Hej Harvester

Biomass Feedstock Innovation
Phase 1 Report

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1. Technical Description of The Hej Harvester Innovation

1.1 Introduction to Hej Harvester

Agricultural hedges in the UK could produce a large amount of Biomass every year, however, this is currently discarded and left to rot, block drains, cause punctures and get stuck in the feet of livestock. In response to this in 2016 I started on the journey of trying to come up with a successful and robust process that would allow agricultural hedges to be harvested in an efficient way that would allow the Biomass to be collected in uniform size pieces that could then enter the Biomass supply chain.

1.2 The Brief

Cut agricultural hedges in a more sensitive way as opposed to the current system of using a flail hedge cutter as the hedge is left badly damaged which slows re-growth in the spring. Photographs below to demonstrate existing method:

Figure 1: Commonly used hedge cutting machinery in operation

Figure 2: Badly damaged hedge branches after cutting

i. Design a hedge harvesting machine that would do two operations in one process:

- Cut the hedge in a sensitive way.
- Cut the hedge into uniform sized pieces at the cutting head then collecting the parts in the same process thus producing ready to burn biomass without the need for any other downstream processing operations.

ii. Design a hedge harvesting machine that is rugged, robust and can be manufactured in a way that makes it commercially viable to produce so it can be sold at a price point that meets market expectations.

iii. Design a hedge harvesting machine that is energy efficient, operates at an acceptable forward speed and can be serviced and maintained easily whilst out in the field to reduce downtime during the harvesting season.

iv. Design a harvesting head that can be manufactured in full operational size within the weight limit dictated by the loadings required for a tractor and power arm to operate within safety margins at full reach.

1.3 The Design Challenge

This has been a very challenging brief and the design process has been in the making over a 6-year gestation period and which has been accelerated and bought to fruition by the support of BEIS in Phase 1 of the Biomass Feedstock Innovation Programme.

Figure 3: Small scale harvesting head and collection system mounted to tractor

Fundamentally it is based on the concept of cutting with a pair of secateurs as this is proven and requires a low energy input and most importantly gives a clean cut which promotes early re-growth. This cutting concept was taken and incorporated in the design in the form of specialised cutters. These cutters are manufactured out of 4mm stainless steel and are mounted onto hubs in two pieces allowing for easy replacement in the field. The cutters are in turn driven by a proven hydraulic motor and carbon drive belts which are exceptionally tough and reliable. The main housing is manufactured from steel in thicknesses that are calculated to exceed any loading exerted in the most extreme circumstances. Stainless steel was used for the collector housing and covers to reduce weight.

2. Contribution to Increasing the UK's Sustainable Biomass Supply

2.1 Introduction

There are an estimated 500,000 miles of agricultural hedges currently in the UK and at the end of World War 2 this figure was closer to 1m miles. Since World War 2 there has been a trend of hedge removal which continues albeit at a much-reduced annual rate these days. The reason for this is that farmers and landowners have been keen to increase field sizes for economies of scale and reduce the annual financial burden of having to pay to cut the hedges with absolutely zero benefit. So historically agricultural hedges have been viewed as a cost negative asset that has been the driving force for the 77-year trend of hedge removal and a large percentage of existing hedgerows are in poor condition as they are cut very short and hard with the conventional flail hedge cutting system.

2.2 Project Reasoning

Six years ago having lived on a farm and paying to have an agricultural contractor cut our hedges which just discards to crop to rot, block up ditches and drains, cause a hazard on roads and the discarded crop getting stuck in livestock’s feet I embarked on a journey to find a way of harvesting agricultural hedges in a sensitive way that allowed the crop to be collected in the same operation so it could then enter the Biomass supply chain.

2.3 Harvest Projections

Based on trials undertaken it would seem that harvesting agricultural hedges could produce a significant amount of Biomass that could enter the UKs Biomass supply chain.

2.4 Crop Benefits

As well as turning a perceived negative farm asset into a perceived positive farm asset the existing wholly negative operation of trimming hedges using a flail hedge cutter would be turned into a positive commercial operation much like harvesting any other agricultural crop i.e. wheat, potatoes, apples etc. As agricultural hedgerows are an existing resource there is no investment required or allocation of land to be taken away from food production.

3. Wider Environmental Benefits

3.1 Introduction

As previously mentioned there are currently estimated to be circa 500,000 miles of agricultural hedges in the UK alone and a significant percentage of these hedges are badly managed, primarily as they are not valued. Please see Figure 4 as a representative photograph of a poorly managed hedge.

Figure 4: A section of poorly managed hedge

3.2 Improved Management Effects

As a result of the new approach, agricultural hedges will start to be viewed as a valuable farm asset and will thus be maintained in a much more sympathetic way that maximises yields by maintaining them at a healthy size and harvesting them every 2-3 years with a much more sensitive cutting method. This will mean that the UKs hedgerow stock will start to see a transformation in the way that it is valued and managed. In turn, improved management will be transformative for biodiversity in all its forms as 500,000 miles of well managed and healthy hedgerows that are harvested every 2-3 years will provide an environment that will support many bird and insect species. See Figure 5 for a healthy and well managed hedge

Figure 5: A section of a healthy and well managed hedge

3.3 Environmental Land Management scheme

In addition to this there would be incentive for farmers and landowners to plant new hedgerows on the basis that they will boost on farm Biomass production which again will further boost biodiversity.

Another factor for consideration is that Single Farm Payments are being phased out in the next 5 years. I believe they are being replaced by the Environmental Land Management Scheme that rewards farmers and landowners for environmental improvements. As part of this I expect planting new hedgerows will form part of the environmental options that farmers and landowners can opt for which combined with the opportunity to harvest agricultural hedges to produce biomass would likely galvanise farmers and landowners to plant new hedges wherever they can. Thus, the new Environmental Land Management Scheme could also be a major factor in further increasing the UKs capacity for Hedge Biomass production.

3.4 Environmental Risks

All work to date hasn't flagged up any potential environmental risks.

3.5 Carbon Dioxide Life Cycle Assessment

Life Cycle Assessment has been undertaken based on the conceptual operating cycle of new and innovative mechanical hedge cutting technology. The purpose of the assessment was to compare overall carbon footprint associated with current hedgerow cutting practices with the new technology approach. This systems-wide appraisal seeks to evaluate the overall impact of change, along with identifying primary contributing factors.

The baseline scenario allowed for hedge flailing resulting in organic matter being left in situ for natural decomposition in an uncontrolled, and un-utilised manner. Decomposition processes result in the release of carbon to the atmosphere in the form of carbon dioxide (CO_2) and methane (CH_4). Hedge flailing is an aggressive mechanical technique that tends to shatter and splinter branches, rather than cleanly cutting the end. This can inflict damage to plants, affecting their regrowth; this impact has not been assessed within the scope of this assessment. The Hej Harvester approach seeks to cut back hedgerows with a cleaner cut whilst simultaneously chipping and collecting the cut biomass. The cut material is intended to be used as a biofuel for the purpose of generating heat, replacing fossil fuel usage.

The results have been evaluated in the context of tonnes CO_2 equivalent (CO_{2e}) and standardised to CO_{2e} / km hedge cut, based on the cut biomass yield rate (kg / km) provided by Hej Harvester in relation to a sample cut. The results from the assessment indicate that overall carbon emissions from the Hej Harvester system will be approximately 22% lower than current practice. This value reflects that combustion of biomass does release CO_2 and other atmospheric pollutants that contribute to climate change. The majority of this saving is attributed to eliminating carbon emissions from the biomass decomposition phase of the current practice. It is noted that direct carbon emissions from combustion of biomass were calculated to increase by approximately 24%. Should combustion of biomass be considered to be net zero in carbon emission, the system-wide carbon intensity (tonnes CO_{2e} / km) would reduce by approximately 97%.

Figure 6: Baseline – Hedge Flailing, Biomass in situ Decomposition; Heat Energy from Fossil Fuel Source

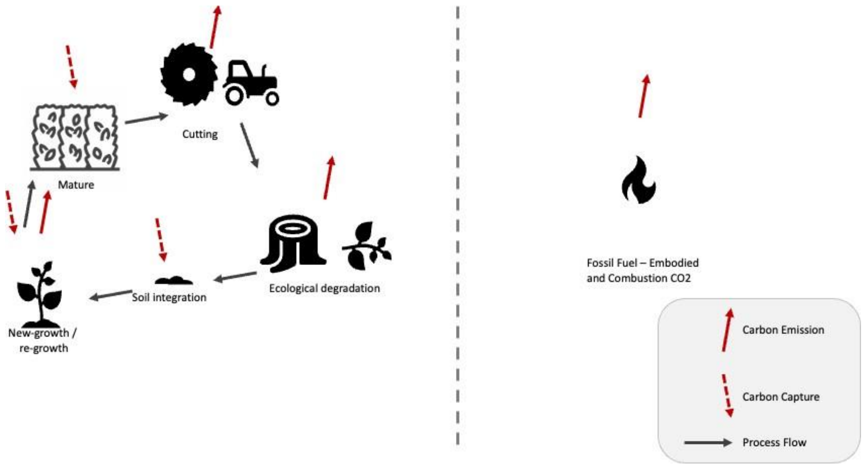


Figure 7: Hej Harvester – Hedge Cutting, Biomass Collection, and Chipping Ready for Biofuel; Heat Energy from Biofuel Source

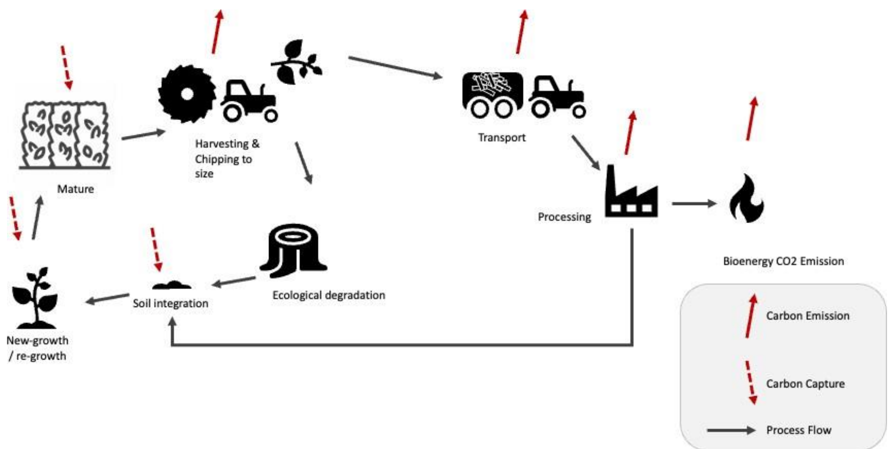


Table 1: Notable Parameters in or Out of Scope of Assessment

Topic	In Scope	Out of Scope
Tractor unit	Fuel used to power tractor and Power Take- off Unit	Fuel to travel from base location (i.e. farm) to cutting location Power load from PTU assumed to be same for all scenarios, therefore no allowance for variation
Biological degradation of cut biomass	Carbon degradation over 3year cutting cycle assumed to release CO_2 to atmosphere; remainingorganic matter integrated into soils. 100% harvested biomass assumed to be become fuel	No allowance for carbon uptake rate associated with hedgerow recovery (i.e. would more sensitive cutting result in less plant stress and quicker regrowth, and CO_2 uptake?)
Transportation of fuel	Emissions for transporting biomass; includes Well-to-Tank and Tank-to-Wheel component of fuel used in transport	-
	Emissions associated with production and transporting (i.e. well to tank) equivalent kWh of fuel oil for generating heat	
Fuel for generating heat Cut biomass will be chipped within the Hej Harvester, and will be transported, by road, to a location for burning. Calorific value of wood harvested determines quantity of conventional fossil fuel consumed	Cut biomass considered as wood chip, Biomass considered as both Net Zero fuel, and “outside of scope” emission intensity Direct emission (“tank to wheel”) of equivalent kWh of fuel oil for generating heat	No additional drying or mechanical treatment of biomass

Table 2: Results from life cycle assessment

	Description	Unit	Baseline (Flailing) - InScope Emissions	Hej Harvester - In Scope Emissions	Hej Harvester - Outside of Scope Emissions
Total (Tonnes)	CO2 Emission cuttinghedge	t CO2e / km	0.01	0.01	0.01
	Decomposition CO2emission rate	t CO2 / km / 3year cut cycle	5.14	0.00	0.00
	CO2 Emission movingfuel	t CO2e / km	0.01	0.02	0.02
	CO2 emission burning Fuel	t CO2e / km	8.62	0.46	10.69
	Total CO2 Emission	t / km	**13.78**	**0.49**	**10.72**
Total	CO2 Emission cuttinghedge	%	0%	3%	0%
	Decomposition CO2emission rate	load	37%	0%	0%
	CO2 Emission movingfuel	0	0%	4%	0%
	CO2 emission burning Fuel	t CO2e / km	63%	93%	100%
	Total CO2 Emission	t / km	**100%**	**100%**	**100%**
	Reduction from Baseline	%	**-**	**96%**	**22%**

4. Risks and Risk Management

4.1 Introduction

The background to this technology is the opportunity to harvest agricultural hedges to produce a Biomass crop. The objective of Phase 1 was to prove that our outline design concept for carrying out this operation achieved all our pre-determined objectives. Throughout the Phase 1 process the development team focused on design and development with a high degree of technology readiness i.e. it was critical that the harvesting head that was designed and produced could both achieve the performance criteria but also when scaled up can be manufactured in a commercially viable way thus ensuring that the final harvesting head could be produced at a price point that would be aligned with market expectations.

4.2 Risks of Scale

The innovation revolves around a totally new concept for cutting agricultural hedges so there will of course be areas of risk when faced with scaling up the design from a small-scale prototype to a production ready robust machine that meets demanding performance and longevity requirements.

The prototype produced as part of Phase 1 proves the basic concept and its robustness in field trials and as previously mentioned scalability was a key part of the outline design parameters of the small-scale prototype that was produced in Phase 1.
The risks associated with scaling up the existing design to a commercially viable harvesting head are to be able to produce the full-sized harvesting head at a weight that will be compliant with the maximum overall weight as the harvesting head operates on a power arm at a distance from the tractor. To mitigate this risk, we will work with modern composites within the design wherever possible where they will meet the strength requirements of conventional steel but at a fraction of the weight.

4.3 Operating Speed

Small risk relates to operation speed, from the outset it was a key objective that this harvesting head would be able to operate at a harvesting speed 50% faster than a conventional flail hedge cutter as this will reduce operating costs and efficiency, as part of Phase 2 this would form a key part of the updated design process.

4.4 Biomass Combustion Properties

Establishing the optimum way to handle and burn the Biomass to give optimum energy yields is work that has to be completed as part of Phase 2, initial feedback is that the sample cuttings come off hedges with a much lower moisture content although to date no trials have been undertaken in terms of processing and burning hedge Biomass in existing Biomass boilers to assess energy yields per ton and optimising flu gas produced. There is obviously some risk here but this is mitigated with the option of being able to mix hedge Biomass with existing forms of Biomass if it proves that burning it on its own doesn’t generate sufficient energy per ton for existing Biomass boilers to run efficiently.

5. Commercialisation Plan

5.1 Introduction

Understanding and appreciating the scale of the potential UK and overseas market for harvesting agricultural hedges for Biomass production has been the driving force behind this innovation which started nearly 6 years ago as an embryonic idea. The UK alone has an estimated 500,000 miles of agricultural hedges that are capable of producing a considerable amount of Biomass every year and the global potential is colossal. So, as well as the significant contribution this innovation could make to the global Biomass supply chain it would also require a significant manufacturing organisation to manufacture, distribute and maintain the Hedge Harvesting machinery on a global basis.

5.2 Project Viability

As part of Phase 1 I have gleaned lots of data about both the potential outputs of hedge Biomass but also having spoken to many operators in the supply chain I have gained an understanding of how the hedge Biomass would be handled, distributed and processed together with ideas of commercial values of the hedge Biomass that would be produced which of course underpins the whole project viability. As I work through Phase 2 I will gain far more detailed information about every commercial aspect of the project from more accurate outputs of Biomass that can be achieved from a range of hedge types, the realistic operating parameters of the scaled-up pre-production machine that will be produced as part of Phase 2 together with how best the hedge Biomass will be processed and fit into the existing Biomass supply chains.

5.3 Rollout Proposal

I anticipate that to achieve the fastest rollout of the Hedge Harvesting machine at the end of Phase 2 the following would be factors for consideration although until Phase 2 is completed these are just proposals:

i. Source funding and set up a manufacturing plant in the UK to manufacture and distribute hedge harvesting machines either independently or tie up with an existing agricultural distribution business who have routes to market in both the UK and overseas.
ii. Tie up with an existing manufacturer with routes to market in the UK and overseas.

5.4 Projected Sales

In terms of promotion, normal marketing channels would be used and with the clear benefits the new system offers combined with the design meeting a commercial price point that aligns with market expectations, I would anticipate gaining significant market share in the first five years of manufacture of the Hedge Harvesting Machine.

6. Project Management

6.1 Introduction

I have had 37 years' experience in predicting market opportunities, developing products and processes. This started in 1986 when working with my father and brother I started developing and manufacturing a unique external door composite design, this went into become the industry standard that is used today and the company that was founded to produce this product is still in business 36 years later - Permadoor.

Moving forwards with my brother I helped develop a new way of protecting fence posts, gate posts, telecoms and utility poles from ground rot, this product was launched in 1994 and has been in production since serving global markets Postsaver & Polesaver. More recently again with my brother we developed an insert that fits in fuel can spouts that prevents over-filling and explosions when filling power tools with fuel, we have been manufacturing this product since 2009 -Fill and Stop. Thus, my skills evolve around project management, product development and commercialisation of such innovations.

6.2 Partnerships

For the Hedge Harvesting project, I am mindful that specialised external expertise will be required to focus on the design and development of the pre-production hedge harvesting machine. For stage 2 development, design and scaling up the size of the harvesting head I would plan to continue working with Wheatway Solutions who are proven specialists in this field. Colin Smith the owner and Managing Director is an extremely creative forward thinker and his input has been at the heart of the working prototype that was produced in Phase 1.

6.3 Power Arm Production

For the power arm design and hydraulic control systems I would look to work with an existing manufacturers of power arms such as Mc Connel who I have been in contact with, if not Mc Connel then I would approach other UK based power arm specialists in the UK.

If for any reason such companies are not keen to get involved then I am confident that Wheatway Solutions would have the capacity and ability to undertake these aspects of the project and they have already said that they would be prepared to engage specialist staff to fill any skills gaps within their existing organisation.

6.4 Tractor Mounted Hopper

For the tractor mounted hopper, we would design this in conjunction with Wheatway Solutions.

6.5 Biomass Handling

For equipment to handle and process the Hedge Biomass I would look to work with existing UK specialists.

7. Timelines for Deliverables Including Milestones

7.1 Introduction

Below is a Gantt chart which clearly outlines the deliverables that will form Phase 2 (see figure 9). The key milestones for Phase 2 will be:

1. Design and produce a full-sized harvesting head (production ready) by quarter 4 2023.
2. Produce a pre-production hedge harvesting machine by quarter 3 2024.

Throughout I have tried to keep everything simple and straight forwards which is how I work to achieve given milestones and deliverables. My approach is results based and based on delivering the itemised deliverables under budget and on time. From my perspective there is a great incentive to accelerate deliverables as getting to the stage where there is a proven pre-production prototype ready to go to manufacture and be marketed and distributed is my sole priority as every day during the harvesting season thousands of tons of Hedge Biomass are being left on the ground to rot.

7.2 Achievements to Date

I have proven in Phase 1 that within a short period of time I have taken an outline design idea to a small-scale prototype that works.

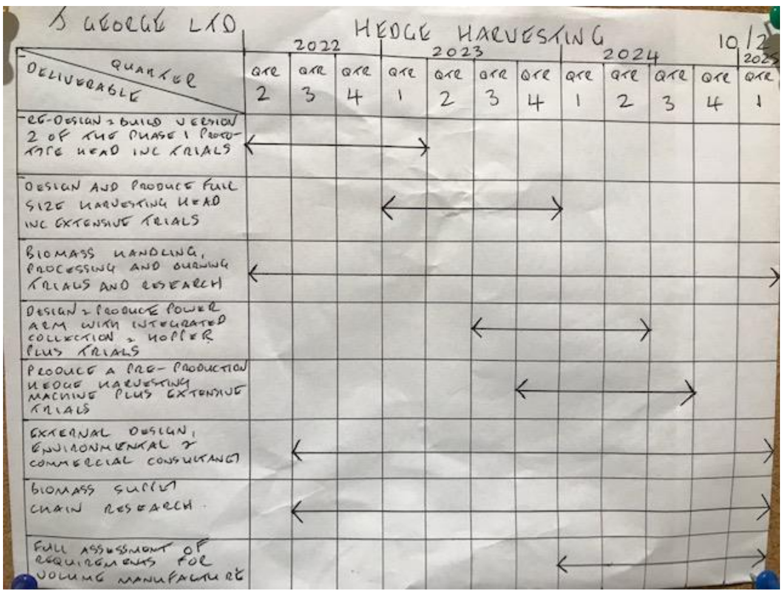
7.3 Project Aims

This projects aim is to make hedge harvesting a standard practice in the UK and overseas markets both dramatically boosting the UKs Biomass supply chain but also establishing volume manufacturing in the UK of hedge harvesting machines for both sale in the UK and overseas markets.

7.4 Expenditure Risk Mitigation

In terms of risks my approach as it was in Phase 1 is to stagger expenditure based on key milestones being achieved so as an example if we come across a major design issue with scaling up of the harvesting head to a full commercial specification, I wouldn't have committed expenditure in other areas until this milestone had been achieved and thus ensure that BEIS funds were spent very prudently throughout Phase 2.

Figure 8: Gantt chart that outlines the deliverables that will form phase 2



8. Project Controls and Governance

8.1 Project Planning

Planning is one of the most important steps in moving through Phase 2. This would include creating project plans, schedules, work-breakdown structures
or cost estimates, planning gives everyone a baseline to work with throughout the project.

8.2 Budgeting

Integrating the budgeting process into project activities is essential to calculate costs accurately and to understand when and why variances occur. By time-phasing budgets and refining the numbers, a transparent model is available for the project lead and team members alike to serve as both a benchmark throughout the project.

8.3 Risk Management

Project controls provide a meticulous approach to managing risk. By pre-emptively identifying risks, monitoring risks continuously, and developing contingency plans to address and mitigate issues, it becomes possible to reduce impact on budget and schedule. It also helps prevent some risks from happening in the future.

8.4 Change Management

If Phase 2 deviates from its original course, it’s often not due to a single factor, but due to the cumulative effect of several factors that tend to go unnoticed. This is why change management is critical. By tracking changes and understanding their impact, while following a clear process for evaluation, approval, and accountability, projects can remain on their charted trajectory.

8.5 Forecasting

By increasing the accuracy of estimates-at-complete, project lead and team members can gain a lot more insight into the current drivers of cost and schedule overruns. Good progress measurement is a critical input to the forecasting process. It serves as the comparison against actual and committed costs that will enable the project lead to extrapolate a forecast using a combination of standard forecasting methods and formulas. Regular, timely updates will aid the project lead by enabling faster response and corrective action to when a project begins to get off track.

8.6 Performance Management

Defining and using key performance indicators (KPIs) to monitor project health and forecast trends is crucial to take corrective actions. I am mindful that if as project lead, I use performance information to manage Phase 2 then performance and efficiency will be greatly improved.

8.7 Project Administration and Reporting Plans

This process involves establishing processes and systems that can help team members communicate and collaborate with each other. The goal is to track status updates, capture meeting minutes and lessons learned, and manage workflows seamlessly so teams can focus on actual execution rather than routine tasks.

It also allows for all relevant information to be captured for regular reporting to and communication with the BEIS team throughout the project.

9. Quality Assurance

For Phase 2 I would envisage using the following steps to produce a Quality Assurance plan at the start and this would be used a baseline tool throughout the project.

1. Define Quality Objectives. The first step to quality control planning is to define your goals.
2. Roles and Responsibilities.
3. Implement the Quality Assurance Plan.
4. Examine the Results.
5. Make Adjustments.
6. Keep Your Team in the Loop.

10. Summary

I have spent 6 years pioneering this ground-breaking Biomass feedstock innovation that aligns perfectly with the objectives of the Biomass Feedstock Innovation programme and has the potential to make a significant contribution to the UKs future sustainable source of Biomass and would help position the UK as a leader in Biomass innovation.