D6.1

BBTWINS Use Case Specifications/ Descriptions

BBTWINS
Agri-Food Value Chain Digitalisation for Resource Efficiency

BBI JU

Bio-based Industries Consortium

Horizon 2020
European Union Funding for Research & Innovation

PROJECT	BBTWINS
PROJECT NUMBER	101023334
PROJECT TITLE	Digital twins for the optimisation of agrifood value chain processes and the supply of quality biomass for bio-processing
PROGRAM	H2020-BBI-JTI-2020
START DATE	1 JUN 2021
DURATION	48 months
DELIVERABLE NUMBER	D6.1
DELIVERABLE TITLE	BBTWINS Use Case Specifications/ Descriptions
SCHEDULE DATE & MONTH	31 Aug 2022 (M15)
ACTUAL SUB. DATE & MONTH	30 Aug 2022 (M15)
LEAD BENEFICARY NAME	CluBE
TYPE OF DELIVERABLE	Report
DISSEMINATION LEVEL	(PU)

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This project has received funding from the Bio-based Industries Joint Undertaking under the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 101023334.

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1. Introduction

1.1. Executive Summary

BBTWINS will develop and validate two innovative Digital Twins (DTs) in two use cases (meat and fruit production) following a multi-actor approach and integrating into a single platform all the processing steps, from crop to final products, as well as the valorization of the bio-streams generated using innovative processing treatments. The use cases will be addressed following a holistic approach including an environmental, social, and economic assessment, and logistic issues. BBTWINS aims to deliver a logistical and technological scheme that will increase the supply of quality feedstock to optimize bio-processing operations throughout the year. To this end, the DTs developed within the use cases will be tested at real world environments and will be assessed for final validation and replication.

BBTWIN's approach brings together strategic partners from the primary sector who will be the suppliers of biomass in the value chains and use cases considered. Under this consideration, through its use cases, BBTWINS will validate at least 3 new products for the bio-based industry, such as bioactive compounds for nutritional foods and nutraceutical products, fertilizers, protein concentrates for feed, and snacks. Additionally, the project aims at increasing food safety by implementing an integrated traceability system based on the integration of the entire production chain into a single digital platform, to enhance the transparency and to outline the quality standards of the processes involved in any stage of the agri-food value chain.

Furthermore, the digital tools implemented in Phases I, II and III, will also be validated in a real environment within the Use cases located in Spain (pork meat processing) and Greece (fruit processing). The Digital Twin technology that is incorporated in the project by WP5, will also integrate real time data from IoT sensors installed in Spain and Greece, data stored in the Data Lake (WP1), Feedstock Optimization Models (WP2), Mathematical Models (WP3), and Blockchain technology(WP4). In order to test the use of the digital counter part of the meat and fruit value chain, D6.1 will set up the experimental validation phase. This will contribute to the validation of the BBTWINS digital tools in a relevant and real-life environment in Spain and Greece, in the aforementioned sectors meat and fruit). To this end, this document contains the specifications and descriptions of the use cases and the methodology to validate the digital tools developed in BBTWINS, by identifying good practices and critical success factors in order to draw conclusions on the methods that can be scaled up to make wider impacts, especially on the degree that the valorization of the existing feedstock is concerned.

1.2. Relationships with other deliverables

D6.1 uses inputs from the work done in WP 1-5. Use case definition is primarily based on the analysis of each step of the processes along the value chains, the projected links between them and their correlation to the datasets that are gathered, analyzed and saved in the data lake. WP2 (Feedstock Optimization), WP3 (Process Modelling), WP4

(Blockchain), are also connected directly to D6.1 (and WP6 in general), through the representations implemented in the Digital Twin. Nevertheless, although the Digital Twin will provide a digital environment that models and simulates the outputs of WP2-5, there is also a conceptual connection between the use cases and the results produced in these WPs, especially with Tasks 1.2, 1.3, 1.4, 3.1, 3.4, and their corresponding deliverables (D1.1, D1.2, D1.3, D1.4, D3.1, D3.2 and D3.4). On the other hand, D6.1 is also linked to deliverables as input, through Tasks 5.5, 5.3, 6.2, 6.4 and 6.5 and the deliverables linked to these Tasks.

2. Digital Twin

The Digital Twin technology was developed in order to address the increasing complexity in industrial environments. The technological advances that are being constantly incorporated in production lines, supply chains and various industrial processes, usually provide novel methods for improving production processes and production systems. Nevertheless, they also add complexity, which in many cases grows exponentially and is challenging to manage.

Therefore, apart from high demand for technological advances, there is also growing need for mechanisms or tools that reduce system complexity. Digital Twins (DT) provide a digital representation of real-world environments and the entities that live and interact within these environments. Their primary objective is to manage assets and systems that are becoming increasingly complex with virtual instances that are simple to use within multiple use case scenarios.

The first definition of the concept was made in 2002 by Michael Grieves in the context of an industry presentation about Product Lifecycle Management (PLM). In its early days, the DT was perceived as a digital informational construct about a physical system, created as an entity on its own and linked with the physical system in question[1].

A more detailed and widely recognized definition within the associated research fields, is given by Glaessgen and Stargel: the "digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a complex product and uses the best available physical models, sensor updates, etc., to mirror the life of its corresponding twin"[2] (The digital twin paradigm for future NASA and US Air Force vehicles. 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference 20th AIAA/ASME/AHS Adaptive Structures Conference 14th AIAA).

Developing Digital Twins requires both traditional engineering as well as sophisticated software development skills. This prerequisite creates a need for deep understanding of both the physical and the digital requirements. Digital Twins that come to virtualize physical entities can broadly be categorized under two broad use cases. The first, is a Digital Twin representing a manufactured product (electric motor, wind-turbine, automobile, packaged goods, etc.), and its basic functionality is to monitor its use. The second use case involves manufacturing or production facilities. Here, the Digital Twin is used to provide insight into the operations of the facility, which will usually consist of an assembly of unique product twins. The latter also stands in the case of BBTWINS, where the DTs implemented will represent entire value chains, including facilities, production lines, logistics and various industrial processes.

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[1] Grieves, M., Vickers, J., Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In: Kahlen, J., Flumerfelt, S., Alves, A. (eds) Transdisciplinary Perspectives on Complex Systems, 2017. Springer, Cham.

[2] Tao, F., Cheng, J., Qi, Q. et al., Digital twin-driven product design, manufacturing and service with big data. Int J Adv Manuf Technol, 2017, 94, pp. 3563–3576.

Entities in a Digital Twin can be used either as a part of the facility or as part of the manufactured product. Therefore, the use cases should create a view of both angles and use a combination of product and facility Digital Twins. Consequently, the Uses Cases will explore scenarios focused on products and the Digital Twin technology will be used on the production line to determine machinery setup and configuration, supply chain requirements and logistics related to the associated value chains. This method aims to collect operations and usage data that will be used for product and bio-based operation improvement.

In additions, during the use case validation, the Digital Twins should be working in real time or near real time fashion, capturing as many internal and external events as possible from sources such as:

- *The related actors' activities (people, infrastructure, processes etc.).*
- *Activities related to suppliers and supply chains.*
- *Activities related to processes (failures, delays etc.).*
- *Real-time response from disruptive technologies embedded in DTs (AI, mathematical models, blockchain, IoT sensors, etc.).*

A Digital Twin typically represents a specific initiative or use case around specific goals. In BBTWINS the Digital Twins will be used to improve efficiency through digitalization and create added value by creating new business models leading to improved value chains and new cross-sector interconnection in the bio-based economy. Therefore, the use cases specified in D6.1, should be able to contribute significantly to the following objectives that set within the project:

- *Improve feedstock availability and sustainability for bio-based operations.*
- *Characterize each step of the agri-food value-chains, gathering information at process level.*
- *Provide novel bio-based products from feedstock valorization.*
- *Develop BBTWINS virtual tools for informing decision-making and optimizing bio-based processes in agri-food value chains.*
- *Provide end-to-end traceability of the products from raw materials to the end users.*
- *Contribute to the reduction of GHG emissions and environmental impacts in the agri-food sector.*
- *Provide new tools for transforming the agri-food sector through digital technologies.*
- *Create new business models in the bio-based industries.*

3. Guidelines

3.1. Multi-Actor Approach

The agri-food sector faces increasing and more complex difficulties, especially in the digitization aspects of its value chains. Thus, it is important to put additional effort into integrating enabling technologies in the agri-food sector, thereby assisting end user to cut down cost and create additional value for their products.

To this end, the conventional, linear approach of knowledge "transfer" from research to the industry is not always as effective as it has traditionally been. Moreover, in the recent years, innovation is increasingly linked to the outcome of interactive and co-evolutionary activities, which engage multiple types of actors[3]. This approach also facilitates a two-way flow of knowledge, by enabling flexible management of the research outcomes based on the actual requirements of the actors participating and any novel issues that emerge during the process.

By its nature, the Multi-Actor Approach (MAA) insists on putting focus on real problems or opportunities for end-users. It also suggests that complementary types of knowledge must join forces and act collectively. As a result, Multi-Actor (MA) activities are able to develop innovative solutions which are more ready to be applied in practice and cover real needs.

Subsequently, those benefiting directly from the results of a collaborative effort, will also be more motivated to use these outputs, since their involvement becomes a significant motivational standpoint. Additionally, having contributed their ideas and viewpoints from the development phase, ultimately gives to the stakeholders involved, a sense of joint ownership over the solutions produced, and helps in gaining and transferring knowledge and expertise.

Collaboration is crucial to ensuring that project results are applied in practice, and it is one of the main intentions of the MAA. Therefore, the MAA goes beyond merely communicating the project results or considering the opinions of a certain stakeholders. Its core principles require active participation of numerous actors from as many stages of the process as possible. The different parties, even if their backgrounds are diverse, should be involved in the project at every stage, from conceptualization and initiation to execution and post-execution. In other words, the MAA brings together a variety of players, involving all the stages of a value chain.

[3] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_brochure_multi-actor_projects_2017_en_web.pdf

3.2. Single Value Chain Integration (agri-food and feedstock)

A value chain is a business model that outlines all the steps involved in producing a good or service. A value chain for businesses in the agri-food sector comprises the processes involved in taking a product from its origins to distribution, as well as everything that happens in between, such as obtaining raw materials, performing production, manufacturing, and packaging tasks, as well as engaging in marketing activities. Accordingly, "Integration is a process of interaction and collaboration in which manufacturing, purchasing and logistics work together in a cooperative manner to arrive at mutually acceptable outcomes for their organization"[4].

BBTWINS will integrate, in a single value chain, each of the project's agri-food value chain (from crop or farm to the final product), as well as the feedstock to be used for bio-based operations, generated in all the steps. The DTs and additional IT tools developed apply to two specific value chains and use cases, therefore a flexible development that encourages reusability and value chain integration will subsequently help further adaptation and application to other agri-food value chains.

In the existing markets of a globalized economy, proper value chain integration is a challenging task. Competitiveness is a key factor in a business' sustainability prospects, thus, any value chain integration attempt must present the essential inherent attributes needed to justify its added value potential, even before its application, if possible. Nevertheless, despite an abundance of resources, the notion of value chain integration remains rather tacit in revealing consistent practices for creating and delivering competitive products.

On the other hand, a greater level of value chain integration implies a logical increase in productivity, better quality performance, reduced costs, and a higher level of customer satisfaction[5]. Yet, organizations often struggle to integrate their value chains due to well-known but difficult to address factors, such as the presence of old-fashioned internal processes, as well as a lack of documentation or systematization[6].

In addition, until recently, there was scarcity of reliable tools for conducting thorough analysis and testing before deploying. This fact increased dramatically the risk related to any value chain integration attempt. Thus, companies should be extremely careful before pushing the button to trigger such an operation, which makes such paradigms rather scarce to come by in corporate environments. On the contrary DTs provide the sandbox required to try and fail without further repercussions.

However, a solid methodology must be used in order to make DTs effective, not only in detaching trial from error in terms of cost, bust in helping companies form creative ideas in how to integrate distinct value chains. The first

[4] Pagell, M. and LePine, J.A., Multiple case studies of team effectiveness in manufacturing organizations. Journal of Operations Management, 2002, 20(5), pp. 619-639.
[5] Basnet, C. and Wisner, J., Nurturing internal supply chain integration. Operations and Supply Chain Management, 2012, 5(1), pp. 27-41.
[6] Pagell, M., Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics. Journal of Operations Management, 2004, 22(5), pp. 459-487.

step is to ensure that the existing value chains are managed and optimized. Thus, the works in WP2 and WP3 are to be used test optimization techniques on the DTs.

Value creating processes must act together and there should be coordinated by using intra-organizational resources, in order to achieve a new value chain models to well-managed structures. Such, well-managed value chains are referred to as an integrated value chain, and they are the ones that provides optimized value for the customer and the companies.

Each function within a company contains different activities that all contribute to the creation of added value. It is not unusual that functions work after own goals, which easily can lead to sub-optimization and thereby making integration efforts hard to achieve.

A big challenge for the top management is hence to ensure that the overall goal is achieved, which requires that the functions within the company to some extent work together. By using and testing the DTs built within the project, the use cases validate in WP6 should identify the enablers of better value chain integration.

4. Requirement Analysis

Our main goal is to form the project's use cases so as to leverage the technologies formed in WPs 1-5 by creating approaches to facilitate efficient definition, implementation, and validation, in a relevant and real-life environment for each case. Overall, WP6 aims at matching agri-food value chain specific requirements to the capabilities of the digital tools developed in the project. These should be aggregated in a single platform, capable to verify in the field the data expected by the prediction techniques proposed. WP6 must also verify that the requirements of the end users are met and that the compliance with these requirements is validated by the use cases.

Additionally, the goals set BBTWINS' regarding pre-treatment, conversion and downstream processing will be compared with the existing operational procedures in the value chains of the meat and fruit sector, to ensure that the solutions proposed meet the expectations set and also present promising potential for effective scaling and exploitation.

Conventional value chain and logistics processes involve substantial paperwork and manual interference. Technologies such as Data Warehouses and SAP systems have revolutionized the way in which value chain and logistics entities work, but the static nature of visualizing and interacting with such entities needs a dynamic upgrade. This is now possible through effective digital transformation which is a key driver for Industry 4.0. Digital Transformation creates digitalized, interconnected logistics, as well as smart supply and value chains[7]. In this context, the Digital Twin technology, although quite challenging to implement and test in real world environments, can play an important role within the digital transformation of the manufacturing sector and thus, the underlying Industry 4.0 concept. However, still more studies and test in real environments are needed to measure the potential for innovation through the Digital Twin technology.

BBTWINS' use cases are an excellent opportunity to investigate how the digital tools and methodologies developed should be used, in order to improve the quality and traceability of the available biomass for feedstock and final products, in the agri-food sector. The use case implementation must, on one hand, identify reusable components, gather validation results and lessons learnt, and, on the other hand, recognize additional support and functionalities that can be facilitated by the DTs. The DT should also deliver a logistical and technological scheme that will increase the supply of quality feedstock to optimize bio-processing operations.

The use cases in development should be based upon the analysis of the value chains, so that the DTs that will be developed, tested, and validated will inherently integrate the modelling of the underlying manufacturing and business processes to be simulated. The use cases will be further broken down into processes resembling the links of each value chain. Each process should be modelled as an input/output procedure that utilizes certain resources

[7] Zaychenko, I.; Smirnova, A.; Shytova, Y.; Mutalieva, B.; Pimenov, N., Digital Logistics Transformation: Implementing the Internet of Things (IoT). In Proceedings of the International Conference on Technological Transformation: A New Role for Human, Machines and Management, St. Petersburg, Russia, 27–29 May 2020, pp. 189–200.

and produces quantifiable results. Therefore, inputs (e.g. data parameters), outputs (e.g. KPIs) and resources (e.g. logistics, machines, operators, products, by-products, waste, etc.) must be clearly defined. An important goal is to measure the correlation and links, undetectable outside the DTs, between distinctive processes across the value chains.

A shared application-programming interface is needed to configure all these parameters for all the processes, so that DT users will be able to propose simulations by varying parameters. The user interface should also indicate the current conditions gathered from the IoT infrastructure and provide interfaces to the Data Lake and the Blockchain. Furthermore, the DT of each the use case must provide near real-time usability, analysis of historical data and generation of scenarios or projections of both processes and costs. Users should also be able to visualize data from the entire value chain and interact with the DTs.

The experimental validation phase must use several treatments for the processing and valorization of the feedstock. Pre-treatment, conversion, and extraction technologies will be applied for the valorization of the remaining biomass in the two value chains. Following the process break down and interaction methodology, the DTs must be fed by the modelling and correlation of the quality and quantity of each intermediate product and feedstock generated.

Thus, the pretreatments that are to be applied to the feedstock can be effectively tested in a gradual optimization process, in order to validate whether the DTs are able to predict the optimal pre-treatment and paths to be followed in case unpredictable conditions occur. Overall, this scheme must be tested thoroughly within the use cases themselves and must also be assessed for final validation and replication.

Moreover, in defining the use cases we need to assess whether the data collection process has yielded adequate data sets. After verifying that enough data is indeed available, organizing and analyzing it to generate input parameters is going to be the next challenge. To prevent convoluting processes, it is critical to assess Portesa’s and Dimitra’s current digital capabilities.

Similarly, developing, running, monitoring, and verifying various simulations through the DTs, requires a coherent data gathering methodology pertaining to each process’s outputs. This must be followed by constructive data analysis, which also requires a strategic approach, because it is challenging, at least, to successfully identify the parameters and processes that have the most potential for value generation.

5. Use Case Specification Steps

5.1. Description

A use case description contains the set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system. The description captures the requirements, typically of a system, in the form of descriptive steps in a logical sequence so that it be understood by the actors involved.

Thus, a use case must describe a coherent work unit or task to be carried by one or more actors with the help of the system. Assuming a suitable set of actors being involved in the work unit, a use case description specifies a sequence of actions that are to be performed, as well as pre- and a post-condition, that represent the assumptions and the outcome of the use case. Therefore, a use case is made up of a set of possible sequences of interactions between systems and users in a particular environment, related to a particular goal. In BBTWINS each use case will describe:

- The goals of each use case.
- The problems that each case must overcome to achieve its goals.
- How these problems can be solved through the Digital Twins.
- Which are the business processes involved.
- How each process relates to the goals of its relative use case.

5.2. Architecture

Definition to critical parameters of the use cases such as localization, input data collection and processing, development of protocols for use case testing, expected outputs and results, etc. The use case architectural structure provides a high-level view of the main concepts and relationships in real environments that relate to the use case. it should describe entities that are relevant either for the DTs or the agri-food value chain. For each use case, we should define:

- The actors.
- The existing systems, processes and physical entities involved (e.g. livestock, equipment, facilities).
- How and for what purpose will the entities (actors, existing systems, physical entities, software tools etc.) interact with each other.
- Possible extensions of the use case, in the form of the project's goals and objectives, in which each use case provides significant contribution.

For depicting the interactions between the use case entities, the chosen formalism has been a standard UML class diagram format, whose basic elements (i.e. entities and relationships) are described in Figure 5.2.1: Generic use case architecture diagram, depicting the use case goal and the actors, processes and extensions involved. The arrows connecting entities specify relationships and data flow between actors and processes.

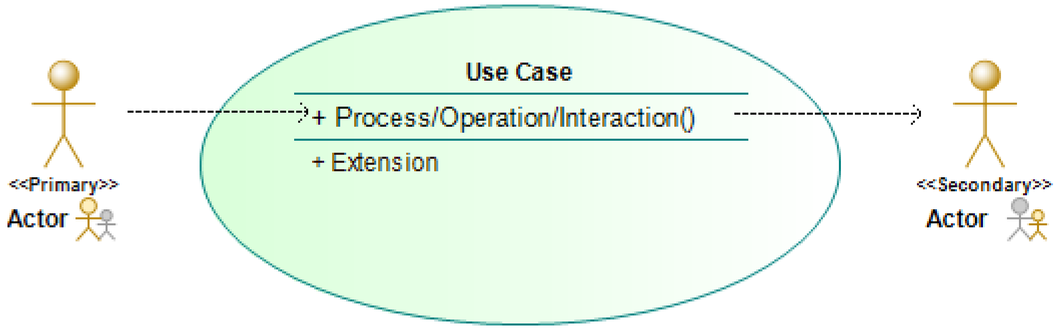

Figure 5.2.1: Generic use case architecture diagram, depicting the use case goal and the actors, processes and extensions involved.

To aid in the understanding of the use case, it may be appropriate to include supporting diagrams into the use case specification, such as:

- Use case specific view(s) of the domain (real world) model – showing the relevant business objects and associations that feature within the use case.
- State transition diagram(s) – showing the state transitions of the key business objects that features within the use case.
- Use case activity diagram(s) – showing a visual representation of the use case flow(s) of events (Note: This should not be a UI navigation diagram*).*

The inclusion of these diagrams is optional, nevertheless we make a reference here for the validation stages as such records will be useful in keeping record of the various parameters in setting, testing and validating each use case on the DTs. This data will subsequently be used in the use case implementation analysis, after the use case testing has finished. The same rules apply to the pre-conditions and post-conditions of each use case.

The pre-conditions pertinent to each use case should be described in a separate section before the use case is set for evaluation on the DT. A use case's pre-condition is the state that the system must be in before the use case is started in order to guarantee that the actor who triggers the activity will succeed in achieving their objective. In validating the DTs, pre-conditions for each use case will be set depending on the various system configurations and data sets that are to be used.

The post-conditions pertinent to the use case should be described in a separate section after the use case the evaluation on the DT has ended. A use case's post-condition specifies the state that the system is in, in after the use case is complete.

5.3. Workplan (Flow of Events)

The use case specification is mostly comprised of the flow of events, which also explain the actors' activities and potential responses. The flow of events describes all of the many ways that a desired goal may be reached. The workplan is the physical deployment of the use case and gives a concrete overview of which entities are deployed, where they are placed and how they interact, answering to questions such as:

- What is the main (predicted) flow of events?
- What are the concrete components (resources) deployed in the use case?
- What are the alternative flows?
- Are there any unusual requirements?

Part of the workplan is the data relationship model which depicts all the data entities across the use case. This includes e.g., databases used in the use cases, data entities in the data lake, data collected from the fields, etc., and in our case will be implemented as a standard UML class diagram. Time series, raw data, and other types of data are all simply represented as objects or classes. Relationships between items are specified using UML arrows connecting classes.

6. Use Cases

The use cases will focus on the following principal areas:

- *Process and logistics optimization through digitization and enabling technologies.*
- *Traceability and transparency assisted by blockchains.*
- *Biomass processing.*

Each value chain will be modelled as shown in Figure 5.3.1, and its digital representation will be implemented as two DTs, one for each value chain. In the use cases Portesa's and Dimitra's value chains will be briefly described, using high level concepts, rather than detailed descriptions. This work has been carried out in D1.1. On the other hand, the DTs will provide simulations of all stages and processes over the entire length of the value chains. In their turn the use cases will provide the methodology for validating the DTs of both value chains.

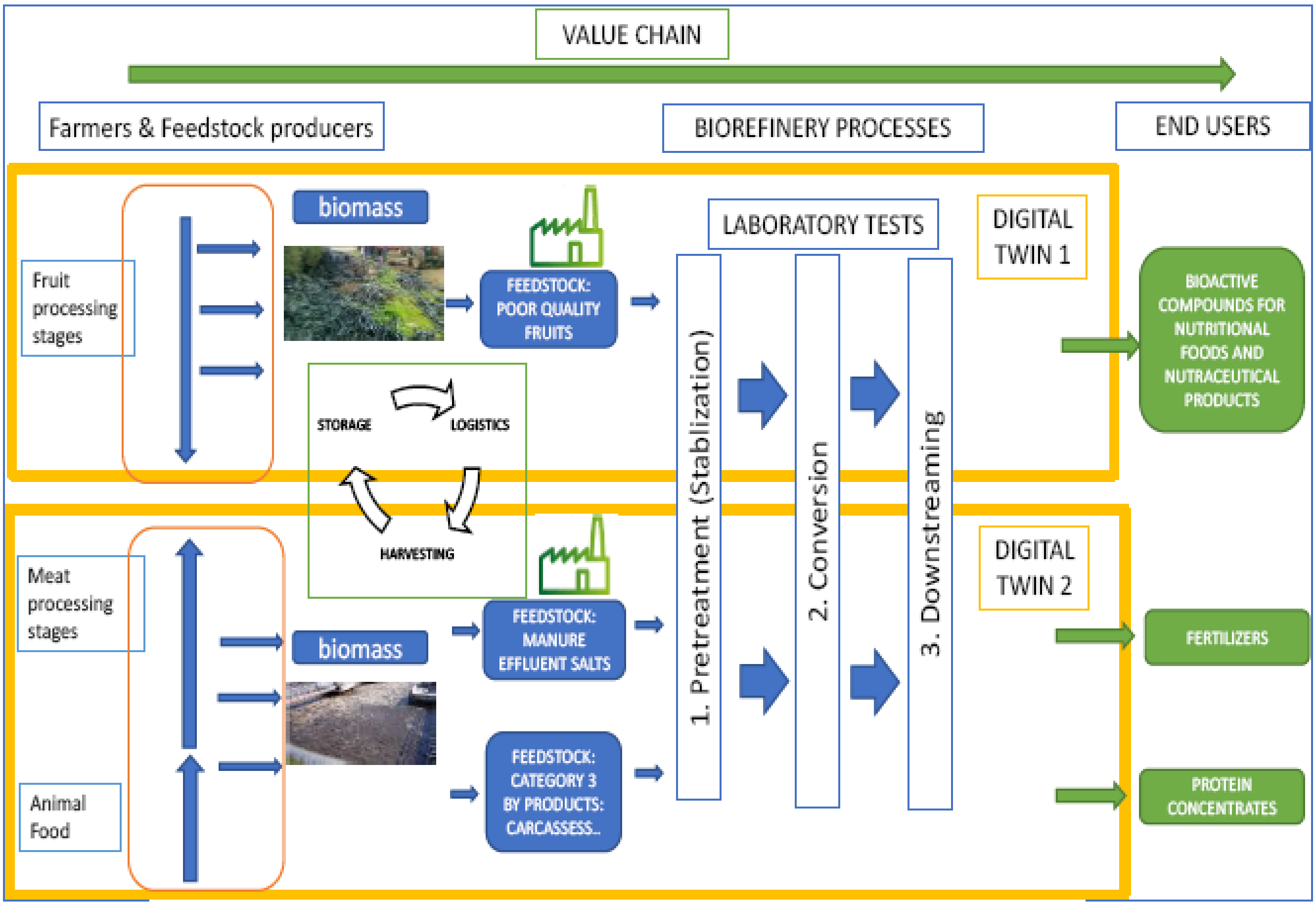

Figure 5.3.1: BBTWINS' Value Chain Coverage.

The DTs will also have integrated all the technologies used in the project, such as AI, Blockchains, Big Data and IoT, in order to deliver the waste optimization, sustainability, energy efficiency, consumer transparency, waste auditability, waste and product traceability.

6.1. Meat Sector

Portesa is a livestock company. Its main activity is pork livestock breeding for the meat (pork) value chain, at farms located in the province of Teruel. The farms and the production process conform to the highest standards, with an optimum level of animal welfare. For the optimal feeding of its livestock, Portesa operates a feed factory and engages in an integrated production process, managing the genetics and choosing the best cereals to feed their livestock (pigs), placing a high value on the traceability of every step, and maintaining precise food security controls.

There are three important phases within Portesa's manufacturing process. Piglet production up to 6 kilograms, weaning piglets from 6 to 18 kg, and fattening pigs from 18 to 125 kg. Additionally, Portesa provides to Carnes de Teruel (Cartesa), the meat industry plant, with all of its production. Cartesa's activities comprise slaughtering, cutting and the producing different formats of fresh pork meat, as well as salted and cured products. Finally, Cartesa provides the shoulders and hams to a third company, Aire Sano. Portesa, along with Cartesa and Aire Sano, form part of an integrated production process, which also conforms to a traceability process that is a benchmark throughout Europe. Furthermore, Portesa, Cartesa and Aire Sano are strongly committed to research and innovation to utilize sustainability and residue recovery models the implement effective circular economy practices.

There are two parts of the meat value chain that follow different directions. The first entails the path from the feed mill to the farms. This part is used to provide to farms animal food to the farms and comprises the following steps:

- *Product provision*
- *Inspection previous to reception*
- *Effective reception*
- *Storage*
- *Selection of ingredients*
- *Feed production*
- *Storage*
- *Preparation of orders*
- *Final inspection and shipment*

On the other hand, I regard to the processes related to the slaughtering house, the salting, and the curing facilities, the value chain starts at the farms, ends at the end-users, and follows the opposite direction. These steps involved, starting at the Slaughterhouse, are:

- *Slaughterhouse*
    - *Slaughter*
    - *Cutting Plant*

  - *Slicing and packaging*
- *Salting Facility*
  - *Reception*
  - *Salting*
  - *Post-salting*
  - *Conditioning*
  - *Shipment*
- *Curing Facility*
  - *Curing of Ham/Shoulders*
  - *Deboning of cured ham/shoulder*
  - *Slicing cured meat (ham and shoulder)*
  - *Slicing and cutting the cured meat in cubes*
  - *Manual slicing (ham and shoulder)*
  - *Finished product ready for shipment*

It must be noted that the meat sector use cases will be more generic than needed in the sense that farms can be, as in Portesa's case, part of the same company or independent economic entities that operate independently. The former is more flexible in relation to communication, coordination, and forecasting. Additionally, the latter case has an extra process, that of the economic transaction required for purchases. Within all the use cases that will be described we will assume that farms are independent economic entities. This approach will not affect the DT validation in Portesa's case and, most importantly will be applicable to a larger number of cases in the meat sector, especially in terms of replication and upscaling potential.

6.1.1. PROCESS AND LOGISTICS OPTIMIZATION THROUGH DIGITIZATION AND ENABLING TECHNOLOGIES.

6.1.1.1. Description

This use case will analyze the animal food production and dispatch process, including production forecasting. Therefore, the use case will evaluate the Animal Food Supply process, which is representative of the value chain from the feed mill to the farmers.

Furthermore, to complete the process and logistics optimization, we have to make a digital counterpart of the meat value chain, which involves the activities carried out in the slaughtering house, the salting, and the curing facilities, so that the DT can be used to generate reliable production forecasts in terms of worker's needs, production losses and demand coverage. This DT implementation will simulate the meat products ordering process and will cover the value chain from the farm to the slaughterhouse and finally, to end users.

6.1.1.2. Architecture

Feedstock forecasting and optimization, involves two main actors. The one is situated in the production facility (Feed Mill) and the other in the consumer's site (which in this case is the Farms). Secondary actors (the ones not present in all the use cases variations for validation) are the entities on the Feed Mill's supply chain. The actors are connected through internal processes that have to have a digital counterpart in the DT. These processes, have to communicate with the models developed in BBTWINS (data models, optimization models, process models, blockchain models), in order to fulfil the use case's extensions. The first extension (objective) is to make accurate food demand forecasts and optimize the food production process, in order to provide food to farms under minimal delays and reduced cost. Furthermore, the orders will be tracked by using the blockchain, for product traceability and for using the food supply data for predicting livestock growth rates and assisting the genetics optimization process. Additionally, the implementation and validation of a DT use case pertaining to the animal food supply process, will also provide useful data to improve and optimize the logistic operations within the meat sector supply and value chains. The interactions between the use case's entities are depicted in Figure 6.1.1.

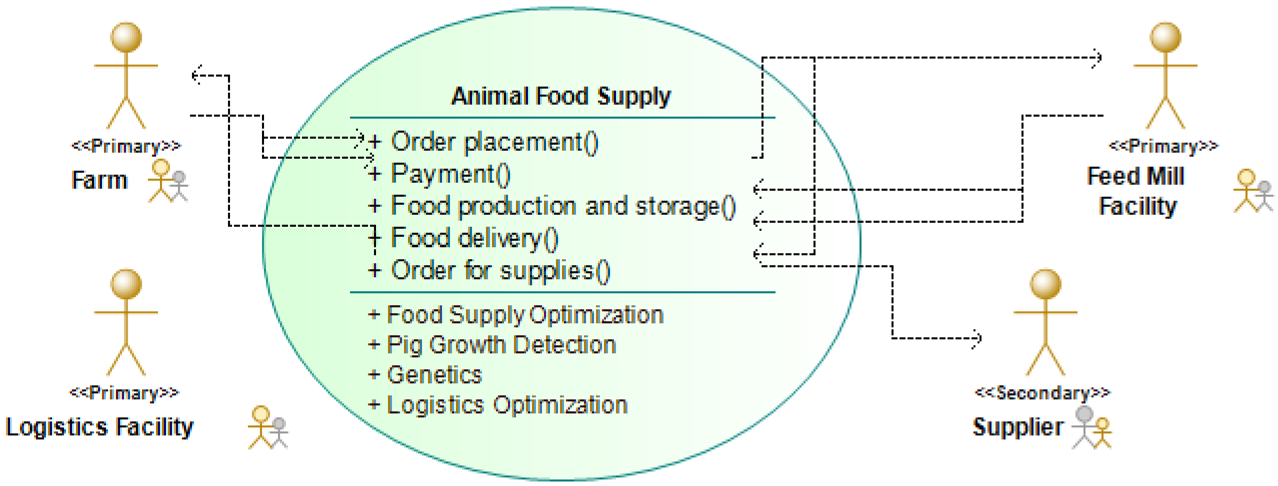

Figure 6.1.1: Animal food production optimization.

Production value chain modelling is a complicated process that involves several primary actors. It is portrayed in detail in Figure 6.1.2. The actors involved are Farms, Markets (Wholesale and Retail customers), and Facilities (Logistics, Slaughterhouse, Salting and Curing). The actors are connected through the processes also illustrated in Figure 6.1.2. For this use case, the DT should also implement and interconnect the appropriate processes with the models that have been developed (data models, optimization models, process models, blockchain models), in order to fulfil the use cases objectives. By modeling and implementing the DT of the ordering value chain our ultimate goal is to optimize the value chain in making accurate food demand forecasts and optimize the food production process by making reliable production forecasts in terms of the resources and processes involved throughout the different production stages (worker's needs, production losses and demand coverage, etc.). Furthermore, the implementation of a DT use case for modeling the ordering process, will also provide data to improve and optimize the logistic operations within the meat value chain.

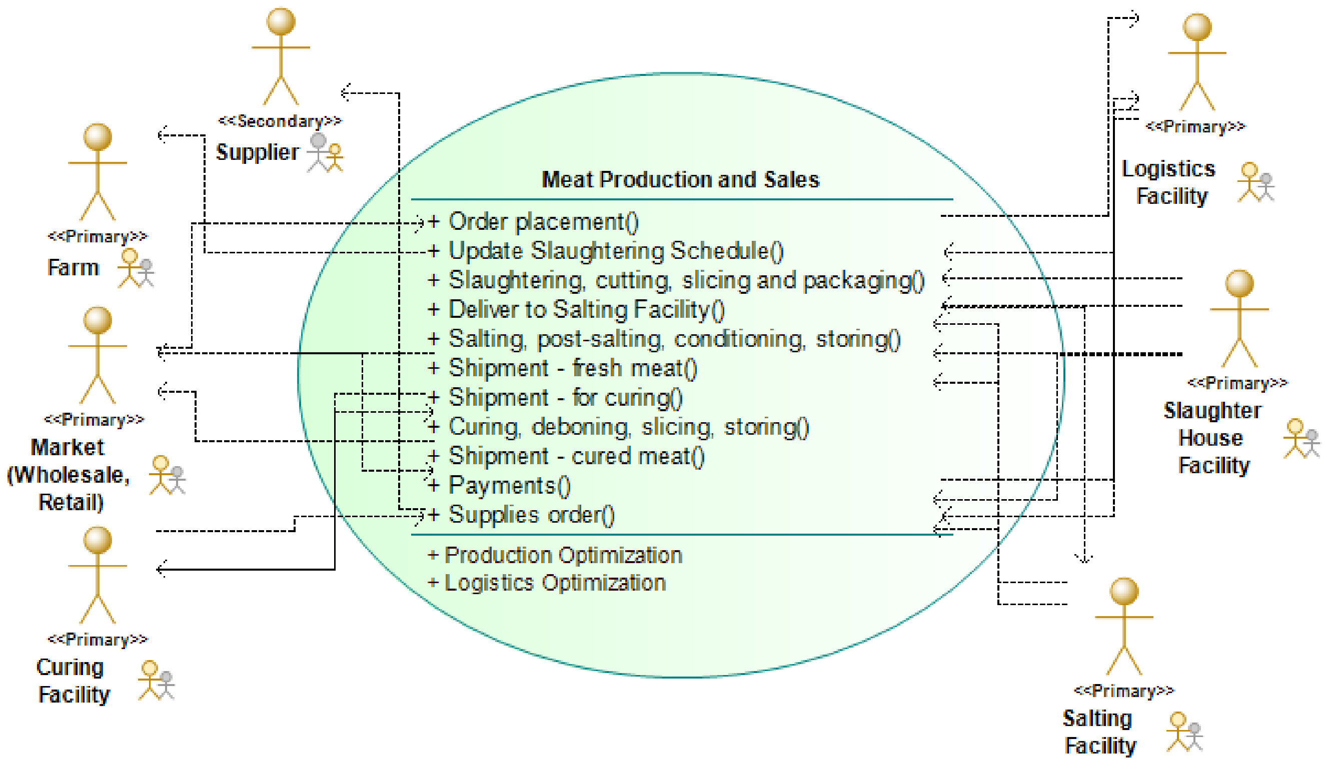

Figure 6.1.2: Production line optimization.

6.1.1.3. Workplan

<u>Food Production Optimization</u>

1. *Farm: Places an order and receives payment schedule, when applicable.*
2. *Logistics Facility: Receives the order and updates the Feed Mill Production Schedule, accordingly. Keeps track of all logistic activities and updates digital records accordingly.*
3. *Feed Mill Facility: Consults daily operations schedule, receives shipments, makes orders to its suppliers and receives supplies, produces, stores, and delivers food to Farmers.*
4. *Farm: Receives orders and finalizes payments, when applicable.*

<u>Production Line Optimization</u>

1. *Market (wholesale, retail actor): Places and order and receives payment options.*
2. *Logistics Facility: Receives the order and updates the Slaughtering Schedule, accordingly. Keeps track of all logistic activities and updates digital records accordingly.*
3. *Farm: Receives request for new delivery in the slaughterhouse.*
4. *Slaughterhouse Facility: Consults daily operations schedule, receives shipments, and proceeds to slaughtering, cutting, slicing, and packaging. Ships to the client directly (fresh meat products) or to the Curing Facility for further processing. Makes orders to its suppliers and receives supplies.*

5. *Salting Facility: Consults daily operations schedule, receives shipments, carries out, storing and dispatching products. Makes orders to its suppliers and receives supplies.*
6. *Curing Facility: Consults daily operations schedule, receives shipments, and proceeds to curing, deboning, slicing, packaging, storing and dispatching products. Makes orders to its suppliers and receives supplies.*
7. *Client: Receives orders and finalizes payments.*

6.1.2. TRACEABILITY AND TRANSPARENCY ASSISTED BY BLOCKCHAINS.

6.1.2.1. Description

An integrated traceability system based on blockchain is among the primary incentives towards using enabling technologies for Portesa. Such a system will inform the consumer about the origin and traceability of Portesa's products in all the stages of the production process and consequently increase and improve the food safety. This use case will test and validate the traceability system implemented in WP4 as is integrated and used by the DT, from the perspective of wholesale/retail clients, as well as from an individual consumer's endpoint (Information exchange will based on blockchain technology provided by Stelviotech which will also provide security and robustness to the data involved). In this scenario a wholesale/retail customer will be able to request logistical data containing costs, dates, quality parameters etc. These data will be linked to order numbers, shipment numbers, etc., any parameter in general that is traceable in any stage of the value chain on a B2B level. On the other hand, a consumer will access information related to food quality, location, and production details, by scanning with a smartphone a certain area on the product's package (most likely a qr-code printed on the package). Both roles are defined and analyzed in D4.1.

6.1.2.2. Architecture

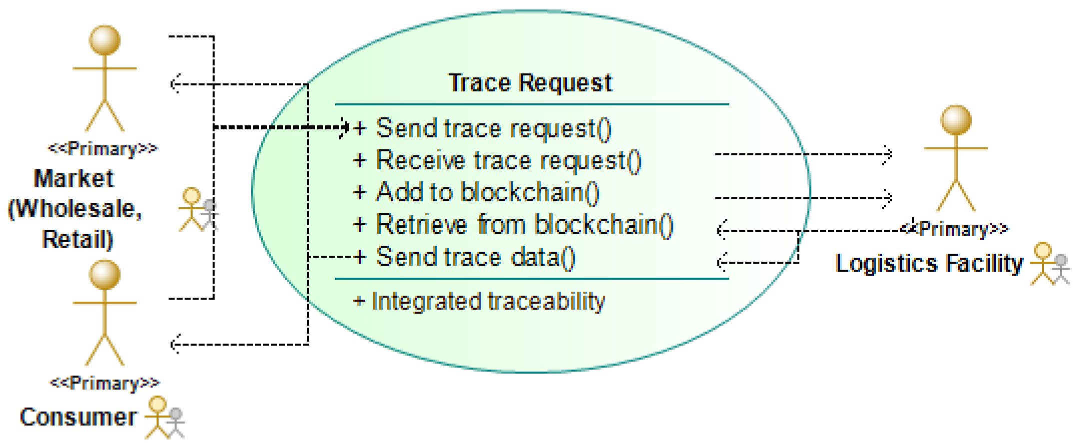

Figure 6.1.3: Product traceability – meat sector.

In this case there are two main actor categories. The ones on the end user side (Consumers, Wholesale/Retail Businesses) and Portesa's Logistics Facility. The DT implementation in this case relies heavily on the Blockchain implemented in WP4. The extension in this case is the creation and operation of an integrated traceability framework to be used in the meta sector value chain. The interactions between the use case's entities are depicted in Figure 6.1.3.

6.1.2.3. Workplan

1. *Market (wholesale, retail actor): Places a trace request involving either logistics (order details by date, batch, shipment, package etc.) or product tracing regarding consumer details (such as farm, pig food ingredients, ingredient suppliers, processing details et.).*
2. *Consumer: Market (wholesale, retail): Places a trace request details such as farm, pig food ingredients, ingredient suppliers, processing details etc.*
3. *Logistics facility: Receives tracing requests and automates the responses, adds to the blockchain the data that will facilitate tracking in every part of the value chain, and retrieves data from the blockchain.*

6.1.3. BIOMASS PROCESSING.

6.1.3.1. Description

The farms produce two broad categories of biomass residues: i) Pig carcasses, which are currently incinerated; ii) Pig fluid manure that is used as an organic fertilizer. In the slaughterhouse, residual biomass is destinated to produce protein flour and fat of animal origin to use in animal feed or biofuels. Furthermore, the sludge from the treatment plant is used as fertilized and the blood as raw material for the amino acids of special fertilizers. In the dryer's factories, residual biomass products are destinated to produce protein flour for animal feed mainly. Therefore, WP6 needs a use case that will drive the optimizations of the feedstock value chain in terms of availability, quality, resource efficiency, and economic profit, as well as an opportunity to test other valorization alternatives. The use case will create the digital counterpart of biomass processing. Findings and data produced by the simulation will be used for waste valorization analysis in order to create value from the several types of waste produce at Portesa's facilities such as pork bones, fat, skin, or hair. Furthermore, the use case will also explore the potential and sustainability of a biogas plant, to cover part of the energy needs of the Portesa's facilities. Furthermore, the use case will also analyze the viability of mixed energy production solutions, by combining biogas alternative renewable sources such as photovoltaics. Those deemed as feasible in terms of cost and location will be included in the DT, to study what-if scenarios of energy production by renewable energy sources.

6.1.3.2. Architecture

Biomass processing involves the actors illustrated in Figure 6.1.4. It is also linked to feedstock valorization which is one of the main objectives in BBTWINS.

The DT of this use case will investigate and validate methods to increase biomass availability, resource efficiency and sustainability for the bio-based industry, lower biomass losses from feedstock supply through the processing stages of the value chain and allow for longer storage time before processing through more efficient pre-treatment steps and storage methods to better preserve the valuable components.

Furthermore, in this case we will validate the potential of building and operating biogas plants, their location, the optimal collection point distribution, the sustainability of biomass valorization in the form of bio-active compounds, fertilizers, and protein concentrates. Finally, we will also analyze the possibility to combine biogas with other renewable energy sources such as photovoltaics.

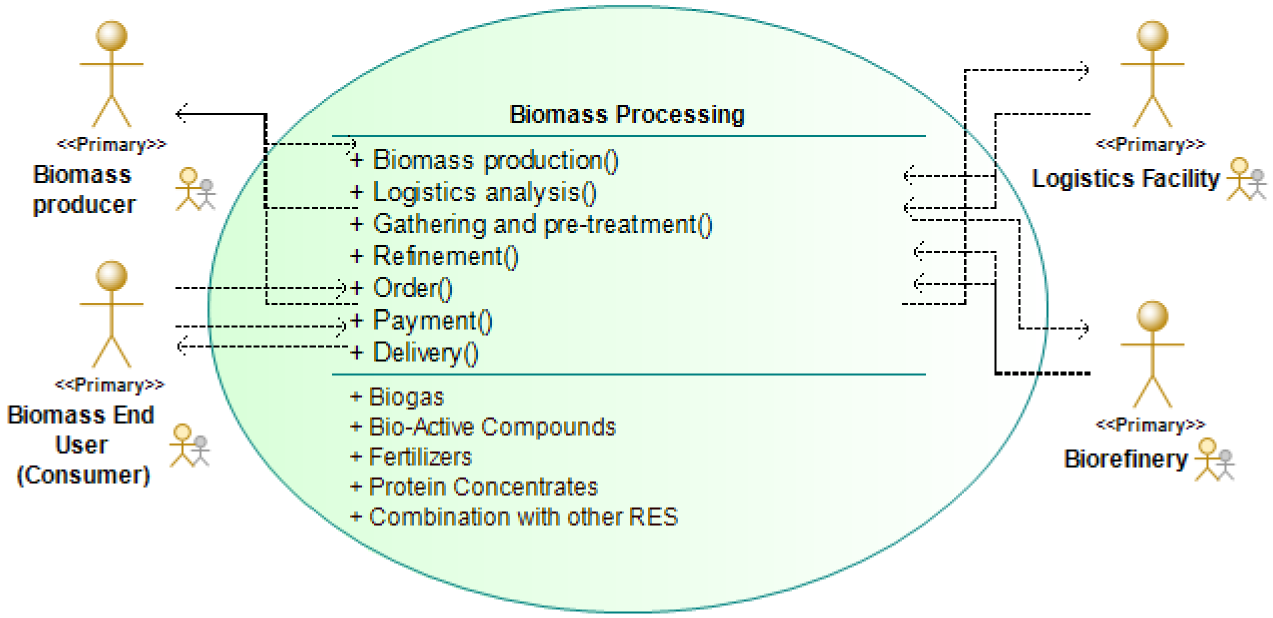

Figure 6.1.4: Waste management for biomass valorization – meat sector.

6.1.3.3. Workplan

1. *Biomass Producer: Produces biomass and collects the agreed quantities into the appropriate containers.*
2. *Biomass End User: Places order and makes the payment for this order.*
3. *Logistics Facility: Receives current quantities availability from Producers, makes or updates the collection schedule and informs the Biorefinery Facility about the daily collection schedule, plans the pretreatment plan that will to be applied to each feedstock batch that is being received and facilitates the payment schedule and transactions, either from End Users or to Biomass Producers.*
4. *Biorefinery: Collects biomass and delivers to pre-treatment/refinement process. Consults biomass reception schedule, performs the planned pre-treatment and refinement, consults the delivery schedule and distributes the refined products to Biomass End Users (Consumers).*
5. *Biomass End User: Receives the biomass ordered.*

6.2. Fruit Sector

Dimitra is a cooperative that focuses on the production, management, and distribution of fresh fruits, such as peaches, nectarines, apples, cherries, and apricots. The cooperative consists of 170 producers of fresh fruits. The producers own the fields on which they cultivate and harvest the produce. Sorting, packaging, and storage of fruits is being carried out in a modern co-owned facility with controlled atmosphere cold stores, various mechanical equipment and advanced technology equipment on the sorting and packaging line. Dimitra also distributes approximately 50% of its fresh fruits, especially peaches and nectarines, in foreign markets.

Dimitra's value chain, form the producers to the cooperative, comprises the following steps:

- *Field*
    - *Cultivation*
    - *Harvesting*
    - *Initial packaging for delivery to the cooperative*
    - *Product shipment to the cooperative*
- *Cooperative*
    - *Reception*
    - *Selection*
    - *Packaging*
    - *Storage*
    - *Pick up by end users (Wholesale/Retail Market)*

6.2.1. PROCESS AND LOGISTICS OPTIMIZATION THROUGH DIGITIZATION AND ENABLING TECHNOLOGIES.

6.2.1.1. Description

The DT will have to simulate the fruit ordering process, which involves all the actors in the fruit value chain. The use case will then be validated in order to use the finding for production forecasting on crops and factory. Data from Panoimagen and CTIC-CICA will be integrated in the DT to assist the generation of reliable production forecasts. The use case is designed to identify opportunities for improving the efficiency of the entire value chain, ensuring the biomass supply, and reducing waste that occurs due to quality defects, conflicting incentives, overproduction, or sub-optimal scheduling of logistics and production. To accomplish this, the data produced by the simulations carried out through the DT, will be compared with data from real environment operations and contrasted with logistics and production plans produced by advanced optimization tools that consider the quality properties of the feedstock and operations through the entire value chain.

6.2.1.2. Architecture

The actors involved, the related processes and the expected outcomes from the use case are shown in Figure 6.2.1.

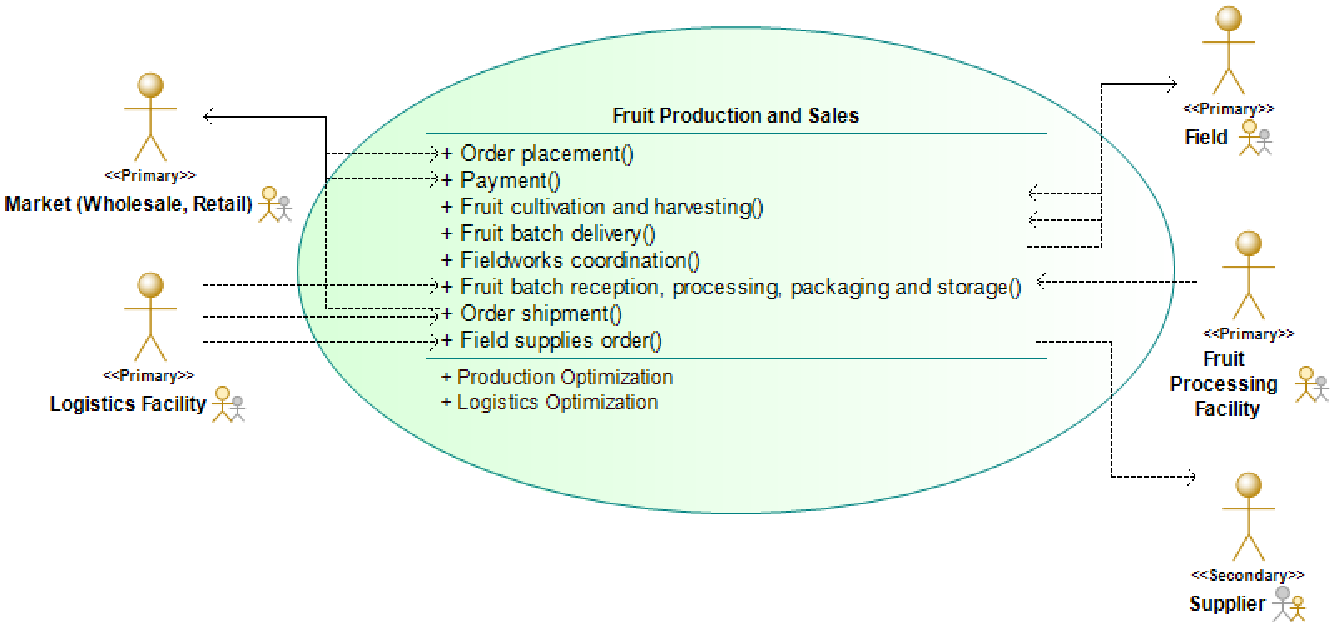

Figure 6.2.1: Fruit Production Optimization

6.2.1.3. Workplan

1. *Market (wholesale, retail actor): Places and order and receives payment options.*
2. *Field (Producer): Cultivates, harvests, delivers fruits to the Logistics Facility (pre-processing) and receives payment for each delivery. Also, receives consulting (coordination) from the cooperative (about how to manage activities related to fertilization, spaying, weather phenomena mitigation, etc.).*
3. *Logistics Facility: Receives the order and updates the Order Schedule, accordingly. Manages payments to producers and from market actors. Receives the products from the producers and updates logistics accordingly (pre-processing). Makes orders to suppliers and handles payments and supply distribution. Keeps track of all logistic activities and updates digital records accordingly.*
4. *Fruit Processing Facility: Consults daily operations schedule, receives shipments from the fruit reception process and performs selection, packaging and storage of the packaged fruits.*
5. *Market (wholesale, retail actor): Finalizes payment and picks up the order from the Fruit Processing Facility.*

6.2.2. TRACEABILITY AND TRANSPARENCY ASSISTED BY BLOCKCHAINS.

6.2.2.1. Description

Blockchain traceability from the perspective of wholesale/retail clients, as well as from an individual consumer's endpoint (Information exchange will based on blockchain technology provided by Stelviotech which will also provide security and robustness to the data involved). In this scenario a wholesale/retail customer will be able to request logistical data containing costs, dates, quality parameters etc. These data will be linked to order numbers, shipment numbers, etc., any parameter in general that is traceable in any stage of the value chain on a B2B level. On the other hand, a consumer will access information related to food quality, location, and production details, by scanning with a smartphone a certain area on the product's package (most likely a qr-code printed on the package). Both roles are defined and analyzed in D4.1.

6.2.2.2. Architecture

The actors involved, the related processes and the expected outcomes from the use case are illustrated in Figure 6.2.2.

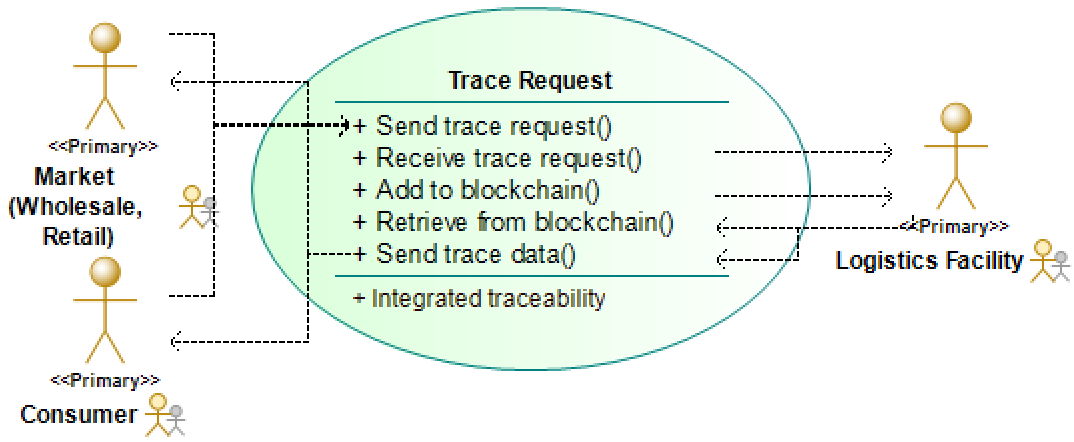

Figure 6.2.2: Product traceability – fruit sector.

6.2.2.3. Workplan

1. *Market (wholesale, retail): Places a trace request involving either logistics (order details by date, batch, shipment, package etc.) or product tracing regarding consumer details (such as farm, pig food ingredients, ingredient suppliers, processing details et.).*
2. *Consumer: Market (wholesale, retail): Places a trace request details such as farm, pig food ingredients, ingredient suppliers, processing details etc.*
3. *Logistics facility: Receives tracing requests and automates the responses, adds data to the blockchain and retrieves data from the blockchain.*

6.2.3. BIOMASS PROCESSING.

6.2.3.1. Description

Dimitra residual biomass is currently treated as follows: i) during pruning, the biomass is left at the field and it is used as green manuring; ii) during the sorting process, all fruits that are not selected for sale are transferred at non-competitive price to a juice production company. Although research has been developed on the analysis of the main elements of peaches and its possible uses in pharmaceutical or cosmetic companies, there are inadequate data to consider this approach as a viable waste management process. Nevertheless, the Cooperative (Dimitra), seeks for alternative uses of fruit waste, through the extraction of high-added value compounds such as pectin, glycosylates, proteins and phenolic and polyphenolic compounds, suitable for functional foods and nutraceutical products. This DT of biomass processing within the Cooperative aims to investigate waste valorization options and the potential to create value from the several types of waste, such as seeds, fruit skin or hair from peaches. The biogas potential will also be considered although Dimitra produces plant (fruit) biomass which contributed at approximately 25% of the raw materials used for biogas production. However, the possibility to use alternative renewable energy sources is more likely. Therefore, the use of photovoltaics is to be included in this use case.

6.2.3.2. Architecture

Figure 6.2.4.1 depicts the actors involved, the related processes and the expected outcomes.

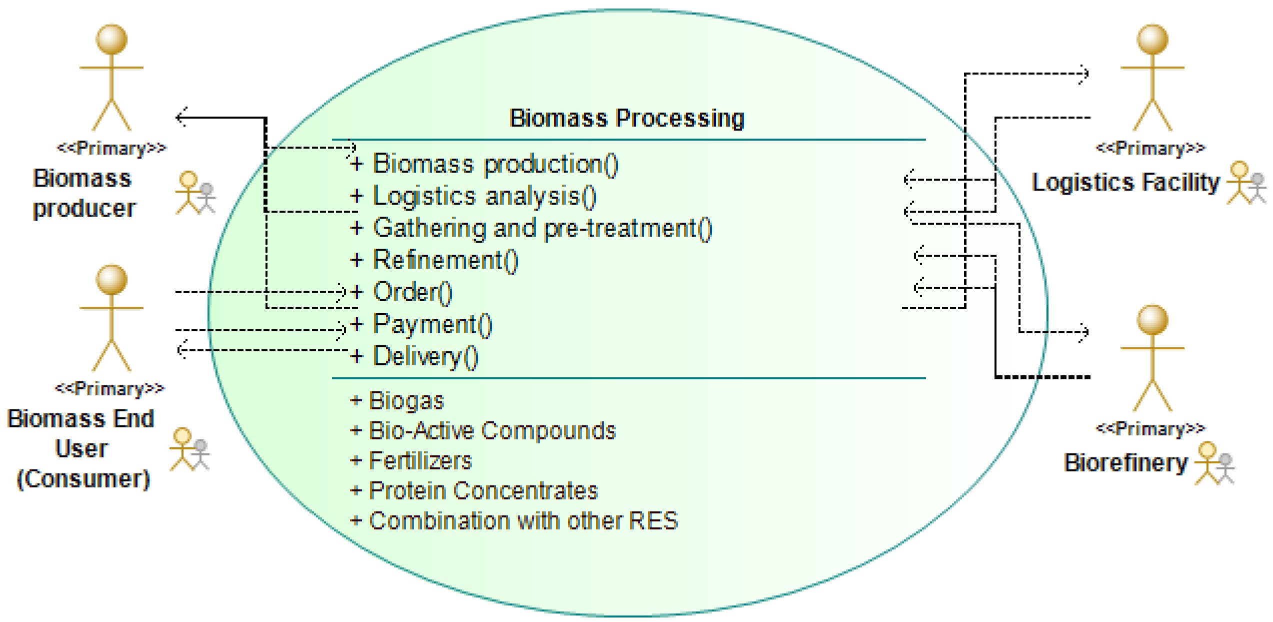

Figure 6.2.3: Waste management for biomass valorization – fruit sector.

6.2.3.3. Workplan

1. *Biomass Producer: Produces biomass and collects the agreed quantities into the appropriate containers.*

2. *Biomass End User: Places order and makes the payment for this order.*
3. *Logistics Facility: Receives current quantities availability from Producers, makes or updates the collection schedule and informs the Biorefinery Facility about the daily collection schedule, plans the pretreatment plan that will to be applied to each feedstock batch that is being received and facilitates the payment schedule and transactions, either from End Users or to Biomass Producers.*
4. *Biorefinery: Collects biomass and delivers to pre-treatment/refinement process. Consults biomass reception schedule, performs the planned pre-treatment and refinement, consults the delivery schedule and distributes the refined products to Biomass End Users (Consumers).*
5. *Biomass End User: Receives the biomass ordered.*

7. Impact

The use cases should help BBTWINS meet EU objectives in areas ranging from economic growth, job creation, the circular economy and resource efficiency to climate change mitigation, security, agriculture modernization and regional development, as well as help the project its environmental, economic, and social goals.

7.1. Environmental

The use cases will provide useful information to WP7 in order to assess the sustainability of the proposed solutions across the entire value-chain up to the production and use of the processed feedstock as raw materials for biobased industries. The sustainability evaluation will address critical environmental aspects, which will ultimately lead to the correct measurement of the expected environmental impacts in reducing:

- *Greenhouse gas (including CO_2) emissions (expressed in CO_2 equivalents) in transport by at least 30% as a result of improved logistics and processing.*
- *Reduce raw-material loss by at least 20% as a result of more efficient logistics and processing.*

Furthermore, the use cases will produce an insightful breakdown of the processes that lead to significant raw material (biomass as feedstock) losses and will also help the identification of cases that are waste-prone and cross-linked, such as:

- *Losses in collection, processing, packaging, and distribution.*
- *Biomass heterogeneity, mixing of several biomass residues, contamination from use and content of hazardous substances.*
- *Processing costs.*
- *Poor information related to the markets associated.*

Furthermore, the use cases will be used to improve pre-treatment technologies and storage conditions for reducing feedstock loss. The quantities of raw material gained from this process will be tested for sustainable energy production, thus contributing to the EU's long-term strategy for a climate-neutral Europe by replacing fossil-based fuels with bio-based, renewable energy sources. Furthermore, the DTs will be used to test circular economy principles, in order to reduce the emissions currently generated within the value chains.

Yet, another issue that the use cases address thoroughly is transportation optimization. The use cases will validate the transport optimization models of both operational vehicle routing (VRP) and tactical logistics planning models. Therefore, the use cases will evaluate the potential of the enabling technologies deployed to reduce the transportation intensity, thus reducing CO_2 emissions, and increasing resource and operational efficiency. Moreover, the use cases will test technologies such as DTs, Blockchain, Big Data and AI, in a relatively unexplored area (agri-food value chains), in relation to their prospects for creating new biomass bio-based operations at commercial level.

7.2. Economic

As already mentioned, the use cases will evaluate the potential of the enabling technologies deployed to reduce raw material transportation costs and increase resource and operational efficiency. Apart from the environmental impact created, the transportation optimization models will also point out the economic advantages stemming from using enabling technologies. Additionally, the current resource efficiency rates (the percentage of residual biomass that is finally reconverted as input for other industries) are at a relatively low rate. Nevertheless, the simulation and study of several feedstock pre-treatments (mechanical, chemical, or thermal) will assist in predicting the optimal treatment and paths to be followed by the feedstock and also tackle unpredictable conditions that may affect their potential. By testing and validating the use cases across the value chain in a single simulation process, BBTWINS is expected to increase resource efficiency, which will also impact positively the related costs.

As agriculture and food processing sectors are both cost-driven, costs reduction form a convincing case in favor or digitalization. Within the associated value chains, from the fields and farms to the feedstock supply, the ability to synchronize the different stages through the use of enabling technologies (digital twin, blockchain, optimization software, new sensors etc.) will enable smoother flows to processing plants and faster delivery times.

As one of the first known examples of integrating transport optimization models to a Digital Twin implementation, BBTWINS will use machine learning components to replace parts of the logistics optimization system and enable interactive use with reasonable computation times. This smart combination is expected to reduce raw material (food, supplies, feedstock etc.) transportation costs up to 25%, when operating at large scale. The achieved enhancements will be measured in the meat processing use case, in the framework of task 7.3 (Cost estimates and techno-economic analysis) once the proper progress KPIs have been established in task 7.1

Moreover, the use cases will test technologies such as DTs, Blockchain, Big Data and AI, in relation to their prospects for creating new and commercially feasible income streams, which broadens the opportunities for biomass producers and other stakeholders involved in the value chains. As the agricultural and food processing sectors are both cost-driven, the uses cases will showcase the capability inherent to enabling technologies to orchestrate the different stages of the feedstock generation process, by producing more efficient flows for the processing plants and faster delivery times.

The use cases, once validated, will signify a step forward on the digitalization of traditional sectors and also increase their potential to become quality feedstock providers for the bio-based industries. They will, in turn, eventually deploy these findings to add value to their products. Thus, the use cases will also contribute to creating new economic activities, which is in favor of rural areas, usually characterized for being less economically developed.

The DTs implemented in the use cases will contribute significantly to the goal of a 30% increase in resource efficiency via the ability of the digital twins to predict the optimal treatment and paths to be followed by the feedstock according, achieving a full coverage of the value chain. Adding to the environmental benefits, as already outlined, this is also expected to have significant economic impact.

The economic impact of the project will also be validated by life-cycle assessment and life-cycle cost analysis (to be performed by ANGAZ) which will ensure the economic viability of BBTWINS developments. Market and value chain analyses will be performed to ensure the economic viability of the products and processes developed in WP6.

Overall, the use cases are expected to contribute significantly to creating new economic activities, especially is in favor of rural areas, by focusing on set of economic activities that are difficult to further develop without the use of enabling technologies. This use of innovative technologies reveals another subtle economic impact, due to the fact that the project creates for stakeholder's the opportunity to gain exposure and involvement in technologies that will open new business ideas and business models. This, of course, is highly dependent on the local characteristics of the BBTWINS use case regions. Portesa is located in a region which is already adequately developed and has a higher GDP and lower unemployment than the national average. Although a traditional agricultural region, contrary to the usual approach, Aragon, in the last few decades, has turned towards advanced industries and services. In this context, the impact of BBTWINS is expected to bring a number of innovative technologies to the livestock sector as well. In contrast, the region of Western Macedonia, where Dimitra is located, has lower GDP and higher unemployment than the Greek average, and is currently going through an ambitious process of decarbonization. After many decades as the heart of the Greek coal-industry, the region is attempting a shift towards green and innovative economic activities. The overall impact of BBTWINS can provide important contributions to this effort, providing one of the region's key sectors with added value and innovative solutions that will increase its competitiveness. In both cases, BBTWINS is expected to establish the basis for the promotion of economic development, and potentially create the basis for further replication and upscaling.

7.3. Social

The use cases are expected to have a significant social impact on the regions of Aragon and Western Macedonia. Social impact is heavily intertwined with economic and, also, environmental impact since economic prosperity and protection of the environment produce important social benefits by themselves. More specifically, however, the use cases are expected to produce several specific social impacts, including:

- *The demonstration of a potential for creating new job opportunities in the bio-based sector, increasing employment.*
- *The demonstration of enabling technologies which can improve the integration of digital applications and human activities, making conditions more convenient and efficient.*
- *The demonstration of enabling technologies which can increase the safety and efficiency of field operations, increasing the well-being of the workforce.*

It is noted that, within the project, sustainability assessment and social impacts are covered by the development of the WP6 tasks. The validation of the BBTWINS use cases is a step forward on the digitalization of traditional sectors that will become quality feedstock providers for the bio-based industries. The use of advanced solutions based on

ICT (enabling technologies) will give an answer to the population's growing demand for sustainable products. This, in turn, apart from fostering new economic activities (as described above when discussing economic impacts), will also contribute to the revitalization of rural areas through the provision of highly skilled research, development and production jobs over the next years. It is remarkable to highlight that due to the COVID-19 crisis rural locations are increasingly being demanded as new residential places. This will mean that this growing population will look for new job opportunities in rural areas. In this context, the BBTWINS use cases can help maintain and further develop a competitive and knowledge-intensive rural economy.

The project's use cases will not only simulate the whole value chain for feedstock and final product optimization of agri-food process (thanks to the Digital Twin technology) but will also allow the digitalization of expert experience in different critical process steps. This information then will be able to be documented, transferred, and modified throughout a company to reduce the knowledge gap. Indeed, through simulation tools and virtual reality tools proposed within BBTWINS, the proposed DTs will deepen the operator's understandings of complex physical entities and processes, contributing to the upskilling of the local human capital.

The upskilling benefit provided by the BBTWINS use cases is also extended to the increase of workplace safety, as well as efficiency. The project solution will be able to be used for the training of users, operators, maintainers, and service providers. In particular, skills in human activities in the agri-food sector that can be dangerous, hazardous, such as dealing with food and animal waste, can be improved through DTs so that the risks associated to non-trained personal are minimized.

Finally, the solutions will an effective means to improve agri-food companies' productivity and efficiency, as well as to reduce cost and time. Together with the sensory data acquisition, big data analytics, as well as AI (machine learning, deep learning) BBTWINS integral solution will be used for monitoring, diagnostics, prognostics, and optimization A key impact is that the project will provide a unique way to understand the resource consumption in farms and the impact in crop yield. This way, combining variations in different process parameters and testing them virtually, will facilitate finding the best process parameters before implementing them on site. Through the assessment of ongoing states, the diagnosis of historical problems, and the prediction of future trends, BBTWINS will provide more comprehensive supports for the decision-making of a wide spectrum of field operations that are related to the agri-food sector, developed in the context of the use cases but also applicable elsewhere.