BIOMASS FEEDSTOCKS INNOVATION PROGRAMME - FINAL REPORT

Technological Innovations in Mobile Pelletisation: Testing the practical efficacy of mobile pelletisers in processing a range of energy crops at harvest site in the UK; including the innovations required to ensure as broad an adoption as possible.

Abstract

White Horse Energy are leaders within the UK biomass industry and the largest supplier of bagged wood pellets in the UK. As a business White Horse Energy has sought to challenge industry supply chain and technical norms. This innovative approach best places them to address the current barriers facing biomass supply in the UK.

White Horse Energy

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Executive summary

During Phase 1 we worked with Metitron GmbH, a global market leader in mobile pelletiser technology, to pursue various configurations of applying this technology to UK energy crops behind the farmgate. Our ambition being to introduce a source of domestic biomass pellets to the UK pellet market, currently the world's largest.

Participating in Phase 1 of the Biomass Feedstocks Innovation Programme enabled us to conduct a thorough feasibility study of three potential innovations and configurations of mobile pelletiser technology:

- Optimisation of existing mobile pelletiser technology for miscanthus use.
- Modifying mobile pelletiser technology to operate in 'Dual Energy Usage mode' – powered by electricity when statically processing material and diesel when used in the field.
- A transportable, static processor version for stationary use.

Project Technical Lead and inventor of the Metitron560 Harald Spaeth conducted the above technical studies, utilising specialisms Metitron has in computer modelling, electrotechnology and process engineering.

Throughout Phase 1, we evaluated these innovations based on their technical feasibility, cost implications and carbon emissions, comparing pellets produced by our innovation to a baseline of imported wood pellets. Our overall conclusion is that the transportable static version represents the greatest opportunity to deliver large scale, decentralised production of low cost and low carbon biomass pellets and is ideally suited to the UK's centralised consumption landscape. Additionally having the benefit of reduced security risks long term.

We intend to deploy our selected innovation within a network of decentralised farmyard production 'hubs,' where a range of feedstocks (miscanthus, SRC (short rotation coppice) willow, non-food lignocellulosic residues, heather, and bracken) can be processed year-round outside of limited harvest windows.

Our commercialisation plan is a demand-led model, where demand from the end user guides establishment of production hubs. The expectation is that a 'demand pull' for commercially viable biomass pellets will incentivise energy crop propagation displacing UK reliance on imported wood pellets.

Looking ahead to Phase 2, our aim is to demonstrate our innovation in producing quality pellets from a range of feedstocks and in operating at farm site production hubs. This will enable us to refine our commercialisation plan based on updated cost, carbon, and feedstock availability modelling.

Reader Guidance: *The following report is a redacted version of Phase 1 findings for circulation within the public domain.*

Part 1: Phase 1 Technical Reports

1. Optimising mobile pelletisation for miscanthus

In our first technical report, we explored how existing mobile pelletiser technology could be optimised for processing miscanthus both on the field and statically. The starting point for this feasibility study being the Metitron560 model, currently in operational use and the only known self-propelled mobile pelletiser to both harvest and pelletise feed material when mobile, with a continuous pellet process enabled by an automatically controlled material feed and a direct press drive.

The Metitron560 is currently optimised to process hay and straw, whilst Metitron have previously tested whether this technology could be applied to energy crops such as miscanthus it was clear that the specific characteristics of miscanthus **(Figure 1)** necessitates modifications for this model to produce high quality miscanthus pellets.

The ambition for our first feasibility study was therefore to further understand the modifications required to enable the processing of miscanthus to produce pellets at the same quality and similar yield as the current Metitron560 model (2-4 tonnes / hour).

1.1 Methodology

The first steps taken by our technical leads, Metitron GmbH, was to undertake a review of scientific literature on the characteristics of miscanthus relevant to pelletisation (summarised in **Figure 1**) and draw this into previous experience in attempting to pelletise miscanthus. With particular focus paid to difference in material weight, density, and toughness compared to hay or straw. The scientific literature supports conclusions drawn in previous trials that the increased toughness and higher density of miscanthus necessitates adaptation of traditional harvesting and processing machinery for hay and straw (see **Figure 1** literature review - Anderson et al. 2011, Johnson et al. 2012 of particular relevance here).

From here the key assemblies of the Metitron560 were analysed in order of material flow, as to how each mechanical part could process a tougher and denser feed material effectively. The key modifications highlighted are set out below.

1.2 Results

The conclusion drawn within this feasibility study was that all main assemblies within the Metitron560 would require modification to produce high quality miscanthus pellets.

The order material flows through the mobile pelletiser being the rationale as to how these key adaptations can be understood.

It was found that the initial processing stages were most vital to modify – being integral in preparing a tougher, more resilient feed material for pelletisation.

Moreover, the differing material consistency of miscanthus necessitates adjustment to the pellet mill itself. The optimal solution for this will require further refinement through extended testing with the Metitron560 model.

Further, more rigorous testing would also allow further consideration as to how the later, but less crucial, processing stages can accommodate the different material used.

1.3 Feasibility

In undertaking this study, we have a clear understanding of the required adjustments. We therefore consider the TRL (Technology Readiness Level) for processing miscanthus as a 7, as these modifications were identified in an operational environment using the existing mode. We are confident that the key adjustments outlined in this study will enable a mobile pelletiser to process high quality pellets from miscanthus, without compromising on durability.

To develop this innovation, the initial focus will be refining the changes to the material infeed and pre-processing stages as these are integral to later parts developed.

From this study, the estimated cost to modify key parts amounts to €49,500**.** The costs to modify key assemblies, are additional to that incurred in constructing a current version of the Metitron to be used as a baseline (€920,000).

The estimated timescales to optimise pelletiser technology for miscanthus is 5 months, including a thorough testing period, with a further 10 months required to build the baseline Metitron560 mode. The vast experience Metitron has in marketing a world leading mobile pelletiser places them well to optimise this process for miscanthus.

2. Dual Energy Use Mode

Our second Phase 1 technical study explored the feasibility to modify mobile pelletiser technology to operate in 'Dual Energy Usage' mode, powered by electricity when statically processing material and diesel when used in the field. The aim being to decrease the CO_2 emissions when processing material statically in stationary use.

Within this study, a range of electrification options were considered – a hybrid mode, battery powered, mains powered and a fuel cell.

2.1 Methodology

In contrast to the first feasibility study, this exploration did not have an operational baseline as a starting point. This being reflected in the methodology employed, broad research was initially undertaken into electric-powered engines used for agricultural vehicles to develop an understanding of different modes and formulations of electric power that could be considered for the current mobile pelletiser system.

2.2 Results

The overall finding of this technical study was that it was not currently feasible to apply a Dual Usage Energy mode to mobile pelletiser technology. However, the work undertaken was valuable in setting the groundwork for developing an electric powered static pelletiser in our third technical workstream. The challenges identified during the second technical study are outlined below in order of significance.

A crucial barrier is the necessity for a steady, high-powered engine supply for a high consumption mobile pelletiser system. This poses an acute challenge when considering the limitations of space within the mobile pelletiser and permissible axle load, particularly if batteries were to be used as an additional energy store.

Furthermore, as a hybrid solution, the proposed innovation faces challenges particular to combining both diesel and electric systems. The additional weight poses a significant barrier, with an estimated addition 3.6 tonnes for the electric engine and its component. This being prior to including an additional energy carrier. This posed a risk of soil compaction and fuel inefficiencies when used on the field and increased maintenance workload in operating two engine systems. These counterarguments for the hybrid solution led to the conclusion that a hybrid dual-use version of the mobile pelletiser is not currently feasible.

Whilst the electric drive was considered able to be developed to withstand harsh working conditions (vibrations, temperature variations, moisture, and dirt) when used in the field. This highlighted the potential of solely using an electric motor due to the benefits compared to the diesel engine, in that the electrical motor can achieve maximum torque at “zero” speed and opens the avenue of applying motors for each axle for use in driver assistance systems.

Along these lines, Metitron further investigated alternative solutions to electrify the mobile pelletiser by researching existing electrified agricultural machinery. Pilot projects found include a project led by John Deere to implement an electric tractor connected to a cable power source. Whilst exciting projects like this exist, they have not yet reached the stage to be applied to a heavy and high-consumption machinery like the Metitron560. Whilst we can expect this landscape to change in the foreseeable future, with potential opportunities to incorporate emergent technologies such as the Equipmake’s magnet motor, with a power / weight ratio applicable for the Metitron560, we are unfortunately not there yet.

3. Transportable static processor

The key motivation for considering a transportable static configuration of mobile pelletisation, was to enable year-round pelletisation statically in the farmyard. The technology would therefore be independent of harvest seasons and small weather windows, with the additional benefit of being easy to relocate over greater distance thereby opening new routes for commercialisation.

Our expectation was that this innovation would be a compact and robust pelletiser, of higher durability and lower maintenance than the existing mobile version. This is due to it utilising technology that is normally used in a harsh working environment, being applied to a more stable environment.

We anticipated that by being electrically powered, either from the grid or, where available, as solar PV, would provide carbon reduction benefits compared to diesel powered configurations of mobile pelletisers.

This innovation was envisaged to build on the learnings from the first technical study, in optimising pelletiser technology developed for straw and hay – to be also applied to a range of feedstocks including miscanthus, SRC (willow), heather and bracken.

3.1 Methodology

The feasibility of our proposed innovations, was assessed as to whether the pelletiser technology could be integrated in a transportable static configuration meeting the following criterion:

- Pelletise two cuboid or round compressed bales side to side (1.5m x 1.5m) and SRC willow chips.
- Operates within a configuration that is stable and easily transportable
- Allow sufficient dissipation of waste thermal energy.
- Utilise parts within the existing mobile pelletiser technology, to produce pellets at the same quality and similar yield as the current Metitron560 model (2-4 tonnes / hour).

The designed integration of key assemblies from the Metitron560 into a static processor, provides a solution to potential challenges identified. Ensuring material flow, sufficient thermal dissipation, and stability / transportability of the innovation.

From this starting point, the design for our innovation was developed using computer-aided design (CAD) software Solidworks3D, to integrate these working parts together.

3.2 Results

Modelling our innovation

The integration of mobile pelletiser technology is as set out within the CAD model developed within Phase 1**.** We have outlined below the key adjustments necessary for this integration.

As a static processor firstly, parts were removed from the Metitron560 associated with mobile operation (gear, the drive, axes, and wheels etc.).

Being electrically powered and without a driver’s cabin, the control system will be operated using a separate control cabinet. Multiple electric motors will be incorporated and adjusted for the components they will power.

An external bale shredder is designed to allow baled material to be placed on a two-part conveyor belt. This opens the possibility of feeding two square bales on their side into the bale shredder, enabling two bales with differing moisture content to be used in conjunction and effectively balance out within the pelletising process. To enable the processing of chipped material (willow SRC chips, heather chips etc.) a further feed system will be developed following initial testing of these materials in Phase 2.

Otherwise, the material flow will move in the same order as for the existing mobile pelletiser, with integration of key assemblies considered. We have also identified the minor modifications to be made to these parts, incorporated both from designing this innovation and our earlier exploration into optimising this technology for miscanthus.

In Phase 2 intensive testing of processing a range of feedstocks using the existing Metitron560 model, will enable us to further refine the identified adjustments. This will occur during the project Initiation Stage and be incorporated into the full electrical and technical plans developed.

Overcoming challenges

The potential engineering challenges were solved during the reconfiguration process, and we are therefore confident that the innovation is deliverable as per the CAD model configuration. The innovation design providing solutions to the identified challenges.

3.3 Feasibility

The pelletiser technology within our innovation has already been demonstrated in robust operational use in the existing Metitron560 demonstration platforms. The parts are designed to operate within limited space and under harsh conditions.

Furthermore, the compact design of the innovation allows for ease of relocation to the feedstock, modularity of production and dissemination, reduction in wear relative to the mobile version, which will provide higher overall throughput.

From our feasibility study, only minor adjustments are necessary to convert the pelletiser mode from mobile to solely static form, and that these adjustments are well understood.

We therefore consider our static pelletiser innovation to be a TRL 5 and have a high degree of certainty to be able to reach a TRL 9 with this technology in demonstrating our innovation in Phase 2.

The TRL assessment for processing miscanthus is a 7, as we have a clear understanding of the adjustments required from the first technical study. We currently assess processing of SRC willow as being a 5. Whilst further testing will be undertaken during the Phase 2 Initiation Stage, we have confidence in our initial understanding of the adjustments required.

Within our third technical report, a detailed cost breakdown was given to develop, construct and assemble the deployment unit of our innovation. Learnings from our Phase 2 construction process are expected to result in a replication blueprint for future construction that allows us to use modular and standardised components to produce additional units at far greater speed and lower cost.

The development and construction are expected to be undertaken over a 2-year period, followed by a thorough Commissioning and Testing Phase prior to deployment and field testing in the UK.

Part 2: Introducing our innovation to the UK biomass landscape

Our innovation presents a significant opportunity to decentralise pellet production. Thereby overcoming one of the main barriers to UK energy crop pellet production - prohibitive transport costs in moving bulk feedstocks to pellet production plants.

We anticipate that the pelletiser will operate at farmyard 'hubs' year-round and are easily transportable between hubs. These hubs will form a network of decentralised pelletiser production sites, behind the farmgate, with a supply chain in place to ensure regular collection of pellets produced that will be sold onwards to the end user.

The establishment of new hubs will reflect demand from the end user and will be selected as having sufficient supply of a range of feedstocks onsite, or nearby. The pelletiser will process a range of feedstocks to enable year-round pelletiser, the machine being easily adjustable for processing different feedstocks by one handler.

Our demand-led business model aims to work by a 'demand pull' from the end user, resulting in an increase in biomass supply to meet demand. By connecting potential growers to the end user, our model overcomes the current supply challenge facing UK biomass.

4. Impact on UK biomass supply

4.1 Overview of UK Feedstock Production Landscape

The Climate Change Committee (CCC) recommend, in their Sixth Carbon Budget report published in December 2020, that by 2025, 27,000 ha of energy crops should be planted in the UK annually, increasing to 30,000 ha from 2030 onwards. Currently, the UK is falling short of this recommendation with the area dedicated to miscanthus and SRC only increasing by 540ha per year, to a total 10.4k ha in the past five years to 2019.

White Horse Energy believes this is caused firstly by a fragmented and opaque energy crop market with potential producers having no or limited visibility of an end market for their crop. This being a deterrent to producers undertaking an expensive propagation programme without a clear view of what yield they may receive from their investment.

The second barrier is a high-cost supply chain, with inefficient processing. Energy crops are, in their unprocessed state, large, bulky, and inefficient to transport. Traditionally the processing of energy crops into homogeneous fuels such as pellets tends to occur in large, centralised facilities decided for feedstocks that are harder to process such as wood fibre. This forces the supply chain to engage in inefficient transport of feedstocks and to process the feedstock using sub optimal technology. As a result, current UK production of energy crop pellets cannot compete on a cost or scale basis with imports of wood pellets. Consequently, the UK pellet market, current the world's largest, is heavily reliant on imports with 9.1 million tonnes imported into the UK in 2020 according to Forest Research UK Data.

4.2 Our ambition

Our findings from Phase 1, demonstrate that our innovation offers a solution to the second part of the supply challenge outlined above. By pelletising feedstock behind the farm gate it reduces or removes the expensive and inefficient raw material transport seen in traditional processing supply chains. Furthermore, our innovation is more energy efficient than current methods in pelletisation, and thus reduces the financial and carbon cost of this process.

By White Horse Energy securing long term supply contracts with end consumers of pellets and resulting offtake agreement with a network of growers, resolves the current market visibility issues and creates a cost-efficient supply chain that rewards all participants. Therefore, tackling the current barriers to large scale energy crop uptake, by creating a demand pull for additional energy crop plantings and consequently increase sustainable biomass feedstock supply in the UK.

During Phase 1, the significance in focusing on a demand pull to incentivise uptake was evident in our UK Farmers Survey. It was found that a stable market for biomass pellets and increased income stability for the grower were vital considerations to farmers taking up our innovations and processing energy crops **(Figure 2).** In fact, a high proportion of participants demonstrated an openness to diversify or alter their practices to achieve an increase in Net Revenue.

4.3 Key performance metrics

Our commercialisation strategy hinges on the domestic pellets produced by our innovation displacing imported wood pellets, providing energy at an equivalent or lower cost than the incumbent fuels with an additional benefit of a significant carbon saving. The positive impacts our innovation will have on UK feedstocks, can be considered primarily in terms of cost reductions from production and carbon savings. Given that these factors are key to ensuring a successful commercialisation strategy, we intend to measure these against the current costs and emissions of imported wood pellets which we will consider our baseline.

Cost performance has two components, the cash cost of supply and CAPEX recovery per tonne. As CAPEX will be fixed per unit, this metric will be driven by annual production throughput. Therefore, annual production will be considered here as a second performance metric.

Therefore, our key performance metrics are as follows:

- Cash Cost of Supply (Per MJ)
- Annual Production (Tonnes)
- Carbon Emissions (gCO_2/MJ)

We set out below how these performance metrics were used to evaluate our proposed innovations during an Economic and Market Study undertaken in Phase 1, where relevant particular focus was given to our selected innovation which will be demonstrated and assessed against these metrics during Phase 2.

4.4 Introduction to our Economic and Market Study

In Phase 1 we commissioned independent consultancy Hawkins Wright to undertake an Economic and Market study to assess these metrics. Further analysis within this study also included a construction of potential supply chain scenarios and an exploration of the international opportunities in exporting mobile pelletiser technology.

Cash Cost of Supply and Annual Production - Methodology

In assessing the first metric, Cash Cost of Supply, the entire supply chain was incorporated into the 'field-to-furnace' costs and compared to that of imported wood pellets in supplying pellets to a hypothetical biomass power station in northern England (from Baltic States, Canada, and US South). These were compared between different feedstocks (miscanthus, non-food lignocellulosic agricultural residues i.e., 'agri-residues' or straw, SRC willow) and across different configurations of mobile pelletisation on and off field.

The supply cost data was segmented into six categories: feedstock, labour, energy, maintenance, SG&A (overheads) and transport. Data for the performance and use of the pelletiser technology was based on assumptions and use-data from Metitron GmbH. To decrease uncertainty, a Monte Carlo simulation was run to assess the distribution of the following factors across multiple 'what if' scenarios; annual operating hours, feedstock prices, moisture content, diesel consumption per hour, diesel price, maintenance, SG&A, transport distance, transport cost per tonne/km.

Assumptions made in terms of annual working hours, throughput and annual scheduling were a basis to consider annual production for all configuration modes. Addressing these assumptions will be a key focus in our Phase 2 approach.

Carbon Emissions – Methodology

The carbon emissions were also calculated throughout the pellet supply chain from 'field-to-furnace,' starting from the establishment and cultivation of the feedstock, with carbon sequestration of the feedstocks also being considered. The emissions for our transportable static pelletiser supply chains were then compared to those by imported pellets (from Baltic States, Canada, and US South) to assess whether the resulting supply chain scenarios constructed within our Market Study would have carbon reduction benefits. The emissions for our innovation were compared against two scenarios; being powered by GB average grid electricity and a solar PV located on the farm site (a proxy for decarbonised electricity).

Hawkins Wright used the UK's *official Solid and Gaseous Biomass Carbon Calculator (Ofgem)* for their analysis. Some assumptions were necessary but were formulated on data taken from White Horse Energy's biomass supply chain experience and Metitron's end-use data.

Assumptions and Knowledge Gaps

In demonstrating our innovation within Phase 2, we will be able to refine these metrics based on real life deployment data and refine assumptions made in how our innovation will operate and the broader supply chain established.

Prior to the commissioning of the demonstration unit, we will undertake a significant testing phase using the existing Metitron560 model, to better establish the hourly throughput of various additional feedstocks and the quality / composition of pellets produced from these (SRC willow, heather, bracken, etc). This alongside our Feedstock Supply Study will help inform us as to the viability of using these additional feedstocks considered.

Throughout the Field-Testing Phase and whilst the demonstration unit is in operation, we will assess its duty cycle to understand the short-term potential utilisation of the innovation. This will build our understanding of how many hours per day or week production can be maintained.

We will also be able to consider the annual scheduling of the innovation – how it can be utilised year-round in processing a range of feedstocks. With particular focus given to understanding feedstock availability, costs of storage, and seasonal pricing to understand the maximum utilisation of the equipment.

We also endeavour to understand the costs of transporting our innovation from one farmyard to another, this being important as the lower the movement cost the more viable it makes moving the equipment to take advantage of different raw material catchment areas.

4.5 Performance of a Transportable Static Innovation

The calculated 'field-to-furnace' costs for our innovation, represents a reduction in transport costs overcoming the current barrier of prohibitive transport costs when processing low-density raw material feedstocks at the pellet production plant.

Furthermore, the difference in cost between UK biomass pellets produced by our innovation and imported alternatives are narrowed by this reduction in transport costs**.** As part of our commercialisation plan, focus will be given to reducing controllable cash costs within the UK supply chain (notably transportation and overhead 'SG&A' costs), in order to ensure the pellets produced are as competitive as possible with imported pellets on a cash cost basis.

Throughput data from the existing Metitron560 mobile pelletiser and manufacturing cost data from our technology partners, was used to compare the capex cost per annual tonne of our innovation against that of imported pellets. It was found that our innovation compared favourably against imported wood pellets and a key reason for pursuing a static pelletiser model with high annual production potential in Phase 2.

The final performance metric to be considered is the CO_2 savings made by introducing our innovation to UK pellet supply chains. The transportable static pelletiser system using UK sourced biomass feedstocks (both energy crops and non-food lignocellulosic agricultural residues) and powered by electricity (rather than diesel) is competitive in CO_2 terms compared with all imported pellet supply chains examined and other mobile configurations explored in Phase 1. The reduction in emissions associated with long-distance transportation being particularly relevant.

4.5 Further analysis of Environmental Benefits

The key environmental benefit our innovation will bring is a reduction in GHG emissions, notably CO_2. A reduction in the overall transport associated with pellets from our innovation compared to imported pellets translates into reductions in supply chain emissions, especially when power is provided by Solar PV.

Pellets produced by a Solar PV powered innovation resulted in the lowest carbon emissions, compared to all other configurations considered within Phase 1, followed secondly by the same innovation powered by grid electricity. With higher emissions associated with static processing when powered by diesel.

All the biomass feedstock supply scenarios evaluated in this study demonstrating lifecycle emissions below thresholds required for biomass power plants to receive support under UK Renewables Obligation or Contracts for Difference schemes, where available, both with rigorous sustainability criteria. These also meeting the criteria for biomass heat plants to receive support under RHI (Renewable Heat Incentive).

The scale of impact our innovation will have in reducing carbon will only increase once low-carbon transport fuel and technologies are developed, further reducing emissions feedstock processes and pellet transports.

In terms of other environmental benefits and trade-offs, our innovation will be operating off field and therefore only expected to have an indirect impact on air, water, soil, and biodiversity and within the expectations of the CCC's Sixth Carbon Budget Net Zero Scenarios.

For pellets produced from non-food lignocellulosic agricultural residues these only represent a change in end use for pre-existing residues and are not expected to have any broader environmental impact.

Whilst there are potential environmental and biodiversity risks in the case where miscanthus or SRC willow is established on unfarmed land. However, our innovation is not expected to push demand beyond the land use already envisaged in the CCC study, but merely to assist in achieving some of those ambitions.

During Phase 2, in demonstrating our innovation and refining operational and supply chain assumptions, we will be able to update our carbon model in line with our commercialisation plan. We will also seek to continually review the environmental benefits our innovation presents.

4.5 Phase 1 Findings: Pellet Supply Projections

Within the Phase 1 Economic and Market Study, three scenarios were assessed for pellet supply from UK sourced biomass feedstocks by 2050 **(Figure 3)** based on CCC scenarios from the Sixth Carbon Budget of low, medium, and high use cases (December 2020). In these projections, the miscanthus crop area in 2050 ranged from 138,000 ha to 840,000 ha and the projection for UK energy crops and short rotation forestry-based pellet production in 2050 subsequently ranged between 1.1 million and 12.6 million tonnes, with a base case of 4.4 million tonnes.

Based on the three CCC scenarios, the total plantings, harvest and assumed pellet production as a proportion of that harvest by 2050 is as follows:

Scenario	**Low**	**Medium**	**High**
Planted Area	230k ha	700k ha	1,400k ha
Annual Harvest	2,369k tonne	8,942k tonne	20,335k tonne
Pellet Production	1,090k tonne	4,422k tonne	12,584k tonne

This highlights a significant future opportunity for pelletised energy crops to positively impact and decarbonise the UK energy market, with the most cautious estimates projecting 70% of miscanthus produced to be pelletised.

Our innovation could potentially increase the likelihood of the UK moving from a low use case to a mid or high case by overcoming some of the supply barriers facing the energy crop market and drive a demand pull from end users for domestic energy crop pellets. In these scenarios, the UK market would be able to move away from pellets imports in themselves posing a political risk burden to energy security and the high carbon emissions associated with shipping and long supply chains.

5. Commercialisation of our innovation

5.1 UK Landscape

The UK is the largest consumer of wood pellets in the world. Forest Research UK Data suggests that in 2020, approximately 9.3 million tonnes of wood pellets were consumed in the UK with global consumption at circa 41 million tonnes. The vast majority of UK wood pellets were imported (9.1 million tonnes), predominantly from the US, Canada, the Baltics, and Russia (Forest Research UK Data, 2020). UK wood pellet production is not currently cost competitive, even for premium domestic pellets and considerably less so for industrial pellets.

To change this energy supply mix towards domestic pellets, will require a cost competitive alternative with additional benefits. Our findings in Phase 1 support our belief that the innovation will introduce a UK produced pellets that can displace imported pellets at an equivalent or better cost, with an additional benefit of significantly reduced CO2 impact.

Further expected benefits for introducing domestic pellets to market include energy security benefits for the UK, and a boost to rural economies as a considerable share of the pellet value chain will be kept within the farm gate and local communities.

5.2 Commercialisation Plan

We are engaging with potential consumers to disseminate some of our learnings to date and the cost, carbon, and energy security benefits of our innovation are already generating real interest.

Throughout Phase 2 we will be engaging directly with our potential target consumers in preparation for commercialisation post-Phase 2 and look forward to being able to demonstrate successful pellet production and gain operational data from our rigorous testing phase.

We will also work to build a pellet supply chain to be operational post-Phase 2, with the distribution of each processing hub to be carefully considered to minimise transport cost and maximise potential yield.

5.3 International Opportunities

Once our innovation has reached commercialisation and been successfully deployed in the UK, the opportunities for us to export our innovation to countries with abundant non-food lignocellulosic agricultural residues within 5-10 years post-Phase 2 are substantial. During Phase 1 we explored this further by evaluating specific global case studies all having in common an abundance of non-food lignocellulosic agricultural residues that have no inherent value or end use.

Throughout Phase 2 we look to work towards our goal of exporting this technology by meeting with established international contacts, with demonstratable demand for biomass pellets.

Part 3: Phase 2 Plan

6. Phase 2 Planning Rationale

Our project milestones reflect the key linear stages to develop, construct and demonstrate our innovation:

- Initiation stage (end: Dec-22)
- First innovation stage (end: Apr-23)
- Second innovation stage (end: Nov-23)
- Assembly (end: Apr-24)
- Commissioning and Testing Stage (end: Aug-24)
- UK field testing and pre-commercialisation stage (end: Mar-25)

The progression through these technical milestones, guides our project rationale and timelines for project work packages and subsequent deliverables.

6.1 Timescales

Our Phase 2 project work packages are as set out below, a dedicated owner being responsible for subsequent deliverables.

Work Package ID	Work Package Title	Work Package Lead	Timescales
1	Project Leadership	Lucy McIntyre and Stuart Fitzgerald (White Horse Energy)	Apr-22 – Mar-25
2	Sub-contractor Management	Lucy McIntyre and Julius Guntermann (White Horse Energy and Camberwell Energy)	Apr-22 – Mar-25
3	Strategy and Technical Programme Management	Lead for Strategy: Ben Moxham, Lead for Programme Management: Julius Guntermann (both: Camberwell Energy)	Apr-22 – Mar-25
4	Technical Development and Innovation	Project Lead: Katharina Mueller, Technical Lead: Harald Spaeth (Both: Metitron)	Apr-22 – Feb-25
5	Development of control system and supporting testing of innovation	UK-based engineering firm – TBC	Feb-23 – Feb-25
6	Carbon, economic and market analysis	Fiona Matthews and John Bingham (Both: Hawkins Wright)	Jun-22 – Dec-24
7	Field testing of innovation	White Horse Energy, dedicated Project Manager and Coordinator to oversee field testing TBC	Jun-23 – Feb-25
8	Preparing for commercialisation	Stuart Fitzgerald, White Horse Energy, supported by Ben Moxham, Camberwell Energy	Apr-22 – Mar-25
9	Quality Assurance	Julius Guntermann, Camberwell Energy	Apr-22 – Aug-24
10	UK Farmers Consultation	White Horse Energy, Project Manager TBC / Stakeholder engagement: Ben Moxham, Camberwell Energy	Oct-22 – Mar-25

6.2 Aims and Objectives

We consider our overall approach to Phase 2 to be two-fold, in firstly demonstrating the technical merit of our innovation to construct and assemble our innovation, following detailed mechanical and electrical plans to develop a specific control system. The second part being to demonstrate our innovation and business model on the ground.

Our key aims and objectives for Phase 2 demonstration stage are as follows:

- To develop and test our innovation in processing a range of feedstocks and quality / composition of pellets produced from these
- To demonstrate our farm 'hub' model - connecting farmers to end users
- To further our understanding of the annual scheduling and potential utilisation rate for our innovation
- To refine our performance metric data (Cash Cost of Supply, Annual Production and Carbon Emissions) and therefore construct updated supply chain scenarios to inform our commercialisation plan

6.3 Project Delivery Team

The three core organisations within our Phase 1 Project Team remain for Phase 2, each being market leaders or specialists within their respective fields. White Horse Energy Ltd, the lead organisation, is a leading UK biomass supplier. Metitron GmbH are global leaders in mobile pelletisation technology and Camberwell Energy Ltd a specialist consultancy firm in UK & European biomass markets with programme management expertise. Each have the expertise and capacity to undertake their assigned work packages within Phase 2 and remain the core for project delivery.

Following their invaluable contribution to our Phase 1 Economic and Market Study, we look forward to continuing working with John Bingham and Fiona Matthews of Hawkins Wright Ltd in Phase 2. During Phase 2, we will also work with a UK-based engineering firm to support Metitron in undertaking key technical deliverables and to provide an additional layer of project governance and technical support during our UK Field Testing Phase. All technical models and plans will be reviewed by our appointed technical advisor to provide an independent perspective and quality assurance.

Key persons within the core organisations for project delivery and management are as set out in **Figure 4.**

6.3 Project Management and Governance

To enable close project governance and facilitate regular reporting and reviews – we have developed a structured framework for regular team meetings. The project team having been allocated to dedicated delivery groups (Operational, Technical Development and Strategy), comprising team members from different organisations with dependent workstreams, and meeting to update their team on progress made. Each team has a dedicated Lead who is responsible for ensuring a consistent approach to reporting and governance within their team.

Framework for Reporting and Governance

The following review process is structured on a quarterly basis to enable construction of a more detailed weekly plan for the quarter ahead and for progress to be assessed against longer project milestones ahead.

Julius Guntermann will draft a quarterly Highlight Report, detailing updates from both the Operational and Technical Development Teams to complement a monthly summary of both teams' meeting minutes ahead of the monthly update meetings with our assigned BEIS Monitoring Officer. This Highlight Report will feed into a broader Stage Report to be drafted by the Project Leadership Team, incorporating progress within all workstreams against the project plan (considering the interdependencies of these), and wider project dissemination progress. This Stage Report will be submitted to the Strategy Team ahead of their quarterly meetings, to be signed off for approval and incorporated into broader discussion of project progress and commercialisation planning.

An independent process engineer with relevant industry experience will attend Strategy Team Meetings, for technical quality assurance of technical models and plans. Technical work undertaken will be monitored in weekly meetings by Julius Guntermann, with quality control assessments and action taken to be recorded ahead of Operational Team Meetings. Quality Control within work packages 4 and 5 being undertaken by either the UK engineering team or Metitron, assessing work done by the other party. Physical monitoring will be undertaken during in-person visits 3-4 times a year during relevant workstreams by Julius Guntermann (overseeing Metitron's work) and White Horse Energy Project Leadership Team (overseeing the UK engineers' approach). This approach ensures quality assurance is objective and working within established channels of communication and feedback. Our quality standards and control steps will be defined in the Quality Management Approach, a deliverable undertaken within the Initiation Stage.

6.4 Risk management

We take project risks seriously; those identified at this stage are outlined within our Phase 2 Risk Assessment. Julius Guntermann will continue to oversee the updating of the risk and issues register and recording actions taken. Within the Communications Management Approach, a process will be outlined in monitoring identified risks and issues, detailing how these will need to be assessed, monitored and where necessary escalated. Our fortnightly Operation Meeting will consider project risks as a standing item.

Appendix

Figure 1

Literary review of miscanthus characteristics

Miscanthus characteristics		
Yield	10-25 t/ ha (dry matter)	Eric Anderson, Rebecca Arundale, Matthew Maughan, Adebosola Oladeinde, Andrew Wycislo & Thomas Voigt (2011) Growth and agronomy of Miscanthus x giganteus for biomass production, Biofuels, 2:1, 71-87, DOI: 10.4155/bfs.10.80
Benefits as energy crop	Comparably low fertilizer and pesticide requirements , high water use efficiency and high productivity because of C4 photosynthesis and re-translocation of nutrients in to rhizomes before harvest; can be pelletised without drying offsets (lower energy consumption than woody pellets)	Fusi, A.; Bacenetti, J.; Proto, A.R.; Tedesco, D.E.A.; Pessina, D.; Facchinetti, D. Pellet Production from Miscanthus: Energy and Environmental Assessment. Energies 2021, 14, 73.; Jørgensen (2010) Benefits versus risks of growing biofuel crops: the case of Miscanthus
Challenges	Harvest technology is still an active field of research and current harvesting machinery is designed for hay and straw which makes harvesting and processing slow and inefficant; harvest goal is to cut stalks at 5-10cm but ill-suited equipment leaves more than 30cm (which is more than 2 t / ha of biomass that is not harvested)	Johnson, Phillip C., et al. "Cutting energy characteristics of Miscanthus x giganteus stems with varying oblique angle and cutting speed." *Biosystems engineering* 112.1 (2012): 42-48; Heaton et al. (2010), Miscanthus: A Promising Biomass Crop
Special characteristics of material	Tougher and higher density compared to hay and straw	Eric Anderson, Rebecca Arundale, Matthew Maughan, Adebosola Oladeinde, Andrew Wycislo & Thomas Voigt (2011) Growth and agronomy of Miscanthus x giganteus for biomass production, Biofuels, 2:1, 71-87, DOI: 10.4155/bfs.10.80

Figure 2

Cluster chart indicating the mean ranking respondents gave potential benefits of our proposed innovations. Whilst not an option in this ranked question, thematic content analysis of qualitative data collected from survey respondents indicated a key theme amongst respondents being for a need for a 'stable market' to take up innovation.

Source: White Horse Energy – Deliverable 2.2 Phase 1 UK Farmers Survey

Sample size for quantitative data was 73 participants.

For the quantitative data, our final sample size was 73. Given our surveys reach through several key farming associations, charities, and networks – we have given a confidence level at 90% (probability our sample is representative of the total population), with a margin of error of 10%. When analysing this data we maintained an awareness of this margin in drawing conclusions from our results, however we were confident that these results remain representative of the broader population.

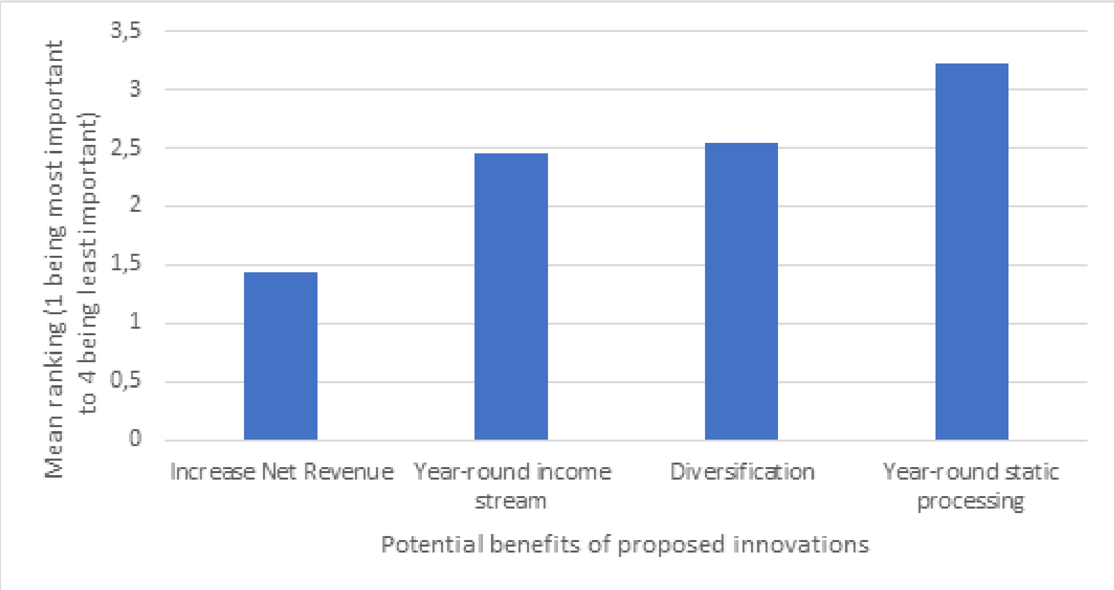

Figure 3

UK pellet supply scenarios flowing from mobile pelletisation (based on the CCC Sixth Carbon Budget scenarios)

Source: Hawkins Wright - Phase 1 Deliverable 3.2 Economic and Market Study

	CCC Scenarios		
	Widespread engagement	**Balanced Net Zero Pathway**	Widespread innovation
High Level summary of the scenarios devised by the CCC, with a focus on the land use sector	The public's engagement in climate change mitigation is high. A high level of afforestation (70k ha/y) reduces the requirement, and the area available, to grow energy crops	Balances the need to reduce land-based emissions with other essential functions of land. Afforestation rates to accelerate to 30k ha a year by 2025, rising to 50k ha a year by 2035.	Focus on technological solutions, increasing yields of food crops, trees and energy crops and a doubling in the planting rate of energy crops compared with the Balanced Pathway.
Energy crop planted area (thou. ha)	Low energy crop planting (total **230kha** in 2050) and yields	Planting of Miscanthus, SRC and SRF accelerates to 30k ha/year by 2025, such that **700k ha** are planted by 2050	High energy crop planting (total **1.4Mha** by 2050) and improved yields.
Percent and energy crop area planted to:			
- *Miscanthus*	60% (**138k ha**)	60% (**420k ha**)	60% (**840k ha**)
- *SRC (Willow/Poplar)*	25% (**57.5k ha**)	25% (**175k ha**)	25% (**350k ha**)
- *Short rotation forestry*	15% (**34.5k ha**)	15% (**105k ha**)	15% (**210k ha**)
Average yield *(oven dry tonnes/ha)*			
- *Miscanthus*	11.00	14.00	16.00
- *SRC (Willow/Poplar)*	10.00	11.50	12.50
- *Short rotation forestry*	8.00	10.00	12.00
Annual production. (*thousand odt/year*)			
- *Miscanthus*	1,518.00	5,880.00	13,440.00
- *SRC (Willow/Poplar)*	575.00	2,012.50	4,375.00
- *Short rotation forestry*	276.00	1,050.00	2,520.00
- Total	**2,369.00**	**8,942.50**	**20,335.00**
Percent of production pelletised			
- *Miscanthus*	70%	70%	85%
- *SRC (Willow/Poplar)*	0%	10%	15%
- *Short rotation forestry*	10%	10%	20%
Total pellet production *(thousand odt/year)*			
- *Miscanthus*	1,062.60	4,116.00	11,424.00
- *SRC (Willow/Poplar)*	-	201.25	656.25
- *Short rotation forestry*	27.60	105.00	504.00
- Total pellet production	**1,090.20**	**4,422.25**	**12,584.25**

CCC scenarios

Hawkins Wright projections

Figure 4

Project Delivery Team profile

Team Member	Organisation	Summary of role
Stuart Fitzgerald	White Horse Energy Ltd.	Stuart is our overall Project Director and leading our project Strategy Team and work package 8, in laying the groundwork for commercialisation post-Phase 2. Stuart looks forward to applying his entrepreneurial talents and industry experience to steer our overall approach and bring a real shift to the UK's biomass supply landscape, driving a more sustainable future for domestic energy supply.
Lucy McIntyre	White Horse Energy Ltd.	Lucy has led White Horse Energy's Phase 1 workstreams, overseeing communication with BEIS and project financial management, tracking and auditing processes. Lucy is certified in Prince2 Project Management applying key principles to our Phase 1 approach and has been integral in planning for Phase 2. Lucy will continue to operate as overall Project Manager, leading work packages 1 and 2 and the Operational Team.
Harald Spaeth	Metitron GmbH	The technical foundation of our innovation is the Metitron560, invented and developed by Harald Spaeth founder of Metitron GmbH. Harald has applied this niche expertise to our innovation, already demonstrated by the development of a CAD model within our Phase 1 Technical Report. Harald will continue as our overall project Technical Lead (focused on work package 4) and will be supported by in-house specialist engineers to complete Phase 2 deliverables.

Katharina Mueller	Metitron GmbH	Katharina Mueller supported our Phase 1 technical workstreams in the capacity of Project Manager, her fluency in English being a benefit to bridge the Project Delivery team to the wider technical team. She will be integral to managing our Phase 2 technical development workstreams, applying her experience of Business Administration. In planning for Phase 2, Katharina has a comprehensive understanding of the resources required to complete key deliverables and constructed their project timelines accordingly to ensure the engineering team at Metitron have capacity to complete the work within the project timelines, Katharina being Project Lead for work package 4.
Ben Moxham	Camberwell Energy	Ben Moxham has more than 15 years' experience working at the frontier of the low-carbon transition in strategic roles across business, government, and finance. His biomass experience includes serving for five years from 2015-20 as European Market Development Director for Enviva, a leading supplier of sustainable wood pellets to UK, European and Asian markets. Ben serves on the Board of Directors of the World Bioenergy Association. He has been keying in supporting our project throughout Phase 1 and will be integral to Phase 2 in the role of Strategic Advisor – supporting the Strategy Team in preparing for commercialisation and considering potential opportunities.
Julius Guntermann	Camberwell Energy	Julius has supported the team in managing our Technical Partnership with Metitron and overseeing the technical feasibility work undertaken in Phase 1. Julius speaks fluent English

		and German he has excelled in communicating and building strong working relationships connecting different parties throughout this project and leading the broader project structure and coordination. Julius will continue to support our project in the capacity of Technical Partnership Director and looks forward to bringing his technical biomass expertise into Phase 2.