  

Wetland Biomass to Bioenergy Project

Phase 3 Report

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Our special thanks go to Sally Mills (RSPB Bioenergy Project Manager) for her dedication and commitment to us throughout the project and to Jenni McDonnell of Knowledge Transfer Network (KTN) for her invaluable assistance during our Open Day Demonstrations.

Thanks also to Jeremy Rix, Director of North Energy Associates Ltd, for his help in producing this report and his help understanding the implications of our findings during the project!

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Section 1 – Executive Summary

1.1 Objectives of the Project

Our project set out to produce bioenergy in the form of 'briquettes' - from reed and rush harvested from wetland conservation sites on the Somerset Levels and East of England. These areas have traditionally been harvested by much slower and costly means, where the arisings have been seen as a problem, rather than a potential energy feedstock.

The objectives of our concept were to harvest these wetland areas using large and medium-sized, tracked machinery - *PistenBully* and *LogLogic Softrak 120* – readily available from manufacturers, which we would adapt and develop to be as efficient as possible in these sensitive areas. Both these machines were to be fitted with 'header' attachments (the cutting mechanism that forages the reed or rush), specifically chosen for their ability to deal with the type of material to be harvested and the desired after use.

Fig 1 – PistenBully (typically used for grooming ski slopes)

Fig 2 – Softrak 120

Arisings were to be hauled - using specially adapted tracked vehicles with low ground pressure - to the side of the harvesting site and then transported to a storage site using conventional tractors and trailers, keeping distances as short as possible by storing biomass close to the harvesting site.

The harvested material was to be stored in AgBags -our current core business, which is basically a flexible, sealed storage system usually used on farms and AD plants to store feedstock, with minimal nutrient losses. The contents within the AgBag were to be dried using solar fans providing an air flow through perforated pipes in the AgBag.

Fig 3– An AgBag machine storing grass silage in AgBags

A large commercial briquetting machine would be used to convert the dried biomass into briquettes, with the intention of burning them in a biomass boiler installed at RSPB offices at Dewlands Farm, West Sedgemoor, within the wetland of the Somerset Levels. Having a dedicated biomass boiler to burn biomass briquettes would fully demonstrate the ‘end to end system’ – and complete the cycle from biomass to bioenergy. It would also keep transportation distances to a minimum and help the carbon footprint of the whole concept.

Fig 4– Briquetting Machine

Fig 5- Typical Biomass Boiler

For material harvested on the Somerset Levels that required further drying before processing, we envisaged installing a drying floor or similar equipment at Dewlands Farm, using heat from the biomass boiler. This would dry the arisings further, prior to burning in the biomass boiler. We envisaged wetter material to potentially be used in nearby Anaerobic Digestion (AD) plants as a feedstock for energy production.

We intended to look at potential markets for the ‘loose’ biomass (prior to briquette processing) – such as other briquette or pellet producers - to find out if this was a more viable commercial option for our business.

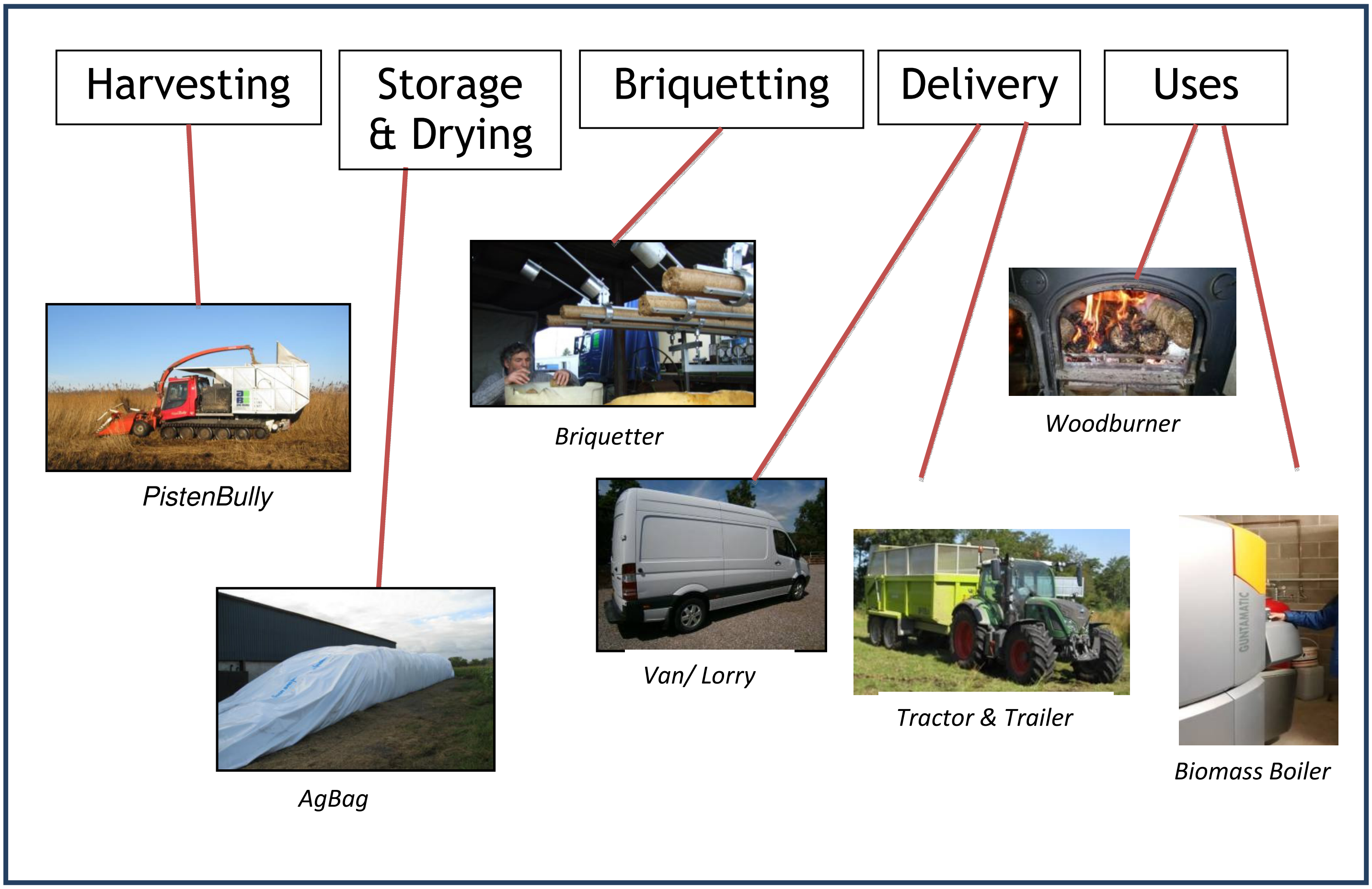
The biomass briquettes were to be marketed in any (or all) of the following ways:

- Sold at the retail outlets within the RSPB nature reserves where the arisings have been collected;
- Used in biomass boilers like the one installed at Dewlands Farm, West Sedgemoor – replacing the fossil-fuelled powered heating with local biomass arisings;
- Packaged and sold to external retail or wholesale outlets.
- At local schools, hospitals or community buildings where a biomass boiler is installed.

We would also explore the potential for gaining Renewable Heat Incentive (RHI) payments for the energy produced using reed briquettes - in both commercial and domestic biomass boilers, and specifically for the biomass boiler installation at Dewlands Farm which was purchased as part of our project.

To take our concept forward commercially, DECC assigned ‘Carbon Limiting Technologies’ (CLT) to provide incubation support for the business planning side of the project.

Fig 7: The 'simplified' end-to-end process



1.2 Key Findings

This report shows a 'snapshot view' of where we are with our findings – both in relation to the bioenergy produced and the rate of return for other potential buyers of the concept. We have shown that with various adjustments within the harvesting and bioenergy production processes, there will be varying successes with the marketability and commercial viability of the resulting bioenergy.

A summary of our key findings:

- **The Life Cycle Analysis (LCA) results show Green House Gases (GHG) saving of 92%, compared to traditional wetland management and the burning of coal.**

  Compared to the counterfactuals of current harvesting methods for reed (brush-cutters and pedestrian mower or raked and burned by hand) and rush (traditional tractors and mowers when terrain allows) - our system is more economical and carbon efficient.

  The reed and rush briquettes produced during the project have taken less energy to produce than they provide as bioenergy when combusted - compared to coal. The energy content of the biomass at each stage from harvest to combustion has been measured, along with the (fossil) primary energy consumption of each main stage of the process. From this, we have determined that the energy input to briquetting operations as a percentage of the energy content of briquettes produced is 10.5%.

  Furthermore, we identified that it is even more cost and carbon effective to use the harvested material in loose, bulk format (rather than in briquette form) close to the harvesting site.

- **A discounted cashflow for our concept shows a large positive value of just over £1M, with a return on investment of 48%. However, it also shows that the briquetting is a loss-making operation, due mainly to the high labour requirement.**

  The sale of loose biomass is more economically and carbon efficient over a distance of up to 50 miles, compared to briquetting prior to combustion. This is largely due to our higher labour charges, i.e. £9 / hour – which is the current rate for our AgBagging operators in our core business. This rate could be lowered if specific staff were brought in for this line of work.

- **Our concept is a sound and simple way to produce bioenergy from wetland biomass - but it has to be in line with land management goals in these sensitive environments, and further understanding of the supply and demand chain is required.**

  A 'Biomass Calculator' is being developed by Sally Mills (RSPB Bioenergy Project Manager) in liaison with North Energy Associates Ltd, to provide nature reserve managers with as much information as possible when making decisions (both financially and conservation-wise), when utilising the biomass off conservation land. This calculator will include methods of harvesting, the costs involved and the alternate ways in which the biomass arisings can be turned into bioenergy.

  As the biomass market matures, we could see a greater demand for briquettes and dried biomass. Together with further understanding of the biomass supply (which is dependent on and driven by conservation objectives), we aim to have a greater understanding of the supply and demand chain.

A *Guntamatic* biomass boiler has been installed at RSPB offices in West Sedgemoor, Somerset by TRECO, although neither reed nor rush has been test burned in this boiler as yet. Whilst this boiler has been commissioned using woodchip, we have test-burned loose reed in a 'new generation' ceramic fire-chambered boiler at a local Devon commercial site. These types of biomass boilers are becoming more widely available, as the market grows and new boilers are developed.

Figs 8 – Guntanatic biomass boiler installed at Dewlands Farm, currently taking woodchip fuel

- **'Ownership' of the biomass arisings needs to be considered prior to harvesting, as this will have an impact on the commercial viability of briquette production – and the costs involved for conservation management.**

Our rate for harvesting wetlands is envisaged to be £1,200 per day for each harvesting machine, plus transportation costs (the machines are hauled on an artic lorry at £1 per mile). Truxors (amphibious machines to cut and collect reed), which are currently used in some wetland areas cost £750 per day, plus delivery and collection at £900. With our faster, more efficient machines, our rate is significantly less and we accomplish more hectares of harvesting per day.

Fig 9 – Truxor

The cost of harvesting needs to be considered when deciding how arisings will be utilised. If the conservation body are to retain the arisings and pay us to harvest *<u>and</u>* produce briquettes, then both these costs have to be considered before agreeing on a suitable marketable price for the briquettes. The costs of briquette production are significantly related to yield and so the more we can harvest and briquette, the more cost efficient the whole process becomes.

The RSPB and other nature reserves are probably best placed to sell the high quality briquettes to the higher end of the marketplace, although how the 'supply chain' for this would work out economically, still needs to be addressed further.

To aid this decision process, the RSPB have initiated a DEFRA Payment for Ecosystem Services (PES) research project – namely 'Energy for Nature', which aims to build on the DECC Project and will look at the issues surrounding the ownership of the harvested biomass.

- **Sulphur levels and SOx emissions for the reed and rush briquettes examined by the University of Leeds were suitably low and not problematic.**

Chlorine (Cl) levels of the fuels were also suitably low (described as trace amounts). This is positive as low Cl levels are important especially if the fuels are to be used in some commercial burners where corrosion can occur if Cl levels are high. *(Ref: John Corton, IBERS)*

We also undertook controlled fuel trials with boiler manufacturer BGI (Bio Global Industries) who confirmed that no clinker was produced by either reed or rush. These were not full fuel trials, which are still outstanding.

- **Our harvesting and haulage equipment is robust, sensitive to wetland areas and definitely 'fit for purpose'. It is also more economical than current methods.**

Compared to current harvesting methods, our technology is faster, less labour intensive and more economical. The time taken to cut 1 hectare of reed by a group of volunteers includes
brushcutter operation (4 hours) to cut edges and inaccessible spots; pedestrian mower operation (35 hours) cutting; followed by raking up and burning (199.5 hours) - *ref Sally Mills 'Counterfactuals' document 2014*.

Harvesting operations by the PistenBully were timed at Ham Wall, Somerset and Minsmere, Norfolk where continual cutting was performed - and the average time to cut a hectare was 40 minutes.

A Truxor has also been regularly used by the RSPB at reedbed sites, including Ham Wall and Minsmere. It is essentially a floating cutter, using a broad cutter bar that can be raised or lowered with a rake attachment to clear cut material. The Truxor costs around £750 per day to hire including an operator and can cut and remove a hectare of reed in about 40 hours (250m²/hr) for a price of £2-3K/ha, so compared to our rates for the PistenBully and Softrak, it is less economical.

The RSPB undertook a Monitoring Programme of the effects of our harvesting machines on the various landscapes which has shown that we maintain the ecological balance in a cost effective way. It also showed that the machines leave little impression on the landscape, with temporary disturbance only seen at pinch point and gateways on wet ground.

Fig 10 – Soil Sampling

Fig 11 – Substrate Monitoring

Fig 12– Cranberry Rough (before)

Fig 13 Cranberry Rough (after)

- **RHI regulations changed during the life of the project and so there are further costs involved to progress RHI compliance for our fuel type.**

  We are working closely with 'Carbon Limiting Technologies' who are providing incubation support through to commercialisation of our briquetting and 'loose' biomass business. This includes looking at the additional costs involved to progress RHI compliance and the associated standards for fuel types.

- **It is vital to have a 'liaison officer' role (such as the one Sally Mills as Bioenergy Project Manager has played during the project).**

  For the project to go forward, we definitely see a requirement for someone to have a key liaison function to ensure all parties can work smoothly together, as the differences between larger, charitable conservation organisations and small businesses are manifold and someone with working knowledge of both has been crucial for the project's success. For us all to work consistently together, there needs to be a single point of reference for any difficulties that arise and to streamline the communication process.

  It is vital for site managers and land owners to think in a joined up way and talk to neighbouring sites when working out a harvesting plan, thereby keeping transportation costs to a minimum – and this too could be the role of a liaison officer.

1.2.1 Adaptations & Achievements

1.2.1.1 PistenBully

Adaptations to the PistenBully harvesting machine were made during Phases 2 & 3 of the project, to enhance the manoeuvrability, safety and volume capacity of the forage collecting box. These included:

Fig 14– PistenBully as delivered in Phase 2

Fig 15– PistenBully with adaptations

- The Kemper header was re-mounted closer to the front of the PistenBully to give the operator better vision of the front of the Kemper – but more importantly, it improved the balance of the whole machine.
- A weight was added to the rear, to counterbalance the Kemper header, when raised off the ground.
- The forage box was extended to increase its volume capacity from $11m^3$ to $16m^3$. This reduced haulage runs to the side of the harvesting site and therefore less potential damage to the substrate.
- A safety switch was fitted to the Kemper spout, ensuring it was pointing towards the forage box, prior to harvesting operations commencing.
- A GPS (Global Positioning System) was fitted to the PistenBully, allowing us to collect performance and harvesting rates data.

1.2.1.2 Haulage Machines

Two second-hand harvesting machines were purchased from the Broads Authority and adapted by ourselves – a Wetland Harvester (figs 17 & 18) and a Fenland (figs 19 & 20). We renovated the Wetland Harvester, which is specifically used on rush and it has been trialled in East Ruston, North Norfolk; Cleveanger Farm in Devon and most recently by the AMW Project in Scotland. A large forage box has been fitted to the Fenland, although it has not yet been trialled during harvesting operations.

Fig 17 – Wetland Harvester (before)

Fig 18 – Wetland Harvester (after)

Fig 19 – Fenland (before)

Fig 20 – Fenland (during adaptations)

A powered, tracked trailer *(fig 21)* purchased from LogLogic, was to be adapted by adding a large forage box, and this adaption is still ongoing.

Fig 21– Powered tracked trailer (LogLogic)

We realised that although the modifications to the Pisten Bully reduce tracking movements they have made the machine much heavier and so we looked at reducing the number of passes for the heavier harvesting equipment, by adapting a Marooka dumper truck into a forage haulage vehicle, with ultra-low ground pressure.

Fig 22– Marooka (before) *Fig 23– Dumper Truck (after)*

1.2.1.3 Briquetter

The briquetting machine was split into two smaller, more mobile units – making it easier and more efficient to briquette nearer to the point of harvest or AgBag storage site. The briquetter was previously mounted on a curtainsider articulated trailer, which was extremely difficult to manoeuvre through some access points at conservation sites.

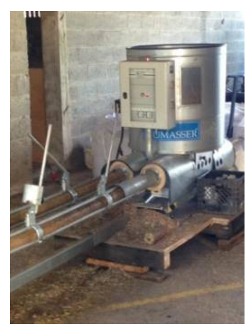


Fig 24– BIOMASSER Briquetter (as delivered) *Fig 25– Briquetter after adaption*

1.2.1.4 Drying Process

We had originally intended installing a ‘Blenheim Floor’ (a suspended steel floor perforated with holes to allow heat from below to dry arisings laid on top of the floor), at Dewlands Farm, in a neighbouring shed near to the biomass boiler installation. In light of delayed fuel trials with Treco, we instead purchased and adapted a second-hand grain dryer, which gave us greater mobility over where drying of arisings could take place.

Fig 26– Blenheim Floor (example)

Fig 27– Adapted grain dryer

1.2.2 Incomplete Objectives

Outstanding Objective	Details	Plans / Next Steps
a) Solar fans	Parts for these have been purchased, although we did not use them for drying material within an AgBag.	Testing will be ongoing - although simulated drying in an AgBag was performed for the trials using heathland materials undertaken as part of the INTERREG CaReLands project. Assembly of the mobile solar panel frames has begun (July 2015) and when complete, will be trialled on rush currently stored in an AgBag at Shapwick in Somerset and on reed bagged at Ham Wall, Somerset.
b) Fuel Trials & RHI	The boiler installed by Treco at Dewlands Farm has been commissioned using woodchip. Reed has not yet been used, due to outstanding fuel trials with Treco.	Discussions with Treco to undertake fuel trials at their own test site have highlighted additional costs totalling £17,148 and an estimated 21 weeks to complete. These figures were not disclosed during the project and have therefore not been budgeted for. As we are not in a position to bear these costs, fuel trials are currently at a stand-still. Problems with fuel trialling have been exacerbated by RHI now being in place. Although not in place at the start of the project, we now need to comply with these regulations - as much as to ensure the biomass fuel can be burned in the future, as well as ensuring RHI can be claimed.
c) Briquettes made from varying mixes of arisings	We had intended to produce mixed material briquettes (i.e. reed and rush, perhaps mixed with wood) to produce optimum calorific values, and to explore a greater commercial potential of these type of briquettes.	Each mix would need to pass the emissions testing for RHI regulations and the cost of these tests is prohibitive. We will not continue future mix testing until the regulators have clarified what biomasses can be burnt.
d) Powered, tracked trailer	This machine has not been trialled during the project, due to delay with delivery.	Trialling will take place during 2015 harvesting season (starting October).

e) Cutter / bundler / baler attachment	We have not yet taken delivery of (or trialled) this attachment for the Softrak 120.	Trialling will take place during 2015 harvesting season (starting October).
f) Fenland	This haulage machine is still being adapted – although it has been successfully fitted with a large volume forage box.	Adaptations have now been completed and it is ready to be utilised commercially.
h) Marketing and commercial plan	A full marketing and commercial plan for the briquettes is still being worked on. However, we have been working with the RSPB to progress the 'Payment for Ecosystem Services' approach.	Our Business Planning is continuing with support from Carbon Limiting Technologies and Mott McDonald.

1.3 Exploitation & Expected Impact

1. To further exploit use of PistenBully and Softrak (in terms of our own Business Plan), we will also look at using these machines for cultivation and sowing work in the Spring months.
2. We will continue working with the RSPB on the development of community energy ideas.
3. We have looked at several AD plants local to the harvesting sites in Somerset and Suffolk, for taking in wetter material and early indications are that *Pretoria Energy* and *Future Biogas* (AD Plants in Suffolk and Cambridge) would be willing to take in volumes of local feedstock.
4. RHI compliance for our briquettes would hopefully assist their marketability, but this still needs to be confirmed in light of other new generation boilers being developed.
5. Samples of briquettes were distributed to attendees at our 2014 and 2015 demonstration Open Days, to give greater awareness of the bioenergy potential from wetland areas.
6. We have considered woodchip briquette suppliers purchasing loose biomass for mixed material briquettes and have been in discussion with a woodchip merchant in Norfolk.
7. Analysis of the characteristics of the biomass, together with further emissions testing with boiler manufacturers will allow us to progress the exploitation of reed and rush briquettes to the market place.

1.3.1 Kent Heathland Trials

The RSPB expressed an interest to build on the DECC project and develop this work further by additional funding sourced elsewhere. By collating the lessons learnt from the limited work undertaken on dry conservation biomass and by conducting trials on different materials (such as heather, bracken, gorse and scrub) harvested from non-wetland reserves, this would fill in the knowledge gaps. By transferring the techniques and innovation being developed through the DECC project to inform and assist trials on heathland and woodland habitats in the southeast of England, would broaden our knowledge base; maximise the benefit of the DECC work and facilitate the conversion of all reserve biomass into energy products. This would provide greater options for reserve managers of both wetland and dry reserves to both reduce fossil fuel use and generate an income stream through the development of a payment for ecosystem services (PES) scheme.

This additional project took place during a week in November 2014, running alongside the existing DECC project and benefited from the knowledge and experience gained from that work. The machinery needed for the trials had already been developed using DECC funding, with additional resource only required to fund time for delivery and analysis of work on the dry habitats. The results generated from the additional trials have been used in conjunction with the wetland biomass results to form a portfolio of techniques available to land managers when looking to utilise biomass off their reserves alongside opportunities for income generation.

The work undertaken took place in the southeast of England which helped spread the effect/influence of the biomass to bioenergy work, which had been limited to the southwest of England, east of England and Northern Scotland. It had the potential to involve new partners, such as Kent Downs AONB (Areas of Outstanding Natural Beauty) and develop new partnerships, and now has the potential to grow and influence the management of habitats on a landscape scale.

Fig 28–Gorse (Kent Heathland Trials, Nov 2014)

Section 2 – Background

2.1 Objectives of the Entire Project

Our project was to look at harvesting wetland habitats, including reedbeds and areas of largely rush growth, with tracked harvesting machines – making the process as efficient as possible, with the minimum disruption to the delicate environments. Our objectives were to:

- **Design & develop an efficient, flexible harvesting, transport and storage / drying system for wetland biomass, aiding the management of diverse wetland habitats.**
- **Process into a form that is readily utilised as energy - primarily as briquettes, but also as dried bulk biomass aiming at the rural community.**

There are 7,700 hectares of reedbeds and 300,000 hectares of wet grassland across the UK, which all have to be effectively managed by the relevant landowner within regulations for particular sites. Brushcutters and pedestrian mowers are traditionally used to manage reedbeds, where arisings are later raked and burned by hand. Wet grassland with soft rush is usually cut by harvesting equipment such as tractor and mower attachment (when drier conditions allow), and the arisings normally used as poor feed; as animal bedding for local farms or simply left to rot.

The concept we considered was to harvest this previously under-utilised biomass in greater quantities than has previously been possible and to produce briquettes as a fuel for local biomass boilers. Our end-to-end process would have minimal impact and significant environmental benefit to conservation areas with tight environmental regulations and we would be harnessing previously unused material to create bioenergy for local rural communities, where mostly fossil fuel is currently used. By keeping transport of the biomass, storage and process conversion to bioenergy as local as possible to the point of harvest, we aimed to keep the 'carbon footprint' of the process to a minimum as well.

The key technical risk has been the inability of the biomass boiler at Dewlands Farm to cope with the varied feedstocks – therefore preventing us from demonstrating the full end-to-end process. We intended to test burn various types of materials, all in different forms:

- briquettes made from either reed, rush or a mixture of both;
- loose material such as locally harvested wood;
- other loose arisings;
- chopped bales.

This risk is seen to be relatively small though, as Treco had given assurances that the selected boiler should cope with the different feedstocks – specifically reed – in a Letter of Agreement set out at the start of the project in 2012. In reality, there needs to be further test burn trials at Treco's development site, before they are able to confirm reed is a suitable fuel type for their Guntamatic biomass boilers. These tests will incur further (as yet unknown) costs, which will be considered as part of CLT's incubation support plan. We have also potentially source another boiler type with a ceramic flue and fine chamber that could be used to trial the biomass fuel.

2.1.2 Phases 1 & 2

In Phase 1, we envisaged the wetter, greener material would be digested within AgBags to produce methane, which would be used on-site to power the briquetting plant and to carry out final drying if required (prior to briquetting). It could also be pre-treated in the AgBag to be transported off-site for digestion and utilisation in local AD plants.

During Phase 2 however, we felt that as Natural Synergies and AMW/IBERS were already looking at biogas production from reed and rush, we would start to investigate the variation of harvested feedstock materials and the way they are processed by local AD plants. That is, we would look at how the variation in chop length affected the digestion capabilities of the arisings.

Fig 29 - Hagglund

During Phases 1 & 2, we also considered other harvesting equipment and looked at the Hagglund (ex-Army tracked, articulated vehicle) as a suitable machine for adaption, but later felt that the added complication of an articulated unit was unnecessary for the type of work we were being asked to do on some very restricted areas.

We looked at reducing the number of passes for the heavier harvesting equipment, by adapting a Marooka dumper truck into a forage haulage vehicle. We also purchased two Wetland Harvester machines to be adapted – one for harvesting rush and the other to be used as an ultra-low ground pressure, high volume haulage vehicle.

During Phases 1 & 2, we envisaged using a mobile briquetting machine (with a shredder attachment to further chop the arisings) - although during Phase 3, we 'split' the large mobile briquetter into two separate, more mobile units and discarded the shredder as it produced too much noise and dust, and used a lot of energy. We also found that our harvesting machines were cutting the material to an adequate length of chop for the briquetter to cope with, without further shredding taking place.

Fig 30 – the shredder at the rear of the original briquetter

2.2 Detailed description of the end-to-end process

Step 1: Biomass (reed or rush) is harvested using a PistenBully fitted with a precision-chop Kemper header; a Softrak 120 fitted with double-chop ELHO header or a Wetland Harvester fitted with a JF precision-chop header.

Fig 30 – PistenBully & Kemper header

Fig 31 – Softrak 120 and ELHO header

Fig 32 – Wetland Harvester

Machine	Ground Pressure (laden)	Material or areas best suited to harvest	Benefits v Issues
PistenBully	3psi	- Reed - Rush - large areas	- Throughput is high (double that of other two machines here). - 40 minutes per hectare *(not including haulage).* - Care to be taken to avoid aggressive turning.
Softrak 120	2psi	- Rush. - Deep peat with ground flowing water. - Areas with access restrictions.	Reduced impact on very delicate substrates.
Wetland Harvester	2 psi	- Rush. - Deep peat with ground flowing water. - Areas with access restrictions.	Reduced impact on very delicate substrates.

Fig 33– Table to show which areas each machine is best suited to

Step 2: The arisings are collected in the rear forage boxes of the harvesting machines, and also in tracked vehicles travelling alongside.

Fig 34– Reed harvested by Softrak

Fig 35– Tracked Dumper collecting arisings cut by PistenBully

Step 3: When full, the collecting and harvesting machines haul the arisings to the edge of the harvesting site. The arisings can either be tipped directly into an AgBag machine, or tipped into a heap at the edge of the harvesting site, ready for a swing-shovel to load onto a tractor & trailer, for transporting to the AgBag storage site.

Fig 36 – Tracked Dumper unloading

Fig 37– Swing-shovel loading arisings into tractor trailer

Fig 38 – Softrak depositing directly into feed-table of AgBagging machine

Step 4: The arisings are compacted into the AgBag by the bagging machine, to maintain the material in a stable state until required. Perforated pipes are fed through the AgBag to allow airflow via solar fans - to dry the contents further if required.

Fig 39– Feeding air pipes through the AgBag

Fig 40– Filling the AgBag

Fig 41 – Sealing the AgBag

Step 5: Arisings with greater moisture content (e.g. 50% or more) can be dried in an adapted grain drier which has a diesel burner and is powered by electricity. Arisings can then be stored in AgBags or used immediately for briquette production. The drier can also be used to further dry arisings as they are removed from the AgBag.

Fig 42 – Adapted grain drier

Step 6: The AgBag is emptied using a telehandler and the arisings deposited into the drum of the briquetter machine, ready for briquette production.

Fig 43 – AgBag opened for unloading

Fig 44 – Telehandler loading arisings into briquetter drum

Step 7: The briquetter machine produces briquettes which are stored in dumpy bags, ready for haulage.

Fig 45– Operating briquetter

Fig 46 – Finished briquette

Fig 47 – Dumpy bag

Step 8: The finished briquettes are supplied to local retail markets, biomass suppliers or the local community and used as bioenergy in biomass boilers, chimineas or woodburners.

Fig 48 – Biomass boiler

Fig 49 – Chiminea

Fig 50 - Woodburner

2.2.1 Harvesting

The harvesting machines were chosen for their low ground pressure, tracked system and ability to deal with wetland areas. The forage headers were chosen for the specific ability to cope with reed and rush vegetation types and to provide differing chop options – double-chop and precision-chop.

The **Softrak 120** technical specification:

- 600mm Bridgestone Rubber Track System
- 90kw (120hp) Deutz Turbo Diesel Engine
- 425mm (16.75”), high ground clearance
- High Torque single speed (0-15kph) wheel motors
- 50mm rear tow hook and clevis

The **ELHO DC1700 (Double Chop)** harvester is front-mounted to the Softrak. The big cutter-head produces an average chop length of about 40 mm by twelve knife settings. The DC 1700 rotor with 36 cutting J-shaped flails and the rounded front cover is designed for best pick-up performance. A full width auger provides an even flow to the cutterhead. This forager is particularly suited to harvesting rush.

- 1.7m cutting width
- 36 flails
- Integral sharpening system
- Cutting knives on rotor (65mm cut length)
- Electric chute control
- Transport width: 2.4m x 2.7m
- Power requirement (min): 55 kW

Fig 51 – the auger on the ELHO DC1700

The **PistenBully’s** technical specification:

- Steel cleeted rubber track System
- Engine: Mercedes-Benz OM 926 LA, 6 cylinder
- Power output (ECE): 240 kW (330 bhp)
- Track width: 2,300mm
- 350mm (14”), high ground clearance
- Overall height: 3,200mm

The **Kemper Champion C2200 (Precision Chop**) harvester is front mounted to the PistenBully. The rotating intake guarantees an even feed of the crops in vertical direction towards the chopping unit. An excellent chopping quality is achieved by the high speed chopping wheel. The intake drums with aggressive prong sections enable the almost complete intake of the crops harvested even at extreme harvesting conditions.

The chop length can be set from 4mm to 200mm. The machine is fitted with a discharge chute, so the arisings can be fed into the PistenBully’s rear forage box (or tracked dumper alongside) as the harvester is going along. The short lengths of arisings take up less space and this reduces transport. The harvested arisings are easy to handle and compact well. This forager is particularly suited to harvesting reed.

- Length 2.55 m
- Width 2.35 m
- Height 3.70m
- Working position 4.20 m
- Transport height 3.70 m
- Working width 2.28 m
- Power requirement 80 kw
- Weight approx. 2050 kg

Fig 52 – the Kemper Champion header

The **Wetland Harvester** (from LogLogic) is a purpose built, low ground pressure machine for the restoration and harvesting of all types of vegetation on wetland habitats where it's extremely low ground pressure and unique flexible rubber track ensures minimal damage. The cutting head is a rubber-mounted double reciprocating knife system with overload protection and an automotive traction stop for the occasional incidence of tree stumps, etc. The fully floating suspended head is on large skids with variable ground pressure. This enables it to both roll, and follow ground contours and harvest on the most difficult of terrain.

The precision chopping system is integral to the machine and is capable of reducing the harvested material to 10-40mm mean length using an efficient, high speed cutting rotor with 18 tungsten carbide tipped blades. Due to its unique construction, the cutting rotor is relatively insensitive to foreign objects such as stones. The blades can be easily sharpened with the built-in sharpening system.

The chopped material is blown into the high tip sealed bulk bin complete with automatic door.

Wetland Harvester and precision chop technical specification includes:

- Hydrostatic drive system with variable speed control and single joystick control
- Cutting head with double reciprocating knife system with stall detect
- High tip bulk hopper with automatic door
- Engine: VM HR 494 HT 4 cylinder cooled turbo diesel
- Engine Power (DIN 70020) 73.5 kW (100 HP)
- Track Width : 600 mm
- Machine Weight : 3.7 tonnes
- Double Reciprocating Knife Cutting Width : 2250 mm
- Chopping System -Throughput Capacity 10,000kg/hr
- Chop Length : 10 - 40 mm

Fig 53 – Wetland Harvester

We have further adapted the Wetland Harvester by:

- Increasing the size of the opening between the header and feed-rollers
- Tapering (or ‘curving’) the modified opening for smoother flow of material
- Fitting ‘paddles’ on the auger mechanism to push in material to the feed-rollers.

2.2.2 Transportation of arisings

Site Managers had expressed concern over *potential* damage to sites, through many ‘passes’ of the PistenBully (i.e. the land would be ‘churned up’ with many trips to the side of the field to empty the PistenBully’s forage box, due to its aggressive metal tracks). We therefore considered other tracked haulage vehicles to be used for hauling arisings from the point of harvest to the edge of a field (for example), whilst the harvesting machines continued cutting.

The harvesting equipment itself can haul arisings:

- **PistenBully** with an extended forage box of $16m^3$
- **Softrak 120** with forage box of $11.3m^3$
- **Wetland harvester** with forage box of $8m^3$.

We adapted the following equipment to haul arisings:

- **Tracked dumper** (with $22m^3$ capacity)
- **Fenland Blower** (adapted to $26m^3$ capacity)

A **Powered Tracked Trailer** was purchased from LogLogic, to be towed by the Softrak fitted with high-power PTO (Power Take Off) pump. Trailer speed can be controlled to match the speed of the Softrak (both forward and reverse).

- Speed of trailer (34cc/rev PTO pump) : 13 kph (Hi speed)
- Payload : 2,500 kg
- Ground pressure (Laden) : 2.9psi (600 mm tracks)
- 600mm Bridgestone Rubber Track System
- High Torque two speed (13kph/6.5kph) wheel motors.

We also purchased a **Softrak cutter** / **bundler** / **baler**, with the intention of using it to collect and bundle reed – ready for the thatching or woven mat market, but this has not been trialled.

2.2.3 Storage (The AgBag System)

We are the UK importer for the AgBag System, providing a nationwide contracting service. The AgBag is a flexible, efficient and profitable sealed storage system whereby a special bagging machine packs the material in tightly - conserving nutrients and reducing moisture loss to a minimum.

An AgBag is a large plastic bag; up to 3.5m in diameter and up to 150m long. Agbagging does not require planning permission and is traditionally used on farms to store grass or maize silage, wholecrop, fodder beet and grain (moist and dry) and most recently for storing biomass feedstock at AD plants.

The AgBag System can also be used as an in-vessel composting system for all types of waste material and also for road salt storage to minimise losses and lessen environmental impact.

Fig 55– pigs feeding from an AgBag

AgBags have UV protection and due to low levels of UV in the UK, we have known material to last in AgBags for up to 7 years. During 2014, we bagged over 250,000 tonnes of various materials in the UK as part of our core AgBag business.

Fig 56 – AgBag machine

Fig 57 – AgBagging maize on farm in Lincolnshire

The AgBag System is particularly well suited to the storage of biomass as it is maintains more nutrients and losses are less than 2%, compared to 40% in traditionally upright clamps. We saw a need for the long-term storage of the harvested arisings, as briquette production would not keep up with the supply of feedstock – and the arisings need to be stored over winter months. Biogas Plants need feedstock throughout the year not just during the Harvest season.

2.2.4 Drying Process

We considered ways to dry the arisings prior to processing, as it soon became evident that the briquetting machine performed best when material was at around 18% moisture content.

Solar fans

Perforated pipes can be fed through an AgBag to control airflow and adjust moisture levels within the stored material. These pipes are usually connected to electric powered fans, although to further increase the carbon efficiency of the whole process, we considered using solar powered fans mounted on a trailer that could be taken to each AgBag storage site.

Fig 58 – Solar panel

Grain Drier

After deciding not to install a Blenheim Floor at Dewlands Farm, we adapted a grain drier to be used for drying the wetter harvested rush arisings. We soon saw an improvement in the performance of the briquetter when using drier material (we had less steam explosions and a better quality of briquette), and also used it to dry reed. We chose a grain drier for its speed of drying capability – which was more of an advantage during the project than in the future, when there would be more time to dry the arisings within the AgBag over a longer period.

We envisaged making the grain drier to be a mobile unit, hauling it with the briquetting machine, to the AgBag storage sites – and we adapted it to be loaded by a loader.

Our original method of using solar fans to dry the material, is still the preferred means of drying. We envisage trialling use of the solar fans during August and September 2015, once the equipment has been delivered and adapted to our existing fan units. There has been a delay in these trials due to late supply.

2.2.5 Briquette Production

When researching the briquetter in Phase 2, we chose the Biomasser BMP6 (manufactured by ASKET in Poland), for the following reasons:

- It had greater mobility than other briquetters currently on the market.
- It is a ‘rotary’ machine - takes the feedstock into a circular moving drum before pressing it into briquettes and therefore takes more varied feedstocks (i.e. bales, chopped material, loose arisings, etc.).
- It makes briquettes with a hole through the centre, which assists the drying process after production and increases the burning capability.
- The manufacturer was able to increase the diameter of the finished briquette, to improve production throughput and the length of burn when ignited.
- It is able to handle straw-like material of varying moisture content and copes well if an error is made and moist material is fed into the machine. The resultant steam explosion is handled well by this particular type of machine.
- The hole through the centre of the briquette aids the production of the briquette from mixed moisture material as it provides an escape route for the steam. (This also has the added advantage of improved burn characteristics and easier ignition of the briquettes.)
- Our machine is the first machine ASKET have produced with the new parallel 80mm di - this enables us to increase throughput and reduce maintenance costs as the di’s now have replacement wear collars. (Previously, whole di replacement was required).
- We were able to visit ASKET in Poland and receive in-house training at their factory.

2.2.6 Production & Treatment of Waste Material

There is only one ‘waste’ material throughout the process. The used AgBags will be removed by AB Systems for recycling (if local re-use is not identified). Often the resulting plastic sheets are used for mulch at nurseries, or for stack sheets on adjacent farms.

2.3 Potential Use of Bi-Products

Loose briquettes (i.e. flaky ones) not fit for market– can be used in domestic woodburners, or in the large woodburner we intend to install at our workshop in Devon.

Ash can be used on gardens or compressed into a lightweight building insulation block. The University of East of London is also exploring the idea of utilising the ash in the development of an aggregate.

2.4 Environmental and Regulatory Requirements

AgBags are required to be sited at least 10m from any water course – according to Environment Agency guidelines. All AgBags were sited well away from watercourses during the project.

Emissions testing of PM10’s, NOx and other regulatory requirements have been started during the project – these are ongoing with Leeds University and results are expected mid June 2015.

2.4.1 Site designations related to harvesting operations

Before any harvesting operations were undertaken, the necessary consideration was given to all the restrictions imposed by site designations. Information for this was provided by the site management plans and a pre site visit with the site manager. This visit provided the opportunity to talk through any concerns about the harvesting equipment we intend to use (particularly its impact on sensitive sites) and through actual demonstrations, we feel we have helped alleviate some of their earlier concerns about harvesting on a larger scale than current methods (such as hand-held cutters and smaller Softraks).

The following designations were considered and addressed as part of this project:

- Sites of Special Scientific Interest (SSSI) – **all harvesting sites.**
- Special Protection Areas (SPA) – **all harvesting sites.**
- Special Area of Conservation (SAC) – **Minsmere, Dingle Marshes, Cranberry Rough.**
- National Nature Reserve (NNR) – **Greylake, Ham Wall, Shapwick, Dingle Marshes & Cranberry Rough.**
- Ramsar Sites – **Shapwick, Catcott, West Sedgemoor, Minsmere, Dingle Marshes & Cranberry Rough.**
- High Archaeological Importance – **Greylake & West Sedgemoor.**
- Area of Outstanding Natural Beauty (AONB) **– Dingle Marshes.**

Section 3 – Trials and Demonstration

3.1 HARVESTING

Objectives & Plans

- Measure the performance of each of the harvesting machines – providing detailed input to the Life Cycle Analysis (LCA).
- Trial the Wetland Harvester.
- Compare the effects of the varying types of forager attachments on the PistenBully and Softrak. Compare flail pickup harvesting and other cutting heads and chopping mechanisms, to determine the impact of vacuum flail compared to the gentle disc of reciprocating knife headers in terms of power consumption and the benefit of litter clearance.
- Carry out trials on heathlands (specifically gorse, heather & bracken) to ascertain if harvesting machines can cope with these terrains.
- Investigate other ways to make the harvesting machines commercially viable.
- Ensure the harvesting machines can be successfully recovered if stuck in difficult ground.

The following schedules were agreed with site managers to determine harvesting requirements for Suffolk and Somerset, ensuring feedstock requirements for briquette production were fulfilled and different site conditions could be trialled with different machines.

Fig 59 – Harvesting Schedule for East of England

Site	Org	Habitat/ vege type	Area to be harvested	Time of year	Method of harvesting
Minsmere South Girder	RSPB	Reedbed – 1yr growth	2.33ha/ 5.75acres	Mid July /Aug	Harvesting tracked vehicle, haulage rubber tracked vehicle
Minsmere Boomacre / Eastbridge Meadow	RSPB	Fen/soft rush	5ha/ 7.4acres estimated	Mid July /Aug	Harvesting tracked vehicle, transfer to road vehicles as appropriate
Minsmere Scrape	RSPB	Fen	0.8ha/1.97acres	Mid July /Aug	Harvesting tracked vehicle, transfer to road vehicles as appropriate
Minsmere Reedbed	RSPB	Reedbed	To be confirmed at time of Open Day demonstrations	Dec/Jan	Harvesting tracked vehicle, haulage rubber tracked vehicle
Cranberry Rough	Norfolk Wildlife Trust	Rush dominated fen	32ha/ 79acres available.	Aug	Tracked vehicles will be trialled, but this will be governed by access limitations

Fig 60 – Harvesting Schedule for Somerset

Site	Org	Habitat/vege type	Area to be harvested	Time of year	Method of harvesting
Ham Wall Phase 2	RSPB	Reedbed – 1yr growth	7ha/ 17.2acres	Aug/Sept	Harvesting tracked vehicle, haulage rubber tracked vehicle
Ham Wall Phase 2	RSPB	Reedbed litter	3ha/ 7.4acres estimated	Aug/Sept	Using a tracked vehicle for foraging and removing, blowing (See notes)
Shapwick Heath – The Lows	Natural England	Rush dominated wet grassland	5ha/ 12acres available	Aug/Sept	Tracked vehicles will be trialled, but this will be governed by access limitations
Shapwick Heath – The Lagoon	Natural England	Reedbed	1.7ha/ 4acres	Jan/Feb	Tracked vehicles – sensitive to substrate
Catcott Lows	Somerset Wildlife Trust	Rush dominated wet grassland	20ha/ 50acres	Aug/Sept	Season dependent, conventional machinery will be used if possible with trial of tracked vehicles as needed

Methodology

1. The PistenBully and Softrak machines were transported by articulated lorries to the harvesting sites – keeping travelling distances to a minimum by leaving the machines on-site at each location (i.e. Somerset and Suffolk – and not returning them to our workshop in Devon each time).
2. Prior to each harvesting operation, the site was walked through with the Site Manager, to determine access requirements; water levels; areas of difficulty and any tree stumps or protrusions and obstacles.
3. Risk assessments and operational plans were exchanged between the working parties.
4. Each area was foraged and data recorded regarding the harvesting capabilities of the PistenBully and Softrak 120.
5. Data was to be collected and analysed for use in the LCA.
6. The GPS system on the PistenBully was to be used to assist the operator in the reedbed areas.
7. The Wetland Harvester was to be trialled at North Fen in Norwich – by kind permission of The Broads Authority.
8. Research other uses for the harvesting machines.
9. Purchase and adapt a winch for use with all harvesting machines.

Results

(Notes on fig 61 : Tonnes detailed in blue are estimated based on the weights measured from Catcott Lows and have only been applied to similar vegetation types. Timings do not include any haulage or movement times.)

Fig 61 - Summary of Harvesting data 2014 (by Sally Mills, RSPB)

<table>
<tr><th>Site</th><th>Habitat type</th><th>Time of harvest</th><th>Litres per ha</th><th>M^3 per ha</th><th>Tonnes per ha</th><th>Pisten Bully m^3 time Time per ha</th><th>Softrak m^3 time Time per ha</th><th>Comments</th></tr>
<tr><td>Catcott Lows</td><td>Rush dominated wet grassland, large tussocks and thick thatch</td><td>29th/30th July 2014</td><td>29.3
52.7</td><td>30.2
54.3</td><td>3.9
7.3</td><td>Not taken – harvested for Natural Synergies</td><td>Not taken – harvested for Natural Synergies</td><td>Due to the density of the vegetation, the cutting height meant that the base of tussocks and some of the thatch was left amounting to an average of 80% more material could have been collected. Calculated adjustment figures are in red.</td></tr>
<tr><td>Ham Wall</td><td>1-year old common reed</td><td>5th – 7th August 2014</td><td>103</td><td>138</td><td>17.75</td><td>52 sec/m^3
1hour 59mins 6secs/ha</td><td>1min 4sec/m^3
2hour 27mins 2secs/ha</td><td>M^3 per hectare calculated as a percentage of the material cut and blown</td></tr>
<tr><td>Shapwick Lows</td><td>Wet fen dominated by soft rush (not tussock forming)</td><td>12th August 2014</td><td></td><td></td><td></td><td></td><td></td><td>Material first cut with Badina mower on the Softrak, although mower bent under thickness of vegetation. Third of the material had already been cut and needed to be collected.</td></tr>
<tr><td>Minsmere East Scrape</td><td>Fen</td><td>20th /21st August</td><td>42</td><td>34.1</td><td></td><td>1min 22sec/m^3
1hour 54mins 5secs/ha</td><td>2mins 14sec/m^3
3hours 7mins/ha</td><td>Litres per hectare not as accurate – as includes internal banks and south girder – made up of sparse and mixed vegetation</td></tr>
<tr><td>Minsmere Eastbridge Meadow</td><td>Rush dominated wet grassland, large tussocks and thick thatch</td><td>22nd August</td><td rowspan="2">41.3</td><td>65.4</td><td>8.43</td><td>1min 6sec/m^3
1hour 12mins/ha</td><td>1min 13sec/m^3
1hour 23mins/ha</td><td></td></tr>
<tr><td>Minsmere Boomacre</td><td>Fen with common reed</td><td>22nd August</td><td>62.3</td><td></td><td>55sec/m^3
57mins 1sec/ha</td><td>1min 5sec/m^3
1hour 7mins 5sec/ha</td><td></td></tr>
<tr><td rowspan="2">Cranberry Rough</td><td rowspan="2">Rush dominated fen</td><td rowspan="2">27th August</td><td rowspan="2">42</td><td rowspan="2">56.1</td><td rowspan="2">4.81</td><td>49sec/m^3
46mins 55sec/ha</td><td>62sec/m^3
59mins 30sec/ha</td><td></td></tr>
<tr><td colspan="2">42sec/m^3
40mins/ha</td><td>PistenBully loading Softrak</td></tr>
</table>

Pickup times – *Fig 62*

Site	PistenBully to load 16m³ bin	Softrak to load 11m³ bin	Notes
Catcott Lows	Data not recorded	Data not recorded	Harvested for Natural Synergies
Ham Wall	13 mins 55 secs	11 mins 55 secs	
Shapwick Lows		12 mins 2 secs	Problems experienced picking up previously cut material as it was left in unnatural thick lumps. Softrak became clogged.
Minsmere East Scrape	22 mins 32 secs	25 mins 25 secs	
Minsmere Eastbridge Meadow	11 mins 30 secs	13 mins 44 secs	Average timings
Minsmere Boomacre	9 mins 14 secs	12 mins 11 secs	
Cranberry Rough	N/A	N/A	PistenBully loaded Softrak

Key Results:

- When harvesting reed using the precision-chop PistenBully, 39% more material per cubic metre was gained, compared to the double-chop material stored in the bin of the Softrak.
- More litter was taken in by the Softrak, because of its suction from the flails. It has the advantage of better litter control - but the disadvantage of greater contamination inclusion (soil). This was the same for reed and rush.
- The chopping rate of dead and green material is different – more dead material is stored per m^3.
- Both litter and stem density have a significant effect on volumes.
- The PistenBully harvesting rush and loading the Softrak alongside, achieved a cutting time of only 40 minutes per hectare at Cranberry Rough.

Fig 63– Double-chop rush (cut by Softrak)

Fig 64– Precision-chop rush (cut by PistenBully)

The Scrape *(Fen on a substrate of silt and sand) – ref: RSPB's Monitoring Programme*

The vegetation in the Scrape was the most varied of the wetland sites harvested this year, with substantial sections of the planned cutting area looking more like herb-rich fen meadows than typical reedbed.

The site was accessed by the Softrak and PistenBully, with a small glitch in harvesting caused when the PistenBully slipped into one of the ditches, and had to remain there until the next morning when a swing shovel was available to recover it. It appeared that no serious damage was done to the ditch or surrounding area, and although it looked a bit muddy and scraped immediately after the incident, it will be interesting to return and take a photograph in six to twelve months time to see the long-term effect.

Fig 65– The Scrape (before)

Fig 66– The Scrape (after)

Fig 67– The Scrape (before)

Fig 68– The Scrape (after)

Fig 69– PistenBully stuck

Fig 70– The area after PistenBully recovered

Ham Wall (*Reedbed on a substrate of clay) - ref: RSPB's Monitoring Programme*

Parts of Ham Wall were cut last year during Phase 2 of the DECC project. These areas were compared to areas that had not been cut last year and soil sampling was spread evenly about the different compartments within the RSPB's study area.

There were a few areas where the machinery had got stuck last year, but evidence of any damage twelve months on was difficult to determine, especially with the addition of the cattle and obvious footfall from them in some areas. The site was accessed by the Softrak and PistenBully, with the whole site being cut (7.1ha) and the material removed in a day and a half (11 hours).

Fig 71– Access area (Before)

Fig 72- After (cuttings laid in track way)

Fig 73– Before (track way at corner where vehicle turning will occur)

Fig 74- After

Fig 75– Ham Wall (before)

Fig 76- Ham Wall (after)

Boomacre ***(****Rush dominated wet grassland on a substrate of silt and sand)* - *ref: RSPB's Monitoring Programme*

This site consisted of low growing reeds, other monocots and herbs. Two scrubby willow trees were present, but these were large enough to be easily avoided by the machinery.

Fig 77 –Boomacre (before)

Fig 78 – Boomacre (after)

Shapwick – The Lagoon *(Reedbed on a substrate of clay) - ref: RSPB's Monitoring Programme*

The Lagoon at Shapwick was cut as part of the DECC Demonstration days and had not been cut for around 7 years. There was quite a depth of litter build-up and dead stems present.

The site was accessed by the PistenBully and Softrak.

Fig 79–Boomacre (before)

Fig 80 – Boomacre (after)

Fig 81–Shapwick harvesting

Fig 82 – PistenBully leaving Shapwick site

Wetland Harvester Trials

The Wetland Harvester trial on areas of rush with the Broads Authority in Norwich showed that the cutter bar and auger worked well, but the auger did not discharge to feed the rollers well enough. We therefore modified the auger paddles and increased the size of the opening between the rollers and auger. The opening was also flailed (or curved), to improve the passage of material from the feeder to the a

Fig 83– the adapted Wetland Harvester

The capability of the forager was good once the arisings had got to the feed-rollers and so we did not increase the horse-power of the forager. The material harvested would be suitable for briquetting (if cut and wilted prior to foraging), but would be ideal for the AMW/IBERS project's pressing process due to its smaller chop size.

*Figs 84 & 85 –Wetland Harvester **trials in Norwich***

Heathland Trials

Trials cutting gorse were carried out in Devon & Kent, and although the Softrak performed well over this terrain, it did not downsize the material enough to allow it to go through the briquetter without further processing (i.e. further cutting by the PistenBully). Heather cut in the same way during Kent trials, did not need further processing before being briquetted, although a mix of heather and gorse needed precision-chopping before briquetting – which was quite surprising.

Reed cut by the Softrak or the PistenBully was suitable for briquetting, although this could have been because we mixed double-chop and precision-chop lengths of reed, prior to briquette production – as we had more reed harvested by the PistenBully during the project. Some of this may be down to the brittle nature of the material, which caused it to be bashed into a smaller particle size. We would have concerns over briquette production if we just had double-chop harvested reed.

Fig 86– Softrak on gorse in Devon

Fig 87– The Softrak's ELHO auger

Softrak

The J-shaped flails on the Softrak have been shown to significantly reduce contamination levels (soil and stones) in the biomass compared to flat-bladed, single chop machines. This reduction in soil contamination has a significant impact on the calorific value of the end product. The Softrak has a secondary blowing and chopping cylinder and its power consumption is less than the Kemper on the PistenBully. The J-flails create less suction, so we assume this would also reduce the removal of small animals and invertebrates, compared to flat-blades.

Fig 88– The Softrak's J blades

Trials showed greater flexibility of the flail pickup, to handle a far greater mix of vegetation type. There was significant removal capability of matted litter clearance, but it is at a cost to the throughput rate. We have determined that drum-type headers (on the PistenBully) can give greater throughput in ideal conditions and standing crop than the flail-type (on the Softrak), but they have limited capacity with matted litter and material with larger stem diameter.

PistenBully

The Kemper header is not as robust as the EHLO double chop and this was experienced at Cranberry Rough., where we hit a tree stump. The tynes on the PistenBully bent and had to be straightened. The harvesting site is ex-forest terrain, and has tree stumps hidden by rush and reed. The PistenBully has crop-dividers (known as 'tynes') and as the drum rotates, the arisings have already been through these tynes and that gives the rotating knives something to cut against.

Fig 89 – The PistenBully's Kemper header

Discussions / Conclusions

- The harvesting machines were chosen for their low ground pressure, tracked system and ability to deal with wetland areas – and they all coped extremely well with wetland terrains. The forage headers were chosen for the specific ability to cope with reed and rush vegetation types and to provide differing chop options – double-chop and precision-chop – and readily coped with all of these.

- The PistenBully did not cope well with 30-year-old gorse, but the Softrak performed much better – by using a 'going forward and reversing out' method of cutting. It would be difficult to harvest this older type of material on a commercial basis though, due to the inevitable wear and tear on the Softrak. Younger growth of gorse, bracken and heather is best suited to the Softrak, as it is also better at getting into tighter access areas than the PistenBully, but contamination is better controlled by the Kemper so calorific value of Kemper arisings is greater.

- It was noticeable when turning on headlands, the advantage of the Softrak's design to handle corners as it did not cut into the substrate in the same way as the PistenBully or tracked dumper.

- The forward speed (horsepower) of the PistenBully is twice as high as the Softrak, so any tree stump is hit with more momentum (9 tonnes) and at a higher speed. The Softrak is much lighter and slower than the PistenBully, so when a tree stump is hit, it just tends to stop. Also, the flails on the Softrak just fold back when hitting a foreign object; make a lot of noise and then swing back, with no visible damage.

- The Wetland Harvester has been sent to Scotland for further trials with the AMW/IBERS project, as it seems better suited to the pressing process rather than harvesting arisings for our briquette process. This is due to its smaller chop size.

- There will not be a fixed price for harvesting every site – as we can possibly look at other harvesting jobs in the same area to keep transport costs to a minimum and share these amongst landowners. Our cost of £1,200 per machine per day could also be shared amongst neighbouring landowners.

- Land management should always be the driving objective for any wetland conservation area – rather than any financial incentive to be gained from briquette production and sales.

- When asked to harvest reed in summer months, we would recommend seeking digestion outlets for it. Rush harvested in the summer months does not have the structural capability (if no field drying can be done), to retain air porosity, so drying becomes more difficult.

- The following table shows the suitability of each harvesting machine for the various conversion technologies:

Machine	Chop size	Suitability
Softrak (ELHO)	Double-chop.	Extra care needs to be taken to select the post-harvesting conversion process because of the non-controlled chop length presented. It needs to be verified that any commercial digesters taking the material would be able to handle the longer chop length. The briquetter can handle reed from the double-chop, but rush harvested this way proved to be more problematic (as it has a greater binding characteristic).
Wetland Harvester	Precision-chop (only 1 set of feed rollers, so less able to control the speed of delivery of the material to the chopping cylinder. There is a slightly reduced control of the chop length compared to a 'true' precision-chop).	This produces a controlled chop length that would be suitable for all post-harvesting conversion technologies trialled during the project.
PistenBully (Kemper Header)	True precision-chop (this machine is fitted with 4 feed rollers - 2 sets - this gives a very accurate control over speed of delivery to the chopping flywheel).	The PistenBully produces material suitable for all post-harvesting conversion processes trialled during the project.

Lessons Learnt / Future Implications

- Wetlands are very challenging habitats and need specialist equipment used with care. The PistenBully got stuck at sites during harvesting at Cranberry Rough and Minsmere Scrape – due to operating near very wet and muddy areas. At Cranberry Rough, this occurred even with the Site Manager in the PistenBully cab, showing just how difficult it is to navigate through wetland areas.

- The Softrak coped better with hitting objects, such as tree stumps. To rectify any damage caused to the tynes on the PistenBully's kemper header if tree stumps are hit, we now carry a tyne-straightener tool with the machine.

- The GPS fitted in the PistenBully helped the operator to drive in a straight line within the reedbeds. This is especially important in very high reed growth where visibility is poor, as there are no landmarks (e.g. trees, posts) to focus on and allow the operator to keep to a line.

- The presence of willow stumps over 2" wide would stop our harvesting operation, and anything over 1.5" would be a concern. Willow is easier to cut than most other scrubby materials like this though and denser hawthorn or blackthorn would need to be less than 1" diameter to be cut by either the PistenBully or Softrak. The Kemper does not handle bushy material very well, but the flail on the Softrak can accomplish more (albeit slowly). The Softrak clears ingress of any sort pretty well – and can even cut a hedge back, by using the 'going forwards and backing out' method. For future operations, we would endeavour to 'grind down' any tree stumps before harvesting.

LogLogic have confirmed that if a tree stump is well rotted, then the Softrak would take it out anyway.

- A winch had already been adapted to recover the harvesting machines if they got stuck during Phase 2 of the project - although in Phase 3 we further adapted the winch by adding a hydraulic motor. It can now be fitted to the Softrak, PistenBully or Fenland and is taken to every harvesting operation. Walking over sites with a Site Manager before harvesting will not totally avoid the possibility of a harvesting machine getting stuck during operation, as it is not possible to walk every single pass to see any hidden features. Every effort will be made to avoid getting stuck, by viewing site maps and being cautious near water edges. We will take two machines to each site (together with the winch) so that any machine can be recovered quickly.
- The PistenBully coped well with getting stuck during Phase 2. It had remained in water overnight before being recovered using a swing-shovel – and started immediately with minimal damage. We also make contact with local contractors with swing-shovels prior to harvesting jobs, to ensure we have further assistance on hand if required.
- It became even clearer during Phase 3, that harvesting biomass for briquette production should ideally be of 'senesced' material (that is, at a mature stage of growth). The added complications of drying down 'younger, still growing' arisings (such as summer reed or rush) were difficult due to its increased density - therefore harvesting rush whilst it is still growing would be best avoided, unless field drying can be achieved or a digestion outlet found.
- We have asked the GPS provider to put weigh cells on the PistenBully's forage bin, to accurately measure input, ensuring we can gain more accurate weights and volumes for the whole process. We will also look at using the GPS in conjunction with the RSPB's mapping system.
- The suitability of each machine for different tasks has been demonstrated during the project. The very light construction of the Softrak and Wetland Harvester give them ability to harvest smaller areas with less impact on the substrate. The high-powered Softrak fitted with the ELHO has the advantage of better clearance of litter and dense inter-twined vegetation, but reduced throughput in comparison to the PistenBully and Kemper. It also limitation of conversion technologies due to lack of control of consistent chop-length.

3.2 TRANSPORT & HAULING ARISINGS

Objectives & Plans

- Continually improve the efficiency of transporting harvested material from wetland areas.
- Trial a powered-tracked trailer purchased from LogLogic.
- Trial a cutter/bundler/baler purchased from LogLogic – with the aim of bundling reed.

- Purchase and adapt a second-hand Fenland from The Broads Authority– a high capacity, large-tracked machines with low ground pressure – ideally suited to the environments we have been harvesting.
- Collect data on the performance of the haulage vehicles, for inclusion in the LCA.

Methodology

1. Transport the haulage vehicles to the harvesting sites, using articulated lorries.
2. Trial each of the vehicles (tracked dumper; powered tracked trailer and Fenland) – working alongside the harvesting machines.
3. Take measurements of the capacities of each haulage vehicle during harvesting operations.
4. Monitor the impact of the tracked vehicles on the wetland environment (part of RSPB's Monitoring Programme).

Results

We were unable to trial the use of the Fenland, powered tracked trailer or cutter / bundler / baler, due to further adaptations being made before first use. These trials will now be ongoing.

The tracked dumper was used at Minsmere, Ham Wall and Shapwick – and coped well with transporting arisings, leaving minimal impression on substrates. Although its short tracks did mean it could be prone to getting stuck in the very wet areas, but was easily pulled out by the harvesting machine.

It will be interesting to see how much the increased track width and length of the Fenland will affect the stability and operation and subsequent substrate impact when used in comparison to the tracked dumper. Any increase in the haulage capacity of the machines will improve the LCA as very little extra fuel will be used, but a lot more material will be hauled on each occasion.

Discussions / Conclusions

Further work with the tracked dumper during Phase 3 has shown the disadvantage of short tracks other than just ground pressure. The stability of the longer tracked Softrak compared to the tracked dumper was easily seen. During operation, the PistenBully and Softrak simply trundle along and any variation in ground conditions or topography is not noticed. However, with the shorter tracks of the tracked dumper, any undulations were clearly visible as the dumper went 'up and down' over the differing ground levels.

The implications of this are greater fuel consumption and more wear and tear on the tracked dumper. We have also seen greater impact on the substrates, as dips and undulations would be further enhanced by the shorter tracks, rather than levelled out or simply driven straight over by the longer tracked vehicles.

Lessons Learnt / Future Implications

A contract for selling bundled reed for thatching (using the cutter/bundler/baler) could be sought, once trials have taken place and this is an area that the RSPB is looking into.

Having a portfolio of haulage equipment to suit different terrains is especially useful for wetlands – and for further trials / work we do on heathland landscapes.

Having a good selection of different haulage vehicles makes us well equipped to cope with the different harvesting scenarios that we may encounter. We can either use a smaller, lower ground pressure vehicle and make more passes, or a larger, heavier vehicle with less passes.

3.3 STORAGE & DRYING OF ARISINGS

Objectives & Plans

- Store reed and rush in AgBags, as close to the point of harvest as feasible.
- Develop a solar fan system to carry air-flow through the AgBag, further drying arisings.
- Develop a 'drying floor' or similar equipment to dry reed and rush to a moisture content suitable for later use in the biomass boiler at Dewlands Farm – using the residual heat from the biomass boiler installation.
- Compare floor drying of miscanthus with reed drying through the batch drier.

Methodology

1. Transport the AgBag machine to the point of storage and load arisings of reed and rush into AgBags, feeding perforated pipes through the bag to allow airflow to further dry the contents.
2. Install and operate solar fans to allow airflow through the pipes in the AgBag.
3. When ready for briquette production, unload the AgBag using a telehandler.
4. Further dry the contents if necessary, using the drying floor at Dewlands (or similar method).
5. Collect data on the moisture content of material prior to storage, and just before briquette production.

Results

- Senesced material (very mature or dead material) at a moisture content of less than 18% is the optimum way to store the arisings. Although the AgBag can store any material, it is much easier at this moisture content (i.e. the bagging machine compacts it well and there is less moisture to collect at the tops and sides of the material in the AgBag).

- We identified a farmer in Somerset who is drying miscanthus on a standard aerated grain floor – which would be the best way of using low heat output from a boiler to further dry arisings.

- A drying floor was not installed at Dewlands Farm – we adapted a grain drier instead, which was mobile enough to be taken to the AgBag storage site.

Fig 90– The grain drier

- We used a drier which has a large fan designed to dry quickly. The extra power consumed by the mobile drier is compensated by the flexibility and speed, enabling us to dry small quantities quickly, but if large quantities need to be dried, the drying floor using biomass generated heat is a more efficient method.
- It took 30 minutes to dry rush in the mobile grain drier, from a moisture content of 50% down to 13% and 11 litres of fuel to dry a grain drier full of material (7.5m²).
- Moist air is emitted from the grain drier – no liquid.
- The grain batch drier is faster and produces quicker results than a drying floor, but it has a high power consumption. We are unable to quantify this currently, because of delays to Treco fuel trials preventing any testing of a drying floor.
- When drying rush (that was wetter than reed), it tended to 'bridge' across the drier. We found we had to manually separate the arisings prior to drying and feed them in smaller amounts, at a much slower rate than the reed. Reed was chopped shorter and is naturally freer flowing than the rush, which easily binds together. Both material types were precision-chopped materials - although the rush was slightly longer-chopped.

Discussions / Conclusions

- Without using solar fans during the project, we simply stored arisings in AgBags without controlling the airflow to allow further drying. We found that at a moisture content of more than 28%, arisings in the AgBag will start to ferment. Between 18% - 28%, the contents start to degrade, but do not ferment. They begin to 'sweat' at the top and sides of the AgBag. Briquetting is reliant on a consistent moisture level, so taking arisings from the centre of the AgBag is important if they have not been stored at the optimum moisture level.
- Limiting the moisture in the AgBags by use of the solar fans would reduce the need for further drying by the grain drier.
- We saw up to 20% of the contents of the AgBag too wet to briquette, when material has been stored at the incorrect moisture level. Using the mobile drier on-site would allow us to dry this to 20%, allowing us to briquette all of the material.
- On conservation sites, the visual effect of AgBags will be important. AgBags can be put up in 3 colours – green, white or black (bags are white on the outside and black on the inside). For drying biomass, the AgBags can be used with either the white or black side exposed, but for AD plants where they aim to get the maximum compaction in, having the black side exposed will heat the contents up to 20% more

than if the white side was exposed. So, if tight compaction is required, then the white side should generally be used.

Lessons Learnt / Future Implications

- Loose, dried arisings can be stored in AgBags until required. This drier material will have much less deterioration - we know this from our normal bagging operations business.
- We could identify other local biomass boilers that could take in (or buy) the loose arisings.
- We have supplied our 'drying' system (*an AgBag machine and AgBags*) to AMW/IBERS in Scotland, to use waste heat from the Combined Heat & Power (CHP) unit or kiln, to store and dry reed harvested by the AMW project in the Tay Reedbeds.
- We need to explore the whole drying issue further - to deal with the findings/conclusions shown here. We will be drawing up plans for testing the solar fans.
- We have established that even when storing almost dry material in AgBags, a certain amount of moisture deposits take place at the top and sides of the bag. So the adaption of the drier to make it mobile has proved useful to quickly dry the material stored near the sides of the AgBag at the point of removal, prior to briquetting. This has also stopped the steam explosions we were experiencing when briquetting with this moist material.
- We will continue to trial the drying of greener material in AgBags using solar fans at Shapwick where summer harvested rush is stored.
- The flowing characteristics of the rush inhibited emptying of the grain drier - we had to manually encourage it out using implements.

3.4 BRIQUETTE PRODUCTION

Objectives & Plans

- Explore different points of maturity (of reed and rush) at harvesting, to ascertain the effect on manufacture of briquettes.
- Improve the quality of the briquettes, thereby making them as marketable as possible.
- Resolve how to deliver conservation biomass briquettes in the most carbon efficient and economically viable way.
- Produce briquettes using a mix of arisings (e.g. rush with reed), to determine the optimum mix for marketability, energy production and ease of briquette production.
- Carry out trials using gorse, heather & bracken to investigate the potential for further biomass supply for briquette production from heathlands.
- Monitor the types of material harvested and measure moisture contents for optimum briquette production.
- Perform analysis through burn tests –both in-house and at University of Leeds, to establish calorific value and assessment of emissions.
- Explore different mixes of materials for briquette production.
- Undertake moisture content monitoring and the effect on briquette production.

Methodology

1. Transport the briquetter to the AgBag storage site, using a curtainsider articulated lorry.
2. Test use of the shredder attachment, by feeding in arisings using a telehandler.
3. Set up the briquetting machine.
4. Two operators to monitor the machine to produce optimum quality briquettes.
5. Measure the volumes of arisings put into the briquetter and the volume of briquettes produced.
6. Record the length of operation and the volume of briquettes produced.

Results

- The large briquetting machine was eventually split into two smaller machines allowing easier access to sites. Although fairly easy to operate, the briquetter requires 2 men to continually monitor the production of briquettes.

- Briquettes were produced at Dunwich Forest, using rush harvested at Dingle Marshes. The briquetter was also used at Minsmere to process locally harvested reed, and later at Ham Wall, Somerset to briquette more locally harvested reed. We also briquetted 50% of the rush harvested in 2013 from Catcott Lows.

- 6 tons of briquettes were produced from rush harvested at Dingle Marshes, Suffolk and 12 tons of briquettes were produced from rush harvested at Catcott Lows, Somerset. We also produced 6 tons of reed briquettes from arisings harvested at Ham Wall.

- Steam explosions were experienced when the material being fed into the briquetter was too moist. Material that is too wet does not allow a clear hole through the centre of the briquette to be made (this allows moisture to escape). Where the hole should be, material becomes very hot (and starts to burn) – steam cannot escape and therefore an explosion occurs.

Fig 91 – Briquette becomes too hot in centre

Fig 92 – Material at correct moisture level

- We experienced problems with briquettes falling apart (particularly reed ones) – especially at the beginning of briquette production, early in the production line.

- Keeping the briquettes in a dry environment is very important, as their quality can be affected by any moisture.

- **Rush briquetting** was slow – after 8 hours, only 2m² was produced. We tried chopping the material in the bale shredder, but this made little difference.
  - 200°C was the optimum temperature for rush in the sleeves at 18% dry matter.
  - Only a little weight was needed to be applied to the rails.
  - Rush can make very good briquettes which hold together well, but the material can produce inconsistent results. The briquettes can start to break apart during production, with no changes to the actual briquetter machine.

- **Reed briquetting** was faster than rush and after 8 hours, around 12m² briquettes were produced.
  - 240°C to 280°C was the optimum temperature for reed in the sleeves, depending on the dry matter content.
  - Reed produced poorer quality briquettes that break apart easily.. Mixing rush with reed improved the structure of briquettes and we think this is probably the way forward.

Discussions / Conclusions

- Even though the briquetter is able to briquette material up to a moisture content of around 28%, we have found the throughput is greatly improved with a consistently drier material. A target of 15% moisture should be aimed for. If the material varies in moisture content, then drying prior to briquetting is well worthwhile for both reed and rush.
- Both reed and rush briquettes were flaky and of inconsistent densities early on in the production line. The density, length and overall quality of the briquettes were improved when the drying rails' length were increased to allow them to cool at slower pace. The rush briquettes are denser than reed briquettes in general.

Fig 93– Flaky briquette

- Rush produces a much nicer looking briquette than reed – it is more flexible and binds better.

Fig 94– Rush briquette

- Unloading the AgBag with a standard wheeled loader and bucket (a JCB) is practical to keep the briquetter going. We had initially thought that a 'grab' may have been required.
- By briquetting material cut by the PistenBully, we do not need to re-shred material to allow efficient briquetting (we had previously used the shredder attachment in Phase 2).
- By briquetting material cut by the Softrak, we found we needed to re-shred material to allow more efficient briquetting.
- The briquettes can 'sweat' in the dumpy bags, so it is important not to cover them and to let them cool before storage.
- We are nervous about the ongoing costs of briquetting, but we are looking at getting at cheaper labour to enable it to be more cost effective.
- The briquette operation is very difficult to perform with less than 2 persons. The 'ideal' scenario would be for one person to be fully engaged in operating the machine, with another working in close proximity, so that he/she could be called on when the production line got more than one person to manage. We found that the briquetter can perform efficiently with 1.5 men, as 1 man would be under too much pressure, but 2 men would not be fully utilised.
- To help resolve how to cover the briquetting costs, the ownership of the initial arisings needs to be established to ascertain the costs involved. For example, if the RSPB pay us to harvest the arisings and we produce briquettes, would they then pay us to effectively 'buy back' the arisings in a bioenergy form to later sell for a profit in a retail outlet at their sites?
- The improved combustion of compressed materials gives rise to less emissions so the importance of briquetting is more than just the ease of transportation over greater distances.
- We have seen that being able to control the gas flow through any boiler or burner is important to control the formation of clinker. When we'd seen higher levels of clinker than we expected, this was at faster burn rates. If we reduced the available oxygen by closing the dampers once we had good ignition we found the clinker greatly reduced.

Lessons Learnt / Future Implications

- From our initial findings we feel that it might be difficult for briquette production to be profitable, due to the high labour costs involved. This could be overcome by paying a lower rate per hour for a specifically employed briquette operator – for the project we have used our own bagging operators who are paid £9/hr.

- Understanding the issues which centre around the ‘ownership’ of the biomass and its relationship to how costs are covered, profit margins and associated costs will be significant in determining how the briquettes are then to be sold on. This would not necessarily be an easy situation to resolve, although use of the ‘Biomass Calculator’ will greatly assist site managers decision-making.

- We will be undertaking further trials to find the optimum mix of materials that is fast and produces briquettes good enough to sell to the public – along with the results of emissions testing and briquette analysis.

- Finding a profitable market for a greater volume of briquettes is only achievable if we have a greater volume of reed or rush to harvest – therefore a ‘chicken & egg’ situation.

- As part of our continuing business planning, we would look more closely at selling the biomass in a ‘loose’ form, as this is potentially more commercially viable.

- Transportation of well-chopped ‘loose’ biomass is economically and carbon efficient over a distance of up to 50 miles, compared to briquetting prior to combustion. Briquetting has shown the capability to penetrate local fuel markets, compared to loose chopped material – so even though it is more economical to process it loose, it is easier to find a market for briquettes.

3.5 ENERGY PRODUCTION

Objectives & Plans

- Install and utilise the biomass boiler and drying floor at Dewlands Farm, with the aim of trialling the briquettes as an effective fuel;
- Precision-chop and double-chop cut lengths were to be analysed by a local AD plant for suitability as feedstock.
- Clarify the need for a technical specification of the briquetted fuels to meet any regulations for reed and rush as a biomass fuel.

Methodology

1. A Guntamatic biomass boiler was installed by Treco at Dewlands Farm and it was anticipated that reed would be the primary fuel. However, during the project it was evident that further fuel trials would have to be carried out over a lengthy period to ascertain the boiler’s correct settings and functionality for this non-compliant fuel type.
2. Take samples of both precision-chop and double-chop materials and send samples to commercial digesters for visual assessment.
3. Explore the potential of gaining RHI accreditation for reed and rush as a biomass fuel.
4. Investigate performing fuel trials with other boiler manufacturers - specifically BGI.

Results

- The biomass boiler was installed and commissioned in December 2014 and fuel trial plans are still being progressed with Treco. Although it has always been our intention to burn reed in the boiler, fuel trials have not been able to be undertaken. Sample briquettes were sent to Treco's testing site in May 2014, but results of the test burning have not been forwarded to us. We are now in further discussions with Treco (with the aid of Carbon Limiting Technologies) to resolve the issue of fuel trials.
- The biomass boiler is currently using woodchip as a fuel source, until these fuel trials are completed. We did attempt a very short trial to see how the feed-table dealt with loose, flaky briquettes – but it was evident that they would get stuck in the current auger arrangement.

Fig 95– Feed-table for biomass boiler (woodchip shown)

- Conclusions were that commercial AD plants would prefer precision-chop rather than double-chop unless they were a food waste processor and had aggressive primary maceration.
- The methane potential of both reed and rush is between 50% and 60% of the methane potential of arable crops.
- Because of changes to regulations during the project, the requirement for RHI accreditation has become necessary - but the costs of attaining this have so far been prohibitive.
- Results from emissions testing carried out by Leeds University show that the Chlorine (Cl) levels of both fuels types were suitably low (described as trace amounts). This is positive as low Cl levels are important, especially if the fuels are to be used in some commercial burners where corrosion can occur if Cl levels are high. The reports refer to the carbon monoxide emission levels (CO) for both fuels as being similar to pine (apart from the smouldering burn phase). There were some issues with briquettes that would possibly be improved with further drying prior to combustion – although this is not a difficult process improvement to implement. [1]
- The emissions report also describes the NOx emissions as 'similar to pine' so we can assume these levels are suitable for solid fuel use. Particulate matter emissions

[1] Source: Notes on the DECC wetland biomass to bioenergy emissions report: fuel comparisons and further discussion by John Corton, IBERS

results are described as slightly higher than pine in the flaming phase, but similar to pine in the smouldering phase. [2]

- Samples of double-chop and precision-chop were sent for analysis and results are shown below:

Sample Reference :

DOUBLE CP HW

Sample Matrix : FEEDSTOCK

Laboratory References	
Report Number	42600
Sample Number	56621

Date Received	12-AUG-2014
Date Reported	26-AUG-2014

The sample submitted was of adequate size to complete all analysis requested.
The sample will be kept under refrigeration for at least 3 weeks.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units
Crude Protein	5.0	%
Crude Fibre	9.3	%
Oven Dry Matter	33.7	%
Moisture	66.3	%
Ash	2.0	%
Oil-B	0.95	%
Total Gas Yield [Fresh Material]	176	M3/t
Total Methane Content	53.5	%

Sample Reference :

PRECISION CP HW

Sample Matrix : FEEDSTOCK

Laboratory References	
Report Number	42600
Sample Number	56620

Date Received	12-AUG-2014
Date Reported	26-AUG-2014

The sample submitted was of adequate size to complete all analysis requested.
The sample will be kept under refrigeration for at least 3 weeks.

ANALYTICAL RESULTS *on 'as received' basis.*

Determinand	Value	Units
Crude Protein	5.0	%
Crude Fibre	12.6	%
Oven Dry Matter	35.3	%
Moisture	64.7	%
Ash	2.2	%
Oil-B	0.77	%
Total Gas Yield [Fresh Material]	185	M3/t
Total Methane Content	53.2	%

[2] Source: Notes on the DECC wetland biomass to bioenergy emissions report: fuel comparisons and further discussion by John Corton, IBERS

Discussions / Conclusions

- Burning loose biomass through a biomass boiler within a 50 mile radius is the most efficient process according to LCA figures. But the ability of some boilers to burn loose material is limited and the boilers may need adaptations to reduce the movement of light particulates through the boiler and certainly into the flue.

- It was confirmed that the **precision-chop cut** is the most beneficial for most commercial AD units that need a length of around 4mm. Samples of cut arisings by the PistenBully were sent for analysis at a local AD Plant, who currently buy in maize silage at 32% dry matter, which produces about 210m^3 of biogas. The samples of reed and rush that were sent them during Phase 3 were at 32% dry matter and gave a figure of 16m^3 of gas.

  When maize is drier, they always correct the dry matter to 32% and pay on that (this is for maize with a dry matter content between 28% and 36%). This means if the rush and reed was under 32% we would get a bit less per tonne - if it was over 32% we would get slightly more.

Fig 96 – Precision-chopped rush from Catcott Lows

Lessons Learnt / Future Implications

- Costs involved with progressing RHI compliance for reed or rush briquettes, could be prohibitive with the volume of material available, as early indications show that this could be as much as £17,148 if we were to go to full trialling with Treco or another boiler manufacturer (such as BGI) who have quoted £25,000.

- Both the boiler and fuel type has to be RHI compliant and we need to progress with Ofgem to determine which boilers our briquettes or loose biomass can be used in.

- Not being RHI compliant at the present time only means that RHI cannot be claimed. The burning of a non-RHI compliant fuel at the present time compared to burning coal or oil would however still show a significant saving in fuel costs and less GHG emissions.

- Carbon Limiting Technologies (CLT) are to produce a Scope of Work for us to take the commercialisation of briquettes forward – although funding for this expires in September 2015 and early indications show we will not have completed this work in time.

- We have been unable to make a definite conclusion as to whether it will be possible to burn loose material, so the investigation continues as to the best way to present the fuel to the widest range of boilers.

- It was very noticeable that the feed mechanism (auger trough) of the BGI boiler was superior because of its lead-in angle, compared to the Treco feed-store auger and further work is required to look at the load speed of denser briquette flakes than we have produced to date. We did not set out to produce 'briquette flakes', but have seen that the speed that the augers will take flakes is greater than expecting the augers to break the briquettes into flakes to load into the boiler. The briquetter is easily adapted to produce short-lengths rather than log-type briquettes that we were aiming for.

- Non-woody biomass pelletisers have been developed that would be worth looking at in terms of a biomass treatment to produce a more suitable fuel stock for the boilers that we have tried so far. Both boiler manufacturers (Treco & BGI) that have trialled the briquettes have confirmed this.

3.6 BIOMASS CHARACTERISATION TESTING

Objectives & Plans for reed and rush

- Determine the ash content of briquettes, compared to the calorific value gained.
- Undertake C, H & N samples analysis to determine the calorific value.
- Perform fuel trials in liaison with Treco to determine emissions and correct settings for the boiler at Dewlands Farm.
- Trial use of the briquettes in a local woodburner.
- Determine the density of reed briquettes.
- Perform emissions testing in liaison with University of Leeds.

Methodology

1. Leeds University to perform emissions testing looking at PM10s, Chlorine and NOx.
2. Milled & dried samples of reed and rush to be sent to MEDAC (*Analytical & Chemical Consultants*) to undertake samples analysis for C, H & N.
3. Take dumpy bags of reed briquettes to Treco's test boiler site in Cullompton, Devon, for fuel trials in a Guntamatic biomass boiler (similar to the one installed at Dewlands Farm).
4. To build on the results produced by Leeds University, a domestic woodburner was to be used to trial burning of reed and rush briquettes over a specific burn period, to collect data on ash removal, clinker, length and volume of burn.
5. Undertake fuel trials with Bio-Global Industries (BGI) whilst awaiting feedback from Treco.

Results

- North Energy have confirmed that the **<u>calorific value for dry reed is 15.8MJ/kg and for dry rush is 15.6MJ/kg</u>** (from the MEDAC results in next bullet points).

Calculation of Friedl predicted Calorific Value

Biomass type	Dry mass composition					Dry Biomass		Non-dry biomass			
	C	H	N	Other	Total	Predicted GCV_{dry}	Predicted NCV_{dry}	Moisture Content	Mass of 1kg dry biomass + moisture	Preditcted GCV_{ar}	Predicted NCV_{ar}
	%	%	%	%	%	MJ/kg	MJ/kg	%	kg	MJ/kg	MJ/kg
Reed	42.57	5.55	1.06	50.82	100.00	17.02	15.80	25%	1.333	12.762	11.24
Soft Rush	41.68	5.51	1.70	51.11	100.00	16.79	15.59	25%	1.333	12.593	11.08

Results of Chemical Analysis performed by Medac Ltd Analytical and Chemical Consultancy Services

Biomass type	C	H	N	
	%	%	%	
Reed - Minsmere 1	42.13	5.81	0.81	Results per Medac Analysis dated 2nd February 2015
Reed - Minsmere 2	42.11	5.74	0.80	
Reed - Ham Wall 1	43.04	5.40	1.24	
Reed - Ham Wall 1	43.00	5.25	1.38	
Reed - Average	42.57	5.55	1.06	

Biomass type	C	H	N	
	%	%	%	
Rush - Dingle Marshes 1	41.50	5.50	1.74	Results per Medac Analysis dated 14th January 2014
Rush - Dingle Marshes 2	41.55	5.58	1.47	
Rush - Catcott Lows 1	41.90	5.43	1.75	
Rush - Catcott Lows 2	41.76	5.53	1.84	
Rush - Average	41.68	5.51	1.70	

- MEDAC results for C,H,N analysis of rush harvested from Dingle Marsh during Phase 2 of the project:

MEDAC LTD

Analytical and chemical consultancy services

MEDAC Ltd
Alpha 319
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Surrey
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United Kingdom

www.medacltd.com
Tel/Fax No. 01276 855410
Email: info@medacltd.com

A N A L Y T I C A L   R E P O R T

Date 14th January 2014

Name David Wynne

Sample ID RUSH – DINGLE MARSH

Formula

ELEMENT	C	H	N						
% Theory									
% Found 1	41.50	5.50	1.74						
% Found 2	41.55	5.58	1.47						

- MEDAC results for C,H,N analysis of rush harvested from Catcott Lows during Phase 2 of the project:

MEDAC LTD

Analytical and chemical consultancy services

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Email: info@medacltd.com

A N A L Y T I C A L   R E P O R T

Date: 14th January 2014

Name: David Wynne

Sample ID: RUSH – CALCOTT LOWS

Formula

ELEMENT	C	H	N						
% Theory									
% Found 1	41.90	5.43	1.75						
% Found 2	41.76	5.53	1.84						

- Treco performed fuel trialling of two tons of reed briquettes delivered to them in July 2014, but no results were available due to human error at the test site. In light of this, we performed our own test burn on a domestic Morso Dove 1631 woodburning stove.

  - We burnt 430kg of **<u>rush briquettes</u>** (harvested from Catcott Lows) over 40 hours. The ash removed was 1,664g and the clinker removed was 480g. With this standard woodburner, the ash box would hold all the ash produced during the 40-hour burn, so daily emptying would not be a problem.

  - We burnt 31kg of **<u>reed briquettes</u>** (harvested from Ham Wall) over 24 hours. The ash removed was 505g and the clinker removed was 66g. With this standard woodburner, the ash box would hold all the ash produced during the 21-hour burn, so daily emptying would not be a problem.

- Results are presented from the emissions testing of two briquette fuels in a domestic stove. The briquette performance and emissions have been compared with pine wood, which is a well characterised commercially available solid fuel. The results showed good performance for the reed briquettes, however the performance of the rush briquette worse in terms of combustion and emissions- this could be due to a higher moisture content. The briquette fuels both had comparable CO compared to pine. The NOx levels were highest during flaming combustion and lower during smouldering combustion; however the general trends and concentration levels were similar for all the fuels tested. Other emissions indicating poor combustion such as formaldehyde and ammonia were higher for rush briquettes.

The particulate mass emissions from the reed briquettes and the pine were similar, much higher particulate mass emissions were observed with the rush briquettes.
It is suggested that emissions abatement technologies are considered for the rush briquette fuels in their current formulation. It is possible that pre-drying of the rush before briquetting or blending with other fuels would improve the performance.
The proximate and ultimate analyses of the fuels should be determined and correlated with the emissions results for better understanding of the fuel behaviour.
The fuels in their current form were difficult to ignite and burn and their emissions were higher than the baseline pine samples. However, once combustion was established, the reed briquettes burnt out more quickly than the pine. This is related to the more open structure of the briquettes compared to pine. Poor combustion performance was experienced with the rush briquettes, which could be due to a high moisture content.
Differences in the fuel-N content are expected to correlate with the NOx emissions.
The particulate mass emissions from the reed briquettes and the pine were similar. Much higher particulate mass emissions were observed with the rush briquettes. Differences in fuel properties such as moisture and volatile content might be correlated with the PM emissions.

It is suggested that emissions abatement technologies are considered for the briquette fuels in their current formulation. Other options are to investigate pre-treatment/ upgrading of the fuels in order to slow down the combustion or decrease the 'flaming combustion' duration and extend the 'char burning' duration. This would result in reduced peak emissions.

Discussions / Conclusions

- Both reed and rush can produce high quality, dense briquettes that burn well in a domestic woodburner.
- We have been unable to establish if the biomass boiler at Dewlands Farm can take reed as a fuel – but based on our other trials, we expect this to be successful when we progress fuel trials with Treco or BGI.
- In comparison to other alternative fuel briquettes (such as soft wood), we have produced a briquette with a similar calorific value, i.e:
    - Woodchip = 12.6 and air-dried at 30% moisture content
    - Wood kiln dried = 19.00 at 5% moisture content
    - Logs air-dried = 14.7 at 20% mc
- Care needs to be taken with the temperature of combustion to control clinker production using both reed and rush briquettes, but this is possible with most commercial and domestic boilers.
- The increased ash production which is about 2 to 3 fold of soft wood is not problematic in most domestic woodburners as these are serviced most days and the sample wood-burner used was capable of holding over 3 days' ash when burning both reed and rush briquettes to heat a 4-bedroomed house in the winter.
- We recommend the use of auto-ash removal if used in a commercial boiler.
- Emissions results show that it is equivalent emissions to soft wood, as most soft wood is burnt too moist.
- It has not been established through work carried out so far, how effective the boilers are at burning loose material. Further work with the boiler manufacturers is required.

- The bulk density and the importance of this in deciding about loose material v briquetting, especially in relation to movement of material and the frequency of loading boilers. The bulk density of the briquettes is around 650-700kg/m and of the chapel Reed/Rush ranges (dependent) on chop length and moisture content from 130-323 kg/m. This has an effect on cost of transport but has shown little effect on lifecycle/carbon use.

  The conclusion formed is that if transporting more than 100-150 miles may justify the cost of briquetting. The extra fuel storage needed is about doubled which in most cases should not be too much of a problem but the reduction of emissions by compressing the fuel requires further investigation which we have not yet been able to carry out.

Biomass bulk Density

	Length (cm)	Diameter (cm)	Inner Diameter (cm)	Mass (g)	Volume (cm3)	Density (kg/m3)	Estimated MC (%)	Density (kg_{dm}/m3)	NCV_{dry} (MJ/kg)	Energy density (when dry) (MJ/m3)	Estimted bulk density (kg_{dm}/m3)	Estimted bulk density (kg_{ar}/m3)
Low density reed briquette (left)	16	8	2.2	341	743	459	5%	436	15.80	6,887	261	275
High density reed briquette (right)	17.5	8	2.2	655	813	806	5%	765	15.80	12,095	459	483
Reed - loose double chop				647	5758	112	65%	40	15.80	627	40	112
Reed - loose precision chop				903	5758	157	65%	55	15.80	875	55	157
Rush - loose double chop				304	5758	53	54%	24	15.59	375	24	53
Rush - loose precision chop				524	5758	91	54%	42	15.59	647	42	91
Wood Chip							30%			3,100	175	250
Wood pellets										11,000		650

Loose biomass mass is average of 3 measurements of mass in a 188mm x 175mm x 175mm box
Loose biomass moisture contents as reported by Sally Mills
Reed from Ham Wall Reedbed Harvesting 5th – 7th August 2014 measured by Sally Mills
Rush from Cranberry Rough harvesting 27th August 2014 measured by Sally Mills
AB systems estimate 5% MC for briquettes
Bulk density of briquettes - based on estimate that 60% of volume is filled with solid briquette

For comparison
Woodchip and woodpellet data from Biomass energy centre website
Straw bales density is in the range of 110-200kg/m3

Lessons Learnt / Future Implications

We will be progressing fuel trials for reed and rush (in both loose and briquetted form) with the assistance of Carbon Limiting Technologies, with the aim of taking briquettes forward to the marketing stage. We also hope to determine if briquettes (or perhaps pellets) are the best form for the reed and rush arisings to be used in. Both Treco and BGI have stated that pelletising the material may be a better way to use it in their boilers, to further reduce particulates.

This obviously has an impact on our business planning and costs, as we do not have a pelletising machine. This is also a different direction to the one we have been following with the briquetting process and would incur further capital business costs - there will also be other implications to be looked at in detail, including training; labour costs and marketability.

3.7 SUMMARY OF ENTIRE SYSTEM

Objectives & Plans

- Demonstrate the end-to-end system at sites in Suffolk and Somerset, inviting attendees from conservation organisations, farming and industry.
- Determine the effect on the ecology system - part of RSPB's monitoring programme.
- Determine 'ownership' of the biomass arisings, so we could further explore the costs of harvesting and briquette production, with a view to commercial viability of the finished briquettes.
- Explore other areas of biomass harvesting – specifically heathlands and grasslands.
- Explore how the end-to-end system could work for different sites.

Methodology

- Plan 'Demonstration Open Days' in the East of England and South West, with the help of Jenni McDonnell from KTN (Knowledge Transfer Network).
- The RSPB to undertake a Monitoring Programme during Phase 3.
- Liaise with Site Managers and other interested parties to resolve 'ownership' of biomass issues, as part of stakeholder meetings for the DEFRA PES project.
- Participate in Heathland Trials in Kent during week in November 2014.

Results

- Demonstration Open Days were held at RSPB Minsmere on 14th & 15th January 2015 and at Somerset Levels on "8th January and 4th February 2015. There were a total of 82 attendees from organisations including nature conservation, landowners, county councils and industry. Following these, we have harvested for 3 new clients who attended the demonstrations.
- Through literature search, we have seen that winter harvesting of reed reduces the emissions compared to summer harvesting and as most landowners require winter harvesting to encourage further growth of the reed, this will be advantageous.
- The monitoring programme undertaken by the RSPB included looking at the effect of harvesting on access sites. It was shown there was little impression on these areas and where ground was affected by the machinery, we took care to put down arisings to stop further damage.

Fig 97 – Boomacre access area (Before)

Fig 98- After (faint track marks visible but no major damage)

Fig 99– Boomacre through gate (Before)

Fig 100- After (track marks & puddling, but area was already wet)

The PistenBully and Softrak have coped well with the difficult wetland terrain during the project, making little impression on the delicate substrates. Having two different sized machines with differing 'chopping' capabilities has given us the flexibility to gain access to all harvesting sites and the ability to cut and collect both reed and rush arisings.

- We used the PistenBully and Softrak at the same time during harvesting exercises, to ensure every terrain and access area could be reached. This also proved useful when the PistenBully got stuck in very wet, boggy terrain in Suffolk – and with a winch fitted to the Softrak, it was easily recovered with no damage to the PistenBully's engine, electrical system or bodywork. Although an unexpected event, this proved that the both machines work well together and also addressed some landowners' concerns that if the PistenBully did actually sink, it would not be able to be recovered.

Fig 101– The winch attached to the Softrak

- We attended two stakeholder meetings to look at the delivery of biomass to bioenergy in the future – specifically how the briquettes can be disseminated to local communities, and exactly who will market and own them.

- Heathland trials held in Kent with AMW, showed that we can produce briquettes from heather, gorse and bracken – and that our harvesting machines also coped well on these areas.

Discussions / Conclusions

- Open Days were received and attended well at both sites. There were several questions raised about 'ownership' of the biomass and the costs incurred for harvesting and briquetting.

- The issue of 'ownership' of the biomass is being looked at with other stakeholders – such as landowners and conservation organisations – as part of the DEFRA PES project with the RSPB.

- The following table shows the potential for collecting further currently under-utilised biomass in the UK – and the potential calorific value when combusted. We could use these figures to further understand the supply of biomass when considering the commercialisation of the briquettes.

Habitat type	Area in the UK (Ha)	Percentage of area cut annually	Ha cut	Tonne per ha	Tonnage per year	Calorific Value for combustion MWh/t
Reedbed	7,700	5%	385	5.5	2,117.50	4
Wet grassland	300,000	50%	150000	2	300,000.00	4
Lowland fen	25,800	10%	2580	9	23,220.00	4
Upland acid grassland	1,200,000	10%	120000	2	240,000.00	4
Mixed heath (gorse, heather & bracken)	95,116	10%	9511.6	3.6	34,241.76	4

- We have considered progressing a kind of local community storage for the briquettes – whereby customers can use an electronic card swipe system to fill a bag of briquettes, for use in their own woodburners.

- We would be interested in working with the other participants for a joined up approach to achieve national targets.

- To address the issue of biomass ownership and the harvesting costs involved, we aim to offer a flexible approach. For example, we can consider all the relevant uses for the harvested biomass to ensure costs can be kept to a minimum.

- Our end to end system is also appropriate for other habitats, including heathlands and fenlands which were trialled during Phase 3. It would now be possible to build on these results and attempt other habitats where biomass is currently harvested and not used for bioenergy production.

Lessons Learnt / Future Implications

- Future delivery of the system is continuing to be developed and we will be focussing on working together with all parties involved in the project – including all stakeholders. We will build on these relationships to take the system to local communities, with the aim of developing community hubs. However, all this can only take place once a plan for biomass ownership is established. We will therefore continue to work closely with the RSPB under the DEFRA PES project.

- The 'liaison' and overall management role performed by Sally Mills during the project, was of great benefit to all parties. Her working knowledge of the environments and organisational needs have assisted all parties to understand the joint goals and challenges along the way. We therefore recommend that a similar role is kept in place for the project to go forward to commercialisation.

- The more we can amalgamate reserves and landowners to perform harvesting, the more cost effective the whole process will be. Having sufficient hectares to harvest will be a key factor for taking the project forward to commercialisation

Section 4 – Technical Analysis: Summary report on Greenhouse Gas (GHG) and Energy Life Cycle Assessment (LCA)

(Compiled By: Jeremy Rix, North Energy Associates Ltd)   Version: 08.04.15

4.1 Introduction

A key requirement for the wetland biomass to bioenergy process is that it should result in positive environmental impact when compared to current wetland management practices. An important aspect of its overall environmental impact is its effect on emissions of GHGs such as carbon dioxide (CO_2).

Currently, typical wetland management practice is for the wetland biomass (e.g. rush and reeds) to be cut by hand or mechanical means and then burned at the side of the wetland area (predominantly reed) or used as animal bedding (predominantly rush). In situations where the biomass is burned, although CO_2 is emitted directly to the atmosphere during the combustion process, an equal amount of CO_2 had previously been absorbed from the atmosphere by the biomass whilst it was growing, so over the life cycle of the biomass, the overall 'direct' CO_2 emissions due to biomass combustion are zero and, hence, these 'biogenic' CO_2 combustion emissions are not included in GHG emissions calculations. However, it needs to be recognised that the harvesting process gives rise to other GHG emissions, such as the emissions from vehicles used to transport tools, equipment and personnel to site. To give a more complete assessment of the overall impact of harvesting, these 'indirect' emissions should also be considered.

Similarly, when considering alternative mechanical harvesting methods, the GHG emissions due to the overall harvesting process should be considered, including the emissions from transporting equipment to site, the operation of equipment, processing and transport of harvested biomass etc. Due to the mechanised nature of such alternative harvesting methods, they are likely to use more fuel than the traditional hand-harvesting methods and, hence, these 'indirect' GHG emissions are likely to be greater. However, the mechanical methods are faster and result in the availability of commercial quantities of harvested biomass that can then be processed further and used as a fuel in domestic, commercial or industrial processes; instead of the biomass being burned at the side of the field and the heat being lost, it can be used as an alternative to other fuels. When the biomass is used in place of other fossil fuels such as natural gas or coal, then GHG emissions 'savings' are made that are equal to the GHG emissions which would have resulted from the displaced fossil fuel.

The purpose of the LCA for GHG emissions is to estimate the extent of the net reduction in GHG emissions due to the use of wetland biomass for bioenergy. This net reduction is given by the equation:

GHG emissions due to the provision of biomass for use as a fuel, including emissions due to harvesting, drying, processing and transport but *excluding* biogenic CO_2 emissions from the combustion of the biomass (since these are deemed part of the natural carbon cycle)

Less

Avoided GHG emissions of fuel displaced by used of biomass for energy

Less

Avoided emissions of conventional management of the harvested wetland.

4.2 Results Summary

Detailed LCA results are given in the Appendix. The results cover 5 main areas:

1. ***The GHG savings compared to conventional wetland management***
2. ***The bioenergy efficiency of the system, equal to the percentage of the biomass energy available that is delivered as useful energy***
3. ***The level of emissions of particulate matter (PM_{10}) and oxides of nitrogen (NOx) compared to conventional wetland management***
4. ***The sensitivity of the results to various factors***
5. ***Measures to improve process efficiency***

1. The GHG savings compared to conventional wetland management and use of fossil fuels to deliver heat.

The net GHG emissions saving compared to the counterfactual situation of traditional wetland management and the burning of coal (rather than biomass/briquettes) to provide heat was 92.2%. This significant saving reflects the fact that the emissions associated with the harvesting, processing and transport of the biomass are small compared to avoided emissions from not having to burn coal. Sensitivity analysis indicated that the emissions savings compared to other fossil fuels was as follows: natural gas–84.8%, oil–89%, LPG-87.5%.

2. *The bioenergy efficiency of the system*

The bioenergy efficiency of the system is given by the percentage of the energy contained within the biomass 'in the field' prior to harvesting that is delivered to an 'end-use' such as heating. The bioenergy efficiency achieved was 59.4%, with the most significant loss of bioenergy occurring within the final combustion of the briquettes or loose biomass in biomass boilers.

3. The level of emissions of particulate matter (PM_{10}) and oxides of nitrogen (NOx) compared to conventional wetland management

The results indicate that PM_{10} emissions are approximately 55% greater for the bioenergy process than for the counterfactual situation. Reasons for this include:

- The fact that tests indicate that PM_{10} emissions per unit of delivered heat from burning biomass in boilers and stoves are generally significantly higher than for the combustion of conventional fuels;

- The wetland management counterfactual for rush, which constitutes approximately 30% of the harvested biomass, does not involve the combustion of biomass;
- It is extremely difficult to estimate the PM_{10} emissions for the reed wetland management counterfactual which involves burning of reeds “in the field”. Not only do the emissions depend on the particular combustion conditions (biomass moisture content, burning arrangements such as size and density of the gathered reed, wind speed etc) but also the availability of data is limited as open field burning PM_{10} emission measurement is costly and complicated. PM_{10} emissions reported in the detailed results were estimated using published emissions factors for open field burning of grassland.

The approximate nature of the result reinforces the importance of obtaining more accurate PM_{10} emissions factors by conducting emissions tests for traditional wetland biomass management involving ‘in the field’ burning of biomass.

The results for emissions of NOx indicate that these are approximately 35% lower for the bioenergy process than for the counterfactual situation. However, as for the PM_{10} emissions, the estimate of NOx emissions for ‘in the field’ burning of biomass is subject to significant uncertainty due to the limited emissions factor data available.

4. The sensitivity of the results to various factors

Results for sensitivity analysis are summarised below. Note that the increase or decrease refers to the level of emissions savings, not to the level of emissions.

Sensitivity to increase in parameter: / **Parameter**	**GHG emissions savings**	**Net primary energy savings**	**Net PM_{10} emissions savings**	**Net NOx emission s savings**
yield of reed	Low increase	Low increase	Medium increase	Low decrease
moisture content of reed	Very low	Very low	Very low	Very low
gross calorific value of reed	Medium increase	Medium increase	High decrease	High decrease
distance for transporting harvesting equipment between sites	Very low	Very low	Very low	Very low
choice of counterfactual heating fuel	Low	Low	High	High

It can be seen that PM_{10} particulate and NOx emissions savings are more sensitive to variations in the selected parameters than GHG emissions and primary energy savings. The results should be interpreted in the context of the use of generalised emissions factors for the calculation of PM_{10} and NOx emissions, including emissions factors based open field burning of grassland.

5. Measures to improve process efficiency

Process efficiency can best be improved by the improvement in production rates, such as mass harvested per day or briquettes produced per day, leading to a decrease in fossil fuel consumption per unit mass of harvested biomass. Improvements in compression techniques for loose biomass would also assist with decreasing the fuel required for transport to point of use.

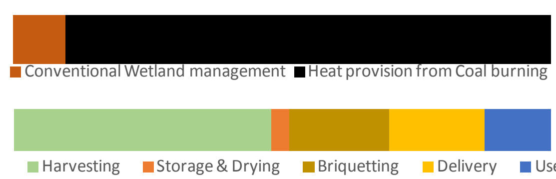
Specific measures could include:
Improved detailed knowledge of harvesting sites, especially the existence of harvest impediments such as ditches, pools, tree stumps etc. – possibly through links to Geographical Information Systems and the use of satellite technology;

- Harvesting of larger contiguous areas;
- Development of access points along the side of wetland areas to reduce in-field haulage distances;
- Development of efficient compression techniques and technologies for transport of loose biomass;
- Improvements to briquetter production rates though experimentation with feedstock chop size, moisture content, mix of biomass types etc.

Fig 102 – Table showing GHG savings

	kg eq. CO2/MJ	**Annual GHG emissions (kgeq CO2/a)**
Harvesting	0.00573484	367,313
Storage & Drying	0.000421003	26,965
Briquetting	0.002209763	141,534
Delivery	0.002138943	136,998
Use	0.00145572	93,238
Total	**0.01196027**	**766,048**
Avoided Emissions		
Conventional Wetland management	0.014883576	953,284
Heat provision from Coal burning	0.137801935	8,826,130
Total	**0.152685511**	**9,779,414**
Saving	*92%*	
Annual Delivered heat output MJ	64,049,391	

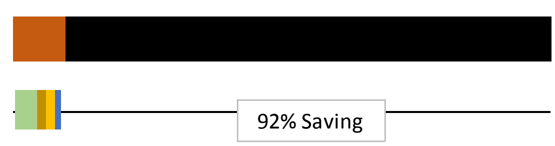
Breakdown of Emissions for Counterfactual and Process



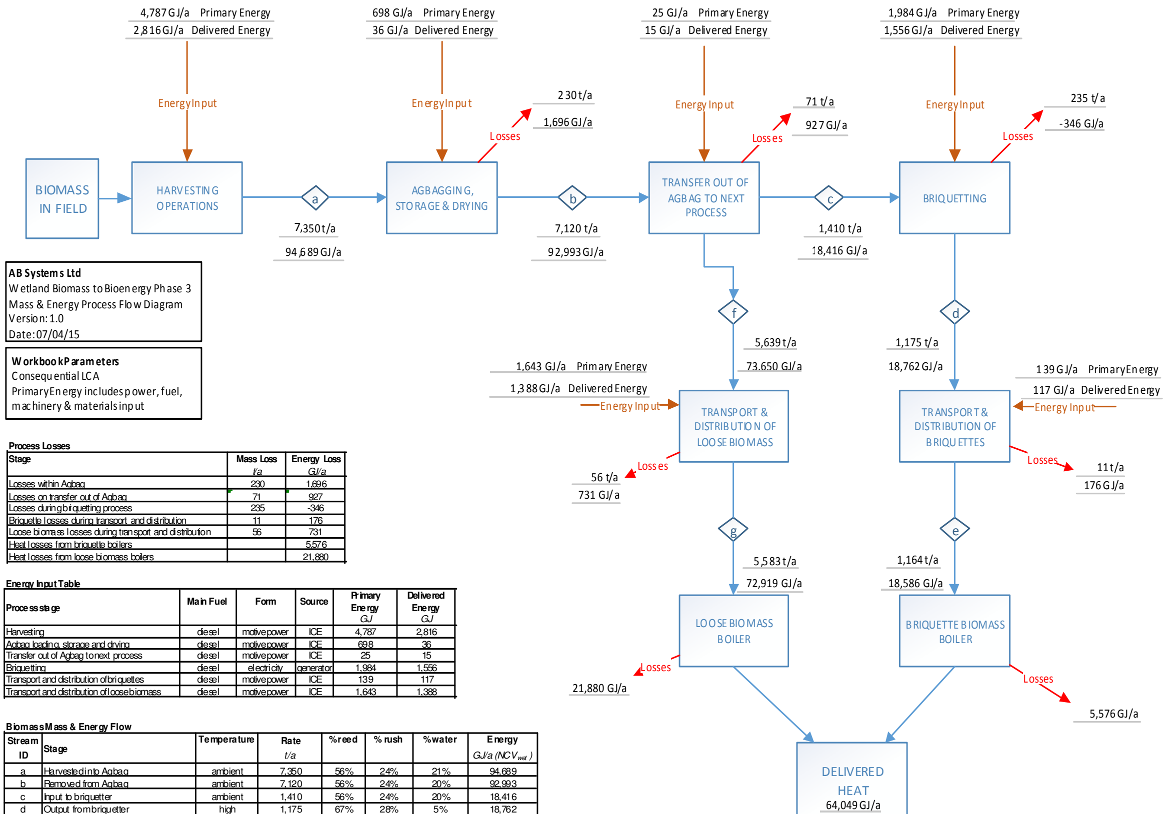
Results table from Phase 3 Final report

Contribution	Annual Greenhouse Gas Emissions (kg eq. CO_2/a)
	Phase 3 (Final)
Transportation of Equipment to Wetland Site	687
Biosecurity Steam Cleaning	350
Harvesting of Reed	231,507
Harvesting of Soft Rush	134,769
Biomass Storage in Agbags and	26,965
Briquetting	141,534
Briquette and Loose Biomass Distribution[c]	136,998
Briquette and Loose Biomass Combustion[c, d]	93,238
Sub-Totals for Emissions	*766,048*
Conventional Wetland Management (harvest counterfactual)	953,284
Coal-fired Heating (briquette + loose biomass counterfactual)	8,826,130
Sub-Totals for Avoided Emissions	*9,779,214*
Emissions Savings (avoided emissions - emissions)	**9,013,367**
Net Greenhouse Gas Emissions Saving	**92.17%**

Relative Emissions (approx scale)



6. Process Flow Diagram



AB Systems Ltd
Wetland Biomass to Bioenergy Phase 3
Mass & Energy Process Flow Diagram
Version: 1.0
Date: 07/04/15

Workbook Parameters
Consequential LCA
Primary Energy includes power, fuel, machinery & materials input

Process Losses

Stage	Mass Loss *t/a*	Energy Loss *GJ/a*
Losses within Agbag	230	1,696
Losses on transfer out of Agbag	71	927
Losses during briquetting process	235	-346
Briquette losses during transport and distribution	11	176
Loose biomass losses during transport and distribution	56	731
Heat losses from briquette boilers		5,576
Heat losses from loose biomass boilers		21,880

Energy Input Table

Process stage	Main Fuel	Form	Source	Primary Energy *GJ*	Delivered Energy *GJ*
Harvesting	diesel	motive power	ICE	4,787	2,816
Agbag loading, storage and drying	diesel	motive power	ICE	698	36
Transfer out of Agbag to next process	diesel	motive power	ICE	25	15
Briquetting	diesel	electricity	generator	1,984	1,556
Transport and distribution of briquettes	diesel	motive power	ICE	139	117
Transport and distribution of loose biomass	diesel	motive power	ICE	1,643	1,388

Biomass Mass & Energy Flow

Stream ID	Stage	Temperature	Rate *t/a*	%reed	% rush	%water	Energy *GJ/a (NCV_{wet})*
a	Harvested into Agbag	ambient	7,350	56%	24%	21%	94,689
b	Removed from Agbag	ambient	7,120	56%	24%	20%	92,993
c	Input to briquetter	ambient	1,410	56%	24%	20%	18,416
d	Output from briquetter	high	1,175	67%	28%	5%	18,762
e	Input to briquette boiler	ambient	1,164	67%	28%	5%	18,586
f	Input to loose biomass distribution	ambient	5,639	56%	24%	20%	73,650
g	Input to loose biomass boilers	ambient	5,583	56%	24%	20%	72,919

Section 5 – Business Plan

5.1 SUMMARY

Our plan is to provide a complete end-to-end biomass to bioenergy system that can be used by a wide range of land managers. This will include a specialist harvesting service for wetland areas specifically, but also other habitats such as grassland and heathland.

We will continue to offer AgBag storage facility to store biomass of all types, whether for drying or use in anaerobic digestion (AD). So enabling the landowner to maintain the value of their feedstock for example by ensuring there is no reduction of calorific value.

We will offer service to bring the biomass to market this could be through the harvesting of biomass in a loose form to local biomass boiler owners (schools; hospitals, etc) or as feedstock to local AD plants. We will also offer a briquetting service, to either provide the biomass owner with a finished product; or market the finished briquettes ourselves.

We will also look at hiring out our machines as a potential income source for a range of applications.

5.2 PRODUCTS & SERVICES

5.2.1 What are you going to sell?

- Specialist harvesting service (e.g. wetland / grassland / heathland habitats)
- Biomass storage and drying (the AgBag system)
    - Facilitates continuity of supply
    - Flexibility to deal with peak production times
    - Optimises biomass utilisation
- Hire out harvesting equipment for a range of applications, e.g.
    - Moving of materials over soft ground
    - Estate maintenance on soft ground
    - Restoration/creation of wetland habitats
- Biomass utilisation service
    - Loose dry biomass for combustion
    - Feedstock to AD plants
    - The marketing of briquettes
    - Briquettes for retail consumption
- Hire of briquetter machine

5.3 THE MARKET

5.3.1 Customers:

- Nature reserve managers; farmers and/or landowners, e.g. water companies.
- AD plants.
- Storage facility for any landowner with loose biomass.
- Biomass boiler and log burner owners, specifically, RSPB and other nature reserve members / shoppers.
- Local community energy groups.

5.3.2 Where are your customers based?

For our existing business our customers are based nationally, as we are the UK importers of the AgBag system. This has provided a good foundation for our bioenergy business providing us with the logistically capability to travel anywhere throughout the UK. In addition we are prepared to travel throughout Europe to offer our services.

5.3.3 What prompts your customers to buy your product/service?

We have established an excellent reputation through our Agbag business and new custom is gained through advertising but more commonly through word of mouth through existing clients. We operate in a niche market, there aren't any other companies which offer the services we provide and at a competitive price. This is the philosophy we have adopted for our bioenergy work and to date it is proving to be successful.

In addition we advertise on our facebook page and our website www.agbag.co.uk which is currently being redesigned to accommodate for our range of new services.

We offer an innovative way to use natural biomass that would otherwise be burnt or discarded through conversion into an energy product, which can help reduce fossil fuel use and help offset costs.

We offer a specialist approach, such as adapted harvesting machinery and storage capabilities to maximise the return of the management work undertaken. We can provide a portfolio of techniques to enable efficient and effective management of challenging habitats.

Our service is a complete biomass to bioenergy end-to-end system, which is energy efficient.

5.3.4 Have you sold products/services to customers already?

Since the start of the project we have gained 8 new customers who have all used our low ground pressure harvesters. In addition to sites throughout the UK we have travelled to Southern Ireland with the both the Softrak and PistenBulley to undertake the harvesting of reed and rush areas.

5.3.5 Have you got customers waiting to buy your product/service?

We have a potential list of 17 customers on our books requiring specialist harvesting for this coming year.

5.4 MARKET RESEARCH

We have been involved and interested in the bioenergy sector for over 30 years, which has provide a wide knowledge base on which build. We currently see that the priority for our market research work is to focus on biomass utilisation. We are working with Carbon Limiting Technology (CLT) on this to assist with our commercialisation particularly focusing on boilers and RHI accreditation; this work is due to conclude during 2015.

We will continue to talk to wholesalers to discuss the sale of briquettes, whilst talking with the land managers/owners to make sure we are able to provide the service required.

To increase our knowledge of our potential customers requirements we are attending a number of national and international conferences, focused on biomass utilisation, to exchange ideas and experience, but also to raise awareness of the services we offer.

5.5 MARKETING STRATEGY

Development of our marketing strategy is part of the work that we are currently doing with CLT; this is specifically focused on our bioenergy business. However through our established business we are already developing our marketing approach to accommodate our new services. E.g.

- We will advertise on our website www.agbag.co.uk which is currently being redesigned.
- We will use our facebook page Agbag / AB Systems Ltd to reach new audiences outside our existing contacts.

We will have open days at our existing harvesting sites to compliment the ones we currently hold for the agbagging side of our business and will attend various annual shows, such as:

- Cereals 2016 - a large stand in the Renewables section.
- Agricultural Contractors Association annual conference.
- ADBA annual conference.
- Attendance at Agritechnica and exhibiting with Bag Budissa

These provide opportunities for meeting new clients, marketing and market research.

5.6 UNIQUE SELLING POINTS (USPs)

We have the following USPs:

1. The reputation and work ethic of our family business.
2. Specially adapted machinery for harvesting previously under-utilised biomass on wetlands.
3. We are already the UK's main dealer for the AgBag System – a flexible, sealed storage system for storing and drying down material.
4. We are developing sustainable biomass drying methods – keeping the carbon footprint to a minimum.
5. Environmentally friendly briquettes made from material harvested from nature reserves.
6. Offering an end-to-end system, which has a carbon efficient life cycle analysis.

5.7 OPERATIONS & LOGISTICS

5.7.1 Production:

With the assistance from the DECC funding we have managed to improve the efficiency our service:

- We have been able to build up a very significant fleet of wetland harvesting supplies and equipment, which have significantly increased the speed of harvesting and therefore reduced the cost.
- We have been able to adapt our existing logistics capabilities to assist with the diversification.

- We are able to offer a range of services, e.g. harvesting and storage, which compliment each other.
- We have improved the exchange of information prior to each operation which has greatly assisted our production rates.
- We have implemented of methods of working, such as job completion forms, to assist with smooth on site operation.
- We are looking to find ways to improve our efficiency to deliver labour intensive aspects of our system such as briquetting, which has been shown to be required to make this a cost effective proposition.
- We are always looking for ways to reduce the processing and handling of material to increase our efficiency rates.

5.7.2 Delivery to customers:

We see local delivery to be easily achieved through our existing distributors. In addition to this we have made links with local logistics companies that could provide a nationwide service for the distribution of briquettes both cost effectively and as carbon efficient as possible.

We are also exploring the development of self-service systems, to enable local collection of briquettes and other products required within the community. This could take on the form of a swipe card system that is operated and regulated by weight.

5.7.3 Payment methods and terms:

We are able to handle all methods of payment, although our preference would be via bank transfer. Our payment terms are for invoices to be satisfied by the 14th of the month following the invoice date.

5.7.4 Suppliers:

We have a well-established supply chain, which we have secured over the last 25 years and we are continually looking to build relationships with new suppliers.

5.7.5 Premises:

We have large farm premises, which provide us with the ability to store products and equipment securely**.** In addition we have workshop facilities that enable us to continue to maintain and develop our wide range of equipment. Our office premises are sited 4 miles away and provide space for 4 employees.

5.7.6 Equipment

		If being bought	
Item required	**Already owned?**	**New or second hand?**	**Purchased from**

PistenBully 300 Green Tech	No	Second hand	Kassbohrer Gelandefahrzeug AG
Softrak 120 ATV	No	New	Loglogic
Morooka Tracked Dumper	No	Second hand	A&A Garden Care
ADP145c Cummins Generator	No	New	Simply Generators
Kemper Champion 3000	No	Second hand	EM TIJS Occasions
ELHO DC 1700 Double-chop Forage Harvester	No	New	Loglogic
Loglogic powered Tracked Trailer	No	New	Loglogic
2011 Tajfun 8T PTO Winch	No	Second hand	Brown & Co
Fenland Harvester	No	Second hand	Broads Authority
Wetland Harvester & Blower	No	Second hand	Broads Authority
JCB Telehandler	No	Second hand	John Lake Tractors
Grain drier	No	New	J & S Anderson Ltd
Satellite Navigation	No	New	A S Communications
Biomass Boiler – Guntamtic Powerchip	No	New	Treco
Bespoke Briquetting Factory BM6 Biomasser	No	New	Smartech
Biomass Briquetting Machine	No	Second hand	C J M Auction site
Solar panels\fans	No	New	Solargen
Curtain sider trailer	No	Second hand	ATG
Agbagger 8000	Yes		Agbag Europe PLC
Low Loader CO13230	Yes		
Low Loader C322180	Yes		
Low Loader CO27095	Yes		
Scania Artic Unit	Yes		
Volvo Artic Unit	Yes		
Volvo Artic Unit	Yes		

Smart Car Saab Ford Pick Up	Yes Yes Yes		

5.7.7 Transport

- Fleet of three HGV low loaders (used to transport our ag-baggers)
- Two vans
- One 4x4 pickup
- Two smart cars used in conjunction the low loaders
- Five fleet vehicles
- Two telehandler forklift trucks

5.7.8 Legal requirements:

Through the operation of our existing, successful business in a similar industry we have health & safety policies and procedures, risk assessments and method statements for works in place, which are continually reviewed and updated.

5.7.9 Insurance requirements:

We have Product and Full Commercial Combined Liability cover up to £10,000,000.

5.7.10 Management and staff:

Our staffing structure is as follows:

- 3 Directors (one of whom is our Operations Director).
- 3 Operators.
- 2 Office based staff.
- Seasonal operational staff as required

5.8 PROCESS COST ANALYSIS

From the discounted cash flow analysis we are able to make the following fuel cost comparisons:

Fuel type	Cost per GJ
Biomass briquettes	£5.17
Coal	£11.58[3]
Wind power onshore	£16.62
Solar power utility	£24.93

[3] Based on the £279 per tonne of coal