Executive Summary

White Horse Energy Ltd, working with a global leader in mobile pelletiser technology Metitron GmbH, undertook to develop and demonstrate mobile pelletiser technology to operate behind the farm gate, in processing a range of feedstocks, including agricultural residues and innovative fuels, year-round.

The ambition being to support the UK energy market in decarbonising, by unlocking a source of domestically sourced and sustainably produced pellets through a network of small-scale decentralising pellet production hubs.

Project Scope

The pelletiser technology, developed over the course of the project, is integrated into a 40ft shipping container to allow for ease of relocation to the feedstock, modularity of production and dissemination, reduction in wear relative to the incumbent mobile version, and higher overall throughput. In undertaking this, White Horse Energy (WHE), sought to provide a technical solution to the supply chain challenges associated with a centralised pellet production model and overcome the cost barriers to scaling domestic biomass pellet production. The vision, being cascading offtake agreements downstream to a decentralised network of farm 'hubs', driven by accelerated industrial demand for domestically sourced, low-carbon pellets.

The baseline technology for this project is the market-leading Metitron560, which primarily processes dry crops or residues at harvest on the field. The UK climate is less conducive to this operating method where the harvest window for low moisture content raw material is significantly reduced. Therefore, containerisation and static processing of baled material is how we envisaged our technology operating within the UK.

Therefore, our Phase 2 project approach was structured to deliver the following objectives:

- To develop and test our containerised innovation in processing a range of feedstocks and the 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.

At point of conclusion, we had made considerable progress towards realising these objectives by:

- Developing our innovation to meet the required use-case and demonstrating the technical merit of our innovation, in confirming all electrical and mechanical assemblies and integrating all but one key component into a container.
- Furthering our understanding of logistical and operational requirements for farm 'hubs', from both a farmer and end-use perspective, to realise a high utilisation rate.
- Revising the assumptions made in Phase 1 for our performance metrics 'Cash Cost of Supply', and' Annual Production' to segment and prioritise our end-user engagement strategy and further explore opportunities for delivery into the UK market.
- Constructing an in-depth plan for the field-testing phase to facilitate quantitative analysis of our performance metric data using real use-data.

The outlined project outcomes are in line with our project roadmap. Whilst at project closure we had yet to undertake robust testing of our technology and subsequently collect use-data, we are confident in our commercial learnings and conclusions drawn from analysis of and engagement within the bioenergy market landscape.

Project Conclusions

The overall conclusion drawn from this process, is that whilst our concept provides the technical solution to overcome the inefficiencies of centralised pellet production operations, this is insufficient to overcome the cost barriers to scaling perennial energy crops (PEC's) without a supportive incentive structure. For non-food lignocellulosic agricultural residues (straw), projected over-demand limits the opportunity and scale to produce straw pellets to 2-5 years post-project.

In a market landscape where energy crops are not on a level footing with other land uses in terms of public subsidies, such as forestry, feedstock costs will remain an insurmountable barrier to accelerating the domestic pellet market and increasing UK biomass feedstock supply and we can expect a continued reliance on imports.

However, beyond the UK the opportunities for scaling decentralised pellet production are optimistic. A flexible model of decentralised pellet production, like that developed within this project, can be replicated where there is an abundance of low-value feedstocks such as agricultural residues and an aggregation-based commercialised strategy can be effectively deployed. As such, the project team have further explored opportunities to deploy a model suited for the Indian bioenergy market to support India on its Net Zero journey.

Table of Contents

Design and Development of the Innovation

Phase 1: Feasibility Assessment

The market-leading Metitron560 model, developed by our project partners Metitron GmbH, is the design baseline from which our containerised innovation has been developed. This mobile pelletisation technology has proven robust operational use within Metitron560 demonstration platforms.

Within Phase 1, we explored three potential innovative configurations of mobile pelletiser technology:

- Optimisation of existing mobile pelletiser technology (Metitron560) 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 containerised version for stationary use.

We evaluated these innovations based on their technical feasibility, cost implications and carbon emissions. As a result, we sought to pursue the containerised version within Phase 2 due to our belief that it represented the greatest opportunity to deliver large scale, decentralised production of low cost and low carbon biomass pellets, ideally suited to the UK's centralised consumption landscape.

We assessed the feasibility of the containerised configuration by developing a computer-aided design (CAD) model that re-organised key components within current Metitron560 mobile pelletiser into a 40ft standard shipping container (**Figure 1**).

In undertaking this assessment, we concluded that only minor adjustments were necessary to convert the pelletiser from mobile to static mode and that these were well understood. Thereby we considered our innovation to be a TRL 5.

Our Phase 2 bid, subsequently sought to bring to fruition a protype of our mobile pelletisation technology integrated within a container with an additional application for two novel feedstocks: miscanthus and SRC willow chip.

Phase 2: Technical Approach

Our project was structured by a two-fold approach to demonstrating our technology by the:

1) Technical merit of the innovation
2) Application of the innovation to and robust testing within the operational environment

Technical Merit

As set out in our Phase 2 application, we sought to demonstrate the technical merit of our innovation by:

- Developing a full mechanical and electrical plan of our model
- Developing a specific control system
- Constructing and assembling all parts into a container

Application to the Operational Environment

We sought to apply our mobile pelletiser technology for operational use behind the farm gate, by ensuring that it could:

- Pelletise two cuboid or round compressed bales side to side (1.5m x 1.5m) and SRC willow chips.
- Operate within a container that is stable and stackable for ease of transportation.
- 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).

Phase 2: Technical Development

On conclusion of Phase 2, we had succeeded in designing and developing our mobile pelletisation technology for the required use-case in line with the aforementioned operational requirements. All but one of the mechanical assemblies had been integrated into the container and a bespoke control cabinet was built ready for cabling and signal testing. **Figures 2- 4** demonstrates the physical progress to date and overall specs of our technology in line with the operational requirements.

In developing the containerised design conceptually, the material flow mirrors that within the 'mobile mode', but as anticipated some modifications were required to adapt the mobile technology to a solely static, electric-powered pelletiser. The adjustments to the material flow ensured; continual processing of material by overcoming height differences within the container, sufficient thermal dissipation, stability and transportability of the container. The broad process flow is outlined within **Figure 5**.

The key focus areas for technological development of the containerised pelletiser are highlighted below.

Feedstock in-feed

A dual feed system was developed to enable both the processing of bales, (by a two-part conveyor) and chipped material (by a funnel directly into the knife drum). **Figure 6.**

Dust and heat management

Ensuring sufficient management of dust and heat was a key consideration within the design process, to mitigate the risk of fire and explosion, with several actions taken to address. Firstly, we selected a container with three-side open doors to promote dissipation of thermal energy and ventilation. The expectation being for these doors to be kept open during operation, and the entire container placed outside.

An internal ventilation system was developed, and an appropriate spark detection system incorporated at high-risk stages of production, triggering a shut-down and water quench inside the respective piece of equipment. The internal equipment was designed with connectors and interfaces to contain the dust, and all conveyors enclosed with an anti-static housing.

Furthermore, we engaged the specialist health and safety firm Booth Welsh to undertake a formal Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) assessment and Hazardous Area Classification. This assessment was undertaken on the basis the containerised pellet innovation is a working prototype and that we would reasonably be expected to respond to all known risks. The assessment considered both highly hazardous areas and risks posed throughout should particle sizes be over-sized or concentrated. The high-risk areas considered were those associated with a high dust concentration, namely the pre-bunker, screening machine and return conveyor to the pre-bunker.

The DSEAR report made two main recommendations that were implemented within the design: the installation of additional sprinklers in the ceiling of the container and explosion suppression equipment. Further the learnings were reflected into the Operations and Maintenance guidance for operators to ensure sufficient housekeeping steps are taken to prevent the build-up of dust and thereby reducing the risk of a flammable dust cloud.

Overcoming spatial limitations: access and maintenance

A key challenge in developing this innovation was ensuring access to vital components for maintenance without compromising on the overall stability and transportability of the container.

Screening machine and water tank
A custom-built ladder will be transported within the container, to allow ready access to the screening machine and water tank.

Control cabinet
A bespoke control cabinet was developed by UK-based sub-contractor AC-Sys to the specifications detailed within Metitron's electrical plans. Over the construction period, a peer review process between all technical parties resulted in adjustments to improve accessibility by reviewing the location of some of the wiring and technical components selected. This included use of extended main bars to reduce complex bus bar shapes, reduced capacity of secondary bars, reduced capacity of secondary bars and use of Hi-Flex Cable and laminated bars**. Figure 7.**

Changing blades in knife drum
It was anticipated that the knives within the knife drum would require replacement every 500 hours, however, the positioning of assemblies resulted in the bale shredder blocking access to the knife drum. A solution developed was for the bale shredder to be placed on tracks to be steered outside the container, allowing access to the knife drum. This process would be electrically controlled to limit user intervention required.

Bale shredder safety system

We identified the need for a safety system to avoid the risk of injury from accidental physical contact with the bale shredder (as the only 'open' assembly). As a result, the electrical plans were developed to include an alarm passive safety system to ensure immediate shut down of the machine in the eventuality of any moving objective entering the security perimeter. The addition of a physical barrier to further restrict access to the bale shredder was constructed, to mitigate the risk of reliability in the electronics as noted in Booth Welsh's safety review.

Discharge unit

The discharge mechanism for finished pellets was a focal area for technical development, with multiple iterations considered.

The finalised unit has a telescopic arm to enable discharge direct into a grain trailer, with a blower used to guide movement therein. The telescopic arm is extendable to 4.5m to reach the required height for direct discharge, without need for conveyors, and is foldable into container for transportation (by use of rollers).

The attaching joint was constructed to allow sufficient flexibility for filling into two side-by-side grain trailers, meaning only one operator is required. The finalised version allows the discharge arm to pivot at five points within the 80-degree range of motion, allowing for quicker and more efficient loading of trailers with the finished pellets, compared to the initial fixed design. **Figure 8.**

Pellet cooling

A routine challenge for mobile pellet production is ensuring the sufficient cooling of pellets, without use of industrial-size cooling units, for onwards transportation and storage on-farm. In re-reviewing our process flows within the containerised pelletiser and planned approach for onward process for transportation and storage of pellets on-farm, we considered there to be insufficient opportunity for the core pellet of the temperatures to reduce. Therefore, posing a risk to both the quality of the pellets (as pellets harden on cooling) and more importantly of self-ignition of the pellets. Consequently, an integrated additional cooling system was deemed necessary.

During the resulting peer review process, we discounted integrating a pellet cooling unit within the container, due to insurmountable spatial constraints. Finding a solution that suits our throughput of material, internal processes, and onward discharge process, necessitated a custom solution to be built to combine industry best practice with our innovative technical process. The concept for a foldable, readily moveable cooling unit was thus conceived to be externally situated, but simultaneously connected to internal processes within the container. The integration of additional cooling at an early stage of the pellet production process is designed to prevent loss of integrity or disintegration of the pellets arising from them being handled excessively at a high core temperature **Figure 9.**

Analysis: Key Performance Metrics

In line with our overall project objectives, we refined our assumptions and understanding of our key performance metrics:

1) Cash Cost of Supply (Per MJ)
2) Annual Production (Per Tonne)
3) Carbon Emissions (gCO2/MJ)

The project was structured to facilitate quantitative analysis of our key performance metrics, based on use-data generated from the field-testing phase. In line with our project roadmap, on project closure we had yet to reach the stage of confirming or updating these performance metrics in quantitative terms, however we had revised our assumptions and understanding of these to consider our overall commercial strategy.

Cash Cost of Supply – Barriers and Opportunities

Firstly, we revised assumptions made during Phase 1 relating to the projected Cash Cost of Supply. Four variables in pellet production costs were updated in December 2023 within a broader 'Ability to Pay Analysis' undertaken. The updated variables were thereafter used for comparison against the forecasted 'ability to pay' for strategic end users, based on three different cost scenarios (with varying maintenance and utilisation rates).

These projected costs were thereafter compared to prospective end users' ability to pay for pellets, considering three types of potential end users:

- **A merchant biomass power plant,** a converted coal power unit operating on a merchant basis between 2027-2030 when GB power prices support this. It is assumed that such a buyer purchases pellets under a 1-year contract.
- **A bioenergy with carbon capture and storage (BECCS) power plant,** supported by a dual CfD and buying pellets under a 10-year fixed price supply contract.
- **A sustainable aviation fuel (SAF) production plant,** supported by an SAF offtake contract and buying pellets from 2027 under a 5-year fixed price supply contract.

From analysing these findings, the following key conclusions were drawn:

1. Wheat straw and miscanthus based pellets derived from our innovation are competitive with imported wood pellets from North America on a cash cost basis.
2. Straw pellets are significantly lower cost than miscanthus pellets on a per GJ basis (around 15% lower cost in the Central Case).
3. The use case with the highest ability to pay (in Central Cases) is an SAF production plant using gasification Fisher-Tropsch technology, followed by a BECCS plant with future UK government Contract-for-Difference support and an SAF production plant using Alcohol to Jet technology.
4. The use-case with the lowest ability to pay (in the Central Case) is a biomass pellets based power plant running on a merchant basis.

However, a further important conclusion from the Ability to Pay analysis is the low margin available for miscanthus based pellets. Using Central Cases, the highest cash margin available for miscanthus pellets (given they are effectively excluded from the emerging SAF market) would be around 10% in the BECCS case. Such a margin would be difficult to justify for a business deploying our innovation on a commercial basis, considering the need to fund corporate administrative costs, pay back capital expenditure and earn a reasonable rate of return.

This low margin also implies there would be very limited, if any, surplus economics available to distribute to miscanthus farmers to improve the pricing they receive per tonne of baled feedstock compared with current pricing levels.

By contrast, the economics of using straw pellets are more favourable. Again, using Central Cases, the highest cash margin available for straw pellets supplying an SAF gasification-FT plant would be around 40%.
A collective conclusion drawn by the project Strategy Team, is that in absence of government subsidies for PECs, securing offtake arrangement for agricultural residue (straw) pellets should be prioritised with three major UK based pellets power stations as well as UK based SAF plants that are moving through their development cycle with UK government support. However, it is noted that the opportunity for straw pellets is finite and only viable in the short or medium term.

If the project were to have continued, the next step for engagement with strategic end users would have been to undertake lab analysis of a sample of straw pellets produced. In addition, given the cost variables used in this analysis were broad, the cost competitiveness of our pellet production approach against alternatives cannot be confirmed without use-data.

Fundamentally, while the pelletiser does significantly reduce the CAPEX requirements for pellet manufacture given it's intended on farm location where existing materials handling capacity can be exploited, without a strong PEC incentive that at least matches the incentives available in other sectors (forestry), it is not expected that the pelletiser is a viable option for mass pellet manufacture from energy crops in the UK.

Annual Production

Our commercial strategy is contingent upon having sufficient feedstock to fulfil our ambitions of a year-round annual schedule for production and a high-utilisation rate for our pelletiser. In revising pellet production variables, we refined the utilisation scenarios to reflect this being a solely static pelletising operation.

Carbon Cost to Supply

Similarly to the Cash Cost to Supply analysis, the field-to-furnace pellet supply chain would have been confirmed by demonstration of our 'hub' model in the field-testing phase. However, it is to be noted that the field-to-furnace component of our project remains broadly as envisaged at the start of the project.

Based on these field-to-furnace assumptions made within Phase 1, we calculated the Avoided Carbon Emissions in utilising our innovation was at 1075.5 tCO2e / functional unit / year, compared to an imported wood pellet delivered to the UK. This calculation is yet to be formally verified but was an outcome from attending a workshop hosted by the Carbon Trust (as part of the NZIP Accelerator Programme support).

Commercialisation Plan

Throughout Phase 2, we considered the key economic drivers of the strategy as being:

1. The cost of the raw material inputs into the pelletisation process
2. Production Costs
3. Distribution Costs
4. Sale Price

To summarise, the competitive advantage our approach has for pellet production is the higher relative efficiency of our manufacturing process relative to existing pellet sources. Additionally, distribution costs regarding transport utilisation are relatively low compared to alternative methods of pellet production. These efficiencies are strong proponents for a scaled decentralised production network, but at the time of writing are not considered to overcome prohibitive PEC feedstock costs, to meet the forecasted purchasing power of strategic end users within the near-term.

Buy-Side Analysis

Throughout Phase 2, the project team refined our commercialisation strategy through further market research and an Ability to Pay analysis. Through market engagement we were able the following conclusions:

- Cement companies are unlikely to be in the first wave of potential offtakers of pellets derived from our innovation, as their decarbonisation focus at present is on replacing fossil fuels with lower cost, unrefined low-carbon feedstocks such as refuse-derived fuel (RDF).

- Within the lime industry, whilst pelletised fuel is well suited to the design of modern vertical kilns, the industry's current decarbonisation focus is on procuring wood pellets rather than agricultural biomass-based pellets.
- Anaerobic Digestion (AD) plants were discounted following completion of an Ability to Pay by bioeconomy consultants NNFCC concluding the cost ceiling of £30-40 per tonne and miscanthus pellets £45-55 per tonne - not economically viable for our innovation.

We also explored several opportunities for supply into small-scale, localised biomass boilers, although most technologies at this scale were found to not support miscanthus and/ or wheat straw pellets with significant risk of corrosion due to increased levels of sulphur and chlorine. Ceramic conversion kits are available, although the cost to install these would negate any benefit versus alternative fuels.

These targeted market research initiatives served to confirm our strategy to focus on two primary first use cases for pellets derived from our innovation. The first primary use case is dedicated biomass power plants already using wood pellets interested in diversifying their fuel input, with or without future BECCS support from the UK government. Both miscanthus and wheat straw pellets may be of interest to such users.

The second primary use case is Sustainable Aviation Fuel production plants. Only wheat straw pellets are expected to be of interest to such plants based in the UK, due to the restriction that UK government SAF incentives are only available to projects that utilise residues, i.e. energy crops are explicitly excluded from UK government SAF support.
At the time of writing, the project team had been engaged with two leading biomass pellets-based power companies and two leading UK SAF companies using agricultural waste feedstocks. With all parties engaged to date expressing interest in receiving test volumes.
To enhance our understanding of SAF technologies and companies, the project team commissioned a comprehensive report on the SAF market.

To conclude, as set out within our Phase 2 application, our approach and 5-year forecast is contingent on being able to successfully secure a few large supply contracts, or a large number of contracts with smaller consumers of pellets. To act as a 'demand-pull' for scaling UK biomass supply. Thereby securing offtake from these key users can be considered vital to any meaningful increase of domestic biomass supply. It is likely that pelletisation of these feedstocks will only be economically viable where the technology seeks this type of feedstock processing as part of it's feedstock preparation. Otherwise, the additional cost of pelletisation would be both unnecessary for the mechanics and prohibitive to the economics of the operation.

Supply-Side Analysis

Policy Considerations

A key policy development during Phase 2 was the release of the UK Biomass Strategy in August 2023. Whilst a broadly supportive statement of principles, there were few implementation details. Following on from this, we have since observed no further policy developments, that would support our innovation.
Policy announcements detailing the eligibility of feedstocks within the UK's SAF mandate confirmed that only agricultural waste products are allowed. Our understanding continues to be that this restriction excludes all types of energy crops, including miscanthus where our project has focused, while also creating a risk of future straw scarcity through the potential for SAF to create an over demand scenario.

It was therefore decided to pivot the project's feedstock focus away from miscanthus, and back towards agricultural residues, at least for the immediate to short term, (2 to 5 years), or until further clarity is made available around UK biomass policy. The previously mentioned Ability to Pay analysis revealed that an active government policy, including new incentives for farmers, will be essential to the future success of our technology in the UK, notably for the growth of miscanthus supply where the economics are more challenging than for wheat straw supply, but promise far greater supply security and sustainability through the creation of dedicated supply chains and environmental benefits respectively. The lack of such incentives for farmers represents a significant policy barrier.

However, despite the pivot away from miscanthus, it had been still intended in the field-testing phase to include an equal volume of miscanthus and straw within the testing regime and test sites were shortlisted by feedstock availability and access to end users.

Lessons Learnt

The learnings derived from developing our pelletiser technology are captured within the section titled 'Phase 2: Technical Development'.

Designing for scaled manufacture

In terms of commercial learning points, we considered firstly design changes necessary for scaled manufacture of future units of our pelletiser. The first steps here were undertaken through the Carbon Trust to review our innovation design from the perspective of assembling at scale.

The learnings from this process were considered into subsequent reviews of our innovation design for interrogating offshore manufacturing opportunities. The outcome being a revised schematic developed by project sub-contractor JPR Pro-Tech. This included a specification and part analysis for each component, for the next design iteration that can still achieve optimum throughput and efficiency in processing the target range of feedstocks whilst as a model appropriate for scaled manufacture (**Figure 10**).

This schematic is the first building block to estimate the capital cost for future units of the mobile pelletiser prototype and to develop an understanding of what can be sourced locally to any overseas manufacturing operations, and what might need to be imported or developed for our own manufacture longer term. A more granular understanding of the technical requirements will greatly assist market research of component procurement and contract manufacturing and assemblies.

Power consumption

A commercial learning point during the process of shortlisting test sites was the challenges posed by the high-power consumption of our pelletiser (450kW). Finding suitable test sites with sufficient power available for our pelletiser, proved to be a significant hurdle.

In instances where power supply might have theoretically been feasible, this is already committed under existing contractual arrangements (e.g. powering by AD plants) and increasing the supply available to prospective sites or diverting existing supply was not feasible, from a cost or time perspective, within the project parameters.
We worked hard to address this, in widening our search for test sites beyond our key strategic regions to find a suitable option (whilst ensuring operations are still behind the farm gate and otherwise meeting our required eligibility criterion).

Where there was sufficient power supply available, we investigated the costs for connecting to the pelletiser, however in these instances it proved unfeasible within the project budget.

However, through this process we now have a better understanding for connecting hubs post-project to sufficient supply.

Consequently, we had planned to use a generator within our field-testing phase. Whilst this would have had a higher carbon cost, the same learnings could be drawn in terms of sustained and peak load of power to provide quantitative use-data of Cash Costs to Supply. This outcome would not have hindered the collection of use-data for revising our commercialisation strategy for longer term unit deployment.

Our overall commercial strategy is unaltered in supporting Net Zero transition globally, and this learning can be factored into the planning process for selecting farm hubs going forward. Several of the shortlisted test sites, with footholds in strategic regions, expressed willingness to work through the necessary planning permissions to increase their power supply, should we embark on a longer-term contractual arrangement in the UK market.

Following on from this process, we looked to consider a “scaled down model” for future iterations as detailed in the schematic within **Figure 11**, with a throughput of ~1 tonne per hour. The rationale for this being to consider the potential strategic advantage to deploying a reduced capacity model with lower capital costs, power requirements and operational footprint that might aid rapid deployment both in UK markets and export to international markets.

Environmental Benefits Assessment

The key environmental benefit our innovation will bring is a reduction in greenhouse gases – notably CO_2. In Phase 1, we assessed this metric through a Carbon and Market Study.

Carbon emissions were calculated for the entire supply chain from field-to-furnace, starting from the establishment and cultivation of the feedstock, with carbon sequestration of the feedstocks also considered. The emissions for the containerised pelletiser supply chains were then compared to those by imported pellets to assess whether the resulting supply chain scenarios constructed within our Market Study would have carbon reduction benefits. Some assumptions were necessary but were formulated on both data taken from White Horse Energy’s vast biomass supply chain experience and Metitron’s end-use data.

It had been intended that we would refine these towards the end of Phase 2 once we have real life deployment data, however at the time of writing we do not anticipate substantive changes to our field-to-furnace model.

Carbon Emissions were lowest for the solar PV powered configuration, however the innovation still performed well against imports when powered by grid electricity and a reduction in carbon emissions compared to imported wood pellets from US South, Canada, Baltic States (significant import origins for the UK pellet market).

Given our innovation is on farm, but off field any air, water, soil, and biodiversity impacts from PEC growth will be indirect, but within with the expectations of the Climate Change Committee’s (CCC) Sixth Carbon Budget Net Zero Scenarios. In comparison, pellets agricultural residues will have no impact, given it will simply be a change in end use for pre-existing residues.

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. We look forward to further clarification on classification of indirect land use change for dedicating land to energy crops in DEFRA's Land Use Framework.

Throughout Phase 2 we have continually reviewed the environmental benefits our innovation presents in terms of carbon reduction across the entire pellet supply chain and closely followed wider industry research on the environmental impact of PECs and support development of an 'industry-standard' for measuring soil carbon levels.

We have taken an active interest with ongoing trials including carbon trials (NIAB), water trials (Environment Agency) and work done by the Game & Wildlife Conservation Trust, in building an understanding of current research relating to:

- Carbon storage and accreditation/ codes
- Water (Miscanthus Effects - absorptive capacity, flood defences, run-off, erosion, quality, riparian buffer strips)
- Soil biodiversity

International Outlook

Large scale decentralised pelletisation of either agriwastes (straw) or energy crops (grasses) are of interest in several other geographies, particularly in the global south. However, the benefit of containing a production unit into a container such as in our innovation is questionable. Key to these use cases is a minimisation of CAPEX cost, and packaged "plug and play" mini plants may well be a better method of delivering large scale decentralised pellet production.

Insights into India

We have carried out several field trips to India during 2023/24, including visits to key agricultural regions in Gujarat, Madhya Pradesh and Maharashtra, to assess the suitability for small scale, distributed pelletisation technology. Following these visits we have concluded there are immediate opportunities to enter the Indian pellet production market with a simplified, scaled down version of our innovation.

India has the 2nd largest global reserve of biomass, (after China), and one of the largest global producers of rice, wheat, cotton and sugar, that generate an estimated 750 million metric tonnes, (MMT) of agri residues annually, of which 230 MMT/ year is surplus.

Farmers across India routinely burn these surplus residues, in the form of crop stubble, owing to a short window between harvesting and sowing their next crop. Emissions from crop burning drift downstream into urban areas and are a major contributor to India's urban air quality being rated the worst globally. The annual cost of air pollution attributed to crop burning is estimated at USD 300million measured in terms of impact to health and economic disruptions.

Pelletising agri residues is already a recognised solution in India to tackling urban air pollution. Limited storage options and pressure to plant new crops within 3 weeks of harvest means farmers need to dispose of these residues quickly. Attaching value to residues is widely seen as the most effective way of incentivising farmers to stop burning. However, progress to date has been hindered by challenges in scaling pellet production with critical gaps in the value chain. Aggregating agri residues is also complex within India's network of smallholders, where rural access issues and embedded cultural practices pose challenges at local level. High CAPEX required for mid to largescale static mills has also restricted market access to medium-large enterprises, with most value bypassing smallholder farmers and their local communities. Greater incentives are therefore needed at rural community level to change mindsets.

Based on the concept of our existing innovation, we are assessing viability to initiate small-scale (<1 tonne per hour output) low-cost, compact biomass pellet production units for rapid deployment with minimal infrastructure into rural locations across India’s key agricultural regions. A small-scale community led approach could deliver up to 50% of the annual biomass capacity required to decarbonise large scale industry and thermal power generators, as outlined within India’s Nationally Determined Contribution. This approach also demonstrates scalability through its versatility to process a range of AR year-round.

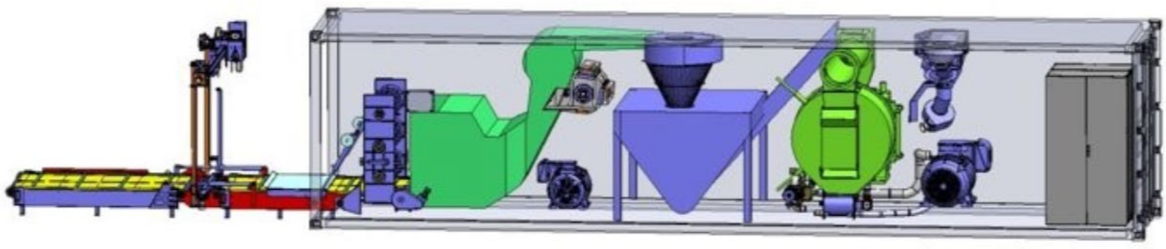
India’s annual domestic solid biomass demand was projected at $\geq$ 50MMT in FY24-25, largely attributed to a cofiring mandate issued by the Ministry of Power in 2021, which requires thermal coal power plants to cofire with 5% biomass pellets, increasing to 7% in FY25-26. This vastly exceeds the current annual production capacity of 2MMT tonnes. Building capacity to 50MMT would make India the biggest pellet market globally.

Opportunities to replicate a smaller simplified “plug and play” version of the technology are also evident across other parts of Asia, where intensive smallholder cereal production similarly results in adverse impacts from widespread crop stubble burning, and similar policy incentives are driving industry transition from fossil fuels towards bioenergy.

India’s recent economic growth, cost-effective manufacturing, and location between the Middle East and Southeast Asia, make it an attractive destination to establish a strategic manufacturing hub for the innovation, to cater for domestic demand, and exports to other regions across Asia.

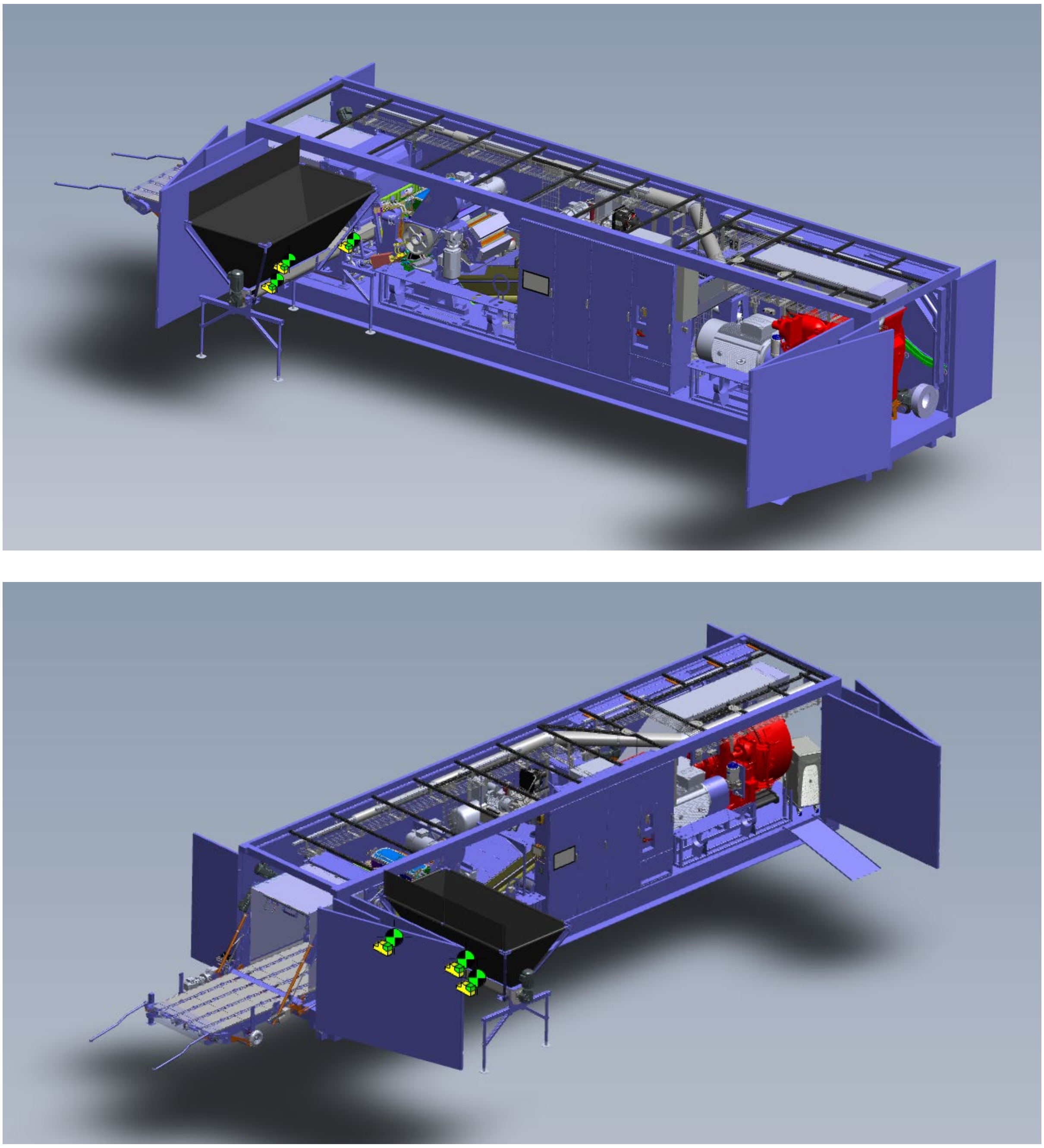
Appendices

Figure 1



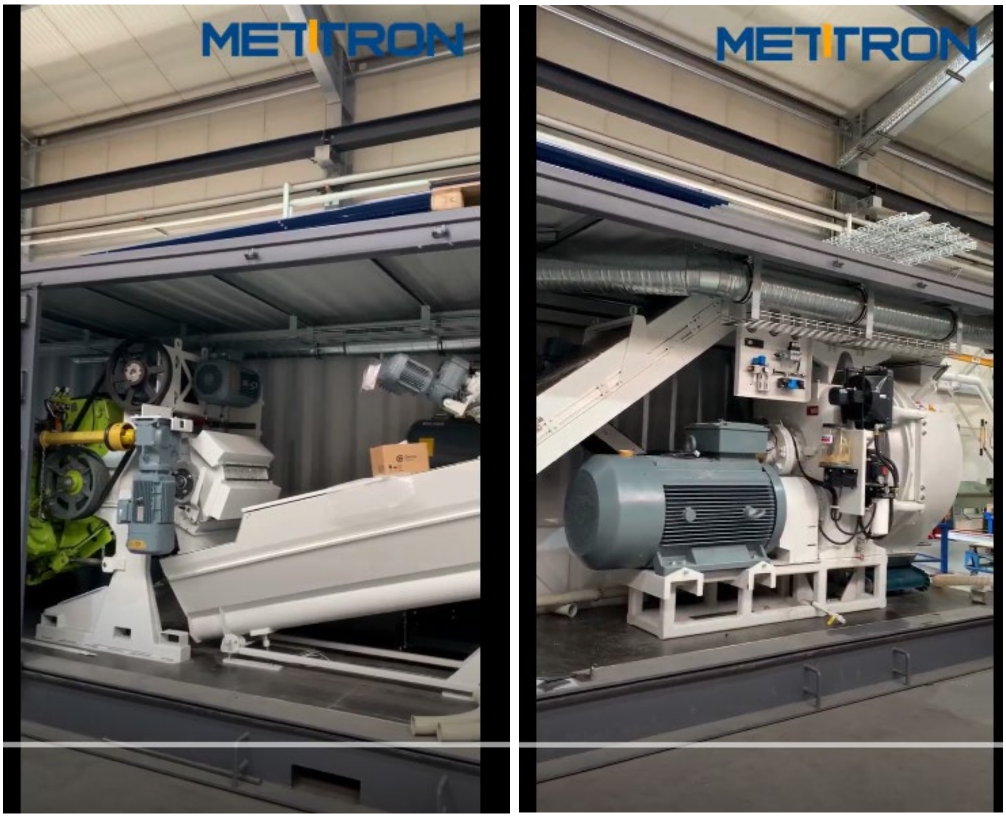
CAD feasibility of the containerised configuration (Source: Metitron GmbH).

Figure 2



Final CAD Model (Source: Metitron GmbH).

Figure 3



Screenshots from video of current state of installation (Source: Metitron GmbH).

Figure 4

General

Power Requirements: 3 phase (800A, 500kW, 750kVA)

Output: Miscanthus 3 tonnes per hour, Straw 5 tonnes per hour.

Class Knife Drum: V-MAX 36 Knife drum with pre-press rollers

Pelletizer:

Pellet Mill

- CPM 7932-7
- Pneumatic cylinder for QDFC
- Die type 32-7 – 8mm
- Standard Toolset
- Remote roller adjustment: Lineator (without Controls)
- Roll Speed Measurement

Power Specifications:

- Feed Line L1/L2/L3/N/PE
- Voltage 400V
- Frequency 50Hz
- Current 800A
- Coincidence factor 0.70
- Power 450kW

Feedstock Characteristics:

Bale Size: The prototype is built to take a maximum bale size of (275x130x120cm – 800kg) that have been tied with nylon baling twine

Baled material:

- Miscanthus
- Straw

Loose Material:

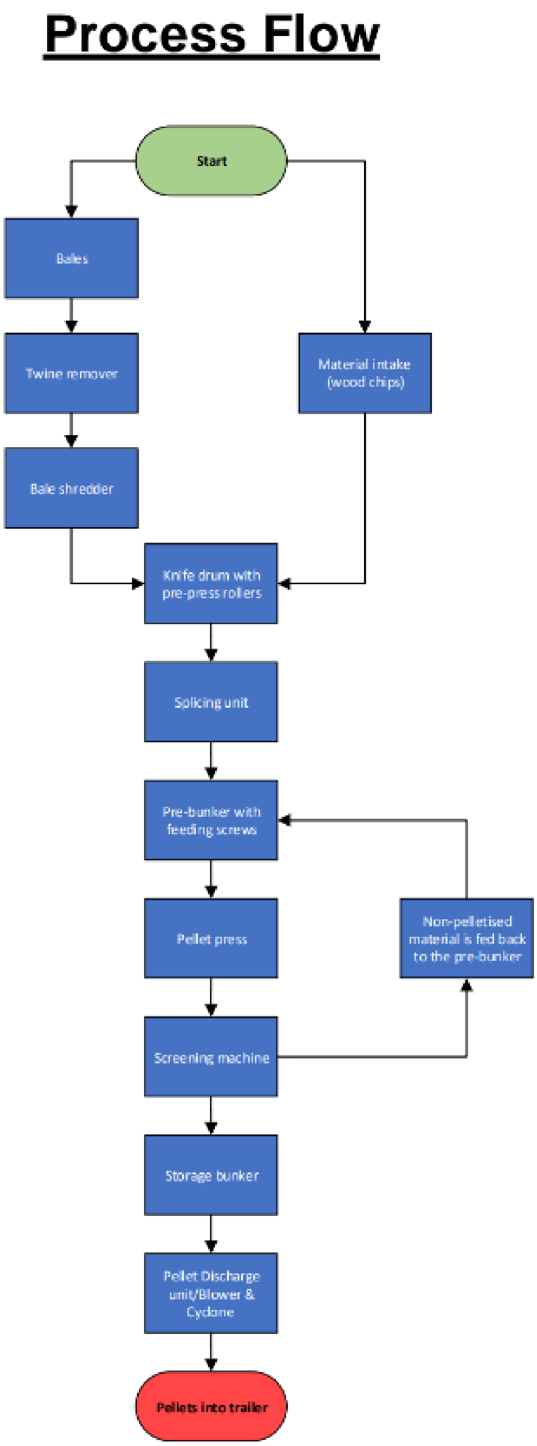
- Chipped SRC Willow

Moisture content:

- Miscanthus: 8 – 14%
- Straw: 8 – 14%
- Chipped SRC Willow: 8 – 14%

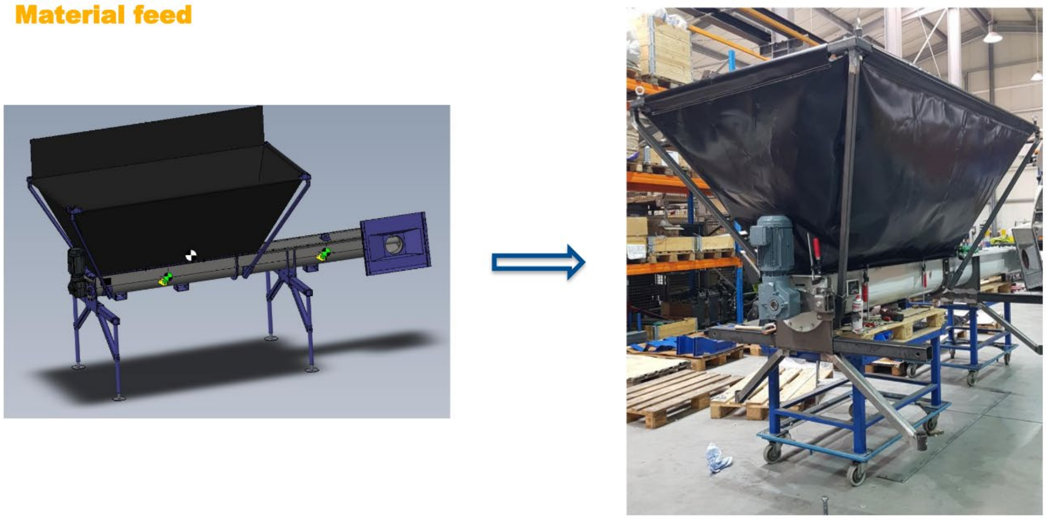
Overall specifications of the prototype.

Figure 5



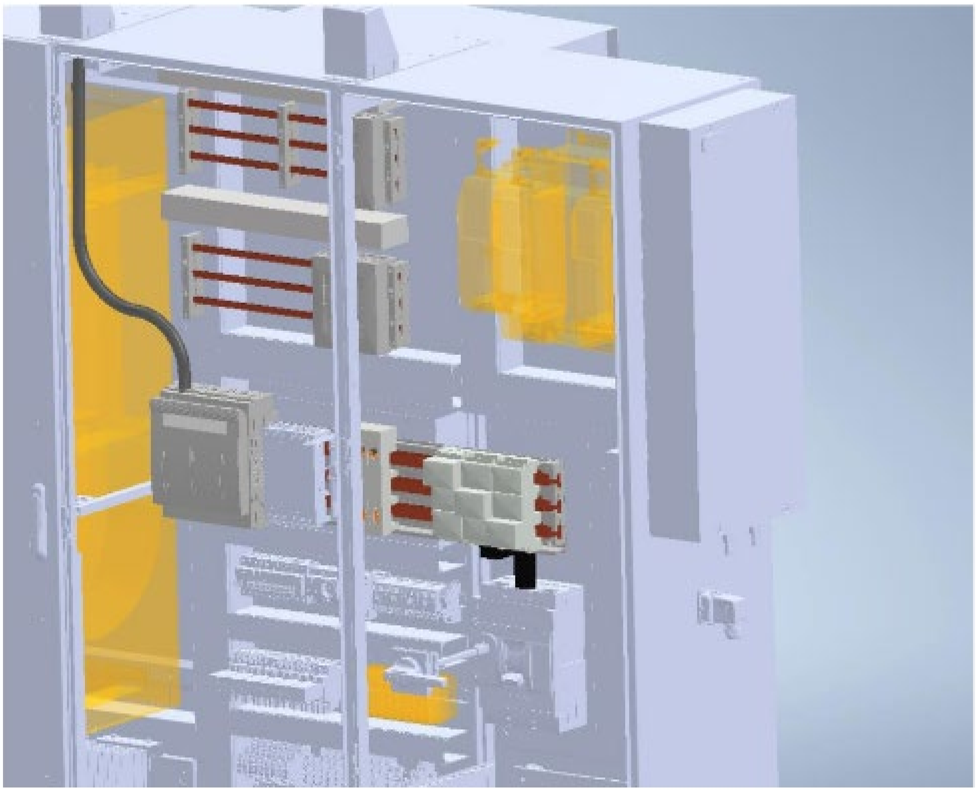
Process flow of the prototype.

Figure 6



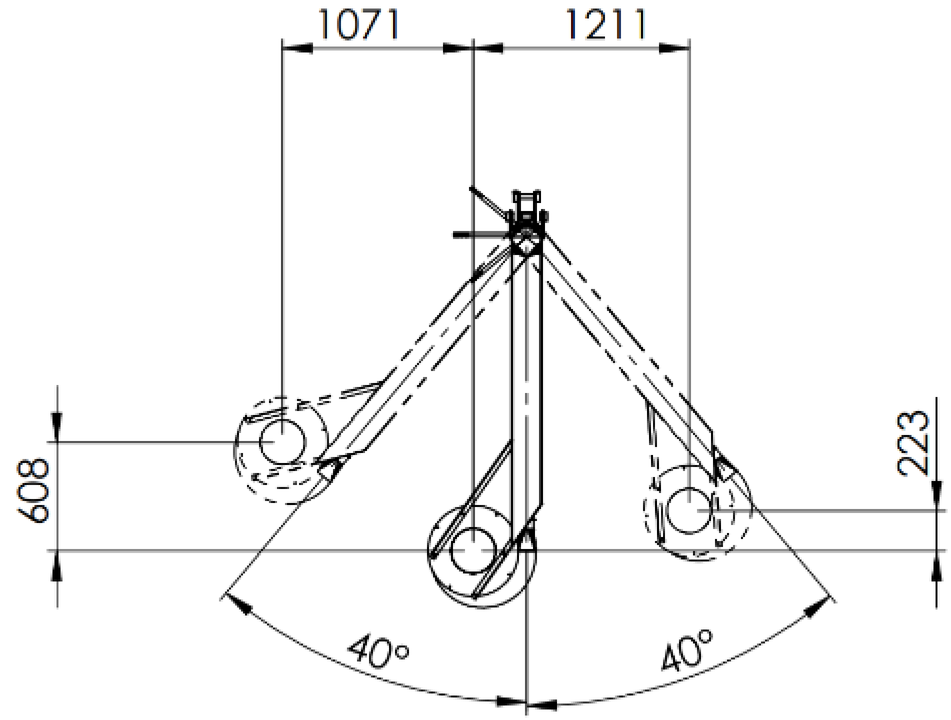
Loose chipped material feed (Source: Metitron GmbH).

Figure 7



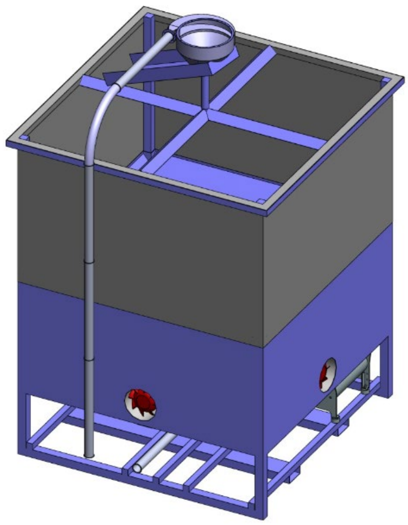
The figure shows the included use of extended main bars to reduce complex bus bar shapes, reduced capacity of secondary bars, reduced capacity of secondary bars and use of Hi-Flex Cable and laminated bars (Source: AC-Sys).

Figure 8



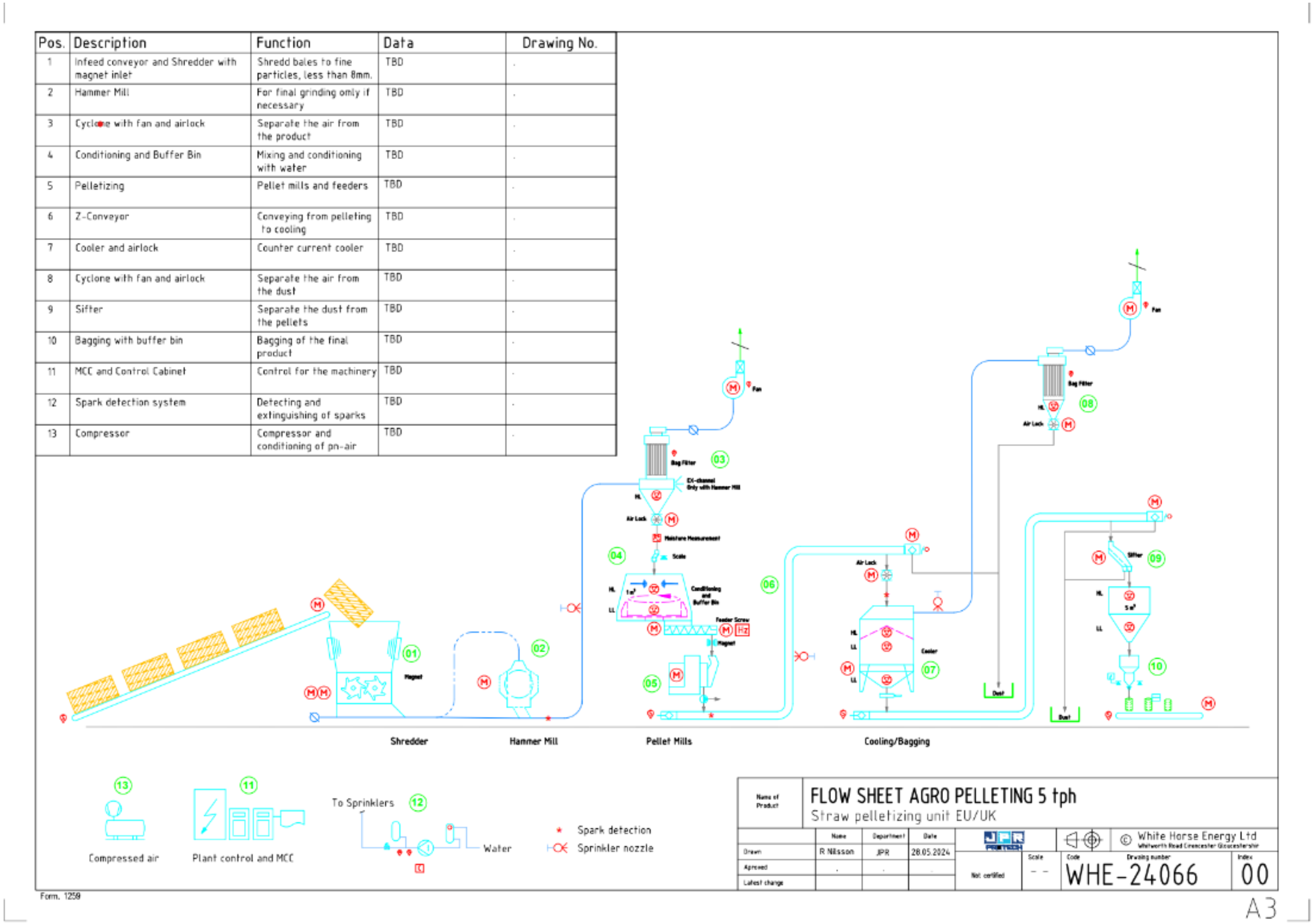
The figure shows the discharge arm with the 80-degree range of motion (Source: Metitron GmbH).

Figure 9



The CAD drawing shows the design of the pellet cooling system (Source: Metitron GmbH).

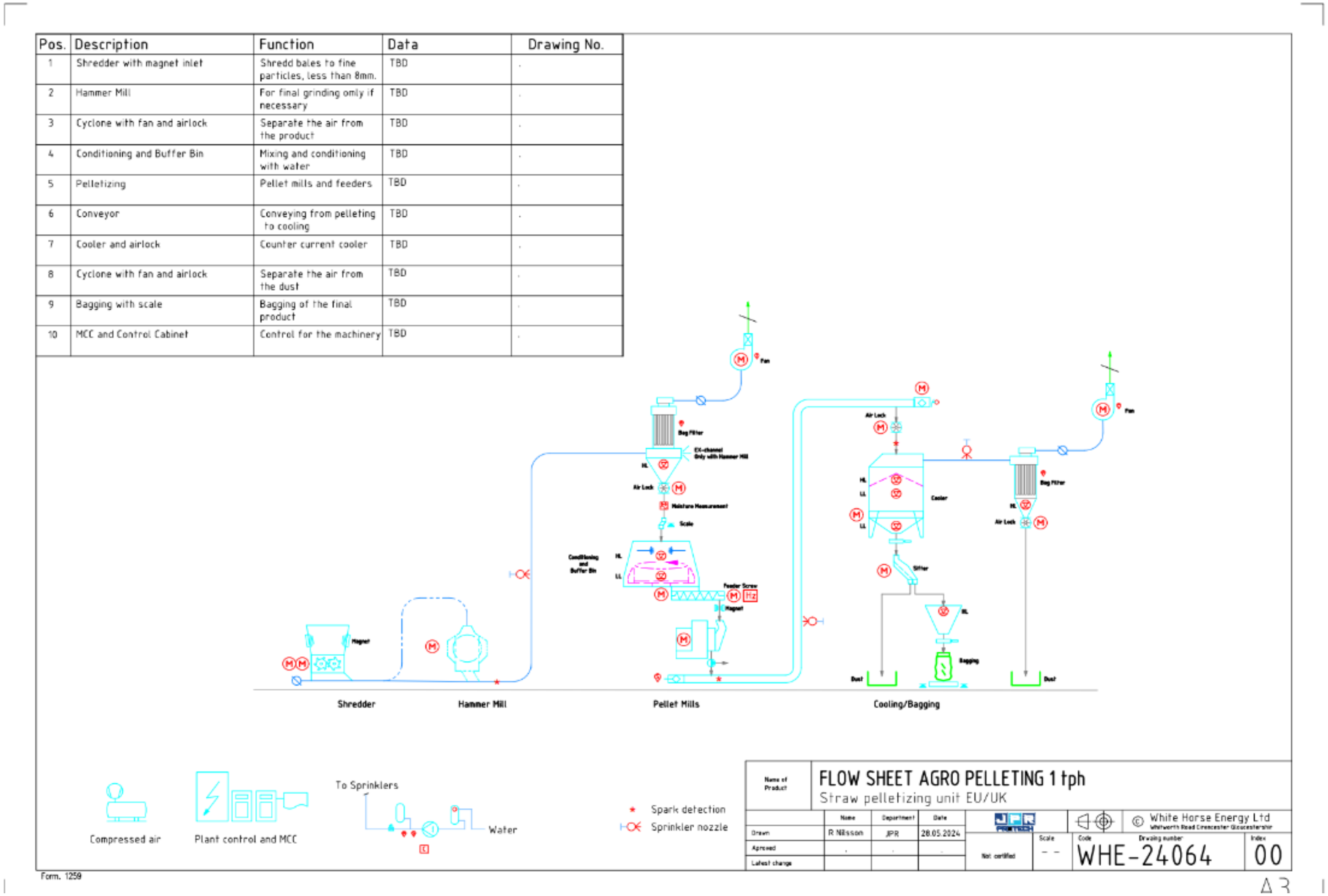
Figure 10



Pos.	Description	Function	Data	Drawing No.
1	Infeed conveyor and Shredder with magnet inlet	Shredd bales to fine particles, less than 8mm.	TBD	.
2	Hammer Mill	For final grinding only if necessary	TBD	.
3	Cyclone with fan and airlock	Separate the air from the product	TBD	.
4	Conditioning and Buffer Bin	Mixing and conditioning with water	TBD	.
5	Pelletizing	Pellet mills and feeders	TBD	.
6	Z-Conveyor	Conveying from pelleting to cooling	TBD	.
7	Cooler and airlock	Counter current cooler	TBD	.
8	Cyclone with fan and airlock	Separate the air from the dust	TBD	.
9	Sifter	Separate the dust from the pellets	TBD	.
10	Bagging with buffer bin	Bagging of the final product	TBD	.
11	MCC and Control Cabinet	Control for the machinery	TBD	.
12	Spark detection system	Detecting and extinguishing of sparks	TBD	.
13	Compressor	Compressor and conditioning of pn-air	TBD	.

Process flow of revised 5 tonne per hour pelletising unit (Source: JPR Pro-Tech, June 2024).

Figure 11



Process flow of revised 1 tonne per hour pelletising unit (Source: JPR Pro-Tech, June 2024).