sized round bale being wrapped in situ.

Figure 15: Miniature round baler possibly suitable for volunteer groups working in conjunction with the micro AD option discussed above.

Figure 16: Lincolnshire verge cutting unit featuring side mounted 1.1m flail and front mounted 2m flail for cutting visibility swaths at junctions

Discussion

Financial viability of AD

The financial options 1a and 1b modelled above indicates that AD processing of LIHD biomass could be a financially viable option for farm based 200kWe AD plants that have been designed to process this category of biomass. The financial performance is higher where the proportion of verge grass is larger. There is the potential for payback significantly within the 10 year term if operating surpluses from electricity, FITs, RHI and sale of AD fibre fuels are aggregated and used to speed the repayment of principle. The principle exclusions from the capital cost would be any site specific civils costs and grid connection fees and could therefore cause some new sites to be uneconomic.

The micro scale AD suffers from a higher capital cost per unit of output but might become viable if it formed part of a small scale, volunteer driven biomass collection process perhaps linked to the existing RNR projects and /or became part of a community energy project where a high proportion of the energy generated is used locally. The potential for the formation of CIC biomass harvesting and briquette fibre operations where the briquettes are sold back into the locality could be investigated.

The relative proportions of ligno-cellulosic material present across the range of plant species within road verges may be seen as problematic in some plant designs and this will need to be further investigated in discussion with operators of existing plants. The potential risks from roadside litter contaminating the feedstock and damaging plant mechanisms especially pumps and augers will also need to be assessed.

Scoping partnerships for delivery

The AD financial options did not include any income from operating on a verge harvesting contract but merely considered the purchase of feedstock at a market valuation.

Option2 therefore indicates the potential to approach existing AD operators to consider joint ventures to supply LIHD as an additional feedstock if the bio-methane potential is proven to be economic.

The distribution, harvesting and conversion of accessible supplies of LIHD biomass into an economically sustainable source of renewable energy draws in a range of stakeholders with differing emphasis on the economic, environmental and social benefits from involvement.

Key potential partners could include:

1. Public and third sector owners of, or those responsible for the management of, soft landscape assets capable of yielding LIHD Biomass within Lincolnshire
    a. LLHA (Lincolnshire Local Highways Authority)
    b. IDB (Internal Drainage Boards)
    c. EA (Environment Agency)
    d. MoD (Defence Infrastructure Organisation)
    e. LWT (Lincolnshire Wildlife Trust)
    f. RSPB (Royal Society for the Protection of Birds)
    g. Etc. e.g. National Grid and other utilities companies, Network Rail

2. Private sector e.g. farmers and landscapers who also manage areas of land capable of yielding LIHD biomass
3. Developers and Operators of AD facilities capable utilising LIHD biomass
4. Mowing and harvesting Contractors who could become biomass suppliers within an LLHA management contract under one of the Option 2 scenarios above

Verge classification and management

The Current LLHA contract draws in 13,135 km of verge. LWT manages approximately 80km as Roadside Nature Reserves (RNR) and verges along a further 233km of road have been identified and designated as Local Wildlife Sites. These would all benefit from an extension of the cut and lift regime.

One overall compromise suggestion might be

- RNRs – continue current management arrangements
- Extend this to all LWSs
- Examine the use of two cuts and lifts on trial areas within the B, C and unclassified roads using a 2.0m swath width with the intention of extending it as far as possible towards the the rest of the network (remaining 95%).

This presupposes success in

1. Demonstrating a satisfactory biogas potential of LIHD from road verges
2. Establishing a pilot to test its use in an AD plant
3. Further examinations to estimate the density of harvestable road verge and the variability of yield per unit area or km travelled. Figure 17 below

Figure 17a: Unclassified road (Riseholme Lane) near Lincoln showing a potentially heavy yield at first cut but with severe scrub encroachment on the right hand verge as pictured. Road runs East – West; looking East

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Figure 17b: The first cut on an unclassified (Thorpe Drove) road near Sleaford showing a much lighter harvest. Road runs North South; looking North

Next steps, opportunities and issues

Next steps

1. To evaluate current cut and lift systems such as are described above to critically compare their performance with the KPI that inform the LLHA contracts.
2. To carry out a field study to assess the range of fresh weight yields over a harvest season.
3. To assess the methane gas potential of fresh and ensiled road verge LIHD biomass.
4. To assess the levels of possible contaminants arising from proximity to highways e.g. Polycyclic Aromatic Hydrocarbons, Potentially toxic elements
5. Establish without prejudice discussions with existing AD operators on the relevance of LIHD biomass to their business models
6. Investigate the feasibility of a locally designed cut and lift unit
7. Further discussions with potential partners on combination pilot
8. Verge mowing machinery and logistics development
9. Resolve regulatory issues
10. Establish appropriate impact monitoring and evaluation specifically

10.1. Economic

10.2. Environmental

10.3. Social

Opportunities

[1] To be able to develop a new feedstock for renewable energy generation that does not take agricultural land out of production and does not require fertilisers or other inputs with a high carbon footprint.

[2] To be able to provide an additional source of income from the rural landscape

[3] To reduce overall carbon emissions

[4] To be able to replicate the experience of pilot projects where the harvesting of Low Input High Diversity (LIHD) verge biomass has positively benefitted biodiversity, thus contributing to Biodiversity 2020 objectives, the County Council's responsibilities under the NERC Act 2006, the proportion of Local Wildlife Sites in positive conservation management reported by local authorities to Central Government against Single Data List Indicator 160-00; the implementation of principles in the Natural Environment White Paper 2012 concerning the improvement of habitat connectivity, quality and extent; and providing benefits for pollinating insects in accordance with The National Pollinator Strategy 2014.

[5] Specifically in the context of Lincolnshire, to be able to use this technique to cost effectively extend the range and connectivity of roadside verges of wildlife value and achieve the strategic objective of providing a network of biodiverse corridors supporting sustainable populations of wild flowers, wild pollinators and other wildlife across the county and reducing the potential vulnerability of isolated pockets of biodiversity to local extinction events.

Issues

[1] The potential for large scale variation in the distribution of verge biomass causing unmanageable variation in the supply and processing of the material through the annual cycle

[2] Repeat harvesting of verges may result in an overall decline in the volume of feedstock – reducing the viability of the AD finance model

[3] The nature of the AD digestate fibre resulting from the LIHD biomass is unknown. If it emerges from a dewatering process as a slurry its use for briquetting will be in doubt and the finance model will need to be adjusted.

[4] The position of the EA on potential contamination of verge vegetation remains to be clarified. It carries implications for permitting especially on the status of the feedstock and the method of disposal of digestate. Failure to clarify this will render market interest unlikely.

[5] Current levels of inconsistency in support mechanisms leading to levels of investor uncertainty.