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Deliverable 3.2

Report on supply chain solutions for the main scenarios detected in the target countries

Technical References

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Project Title	Unlocking a new feather bioeconomy for keratin-based agricultural products
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[1] PU = Public
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RE = Restricted to a group specified by the consortium (including the Commission Services)
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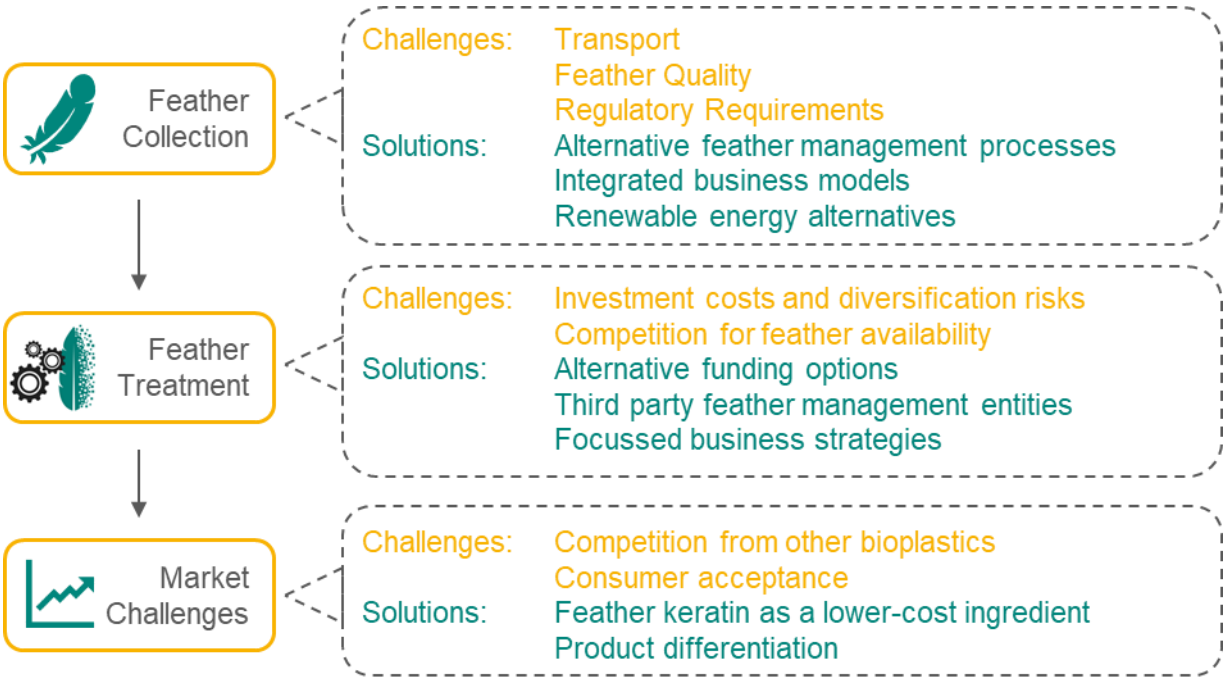
1. Introduction

As reported in Deliverable 2.3, titled, 'EU's Feather-Based Economy; The Challenges Ahead', a number of key challenges exist within the development of a new feather value chain, some of which are rooted in current practices, and others which will become relevant once the novel value chain begins to operate. These challenges are omnipresent across the five target countries of Italy, Spain, France, Germany, and Poland.

This report focuses on solutions to those challenges presented in Deliverable 2.3 and proposes scenarios at various points along the supply chain where these challenges will present themselves. Highlighting these areas now assists in focussing the work ongoing under the project and opens the door for existing players in the feather supply chain to pivot their businesses in order to position themselves to take advantage of opportunities further down the line – both in terms of value to feather suppliers, and to processing entities.

Figure 1 below summarises the relevant stages of the value chain where the key challenges exist and provides a brief overview of the solutions that are explored in greater detail throughout the report.

Figure 1 Summary of Challenges and Proposed Solutions



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2. Methodology

The completion of this report involved considerable primary research into the challenges within the target countries for the novel value chains through Work Package 2, and consequent investigations into solutions to these challenges throughout Work Package 3.

Primary research through consultations with consortium members and industry stakeholders were central in defining the challenges existing in the current value chains, and in highlighting potential challenges in the future. The discussions also looked at possible solutions to the challenges. This qualitative data was then analysed and elaborated upon to create the concrete solutions proposed in this report.

Desktop or secondary research was undertaken to review existing solutions various challenges present across modern supply chains, and to explore how these solutions could be applied to Unlock's value chains. The resulting data was paired with the solutions gathered from primary research in order to create a complete picture of the solutions required for the successful establishment of Unlock's value chains. Figure 2 below provides a summary of the methodology of the work undertaken.

Figure 2 Approach and Methodology

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3. Feather Collection and Management

As highlighted in Deliverable 2.3, the standard method of feather collection and management at slaughterhouses can present a number of challenges, including transport issues, contamination, and moisture content. In this section, potential solutions to these challenges will be presented and described. The process flow below shows the typical feather collection and management process and describes the challenges it presents.

Typical Feather Collection and Management Process as outlined in Deliverable 2.3

Process Flow	Process Explanation	Challenges Presented
Feather removal	Feathers are removed from the animal by scalding and then plucking using rubber fingers	
Feather collection	The feathers are collected below the plucking machine in a water stream containing water and blood from the kill line, as well as some other ABPs	Significant contamination of the feathers with other ABPs, especially blood, exposes the feathers to pathogens which can impact feather quality
Moisture Removal	Roughly 50% of the moisture is removed from the feathers through a screw press	Feathers remain in a wet, contaminated state as moisture is not fully removed, and washing has not taken place
Storage	From the screw press, the feathers are placed into an ABP transport container while awaiting collection	Any storage of damp, contaminated feathers, exposes the feathers to the risk of keratin breakdown
Transport	The feathers are transported to the rendering facility roughly once daily	The transport of the damp, contaminated feathers, exposes the feathers to the risk of keratin breakdown as in the previous step. The transport of water within the feathers is also less efficient from an emissions perspective

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The process flow below shows the preferred method for feather collection and management and outlines how these steps can provide solutions to the challenges presented by the typical feather management process.

Preferred Feather Collection and Management Process

Process Flow	Process Explanation	Benefits/Challenge Avoided
Feather removal	Feathers are removed from the animal by dry scald and then plucking using rubber fingers	
Feather collection	The feathers are collected on a conveyor belt and transported directly to the washing tank	Collecting on a conveyor belt avoids mixing of feathers with blood and water from slaughter line
Washing	The feathers are washed with cold water in a tank with agitators, which push the feathers forward. Fat and other impurities are rinsed from the feathers	Feathers are washed to remove any contaminants, ensuring feather quality is preserved, and in accordance with legislative requirements for 'treated' feathers
Moisture Removal	Following washing, the feathers are conveyed to a centrifuge or screw press where a large proportion of the water is removed from the feathers	Centrifugation or moisture removal using a screw press reduces energy use in the next step by reducing drying needs
Drying/Sterilising	The feathers are dried at around 150°C for 1h until fully dry. Drier capacity is ~1,000kg per hour	The feathers are dried and sterilised in one step, in preparation for grinding and in accordance with legislative requirements for 'treated' feathers

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Challenges and Proposed Solutions

As per Deliverable 2.3, Table 1 shows the challenges which exist at slaughterhouse level where solutions are required:

Table 1 Challenges and Potential Solutions at Feather Collection proposed in Unlock

Area	Challenge	Solution
Transport	• Carbon footprint	• Minimising weights • Vertical integration • Alternative fuels
	• Collection and transport practices	• Improved feather management
Feather Quality	• Contamination • Moisture content	• Improved feather management
Regulation	• Meeting regulatory requirements	• Improved feather management

Transport

- **Carbon Footprint**

  The carbon footprints involved in all supply chains are coming under increasing levels of scrutiny as industries clamour to decarbonise their activities. As this project is being proposed as an environmentally friendly venture, it is vital that all possible steps to decarbonise the value chain are explored, including those involved in the transport of the product.

  Minimising the carbon footprint of transport is a task which involves a multi-faceted approach. Firstly, the weight to volume of the transported product needs to be evaluated, then an investigation into whether or not the distances required to transport material can be shortened, then, decarbonisation of the transport mechanism itself must be considered.

  The preferred feather management process outlined above ensures that the feather material can be transported in an efficient manner, as the feathers are transported in a dry state, free from moisture which increases the weight of the material, and at ambient temperature without any risk of degradation of the quality of the product. This directly contrasts current standard practice which involves the transport of feathers at around 50% moisture content, meaning undesired weights are transported, increasing both the economic and environmental costs involved.

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The best method to reduce distances travelled is by vertical integration of the supply chain. Under Project Unlock, a number of cases for alternative feather value chains are proposed, one of which involves an integrated business model, where the feathers which are collected on site are also treated on site, meaning no transport of the raw feathers is required. This is an ideal situation in terms of reducing the carbon footprint of transport, but also avoids the dilemma of rising transport costs entirely. However, such investments present additional hurdles, explored further under Investment Costs and Diversification Risks (Section 4).

Decarbonisation of the transport mechanism can be considered a developing technology, where typical fossil fuel powered vehicles are replaced by electric or hydrogen powered alternatives. Although both electric and hydrogen vehicles produce no tailpipe emissions, it is important to consider the sources of electricity and hydrogen used to power the vehicles, as these can have significant impacts on the overall carbon footprint of the transport.

- **Collection and Transport Practices**

  The preferred feather management process as outlined above eliminates the challenges presented by current feather collection and transport practices. Through collecting the feathers on a conveyor system, contamination is minimised. The feathers are then washed and dried where any contaminants and water are removed, meaning the feathers can be stored and transported at ambient temperatures without concern for their quality. Transporting dry feathers also increases the economic and environmental efficiency of the transport when compared to wet feathers.

Feather Quality

- **Contamination and Moisture Content**

  Deliverable 2.3 highlighted the requirement for maintenance of feather quality as part of Unlock's value chain, and how current feather management processes as described above can have a negative impact on the keratin available for processing. Both contamination and moisture content can negatively impact upon feather quality during storage and transport. By limiting contamination of the feathers during collection, factory washing and then drying the feathers, all opportunities for bacteria to proliferate and damage the keratin contained within feathers are removed. As mentioned already, these steps involve considerable investment, which is a hurdle in itself, and will be addressed in the next section of the report.

Regulation

- **Meeting the Regulatory Requirements**

  The current processes for feather management present challenges in meeting the conditions required to maintain a high quality of feather material.

  As per EU Animal By-Product Regulation 1069/2009, feathers can be classified as treated or untreated feathers. If classified as 'treated feathers' the feather must undergo a step of washing within the washed followed by steam treatment at 100°C for 30 minutes in order to be placed on the market without restriction.

  If classified as 'untreated feathers' the feather must be processed using one of the permitted methods described in Annex IV, Ch. III of Regulation 142/2011 which sets out the time, temperature and pressure criteria depending on particle size of ABP product to be processed.

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The proposed process for feather management outlined above ensures that these requirements are met, through the washing, drying and sterilisation stage, guaranteeing the elimination of pathogens (e.g., Salmonella species, Enterobacteriaceae, and Clostridium Perfingens) within the material following the process, in accordance with Commission Regulation (EU) No. 142/2011.

However, it must be noted that depending on the demo case (grinding, microbial fermentation, steam explosion) these initial steps of washing/ drying/ sterilisation could be eliminated due provided that subsequent processing steps achieve the same objective as these treatments:

- Grinding: wet grinding can eliminate the need for pre-drying of feather and drying / sterilisation can be conducted post grinding when particle sizes are reduced significantly
- Microbial fermentation: nutrient content of blood is valuable to aid microbial growth during the fermentation process
- Steam explosion – involved high temperature / time combinations which can achieve the same results in terms of elimination of microbiological hazards

These steps guarantee the safety and quality of the feather product for use in the processing processes.

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4. Feather Treatment

Challenges

Investment Costs and Diversification Risks | Competition for Feather Availability

The process of feather treatment presents two key challenges to this novel value chain, both of which have previously been mentioned in Deliverable 2.3. **Investment costs and diversification risks** apply to the feather treatment stage but can also be relevant to feather collection and management discussed above, and the solutions proposed here apply to all challenges present. **Competition for feather availability** is another hurdle, as those seeking feathers for use in these novel value chains will have to compete with existing uses for feathers, the scale of which were referenced throughout Work Package 2. This hurdle will be explained in greater detail with suitable solutions proposed (Table 2).

Proposed Solutions

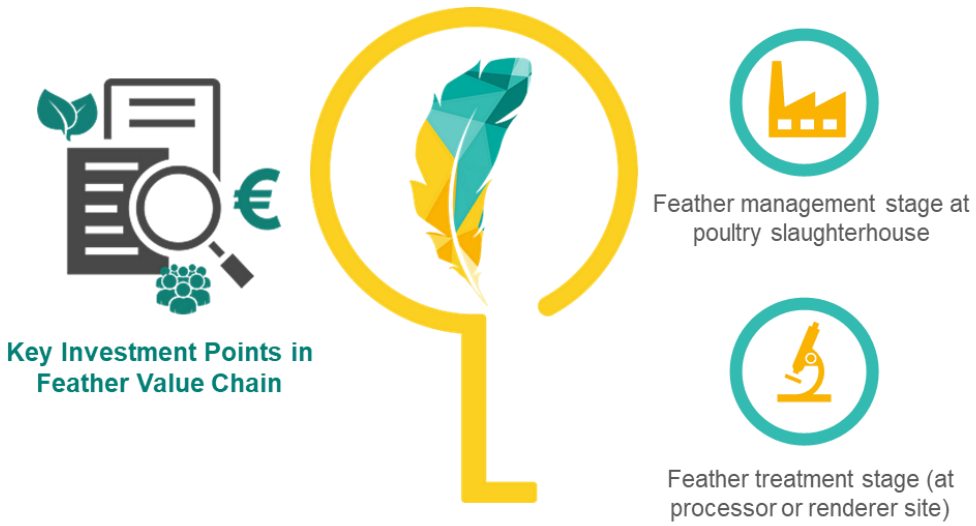
Table 2 Challenges and Proposed Solutions at Feather Treatment in Unlock

Challenge	Solution
Investment Costs and Diversification Risks	• Alternative funding options • Third party feather management entities
Competition for Feather Availability	• Focussed business strategies • Negotiation of long-term feather contracts

Investment Costs and Diversification Risks

The cost of new investments and the risks associated with diversification have the potential to be a significant hurdle to attracting entrants into the novel feather value chains. Additional feather management processes and feather treatment equipment often require substantial monetary investments, without which Unlock's value chains will struggle to succeed (Figure 3).

Figure 3 Key Investment Points in Unlock's Value Chain



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- **Alternative Funding Options for Investments**

  Given the high cost of funding investments in equipment, alternative funding schemes may be one potential avenue available for actors within the feather value chain to explore. A number of schemes targeting circular economic values are currently open for application within the EU. These include:

  ✓ **The LIFE Programme:** The LIFE programme is the EU's funding instrument for the environment and climate action created in 1992. The current funding period 2021-2027 has a budget of €5.4 billion. The 'Circular economy and quality of life' sub-programme provides funding across a range of issues related to the circular economy, including the recovery of resources from waste to facilitate a transition toward a sustainable, circular, toxic-free, energy-efficient and climate-resilient economy.

  ✓ **The European Investment Bank:** The European Investment Bank (EIB) is providing finance and advice for circular economy projects through the European Fund for Strategic Investments and the "EU Finance for Innovators" (InnovFin) Programme. The EIB provides finance to circular economy projects/promoters, including those with a higher risk profile.

  Outside of these EU directed schemes, financing and grant schemes are also available at national level in each of the target countries. Table 3 below provides an overview of current opportunities.

Table 3 Alternative Funding Options in the Target Countries

Country	Scheme	Details
France	• Portail des aides à l'économie circulaire	Along with its roadmap for the circular economy, the French Ministry for ecological and solidarity transition has compiled funding opportunities for public support to economic actors via several programmes, including at subnational level.
	• Investment for the Future	The Investment for the Future programme is intended to support projects fostering innovation through the provision of public support with systematic profit-sharing, known as "repayable advances".
Germany	• Kfw	The bank helps SMEs to carry out investments related to the energy transition and climate investments through low interest rates for loans
	• Environmental Protection under DBU	The 'environmental protection' programme of the German Federal Environmental Foundation supports projects contributing to environmental protection, with a particular focus on small businesses
Italy	• Cariplo	Cariplo is a philanthropic association providing grants to social enterprises or cooperatives active in sustainable projects

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	• Intesa Sanpaolo	The bank is a major partner of the EIB with two credit lines for the circular economy worth EUR 1 billion
Poland	• National Fund for Environmental Protection and Water Management	The mission of the National Fund is to effectively and efficiently support activities for the environment, with particular emphasis on activities aimed at the absorption of foreign funds supported by the National Fund for Environmental Protection and Water Management
Spain	• Circular Economy Demonstration Projects Programme in the Basque Country	The programme promotes new circular economy business opportunities in the Basque Country by conducting semi-industrial or industrial tests (demonstration projects) that confirm the environmental-economic-technical feasibility of new solutions to separate, collect or recover secondary materials, manufacture products with a high secondary material content, or recovery of parts, components, products, etc.
	• Lehiabide - new business model development programme	This programme offers grants for new business models and actions serving the circular economy, such as improvements to a company's own products or those derived from industrial remanufacturing, secondary materials or other waste-reducing business ideas
	• Catalonia's Circular Economy Projects Programme	The objective of Catalonia's Circular Economy Projects Programme is to promote the transition of companies to a circular economy model, improving efficiency in the use of materials and decoupling global economic development from resource consumption

Source: circulareconomy.europa.eu

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- **Third-Party Feather Management Entity**
  The development of a third-party feather management entity is a potential solution to the hurdle of investment costs at the slaughterhouse stage of the value chain. In essence, it involves the creation of a business entity which would assume control of the feathers following plucking across numerous slaughterhouses, bringing the investments required in feather management equipment such as washers and driers, guaranteeing the supply of quality feathers into the value chain and eliminating any risk to the slaughterhouse. The advantages of this business model are highlighted in Figure 4 below.

Figure 4 Benefits of Third-Party Feather Management

A number of businesses are operating under this model which has proved successful in the valorisation of ABP products.

Irish Casing Company (ICC) Case Study

Irish Casings are an example of a success story of the type of business proposition discussed above and shows the value of the presence of such an entity in the supply chain. The foundation of the business was based on a similar premise to Project Unlock, where animal by-products were converted from 'low-value' applications to higher value products in the form of meat casings for human consumption.

Irish Casings Company were established in 1972, with a unique business model focussed on close partnerships with livestock slaughterhouses. Initial focus was on the selection of beef casings for the German market, but the company soon pivoted into producing offal and meat co-products for the European, Asia and Africa markets.

ICC now produce 1,000 metric ton of edible co-product per week available for international export. On an annual basis, ICC produce 3 million sets of hog casings, 3 million sets of sheep casings and have the capacity to produce 1.5 million beef sets per year.

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Competition for Feather Availability

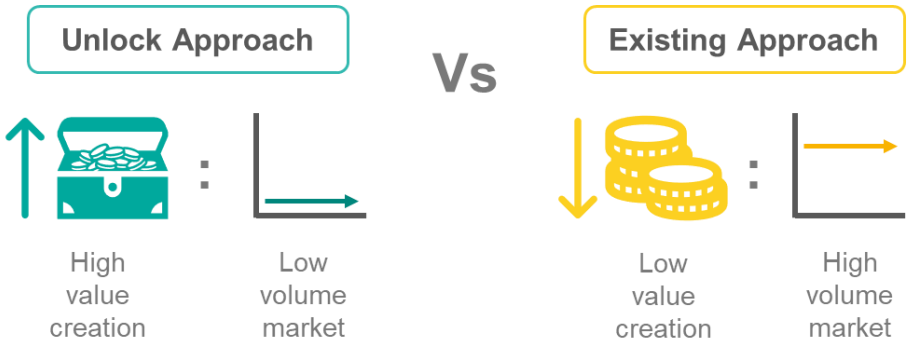
Research conducted during the course of Work Package 2 pointed to the demand currently in existence for poultry feathers for conversion into a range of 'low-value' end-products, including feather meal and fertilisers. Of the major industry players consulted, all sent >95% of their feathers for rendering into low-value end products, which involves an energy intensive processing method called chemical hydrolysis and fails to capitalise fully on the keratin available within the feathers. Therefore, the products being proposed under Project Unlock will lead to an increase in the sustainability of the feather value chain, as the processes involved are less energy intensive, and the end-products produced are of higher value and take the place of oil-based plastics. Nonetheless, these novel value chains have to compete for the feathers available on the market, a challenge to which a number of solutions are available. This challenge is especially pronounced as demand for animal feed and fertiliser increases as a result of the current geopolitical landscape.

- **Focussed Business Strategies**

  One method of overcoming this competition for feather availability is through initial business strategies focussed on high value creation in low-volume markets. This approach can be curated through careful exploitation the results of Project Unlock's research and value chains and ensuring the involvement of existing feather treatment plants in the establishment of the value chains. This strategy is advantageous as once a customer base is established for the end-products, then the novel value chains can compete for feathers through the promise of higher prices to suppliers. This is in contrast to current business models, where low margin applications, i.e., feather meal, are focussed on achieving the large scale necessary to succeed.

  As the products become known in the market, then scaling and commercialising the value chain will happen organically, as suppliers of feathers receive improved prices for their feathers from those involved in the bioplastic value chains. Estimated values for the intermediate products created using Unlock's technologies range from €175-€2,000 per tonne, meaning feather suppliers will be able to command higher prices than the maximum of €40 per tonne currently achieved. Figure 5 summarises the business strategy required for Unlock's value chains.

Figure 5 Unlock Business Strategies



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- **Long-Term Feather Contracts**
  To complement the approach of the focussed business strategies described above, actors within the novel value chains can compete for feathers through the negotiation of long-term contracts for feathers with slaughterhouses. This approach creates a win-win situation for both slaughterhouse and feather processor, as 1. The slaughterhouse is guaranteed a hedge against low prices in times of low market demand, and 2. The processor is guaranteed a constant supply of feathers required for their processes. Additional benefits to such arrangements include the development of a rapport between the actors, leading to a higher likelihood of the consistent supply of the quality feathers required. Table 4 summarises the benefits of long-term contracts for feathers to both the slaughterhouse and feather processor.

Table 4 Advantages of Long-Term Contracts

Slaughterhouse	Feather Processor
Hedge against price volatility during times of low market demand	Guarantee of constant supply of feathers required for processes
Guarantee of constant sale of feathers	Increased likelihood of consistent supply of quality feathers

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5. Market Challenges

Challenges

The main hurdle that faces Unlock's products in the marketplace is **competition from other bioplastics**, as discussed in Deliverable 2.3. Market challenges are as relevant to the novel value chains as those present at other stages, as Unlock products will need to establish themselves in the market in order for the value chain to succeed.

Competition from other bioplastics

As the research develops and focus sharpens on the market strategies of Unlock's products, competition from existing bioplastics on the market will emerge as a significant challenge. Bioplastics for use in agriculture have been developed by a range of private and public institutions over the last number of years, as the industry targeted a shift away from the use of harmful single-use, oil-based plastics. Fortunately, there are a number of steps that can be taken in order to ensure that keratin-based plastics achieve success in the market.

Proposed Solutions

- **Feather keratin as a low-cost ingredient**

  The use of feather keratin as an ingredient in the production of bioplastics has an advantage in that feathers are a low-value product, and therefore there is potential to reduce the cost of production of the bioplastics. Incorporation of the solutions discussed throughout this report into the value chain will ensure that production costs remain low, allowing the value chain to capitalise on the low-cost ingredient, with the potential to pass on some cost savings to the consumer to increase competitiveness.

- **Product Differentiation**

  The products developed through Project Unlock have the opportunity to distinguish themselves from the rest of the market through a number of factors.

  1. Sustainability

     A major part of the value proposition of Project Unlock is the sustainability aspect of the project. The marketing of this as a sustainable venture needs to continue in order to increase end-product competitiveness on the market. While bio-based plastics are being developed across a range of functions with a range of ingredients, Unlock's end-products increase value chain sustainability through both valorisation of a waste stream, and by reducing emissions in the value chain, i.e., through the new feather treatment technologies under development, vs the existing method of chemical hydrolysis. Table 5 compares both the energy use and GHG emissions of the various processes in question.

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Table 5 Energy Use and GHG Emissions of Processes

	Chemical Hydrolysis	Mechanical Grinding	Steam Explosion	Microbial Fermentation
Electricity Consumption	167 kWh/t	30 kWh/t	71 kWh/t	1745 kWh/t
GHG Emissions	851kg CO_2 eq/t	608kg CO_2 eq/t	21kg CO_2 eq/t	515kg CO_2 eq/t

Source: Unlock Business Case

2. Functionality

Unlock's end-products will also strive to compete on the basis of functionality and biodegradability in the marketplace. Aside from meeting the requirements set in biodegradation standards of different certification schemes, the products need to be tailored to the biodegradability timelines required by the end-user, e.g., farmers. For example, through primary research during Unlock, it was discovered that many currently available bio-based mulch films begin to biodegrade too quickly (after 5-6 weeks) when placed on the soil, reducing their effectiveness and hence attractiveness to farmers. This can be solved through increasing the thickness of the films; however, this increases the price and reduces the attractiveness of the material to the consumer. Through product development research in Unlock, these issues can be overcome and the feather treatment stages altered in order to achieve the desired functionalities required by the market.

Placing emphasis on both the sustainability and functionality of Unlock's end-products will also assist in consumer acceptance of the materials, once more increasing competition with existing alternatives.

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6. Conclusion

Deliverable 2.3 in Work Package 2 highlighted the potential challenges facing Unlock's novel value chains. This report provides a range of solutions to these hurdles which may be useful in bringing the end-products to market. The challenges can be summarised into the following categories:

- Transport
- Feather quality
- Regulatory requirements
- Investment costs and diversification risks
- Competition for feather availability
- Competition from other bioplastics
- Consumer acceptance

The solutions for these scenarios rely on:

- Innovation on the part of actors within the value chain;
- Modification of existing solutions and;
- Existing supports available within the EU, through grant or financing schemes.

The tailoring of research towards the tail end of Project Unlock will also have a major impact in terms of overcoming market challenges and highlighting focussed business strategies for the success of the innovative materials. It is clear that the properties of the materials themselves, in terms of cost and quality, will have an important role to play in cracking the market.

To summarise, there are challenges present at each stage of the value chain. However, these challenges are not insurmountable, and can be navigated by the continued use of innovative solutions, as is central to Project Unlock.

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