Creating an inclusive business model for the production of maritime biofuels from olive residues in Jaén, Spain

Master thesis Life Science and Technology
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Abstract

Biofuels offer the potential to significantly reduce greenhouse gas (GHG) emissions in merchant ships by up to 90% and can be seamlessly integrated into existing engines as drop-in fuel. Utilising residual biomass sources for biofuel production presents financial and environmental advantages. In Spain's Jaén province, approximately 2,05 million tons of olive residue are annually available, offering a resource for biocrude production through Hydrothermal Liquefaction (HTL). Biocrude can be subsequently upgraded to biofuel. Additionally, the HTL process yields biochar as a by-product, which holds potential as a soil amendment to combat erosion in olive groves. This thesis focuses on developing a viable, inclusive business model for maritime biofuel production from olive residues in Jaén, Spain, employing the LINK methodology. Three distinct value chain scenarios were evaluated in the initial phase of a two-tier assessment. The analysis revealed that biocrude production either at Jaén's largest secondary mill, San Miguel Arcángel (scenario 1), or at a newly established centralized biorefinery in Úbeda (scenario 2), is more advantageous than establishing a standalone centralized HTL biorefinery for biofuel production (scenario 3). In the second-tier evaluation, the economic, environmental, and social impacts of three value chain implementation options were assessed and compared. These evaluations were integrated and analysed in economic, environmental, and social Business Model Canvasses (BMCs) for the value chain stakeholders. The analysis indicated that while scenarios 1 and 2 marginally contribute to the annual income of olive farmers, they substantially aid in carbon emissions reduction through biochar sequestration, can be used to mitigate olive grove soil erosion and positively impact regional employment opportunities. Scenario 1, with biocrude production at a secondary mill, exhibits greater social benefits due to enhanced smallholder inclusion and autonomy. However, this is counterbalanced by the superior economic and environmental advantages associated with biocrude production at a larger, centralized HTL biorefinery in scenario 2, attributed to economies of scale and reduced local environmental impacts. Recommendations include further research on enhancing smallholder inclusion, exploring the profitability of biocrude production at smaller secondary mills, and conducting a comprehensive financial assessment to ascertain feasibility, profitability, and potential investment avenues.

List of Abbreviations

GHG	Greenhouse Gas
HTL	Hydrothermal Liquefaction
CAP	Common Agricultural Policy
CAPEX	Capital Expenditures
IMO	International Maritime Organization
KPI	Key Performance Indicator
IB	Inclusive Business
VCM	Value Chain Map
BMC	Business Model Case
COP	Crude Olive Pomace
TBL	Triple Bottom Line

1. Introduction

Maritime transport is an essential mode of transport and plays a vital role in the world and the EU's economy. While it is one of the most energy-efficient modes of transport, maritime transport still uses 99.91% fossil fuels. This means the industry is also a large and growing source of greenhouse gas (GHG) emissions. The shipping sector is responsible for more than 80% of the international transportation of goods already, with the maritime sector expected to grow 40-115% by 2050 compared to 2020 (International Maritime Organization, 2020). In 2018 global shipping emissions were responsible for around 2.9% of global emissions caused by human activities (European Commission, 2021). To reach the objectives of the Paris Agreement, which aims to limit global warming to 1.5°C, GHG emissions from international shipping need to be significantly reduced. Due to the inevitable need for maritime transport, we need to look towards using green energy sources. The need to shift towards green energy in the maritime sector is also shown in the recent updates to the policies of the IEA (International Energy Agency) and the IMO (International Maritime Organization), which have set Net Zero Emissions (NZE) targets for 2050 (International Maritime Organization 2020).

While electrification, using hydrogen or E-methanol are all possible future green fuels for the shipping sector, these options are underdeveloped and have a need for large investments in infrastructure, technology, and a re-design of the ships themselves. Meanwhile, the development of biofuels made from biomass has the potential to reduce the emission of Greenhouse Gases (GHG), nitrogen oxides (NO_x) and sulphur oxides (SO_x) of maritime transport in a much shorter timeframe. Biofuels have the potential to reduce GHG by merchant ships up to 90% and are already being used to power ships. They are used instead of fossil fuels or as drop-in fuels where they are being added with varying percentages to conventional fossil fuels to be used in engines, fuel tanks, pumps or supply systems without substantial or any modifications (European Maritime Safety Agency, 2022) (Finco Energies, 2023). Biofuels can be made from several renewable sources such as waste oils or forest residues (Demirbas, 2008). As of now the use of biofuels is hindered by the high selling price relative to fossil fuels and concerns of the industry about the availability, cost, and environmental and social sustainability. Additionally, there are concerns that first-generation biofuel production made from food crops will compete with food production and second-generation biofuels made from biomass residues may compete with or change former land use. Another barrier is the investments in necessary conditions such as infrastructure, machinery development, but also institutional development and knowledge transfer that are needed (Oh et al., 2018)

The Clean Shipping Project at TU Delft works towards responsible and sustainable marine biofuels by working on case studies on three locations: Namibia, Spain, and Colombia. As the Clean Shipping Project aims to develop reliable and secure value chains for shipping biofuels in a sustainable and socially responsible manner, the biohub concept was introduced (Clean Shipping Project, 2019). A biohub is a biorefinery design focusing on sustainability from a social, environmental, and economic perspective. This is done by a cooperative initiative between public and private actors in a particular region to source bio-based (waste)streams and transforming them into marketable products, while promoting sustainable farming practices, traditional biomass uses and fairly distributing costs, benefits, risks and opportunities.

Since the biomass availability, biomass production data and a stakeholder value chain are already available for the Spain case study, this thesis will build on that information to set up a business case for the production of marine biofuels made from residues from the olive oil industry in Jaén. The Andalusia region depends heavily on the olive oil industry financially and produces residual biomass that could be converted into maritime biofuels. During the production of olive oil three main sources of residual biomass are produced. First, after harvesting the olives, the branches and leaves of the trees are pruned, which leave olive tree pruning. Second, only 20% of olives are turned into virgin olive oil by primary mills, the remaining 80% is Crude olive pomace (COP) and produced after the mechanical extraction of virgin olive oil. Third, the low-value product Exhausted Olive Pomace (EOP) is produced in secondary mills after the mechanical and chemical extraction of the olive oil. Due to factors such as volume, transport, policies, economics and a relatively high water-content, COP is the preferred biomass source (De Filippis, 2016)

Figure 1 shows an overview of the workings of the biohub in Andalusia, Spain. In the biohub concept non-edible residual biomass produced by farmers is used to produce bio-oil, which can be converted into a maritime biofuel. The biorefineries are based on hydrothermal liquefaction (HTL) of biomass, which is currently the most competitive route to transform lignocellulosic biomass into drop-in biofuels (Clean Shipping Project, 2019) (De Filippis, 2016). HTL is a thermal depolymerization process used to convert wet biomass into crude-like oil. The HTL process is performed at biorefineries performing biomass extraction. Here COP is converted into biocrude, which is a liquid biofuel processed by liquefaction of biomass using high temperature and high pressure liquid phase thermal processing (IEA Bioenergy, 2017). Further, gaseous (off-gas) and solid (biochar) phases are created. Biochar can be burned to generate heat or electricity, or it can be used as soil amendment to improve olive grove soil quality (Brassard et al., 2019). Finally, the biocrude is upgraded to biofuel by removing impurities using green hydrogen.

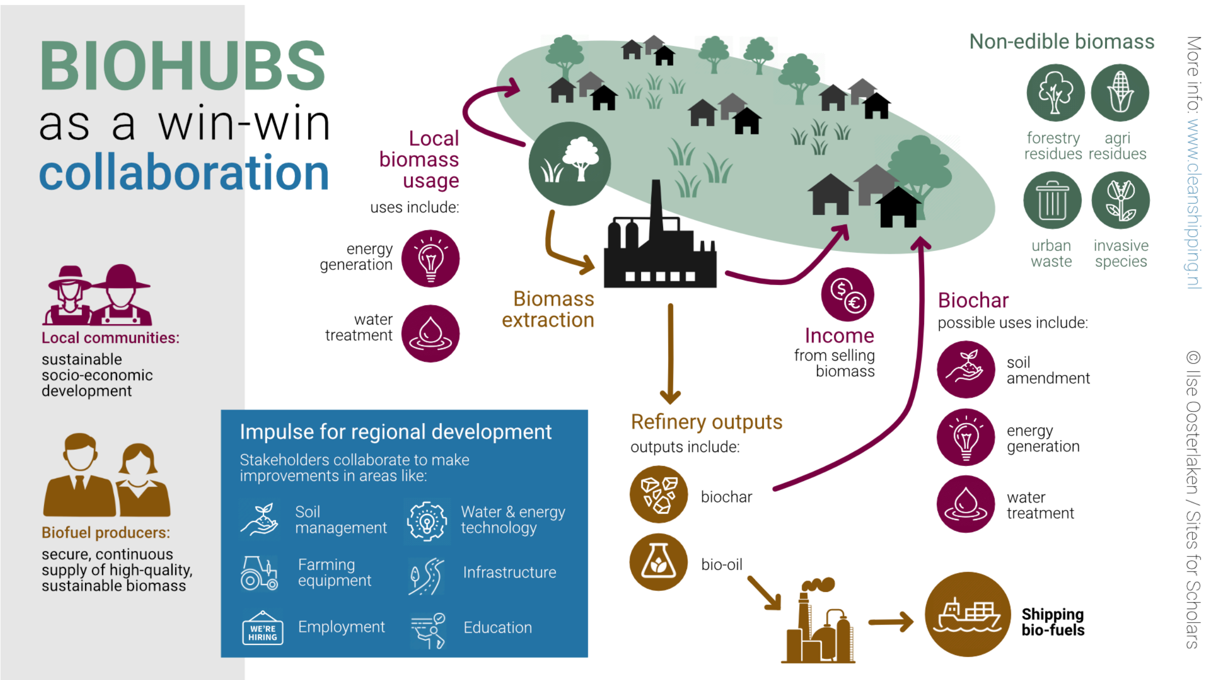

Figure 1: overview of the biohub in Andalusia, Spain (Clean Shipping Project, 2019)

The production of biocrude using HTL can be implemented in the largest secondary mill in Jaén, San Miguel Arcángel in Villanueva del Arzobispo, with the subsequent upgrading done in the San Roque upgrading facility (scenario 1), or a new centralised HTL biorefinery can be built in the centrally located Úbeda in which biocrude is produced, which is also transported to the San Roque upgrading facility (scenario 2) or this new centralised HTL biorefinery could be responsible for the upgrading process itself (scenario 3) as depicted in Figure 2.

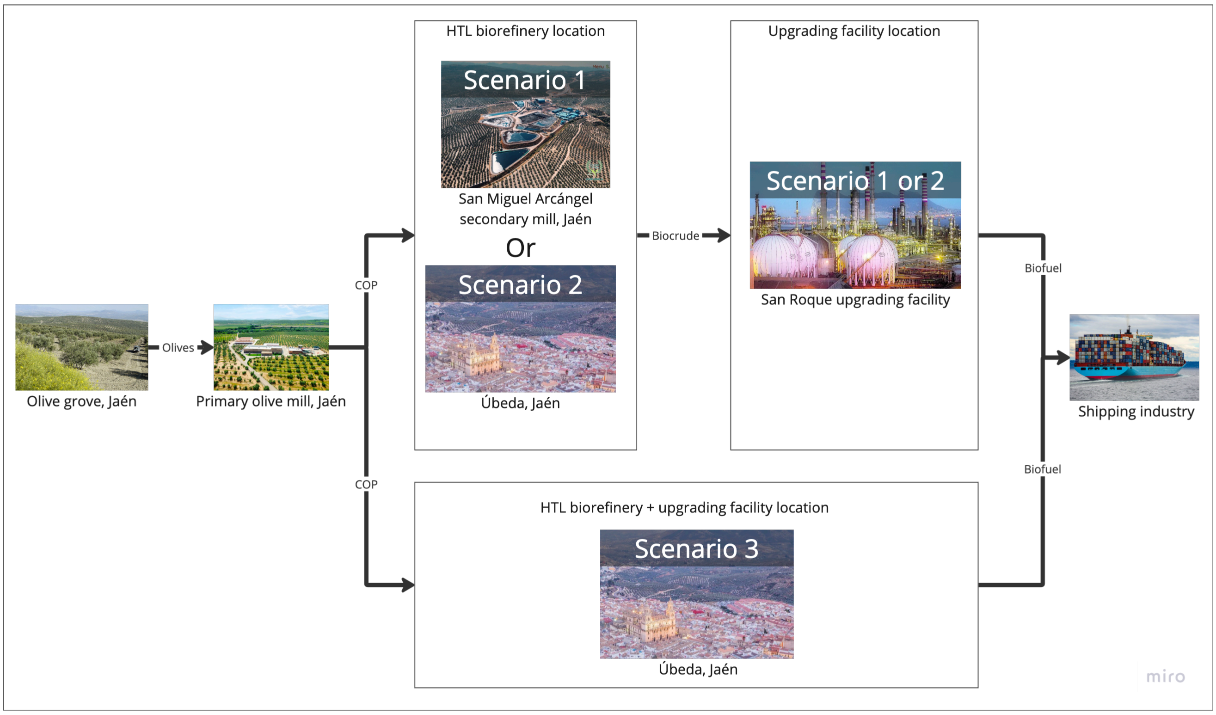

Figure 2: Schematic overview of the possible production routes of olive residue biofuel out of COP produced at primary mills in Jaén, Spainl. Scenario 1 converts the olive residue COP into biocrude at the San Miguel Arcángel secondary mill in Jaén, after which the biocrude is converted into biofuel at the San Roque upgrading facility. Scenario 2 converts the olive residue COP into biocrude at a new centralised HTL biorefinery in Úbeda, Jaén, also using the San Roque upgrading facility to produce maritime biofuel. Scenario 3 converts the olive residue COP into biofuel at a new centralised HTL biorefinery and upgrading facility in Úbeda, Jaén (San Miguel Arcangel S.A., n.d.).

When the biohub concept is used, a viable business case is needed that focuses on building inclusive and sustainable trading relationships linking small-scale producers that deliver to the biohubs to modern markets and industries (Lundy, 2012). To realise this, stakeholders play an important role, with specific attention to stakeholders at the beginning (olive farmers) and the end of the chain. Therefore, an inclusive business model such as LINK is needed to incorporate the biohub system, while also leaving room for advancements in the processing of the fuel to create a viable business case (Lundy, 2012). The development of a sustainable, inclusive bio-based value chain will focus on the opportunities and threats for small-scale, local supply chains and is aimed at increasing resilience and income for the farmers.

Therefore, an inclusive business model is needed to link end-users with the biomass supply while ensuring this is done while building inclusive and sustainable trading relationships that link small-scale producers to the end-users. To this end the following research question and sub questions have been formulated.

Research question: How to create a viable business case using an inclusive business model for the production of maritime biofuels from olive residues in Jaén, Spain.

Sub questions:

- How can an inclusive business model be developed by implementing the LINK methodology?
- What criteria should be considered when evaluating and choosing between various value chain scenarios?
- What are the economic, environmental, and social implications of the implementation decisions made within a value chain?
- How should the distribution of benefits, costs, and risks be optimized across the entire value chain?

These questions will be answered by using the research methods described in the methodology section.

2. Theoretical background

Before an inclusive business case can be set up it is first needed to establish a theoretical framework. This chapter will expand on what constitutes a value chain, inclusive business models, sustainable businesses and the Triple Bottom Line. Next the framework upon which the inclusive business case sits will be explained, which is the LINK methodology and the steps it consists of.

Value Chain

A value chain is a connected series of organizations, resources and knowledge streams involved in the creation and delivery of value to the end customer (Osterwalder & Pigneur, 2010). Traditionally, value chains are viewed primarily from a financial perspective. Every activity in the value chain the product passes through adds value to the product. The chain of activities gives the products more added value than the sum of the independent activities value. Inputs, transformation processes, and outputs involve the acquisition and consumption of resources- money, labour, materials, equipment, buildings, land, administration, and management. How value chain activities are carried out determines costs and affects profits (Porter, 1985).

Business model

The purpose of this thesis is the development of an inclusive business model. However, the terms business model, case, and plan often get confused. At the centre of every business is its business model, which is used to gain a comprehensive overview of the economic prospects and potential of the new company. A well-developed business model describes in detail the services or products offered, the target markets, the cost structures and the resources required. Often, the business model goes hand in hand with a business model canvas, a visual representation of the business idea that summarises all the important aspects on one page. The business plan, on the other hand, builds on the business model and fleshes out the business goals and strategies. While the business model relates to the whole company, the business case focuses on a specific project or investment within the company and checks that it is in line with the overall objectives. The business model is the solid foundation on which the business plan is built and developed. It not only conveys the core idea, but also details the entire process that will lead to commercial success (IAPM internal, n.d.).

Inclusive business models

A business model describes the rational of how an individual firm creates, captures, and delivers value (Osterwalder & Pigneur, 2010). Richardson (2008) defined the business model based on three functions: value proposition, value generation and value capture. Accordingly, the value proposition includes the product or service a company offers, as well as its strategy to convince customers to pay for it. Value generation relates to how the company will create and deliver this value by organizing its resources, capabilities, and position in the value chain. The value capture defines how the company generates profit and the revenue sources. (Bröring and Vanacker, 2022).

An Inclusive Business (IB) model is a business tool, designed to support enterprise activities that increase income and respond to market demands and opportunities (Osterwalder & Pigneur, 2010). IB is defined as a commercially viable business model that benefits low-income communities by including them in the company's value chain as consumers, producers, entrepreneurs, or employees (United Nations Development Programme, 2008). Inclusive trading relationships are the result of business models that do not leave behind small holder farmers and in which the voices and needs of those actors in rural areas in developing countries are recognized.

Making business more inclusive for small-scale suppliers is a way to enhance corporate reputation, gain legitimacy in local markets and create 'ethical' products. Business models that are inclusive of smallholders, provide economic and social development opportunities and more effectively link actors in a coherent and traceable way constitute one way to adapt to a supply-constrained market (Osterwalder & Pigneur, 2010). Inclusion is a pillar used to innovate in a responsible manner, to design for improved accessibility for all stakeholders and to include the underrepresented in the picture by providing access to equipment, knowledge and capital and making sure their values are upheld in the process of innovation (Robaey et al., 2019). This is needed to create an inclusive bio-based value chain in a sustainable business.

When creating an inclusive business model, it is important to not just show the value proposition from the customer's perspective, but to show the producer's point of view as well. Inclusive business models should be responsive to the realities of smallholder production as well as to market demands. For modern agri-food chains, almost all value propositions for buyers are built on high standards for food quality and safety, year-round availability, and, sometimes, lower prices, communicated to consumers through brands. The client-facing value proposition focuses on the assurance of supply, safety and quality of products that tell a story and support the brand. It needs to be considered what creates value for a buyer, such as quality of supply, reliable supply, certificates and standards, competitive price, reliable quality, transparency of processes. The farmer-facing value proposition focuses on what products, strategies, activities or purchasing practices can promote small-holder inclusion and staying the preferred buyer. For a smallholder, stable and consistent demand, provision of supplies, training and technical assistance, financial services, contracts and market information create value. In this thesis the inclusive business model method LINK is used (Lundy et al., 2012). The definition of an inclusive business model in this thesis is as follows: an inclusive business model is a type of business model that seeks to create value for low-income communities by integrating them into a company's value chain. On the demand side as clients and consumers, and/or on the supply side as producers, entrepreneurs, or employees in a sustainable way.

Sustainable Businesses and the Triple Bottom Line

As the goal of this thesis is to create a viable, inclusive business case, it must be considered what constitutes a viable and robust business case. This is often described as a sustainable business. A sustainable business can be defined in two ways. On the one hand it can mean having a resilient business model that will thrive long term. Alternatively, sustainability in business also refers to doing business without negatively impacting the environment, community, or society as a whole (Spiliakos, 2018). The term Triple Bottom Line (TBL) was first coined by John Elkington in 1994 and provides a framework for measuring the performance of the business and the success of the organisation using three lines: social, economic, and environmental, or people, profit and planet (Goel, 2010). The concept of the triple bottom line put environmental and social responsibility on an even footing with economic impact (Grand Canyon University, 2021).

The profit part of the TBL for a business in a capitalist economy heavily depends on its financial performance, or the profit it generates for shareholders. The focus lies on reducing costs and mitigating risk. The people part refers to a business's societal impact, or its commitment to people. While traditionally businesses have favoured shareholder value as an indicator of success, they have now increasingly embraced sustainability and shifted their focus toward creating value for all stakeholders impacted by business decisions. The planet component of the TBL is concerned with making a positive impact on the planet. While businesses have historically been the greatest contributors to climate change, they also hold the keys to driving positive change. Many business leaders are now recognizing their social responsibility to do so. It has been found that in many cases adopting sustainability initiatives has proven to drive business success (Miller, 2020). When the aim is social inclusion and poverty reduction business models are required beyond profit with a social and environmental dimension (Osterwalder & Pigneur, 2010). A viable business model is needed for the intermediaries of the value chain that support the services needed for inclusive sourcing. Osterwalder & Pigneur (2010) describes the Triple Bottom Line as: (1) the need for companies to measure beyond the business' profitability; (2) the space where those measurements can be included in the business model; and (3) the need to incorporate specific indicators on small holder inclusion into any social measurement framework used by a company.

LINK methodology

The LINK methodology guide is based on participatory methods adapted from the school of Participative Learning and Action (PLA). The goal of the LINK toolkit is to build inclusive and sustainable trading relationships linking small-scale producers to modern markets by understanding the current functioning of the market chain and key business models and design innovations that empower producer groups to engage more effectively and buyers to act in ways more amenable to small holder farmers. The LINK methodology works by following four tools: the Value Chain Map (VCM), the Business Model Canvas (BMC), the New Business Model Principles (NBMP) and the Prototype Cycle (PC) to analyse the connection between small-scale producers and the market (Lundy et al., 2012).

The Value Chain Map (VCM)

In order to define relationships and interconnections in the value chain, the direct and indirect stakeholders are visualized alongside the flow of products, services, information and payment in the VCM. Additionally, any external influences that affect the performance of the chain and blockages, bottlenecks and disruptions in the market system are visualised, this so sources of innovation and improvement can be identified. This results in a VCM that consists of three levels of value chain mapping: core processes, partner network and external influences. The VCM framework will be used to explain the new value chain, based on the workings of the current value chain.

The Business Model Canvas (BMC)

The BMC tool assesses how a key business in the value chain functions, by providing a rapid picture of an organisation's business model for analysis. Bottlenecks and (financial) imbalances are highlighted and the viability and inclusivity of the business model is assessed. This is done so areas for innovation and improvement are identified, and complex business issues are presented in an easy and accessible fashion, enhancing business thinking at the farm level. The BMC consists of a "Canvas" made up of the following 4 areas, subdivided into 9 blocks, as shown in Figure 3. The left side focuses on creating value and comprises the set of activities, mechanisms, and relationships for providing a good or service and focuses on improving the production efficiency. The partner network - the supply chain and its coordination – is a vitally important source of competitive advantage. The right side of the BMC is the marketing side and focuses on capturing value. It comprises of the set of activities, mechanisms and relationships for selling that good or service, or in other words for capturing value. Broadly speaking, the production side is associated with costs while the marketing side generates revenues, though marketing also entails costs. Figure 4 shows the nine blocks an economic BMC consists of. More detailed descriptions and questions that can be used to fill these building blocks in the BMC format according to Lundy et al. (2012) are shown in Appendix A.

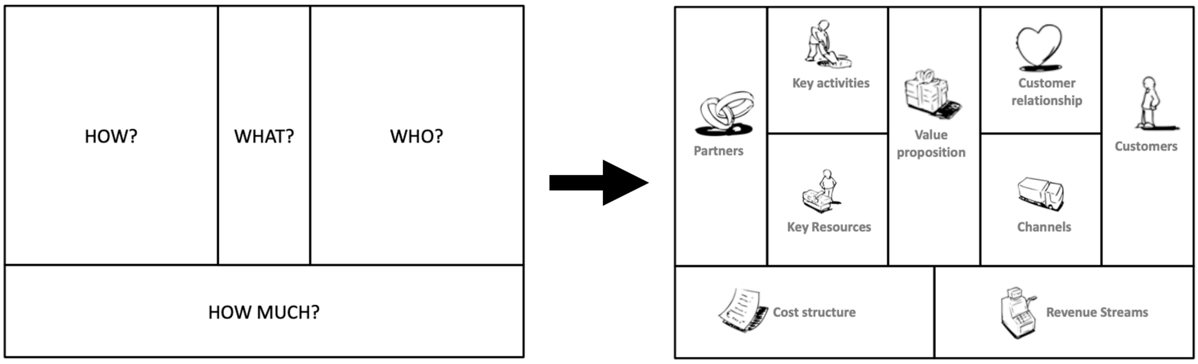

Figure 3: The Business Model Canvas is made up of four areas asking the questions How, What, Who and How Much. These questions are subdivided into 9 blocks: Partners, Key Activities, Key Resources (How?), Value proposition (What?), Customer relationship, Channels, Customers (Who?) and Cost structure and Revenue streams (How Much?). The left side of the BMC focuses on increasing efficiency and creating value, while the right side focuses on capturing the value (Lundy et al., 2012).

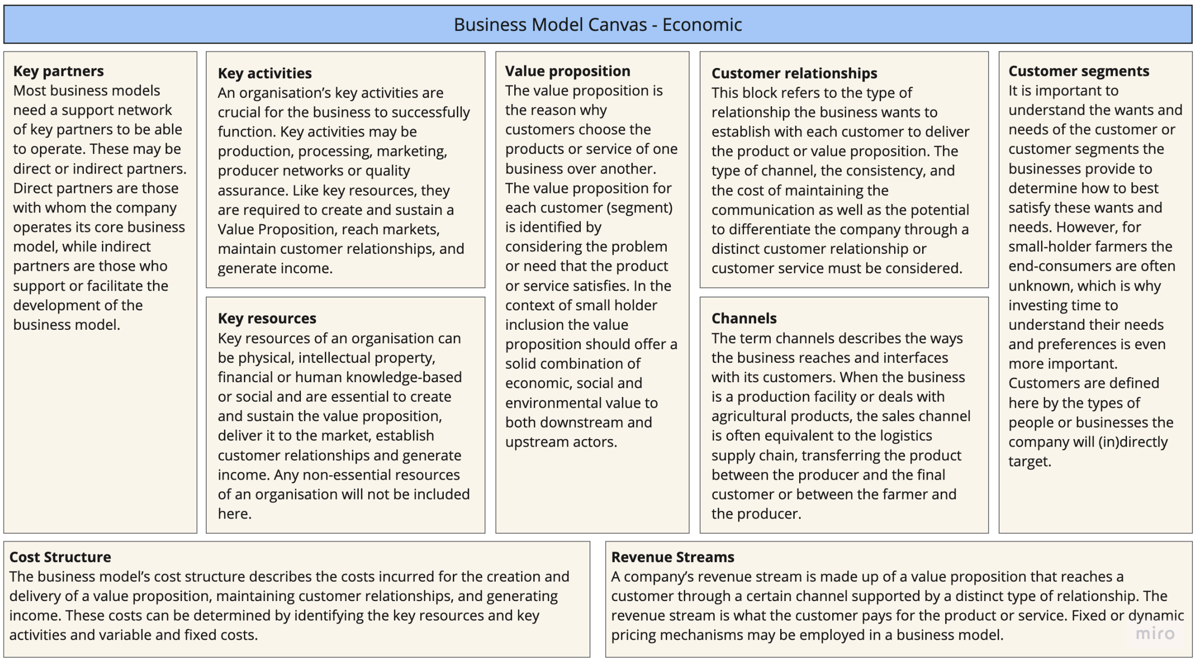

Figure 4: Economic Business Model Canvas area definitions (Pigneur et al, 2015).

Linked business model

A BMC depicts only one key business in the value chain, while the analysis of just one individual business model does not sufficiently represent trading partners located up- and downstream in the chain. Therefore, a linked business model is used. This method uses the idea that in a value chain your customer is another's supplier. Each relevant stakeholder in the value chain will be depicted in a BMC, in which all stakeholders are supplier and customer at the same time, except for the producer at the start of the value chain. Therefore, the blocks "key partners" and "customer segments" overlap, as one business' customer segment is the next business' key partner. This method uses the concept of double value proposition, where a business model offers distinct forms of value when facing customers (downstream) or facing suppliers (upstream).

Triple Layer Business Model Canvas (TLBMC)

The TLBMC is a tool that uses the triple bottom line to explore sustainable business models and extends on the original economically oriented business model canvas concept with new canvas layers exploring environmental and social value creation (Pigneur et al, 2015).

Environmental life cycle BMC

The environmental layer of the TLBMC builds on a life cycle perspective of environmental impact. This stems from research and practice on Life Cycle Assessments (LCA), which is a formal approach for measuring a product's or service's environmental impacts across all stages of its life. While the TLBMC does not integrate a formal LCA into the canvas, it does ensure a life cycle perspective when considering a business model and its environmental impacts. Much in the same way the original business model canvas is used to understand how revenues outweigh costs, the main objective of the environmental layer of the TLBMC is to appraise how the organization generates more environmental benefits than environmental impacts. Doing so allows users to better understand where the organization's biggest environmental impacts lie within the business model; and provide insights for where the organization may focus its attention when creating environmentally oriented innovations (Pigneur et al, 2015).

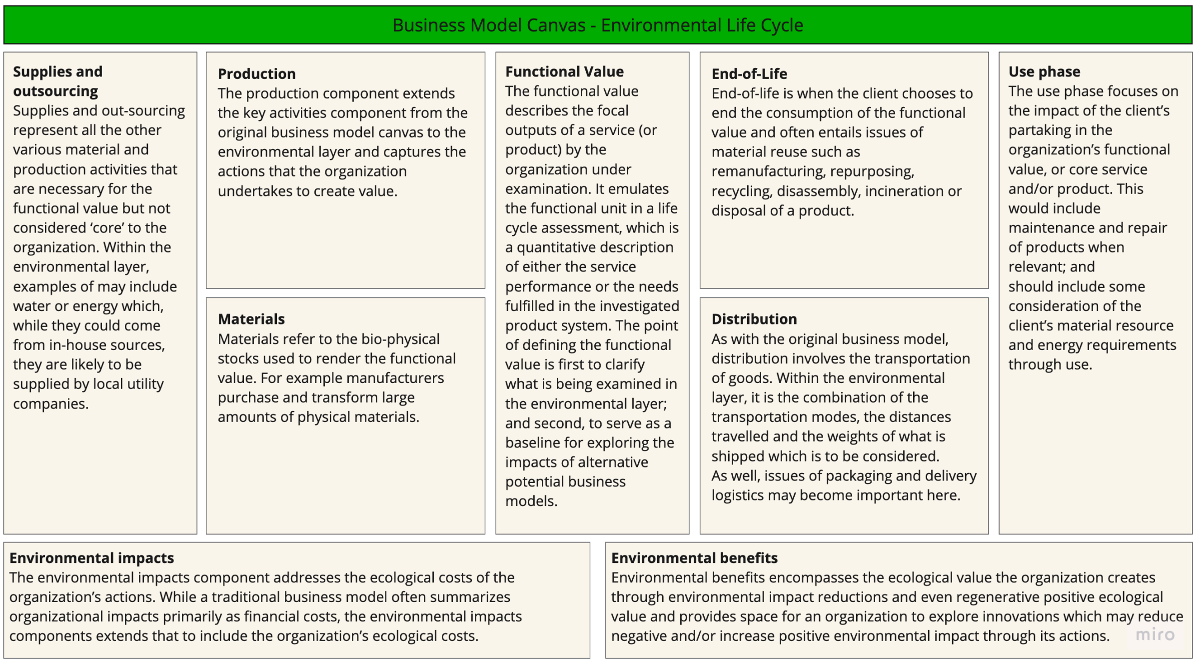

Figure 5: Environmental Life Cycle Business Model Canvas area definitions (Pigneur et al, 2015).

Stakeholder impact BMC

The social layer of the TLBMC builds on a stakeholder management approach to explore an organization's social impact. A stakeholder management approach seeks to balance the interests of an organization's stakeholders rather than simply seeking maximum gain for the organization itself. Stakeholders are considered those groups of individuals or organizations which can influence or is influenced by the actions of an organization. Like the environmental canvas layer, the social canvas layer extends the original business model canvas by filtering an organization's business model and impacts through a stakeholder perspective. A key point of using the social layer of the TLBMC is to extend the original business model canvas through a stakeholder approach to both capture the mutual influences between stakeholders and the organization. Also, this layer seeks to capture the key social impacts of the organization that derive from those relationships. Doing so provides a better understanding of where an organization's primary social impacts are and provides insight for exploring ways to innovate the organization's actions and business model to improve its social value creation potential (Pigneur et al, 2015).

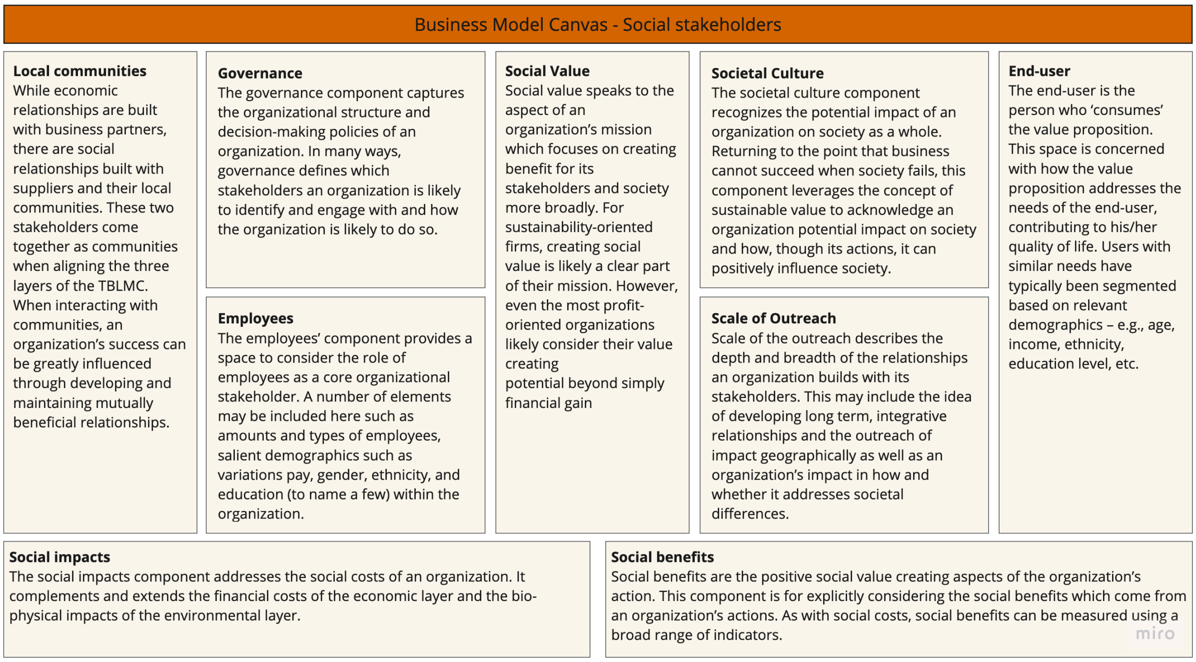

Figure 6: Social Stakeholder Business Model Canvas area definitions (Pigneur et al, 2015).

The Business Model Principles (BMP)

The third LINK methodology tool are the New Business Model Principles (NBMP), which help identify whether the business model generates benefits beyond profit in the context of smallholder inclusion and if so in which areas the benefits occur. Where the BMC is mainly a financial tool, the BMP focuses on promoting the sustained participation of smallholder farmers through a set of design and evaluation principles for business models. The focus lies on the inclusiveness of the business model and what options are available for better inclusion of the smallholder farmers. This is done to help identify possible areas of innovation and improvement in the selected business model and provides inputs for the design of an improved business model for the engagement of smallholder farmers. This is done by evaluating the current business model by the 6 principles of inclusive business models. The BMP is out of scope for this thesis, but the BMC is made as a jumping-off point for the BMP.

The Prototype Cycle (PC)

Finally, the Prototype Cycle (PC) is performed to provide a framework to move from the analysis of the current business model to a process of iterative design-testing-evaluation to improve specific areas of the business model. Innovation paths that proved to be successful are scaled up and redesigned where problems occur.

3. Methodology

The research question "How to create a viable business case using an inclusive business model for the production of maritime biofuels from olive residues in Jaén, Spain" will be answered by answering the sub-questions. The question of how to create an inclusive business model is answered using the LINK methodology designed by CIAT (International Center for Tropical Agriculture) (Lundy et al, 2014). The LINK method consists of four steps: the Value Chain Map (VCM), the Business Model Canvas (BMC), the New Business Model Principles (NBMP), and the Prototype Cycle (PC). The VCM has been performed in previous work by Lans (2023) to start on the development of an inclusive business model for bio-based value chains. This thesis will use the VCM and focus on the next step: developing a BMC for this inclusive business model and adding to the LINK methodology where necessary.

When developing a business case, a lot of options need to be taken into consideration such as transportation, biohub size, processing technologies and system boundaries. These options will be explored by considering how the value chain works and the views, barriers and concerns of the relevant stakeholders identified through previous work done by K. Lans (2022) and M. Arichi (2023). All information on the case study performed in Jaén has retrieved from this previous work, C. Heijdens thesis (2022), and PhD candidates S. van der Veen and S. Chandrasekaran, who conducted this research as part of the Clean Shipping project at the department of Biotechnology & Society at the TU Delft. This information was gathered partially during the field work in Spain in October 2021 and partially during a workshop in April 2022.

The question of what criteria should be considered when evaluating and choosing between various value chain scenarios is answered using the first tier of a two-tier evaluation. In the first tier three different value chain scenarios are evaluated. This is done using a Pugh matrix on the economic, social, environmental, and technical impact of the different scenarios quantified by KPI's set up and weighted in S. Dransfeld's thesis (2023).

KPI selection

The KPI's used are based on previous work done by Maitland (2023), who based the selection of technical and economic KPI's on Kibira (2018). Environmental KPI's were chosen by using an International Organization of Standardization (ISO) standard proposing classification based on Areas of Protection (AoPs) and subsequent impact categories that KPI's are assigned to (International Organization for Standardization (ISO), 2006). Social evaluation KPI's were chosen based on a methodology proposed by the United Nations Development Programme (UNDP) (Traverso et al., 2021).

Dransfeld (2023) refined these KPI's from design variables and design constraints, as these are not considered outputs of the processes and assigned weights to this KPI selection using an analytical hierarchy process (AHP) (Brunelli, 2015). This process is used to evaluate the relative importance of each KPI based on expert input and determining their priority in a sustainability assessment of the marine biofuel value chain. The expert input consisted of 4 context specific experts for the Spain case study and 4 non-context specific experts. The list of interviewed experts and their ranking of the different aspects of the value chain according to priority is showed in Appendix B. Table 1 in the Methodology chapter shows Dransfeld's original list of KPI's. Figure 7 shows the process of the first-tier evaluation, in which the three scenarios are compared based on the economic, environmental, social and technical KPI's formulated by Dransfeld (2023).

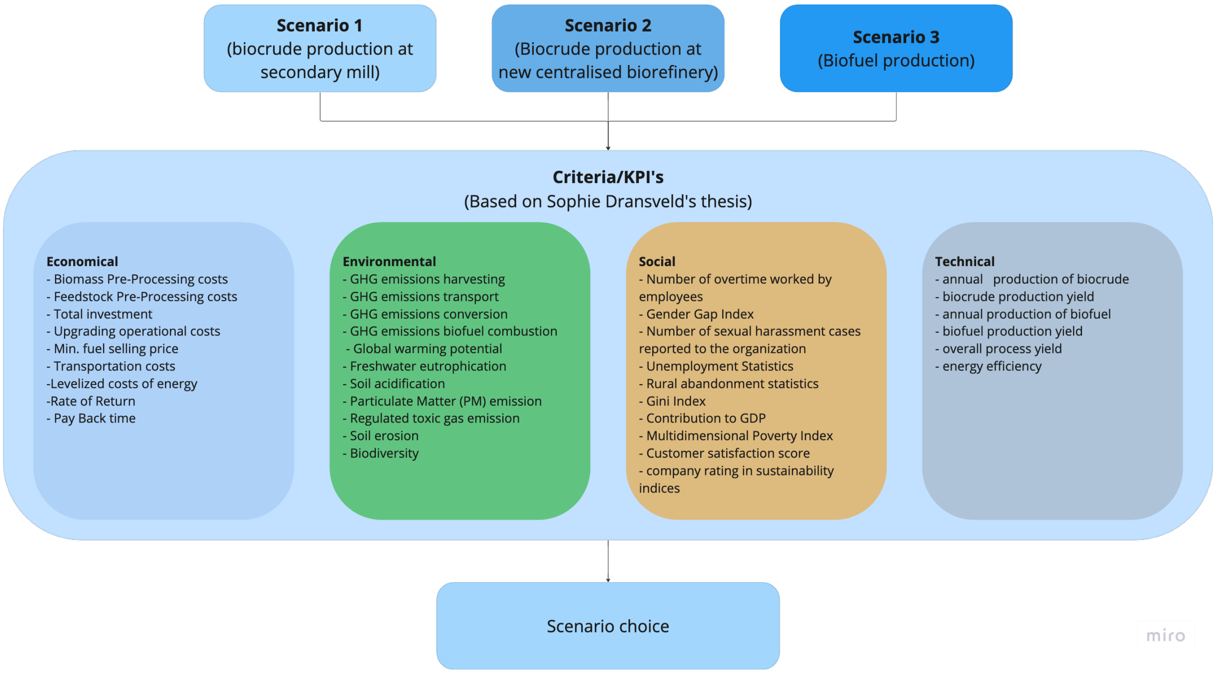

Figure 7: First-tier evaluation based on economic, environmental, social and technical KPI's set up by Dransfeld (2023).

However, using Dransfeld's KPI's resulted in social KPI's that did not differ between the scenarios compared in this thesis, as these social KPI's either could not be measured or were based on country-wide data. Therefore, Table 1 shows new social KPI's based on the original KPI's set up by Maitland (2023), which could be used to differentiate and choose between the different value chains.

Table 1: list of new social KPI's, based on Maitland (2023).

New social KPI's	Description
Cultural heritage	Respect of organization towards local cultural heritage and recognition that all community members have the right to pursue their cultural development.
Community engagement/inclusion smallholders	Assesses whether an organization includes community stakeholders in relevant decision-making processes. Also considers extent to which the organization engages with the community in general.
Local employment	Assesses the role of an organization in directly or indirectly affecting local employment
Wealth distribution	Assesses the extent to which the value is distributed in an equitable way to all actors of the value chain.
Supplier relationships	Organization should consider potential impacts or consequences of its procurement and purchasing decisions on other organizations and act to avoid or minimize negative impacts. Relationship between the suppliers (the farmers) and the rest of supply chain is crucial for efficient employment of the Biohub.
Unemployment statistics	Unemployed /labour force.
Rural abandonment statistics	The development of rural areas in Jaén. Population decline in %.
Contribution to GDP	Assesses to what extent the organization contributes to economic development of the society. Contribution to GDP in €.
Poverty alleviation	measuring the presence or not of proactive activities, such as strategies, action plans, investment, to reduce the poverty of the society.

In the second tier evaluation the economic, environmental, and social implications of value chain implementation decisions are evaluated. This is done by evaluating these choices on a quantifiable economic, social, and environmental factor and using threshold values to measure the positive or negative impact a choice has on these factors, as shown in Figure 8.

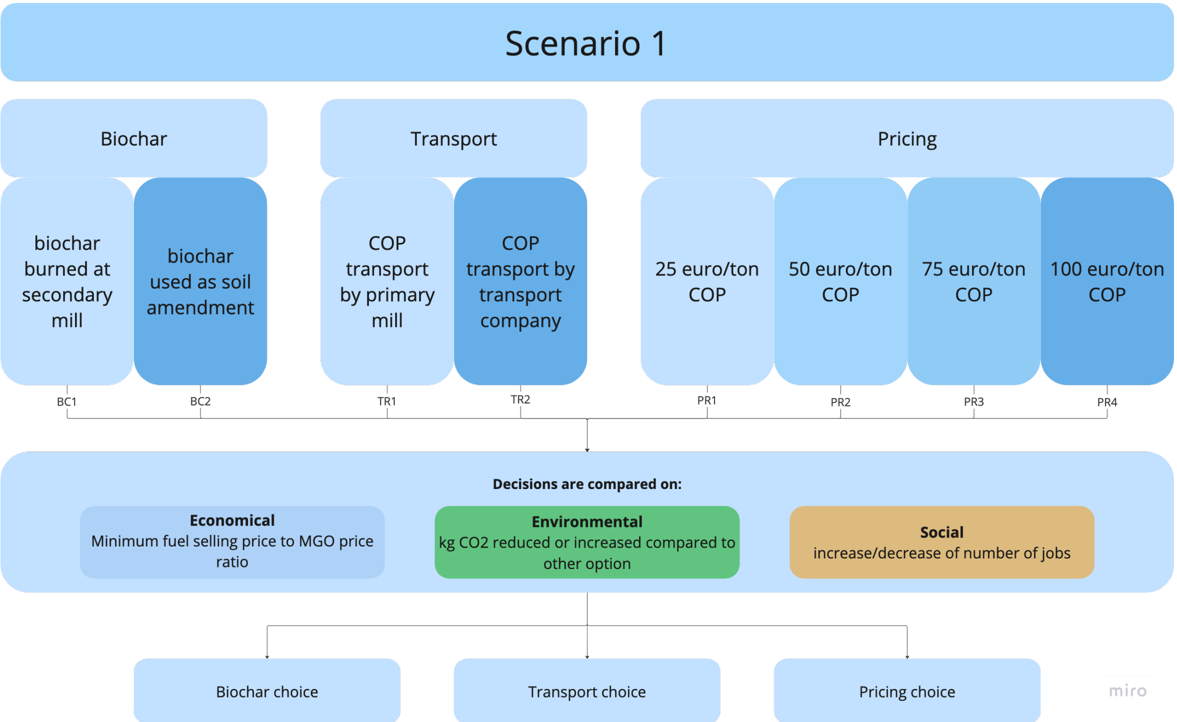

Figure 8: Second tier evaluation on biochar, transport and pricing decisions

This evaluation is used to choose the best performing value chain implementation decisions, which are subsequently used to perform the second step in the LINK methodology: creating a linked Business Model Canvas (BMC) for the chosen value chain, alongside an Environmental Life Cycle and Social Stakeholder BMC. The linked BMC is used to show how the key businesses in the value chain function and to identify areas for innovation and improvement. From there, design requirements for the project can be defined and the feasibility is evaluated. Lastly, additional recommendations, variations, opportunities, incentives, risks, and measures will be discussed so a viable business case can be created, to optimise the distribution of benefits, costs, and risks along the value chain.

4. Results

To create an inclusive business model, the first and second step of the LINK methodology are used. The first step is the Value Chain Map (VCM), which describes the value chain stakeholders and their context. The second step is to set up a linked Business Model Canvas based on a two-tier evaluation of the different scenarios and subsequent value chain implementation decisions.

Value Chain Map (VCM)

The VCM is the first tool of the LINK methodology and describes all value chain stakeholders and their context. the VCM is explained first using the local context and case study of the olive oil and biomass residue production in Jaén. The VCM performed by Lans (2022) on the case study in Spain of the Clean Shipping project, the case study through field work and a workshop by C. Heijdens (2022), and information provided by PhD candidates S. van der Veen and S. Chandrasekaran are used to set up a comprehensive VCM for the value chain.

The VCM tool aims to define relationships and interconnections, understand the flow of products, services, information, and payment, enhance communication between different actors and identify entry points or key leverage points to improve the value chain. The aim of the map itself is to visualize the value chain and the roles of all (in)direct stakeholders and external factors that influence the value chain. The location, stakeholders, products, technologies, transport and investments that all play a role in the value chain are explained in detail in this chapter. Figure 9 shows an overview of the value chain stakeholders and products.

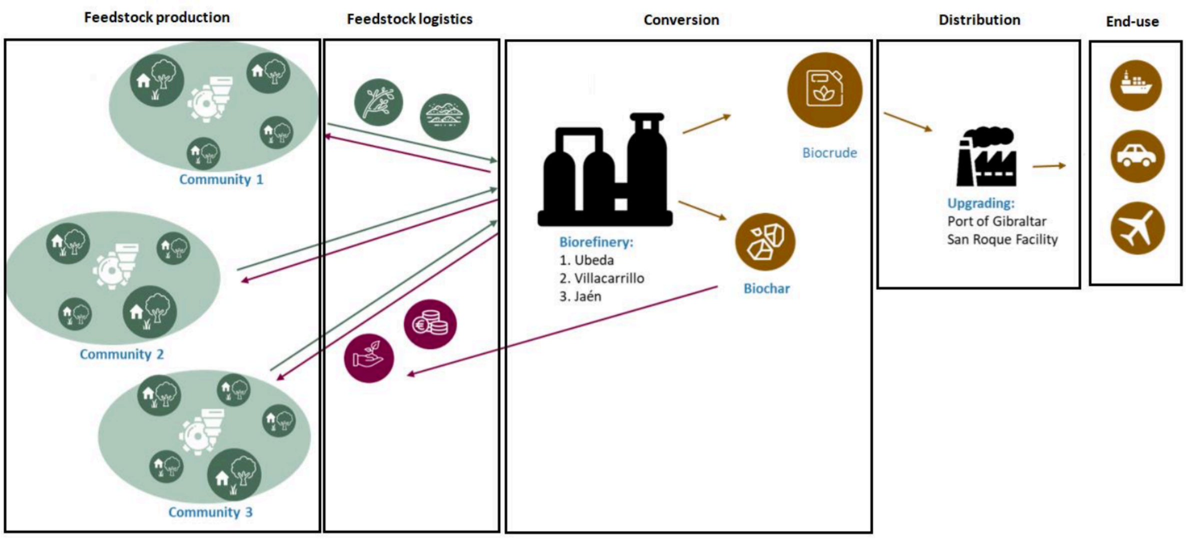

Figure 9: The five stages in the biohub design. Feedstock production at the olive groves and olive mills. Feedstock logistics. Conversion technology and location and scale of the biorefinery. Distribution and updrading of biocrude. End-ue of the biofuel.

In the value chain in Figure 9, farmers produce olives, which are converted into olive oil and the by-product COP by primary mills within their communities. This COP is then transported to either a biorefinery at a secondary industry mill as in the current value chain, or to a new centrally located biorefinery. There either biocrude or biofuel is produced and sold to the customer who upgrades this to biofuel or the biorefinery incorporates the upgrading and sells biofuel directly to the end-user. The biorefinery by-product biochar could be used as soil amendment by the farmers to combat olive grove soil erosion. Next, more detail will be given on the stakeholders, technologies and products.

Value chain location

Within the province of Andalusia, the region of Jaén has the highest production of olives in Spain, as seen in Figure 10.b. The geographical location of Jaén within Spain is shown in Figure 10.a. Therefore, this region has been chosen for the implementation of the new value chain, since it will have the greatest effect here. To this end, field work has been done in the form of partnerships with Jaén's university and interviews with farmers in the region. Therefore, the local culture and olive cultivation infrastructure and customs are known.

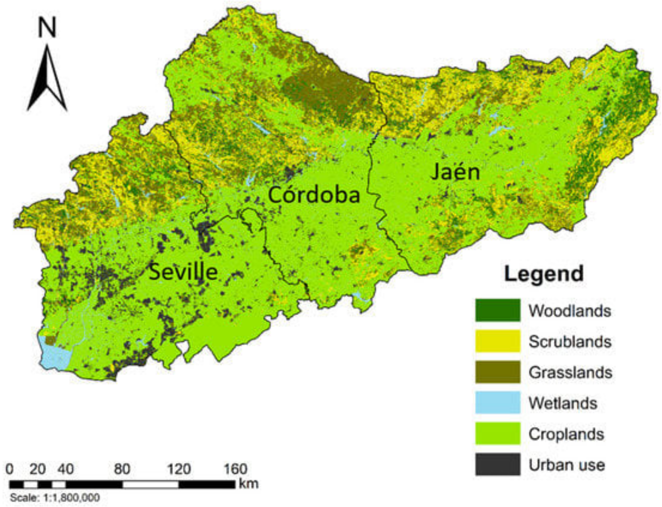

Figure 10: Figure 10.a shows the geographic location of the province of Jaén within the south of Spain and the location of the Strait of Gibraltar where the biofuel will be sold (Wikipedia, 2015). Figure 10.b shows the land use of the provinces of Seville, Córdoba and Jaén, in which it can be seen the province of Jaén has the largest amount of land used as croplands (Cardoza et al., 2021).

Farmers

The value chain starts at the farmers who produce the olives in the province of focus: Jaén. In the province of Jaén, 85% of all the agriculture is olive plantation, where out of the 600.000 inhabitants 200.000 farmers own these fields. In Jaén 90% of the workforce is directly or indirectly dependent on the olive oil industry (The Guardian, 2014). However, due to the environmental dependency of the olive cultivation this can in turn result in poverty in the region (Gratsea et al., 2022). The case study done by C. Heijdens (2022) found farmers to be only moderately interested in the biohub. While they would like to gain new income sources and cost reduction, the farmers were found to be hesitant and would like to see a proof of concept first. The farmers have little power in the current value chain, even though they own the primary feedstock for the current and new biofuel value chain. Most farmers in the province of Jaén are small scale farmers who own on average 3-4 Ha and mostly use traditional cultivation, unlike intensive and superintensive cultivation used in Cordoba and Granada (Heijdens, 2022). Almost all of the olive farmers produce olives for olive oil production, which is done in monocultures. This causes three environmental problems for the farmers: soil erosion, overexploitation of water resources and loss of biodiversity (Sánchez et al., 2008). In the case of olive orchards located in steeper areas, such as in Jaén, with soils of lower water-holding capacity (due to coarse texture and stone content), cumulative soil erosion has already had a high impact on reducing potential productivity of the olive groves (Gómez et al., 2014).

Almost all farmers use artificial fertilizer and pesticides in the region, while the use of irrigation is less widespread. In the province of Jaén 43% of the olive groves has irrigation (Molina- Moral et al, 2021). The farmers produce olives which need to be collected and cleaned. Farmers harvest their olive trees during two seasons - the early (October-November) and the late (November-February) harvest. Most farmers do this themselves with help of their family members and seasonal (migrant) workers. In Jaén most of the harvesting is done manually because of the lacking mechanization of the olive groves due to the mountainous areas, and a reluctance to change agricultural practices. After the harvest ends in February, the olive trees are pruned biannually, which generates branches and leaves and require incurring costs to be treated. This pruning is one of the residual biomass streams produced in the value chain. As of now the large pieces of wood are burned in the (mostly steep) fields or transported out of the olive groves and used for residential heating. The smaller branches and leaves are chipped and left in the fields as compost. Some farmers bring the large wood to the cooperative for a low price, which sells it for them.

Pruning

An additional source of biomass next to COP could be the pruning of the olive trees. This pruning is done biannually and consists of about 1 million tons per year. There are multiple benefits of using pruning in addition to COP to produce biocrude through HTL. Only using COP to create biocrude means that the olive harvest will dictate the amount of COP available and thus the amount of biocrude and biofuel that can be made. Pruning needs to be done regardless of the amount of olives produced, which makes it a stable biomass source and provides the wanted diversification of biomass sources wanted to ensure reliability of biofuel production (Ferrari, 2023). Furthermore, the pruning generated by the olive groves is being under-valorised. While some of the pruning is chipped collected by a transport company to be used in bioenergy producing companies or used as fertilizer, this is not the case for all of the pruning. Especially in steep olive groves the pruning is burned since it is too expensive or not possible to chip and transport the wood. This means 50% of the wood is assumed to be available, the other 50% is burned in the groves due to transportation difficulties in mountainous areas or due to self-consumption for heating (La Cal Herrera, 2020). Burning the pruning waste in the field is the cheapest option at 50€/ha, while chipping and using it as fertilizer costs around 75€/ha (La Cal Herrera, 2014). Lastly, selling the pruning to be converted into biocrude creates an additional income stream for the farmers. Especially when this is done on a contractual basis, the farmers could gain more income stability with this.

However, there are numerous disadvantages of using the olive tree pruning as an additional biocrude feedstock. The part of the available pruning biomass that is not being used in an effective way is not being sold on or used as fertiliser due to the cost of transporting or chopping it at steep olive groves, which will remain the case. As of now pruning is only transported to biomass electricity plants by biomass transporters, but these need to be within a 20km radius of the olive grove due to the transport costs of such a bulky product. Therefore, the profitability of using pruning depends heavily on the location of the HTL biorefinery. Before the pruning can be used in a biomass electricity plant or for HTL, it first needs to be cleaned of stones and dirt, which adds to the costs. Agricultural practices also play a role, since olive variety and weather conditions impact the composition of the pruning waste. Another problem is that the olive trees are pruned biannually after the harvest ends in February, which means in a short span of time a lot of biomass needs to be transported and subsequently stored before it can be converted into biocrude. A prerequisite for EU funding in form of the CAP (Common Agricultural Policy) grant is the removal of pruning waste before the 1st of May, which means all pruning needs to be removed in a matter of weeks (European Commission, 2022). Therefore, storage as well as transportation would prove difficult for such a low-density product for which no existing storage or transportation chains have been set up to any other facilities except very close-by biomass electricity plants.

Primary mill

The olives produced by the farmers are usually sold to primary olive mills. Of the 370 olive mills in Jaén, 70% of the olive oil produced is by cooperatives, while 30% is produced by olive mills that are privately owned (Heijdens, 2022; Parras, 2021). These mills are also called first-grade cooperative mills (Vicario-Mondroño et al, 2023). Most of the farmers are united in a cooperative, owning an olive mill together with many farmers to increase their bargaining power. The size of cooperatives ranges from a few members to thousands of members, and they produce and sell the olive oil in bulk for its members. The benefits are evenly shared according to the amount of olives produced by the farmer. Most cooperatives are led by members meetings in which every farmer, no matter how large its olive grove, has one vote (Parras, 2021). The cooperatives are often united in a cooperative of the second grade that commercialises the olive oil in bulk for the cooperatives (Heijdens, 2022). Further, most cooperatives give trainings to the farmers to improve their cultivation practices and have technical advisors available for consultation. Since the cooperatives represent hundreds to thousands of farmers, they have more bargaining power than individual farmers. The cooperatives are very interested in new income sources for their members by using both pruning waste and COP.

After collection the olives are crushed, and olive slurry is produced. Sometimes water is added to get the right moisture content. Olive stones are recovered from the slurry. These stones are often used in the mill for heating, residual stones are sold for residential heating or as solid biofuel for green energy generation. After letting the olive slurry rest for 24 hours, it is separated in a two-phase decanter, in which the by-product Crude Olive Pomace (COP), and a water and oil stream are generated. Only 20% of the olives are converted into virgin olive oil, 80% becomes the by-product COP. The olive oil is sold in bulk by the cooperatives and secondary cooperatives. This price is prone to fluctuate and depends on the highly variable volume of the olive harvest and global influences. Because Spain is the main olive-oil producer worldwide the weather conditions in Spain have a large influence on olive-oil prices. A dry year will result in lower olive oil availability and high prices, while a good year will result in high availability and lower prices. The olive price is relatively low for farmers in Jaén. First, because outside of the Jaén region, olive groves are more mechanised and produced in intensive olive groves with higher output. Second, the olive oil is sold in bulk to intermediates, instead of in bottles directly to wholesalers. The other output of the primary mills is the by-product COP, which the secondary industry treats for the cooperatives. Since these are large scale facilities there are not many secondary mills compared to primary mills. As the main cost of treating the olive pomace consists of transport, the primary mills do not have much choice between secondary mills. The primary mills pay for COP transport and give the COP itself away for free or even pay up to 8 €/ton to the secondary mills, since the COP cannot be disposed of and needs to be treated. This gives the secondary industry high power over the primary mills.

Transport

Both the biomass (olives and COP) and the biocrude need to be transported to the next party in the value chain. For this, trucks are deemed to be the most suitable option when travelling relatively small distances. The transport costs increase with longer distances (Zafar, 2021). Not only is it more economic than water, air or train transport, but it also builds on the existing transport infrastructure used by the value chain now.

As of now, the olives are transported by the farmers to the primary mills, the primary mills produce the by-product COP and transport it to the secondary mills for free, or even for a small fee. In the new value chain, either the secondary mills or a new centralized HTL biorefinery produce biocrude made from COP. This biocrude needs to be transported as well to the existing San Roque refinery (Cepsa, 2017). Transportation wise there are a multitude of options. A transportation company could be used to facility all transportation of the products in the value chain, or the intermediaries could facilitate the transportation themselves, as is being done now.

HTL technology

Hydrothermal liquefaction (HTL) is a technology that transforms an organic liquid into a solid fuel in an aqueous environment. In an HTL refinery wet feedstock is liquefied for 20 to 60 minutes in a hot (250–550 °C) and pressurized (5–25 MPa) water environment into biocrude oil. The oxygen in the biomass is removed through dehydration or decarboxylation (IEA Bioenergy, 2017). Biochar, off-gas and wastewater are by-products of the process. HTL is being commercialized by a series of stakeholders, with the prominent players being Canadian/Danish Steeper Energy, Australia-based Licella Southern Oil Refining Pty Ltd, ENI from Italy, and U.S. company Genifuel, with the latter among others through India-based Reliance. No large-scale or commercial production of HTL biocrude yet exists. The largest HTL plant existing is the Silva Green Fuel demo plant located in Tofte, Norway, with a production capacity of 4000 L/day (Lindfors et al, 2022). This means large investments need to be made to be able to build a new HTL biorefinery, while there are little proof of concept plants, except for several continuous pilot setups.

In this case study HTL is the conversion technology of choice because this is a fast-developing technology that can produce biofuels from a wet feedstock. HTL is a suitable to produce biocrude out of COP, since it uses water as a reaction medium and catalyst and COP has a high water content (Marulanda et al., 2019) (De Filippis, 2016). This avoids the high energy requirements needed for a drying process when using the more established pyrolysis for the production of biocrude. However, the minimum viable selling price of biofuel is still much higher for HTL compared to other thermochemical conversion routes such as pyrolysis (Fang, Li, & You, 2022). A further concern about HTL is its lower technology readiness level compared to pyrolysis, this makes the investments that cooperatives need to do more uncertain. Additionally, building an HTL plant is expensive, requiring high investments.

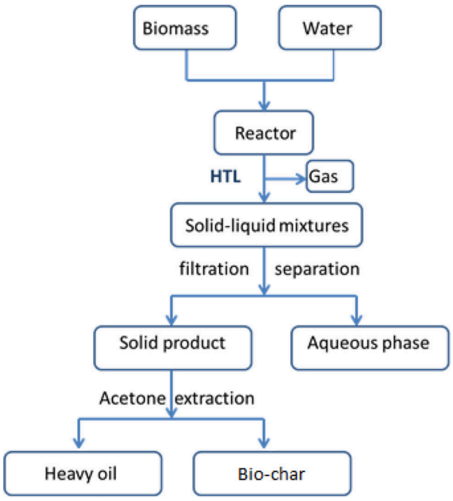

Figure 11: procedures for separation and extraction of HTL products (De Filippis et al., 2016).

The biocrude that is produced during HTL is a crude-like bio-oil which is too impure to be used as fuel, which is why it needs to be treated at an upgrading facility to produce a drop-in MGO or MDO (ICCT, 2020; IEA Bioenergy, 2017; Ramirez, et al., 2015). It has a high hydrogen-to carbon ratio and a high energy density (higher than pyrolysis oil). The oxygen content is 5-20 wt% (IEA Bioenergy, 2017).

Biochar

During the production of biocrude through HTL the by-product biochar is produced, alongside an aqueous stream, which can be mostly recycled and an off-gas stream, which is burned in the HTL heater. Biochar is a charcoal and can be burned in the biorefinery to generate the needed heat for the HTL process or it can be used as a soil amendment to the olive groves to reduce the presence of heavy metals in the soil. Further, it can improve water retention in sandy soil (Brassard et al., 2019). Since olive groves are arid and prone to soil degradation, water shortage and loss of biodiversity, using biochar as soil amendment could help resolve these issues (Sánchez et al., 2008) (Aguilera et al., 2015).

However, not only biochar is a suitable method to prevent soil degradation and improve water retention, life or inert cover crops could be used as well. The method of chipping the biomass and leaving it on the field as inert cover crop is now the most widely spread method of pruning waste handling. Spontaneous cover crops such as natural grass, or dedicated cover crops such as herbs or oats can be used as life cover crops. Regarding the use of live cover crops farmers are hesitant because they fear competition for nutrients and water of the cover crops with the olive trees (Gómez et al., 2014). The use of spontaneous crops instead of tillage can result in improved soil structure and water retention in a semi-arid olive grove such as the olive groves in Jaén (Palese et al., 2014). Still, the main additional benefit of life cover crops compared to use inert cover crops the increased biodiversity in the olive grove, which provides a habitat for biological pest control (Gómez et al., 2018).

Since biochar is not necessarily the best or only cover crop option, it could be valorised in an alternative way, such as burning it for energy generation. This can be done either at the HTL biorefinery itself, preventing the need for transportation. When biochar is valorised as soil amendment, it is sold by the biorefinery. This biochar price could be lowered through carbon credits. Carbon credits, or carbon offsets, are permits that allow companies to emit one ton of CO_2 or other GHG per carbon credit. Polluting companies are given credits that allow them to continue to pollute up to a certain limit, which is reduced periodically. Unneeded credits are sold to other companies that need them, doubly incentivizing private companies to reduce GHG emissions. First, they must spend money on extra credits if their emissions exceed the cap. Second, they can make money by reducing their emissions and selling their excess allowances. Proponents of the carbon credit system say that it leads to measurable, verifiable emission reductions from certified climate action projects, and that these projects reduce, remove, or avoid greenhouse gas (GHG) emissions (Kenton, 2023). However, the Guardian and the non-profit transnational corporate watchdog Corporate Accountability found most of these emission offset projects exaggerate climate benefits and underestimate potential harms. Additionally, opponents of carbon credits say it is not a reliable way to support climate mitigation, as it does not result in a focus on direct emission reductions (Jackson & Tofighi-Niaki, 2023).

A proof of concept is the news agency Reuters reporting on providing biochar to farmers to use as soil amendment in Cambodia. This is a carbon credit project in which organic fertilisers are sold to farmers at a competitive price of $400 to $500 a tonne via a network of agricultural cooperatives and input distributors across the country. The company HUSK is also piloting a “super farmers network” for women, who earn extra income by selling the products door to door and earning a commission. In trials carried out over the last three years, farmers are seeing a positive return on investment of between 15% and 25% from a combination of higher yields and a reduction in the need for fertiliser, the price of which has doubled since 2020. By selling carbon credits for as much as $200 a tonne, HUSK is able to keep prices of the organic fertiliser low. This is important, as the end consumers, farmers, are very price sensitive and are not able to pay much for fertilisers (Luckhurst, 2022). While there are financial and ecological benefits to using carbon credits to fund the sale of affordable biochar back to the farmers, the potential harms must not be underestimated. Not only is transporting biochar a long way expensive, but it also causes GHG emissions by the trucks. It should be considered whether the positive impact of using biochar as an organic fertiliser is offset by its transport.

Secondary mills (Orujeras) HTL biorefinery

There are 12 secondary mills in the province of Jaén (Cardoza et al., 2021). The secondary industry treats the crude olive pomace for the cooperatives. The primary mills transport the by-product COP to the secondary mills. The high phytotoxic load of COP can have disastrous effects on aqueous life when the olive pomace leaks to surface waters. Therefore, olive pomace is a by-product that needs to be processed to avoid environmental damage, this is done at a secondary olive mill (Heijdens, 2022). The secondary mills take the COP and extract the residual Pomace Olive Oil (POO) as main product and produce olive stones and Exhausted Olive Pomace (EOP) as by-products. Since they receive the COP for free but can sell the olive pomace oil for a relatively high price compared to their costs, this is a profitable business. Since these are large scale facilities there are not many secondary mills compared to primary mills. Because the main cost of treating the olive pomace is transport, the primary mills do not have much choice between secondary mills. This gives the secondary industry high power over the primary mills. Because the biohub can give the cooperatives an alternative to valorise their olive pomace, the secondary mills are very interested in the biohub. They see it both as a threat to their business as well as a business opportunity because they have the infrastructure to collect olive pomace for the biohub.

The investments needed to convert the existing purpose of the secondary mills of producing POO and EOP to producing biocrude with HTL could come primarily from the profitable secondary mills themselves to keep all profits made by selling the new product. However, as the secondary mills are currently very profitable already, they would have little incentive to invest in producing a different product. Therefore, a pilot facility needs to be set up, to show profitability. The biohub and cooperatives should be instrumental in this, as they have the most to gain. Additionally, government and EU funding is needed to implement this environmentally and socially sustainable technology.

Central HTL biorefinery

When the decision is made to build a new centralised HTL biorefinery instead of implementing HTL technology in the secondary mills in Jaén, a location of this new centralised facility needs to be found. Cardoza et al., (2021) proposed three regions in the South of Spain to locate a biorefinery due to high olive biomass residues availability. Two of those regions are in the province of Jaén, as is shown in Figure 12. These locations were chosen based on the biomass potential, environmental fragility of the territory. Olive biomass availability for the biorefineries was calculated for a maximum radius of 30 km around the olive biorefineries to keep down transport costs. However, Cardoza et al chose Exhausted Olive Pomace (EOP) instead of Crude Olive Pomace (COP) to be valorised. Since EOP is dried COP, only 0.9 tons of EOP per hectare are produced, compared to 3.86 tons COP per hectare. As EOP is made from COP by the secondary industry, the map in Figure 12 and Table 2 are still correct, the only difference is the increased volume of COP available. Using these requirements, Cardoza et al., selected three sites with high availability of biomass resources in low fragility areas. The three locations chosen included several small and medium-sized olive mills and at least one medium or large extracting industry. This fact is related to the possibility of locating the biorefinery as a process integrated with the extracting industries also called secondary mills, which are facilities with greater technological developments than olive mills (Cardoza et al., 2021).

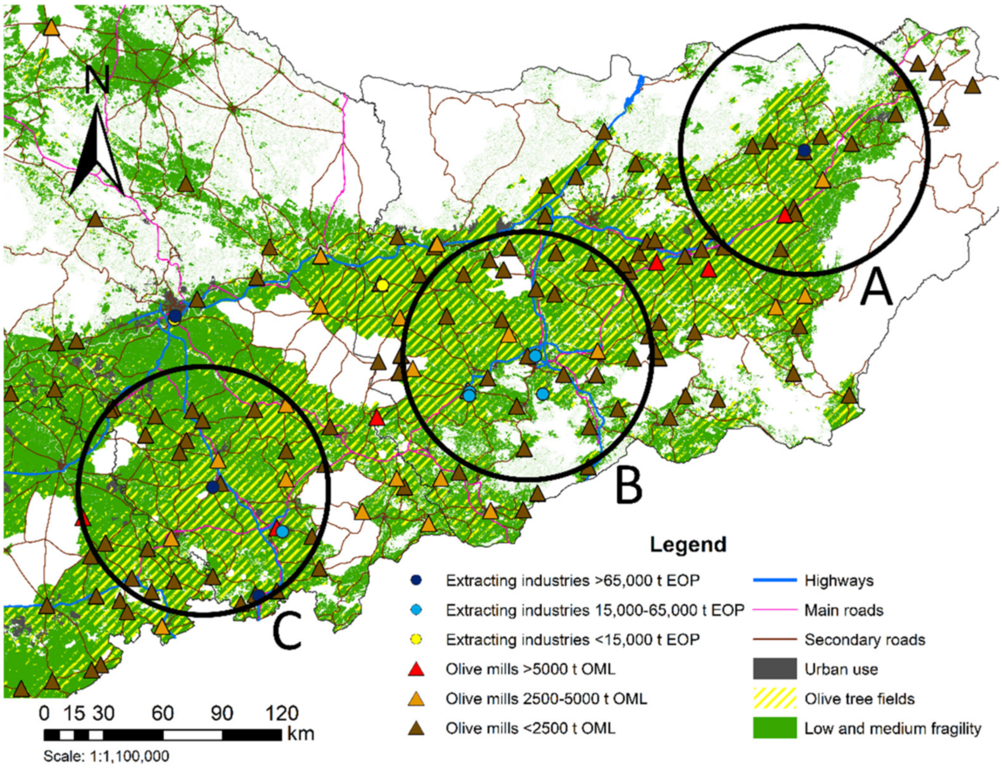

Figure 12: Selected locations for the implementation of olive biorefineries. (Cardoza, 2021).

Table 2: Olive biomass availability for the biorefineries in the selected areas (Cardoza, 2021).

		Biomass Amount (t)	
Option A		**Option B**	**Option C**
Crop Fields			
Olive tree Pruning Biomass			
Non-irrigation and slope > 10%	64,912	100,679	75,956
Non-irrigation and slope < 10%	43,526	69,553	109,101
Irrigation and slope > 10%	8842	22,445	11,887
Irrigation and slope < 10%	8912	25,275	29,824
Olive mills			
Leaves	22,339	32,232	49,927
Olive stones	33,898	48,910	75,762
Extracting industries			
Exhausted olive pomace	124,333	186,057	174,373
Total	**306,763**	**485,151**	**526,830**

The location of the biorefinery needs to be close to the feedstock to keep down transport costs. Transport to the upgrading facility depends on whether the upgrading is done by the HTL biorefinery itself or the existing upgrading facility San Roque in the port of Gibraltar is used. When the San Roque upgrading facility is used, it may be more profitable to choose a location for the biorefinery closer to the port of Gibraltar, which is location C. Another factor to consider is which feedstocks are used in the process. Cardoza et al., used EOP in table 1, which is made from COP. Thus, option B would have the most COP available in the surrounding area. Further, location B is in the geographical centre of Jaén, near the city of Úbeda. Since this location should be in central Jaén, close to the olive groves and thus primary mills and to the highway for transport by truck, the municipality of Úbeda was chosen. The city of Úbeda is near the geographic centre of the province of Jaén and is one of the region's most important settlements, an economic hub and one of the biggest olive oil producers and packers of the Jaén province.

An important design requirement for the biohub is to avoid the spillage of olive pomace to surface waters, the design of the plant should be such to avoid this. Currently the secondary industry uses big ponds to store the olive pomace, this is a safe method to store the olive pomace which could also be used for the biohub plant. However, due to the open pond storage, not only is water able to evaporate, but the COP also gives off an unpleasant smell for those living around the secondary mills. HTL is also referred to as hydrous pyrolysis, due to the fact that water is a crucial reactant in the process. Therefore, the moisture content of the substrate is of importance. Closing off the COP ponds to avoid evaporation will ensure a high water content and reduce the smell. When a centralised HTL biorefinery is chosen for the new value chain, it is likely that those still operating in the secondary industry will continue to store their COP in the same manner, which will mean large investments are needed to create sufficient storage.

A new HTL biorefinery has a high CAPEX (Capital Expenditures) and a low TRL (Technology Readiness Level) of level 4 out of 9 (Annevelink et al., 2022). This means HTL technology is currently mostly being studied at lab scale with batch setups (Platt et al., 2021). Therefore, large investments are needed for a technology that is relatively new and untested. Because of this, it is common to first set up a pilot plant, which is used to show the profitability and reliability of the project. Generally, grants, subsidies or funding programs from the government or the EU are needed to set up such an environmentally and socially sustainable pilot plant. Further, venture capital and private equity firms that specialize in clean energy, bioenergy or sustainable technologies may be interested. They often seek high-risk, high-reward opportunities and may provide the necessary funding for projects with innovative potential. Companies operating in the energy, biofuel, or agricultural sectors may be interested in forming strategic partnerships. They could provide funding, technical expertise, or access to distribution channels, leveraging their industry knowledge to accelerate the project's development. Multilateral development banks, such as the World Bank or regional development banks, may have an interest in supporting projects that align with their sustainable development goals. Thus, during the pilot phase of this project a mix of private venture capital and private equity firms and EU funding invest in a pilot-scale biorefinery, helping to demonstrate the technology's feasibility. Next, energy (consuming) companies will be very interested in ensuring a steady supply of biofuel and will want to invest in a tried and tested technology. Environmental impact investors and multilateral development banks contribute additional funding to support sustainability goals. This phase will rely on private companies and investors to build the biorefinery.

Upgrading technology

Oxygen removal from HTL biocrude is needed to obtain a product with similar properties compared to fossil fuels. Typically, the removal of oxygen takes place through three types of reactions: decarboxylation (oxygen removal as CO_2), decarbonylation (oxygen removal as CO), and hydrodeoxygenation (HDO, oxygen removal as H_2O). In this process oxygen removal as water is chosen, because the removal of oxygen as CO and CO_2 occurs at the expense of a lowered carbon yield and is therefore unattractive (Lindfors et al, 2022).

Equation 1: upgrading reactions to remove oxygen, sulphur and nitrogen impurities.

$$O + H_2 \rightarrow H_2O$$
$$S + H_2 \rightarrow H_2S$$
$$N + H_2 \rightarrow NH_3$$

As shown in the reaction formulas, hydrogen is needed to remove the oxygen and SO_X and NO_X impurities. However, hydrogen is expensive and energy intensive to create. This can be solved by using green hydrogen in this process. The biggest difference between biofuels and petroleum feedstocks is oxygen content. Biofuels have oxygen levels from 10% to 45% while petroleum has essentially none, making the chemical properties of biofuels very different from petroleum. All biofuels have very low sulphur levels, and many have low nitrogen levels. When performing hydrotreatment to the biocrude - so reacting it with hydrogen at high temperature and pressure in the presence of a catalyst (Castello et al., 2019) - it is upgraded to reach the minimum required quality to be used as a biofuel. The aim is upgrading to the minimum required quality, seeing this results in the lowest costs, minimal hydrogen needed and lowest GHG emission.

New upgrading facility

Next, the biocrude needs to be upgraded to make it suitable to be used as marine biofuel. This can either be done by transporting the biocrude produced by either a new centralised HTL biorefinery or by a secondary mill HTL biorefinery to the existing refinery of San Roque in the port of Gibraltar, or in the case of a new centralised HTL biorefinery by performing the upgrading step by itself.

When a new centralised HTL biorefinery is already being built, it may be profitable to not only produce the biocrude, but to upgrade this product directly into biofuel by incorporating the upgrading process within the HTL biorefinery. This has the benefit of ensuring profits and less dependability on another refinery buying the biocrude. However, the incorporation of the refinery process in the new HLT biorefinery also raises the question of how to divide the benefits when this facility decides to make the biocrude into a different product, such as sustainable aviation fuels (SAF), which can be sold for a much higher price, while buying in biocrude for the same price. When the biocrude is upgraded, the extent of removing the impurities determines the suitability of the produced biofuel for different sectors, such as usage in the shipping sector or as Sustainable Aviation Fuel (SAF) (Ramirez et al., 2015). This would mean less benefits are given back to those earlier in the value chain, which is not inclusive. The goal of the Clean Shipping project was to produce biofuel for shipping, so a downside of this choice is that the biorefinery including the upgrading facility may choose to upgrade the biocrude to another product. In the final step of this value chain, the biofuel is sold to bunkering companies at the port of Gibraltar which then fuel shipping vessels, in the case the biocrude is not upgraded into another biofuel.

San Roque refinery

Another option is to use the already existing upgrading facilities at the San Roque refinery to produce biofuel. The relatively dense biocrude is then transported to the San Roque refinery located on the north shore of the Bay of Gibraltar. The benefit of this choice is that the produced biodiesel will be used in the shipping sector, which is the goal of the Clean Shipping project. A downside is that a high biocrude price is not guaranteed since biofuel for shipping cannot be sold for a high price due to the extremely low prices of fossil shipping fuels.

End-users

After the biocrude is upgraded to biofuel, either at a new upgrading facility in central Jaén or at the existing upgrading facility San Roque at the port of Gibraltar, the biofuel is sold to bunker companies operating at the port of Gibraltar. Bunkering is the supplying of fuel for use by ships, and such fuel is referred to bunker (Boutsikas, 2004). Bunkering operations take place at seaports and include the storage and provision of the bunker (ship fuels) to vessels. Gibraltar is one of the largest and busiest bunkering ports in the Mediterranean and captures demand from some of the more than 60,000 vessels transiting through the Gibraltar Strait each year. There are five physical bunker suppliers in Gibraltar that offer low, very low and high sulphur fuel oil. Biofuel bunker blends are already available with several suppliers in Gibraltar Strait ports and supply is backed by nearby production at Spanish biofuel plants. Bulk carriers, crude tankers, oil products and chemical tankers are Gibraltar's most regular visitors (Integr8 Fuels, n.d.). Already bunkering specialist Peninsula started supplying 100% marine biofuel, opposed to blends in Gibraltar and nearby ports in 2021 (Ajdin, 2023).

Value Chain Map

Figure 13 shows the VCM created by Lans (2022) with a focus on the specific and general indirect stakeholders present in the value chain. Lans' previous work did not yet go into detail on the value chain and visualises the main stakeholders impacted by the value chain and external factors that impact the value chain. This VCM and the previous value chain information is used in a two-tier evaluation in which value chain scenarios and implementation decisions were compared, before implementation in BMC's.

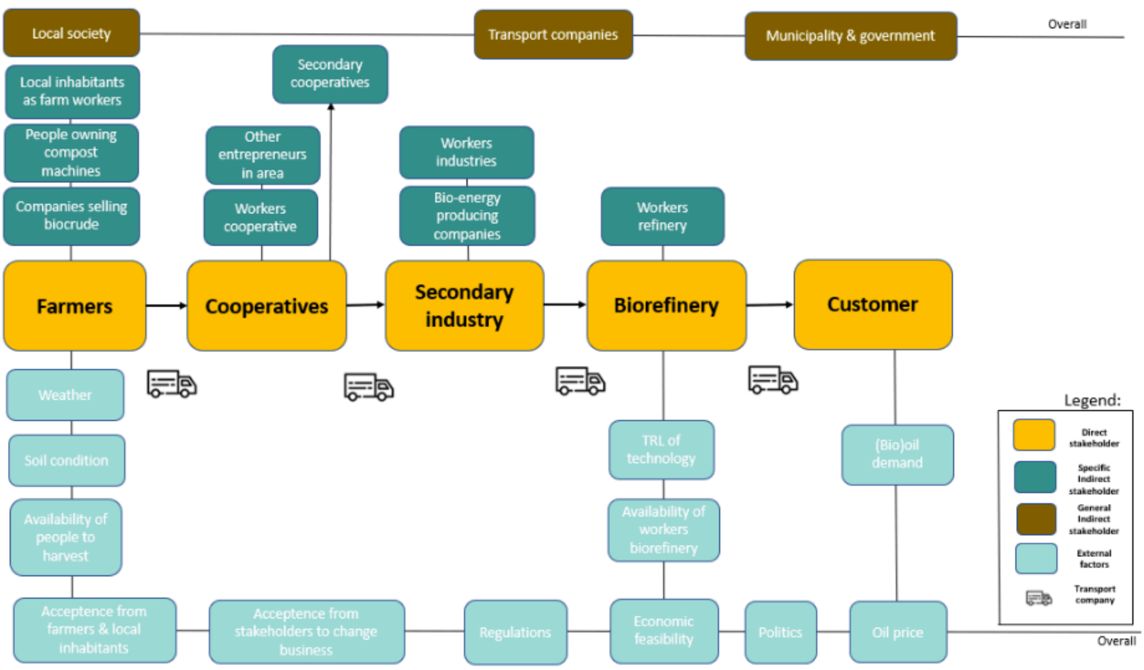

Figure 13: Value Chain Map of the case study in Andalusia, Spain. Yellow depicts the direct stakeholders. Dark blue depicts the specific indirect stakeholders. Brown depicts the general indirect stakeholders. Light blue depicts the external factors (Lans, 2022).

5. Two-tier evaluation

The question on how to create a viable and successful business case for the stakeholders needs to be evaluated. As there are multiple options on how to shape the value chain, these options and their effects need to be considered. A two-tier evaluation is used. In the first tier the three different scenarios of how to set up the value chain are first expanded on, consolidated, and subsequently compared between each other. This is done using a Pugh matrix on the economic, social, environmental, and technical impact of the different scenarios quantified by KPI's (Key Performance Indicators) set up and weighted by Dransfeld (2023). In the second tier implementation choices of the value chain within one such scenario are expanded on, consolidated and evaluated. This is done by evaluating these choices on a measurable economic, social and environmental factor to measure their positive or negative impact. Threshold values are used to ensure options that are not viable or have a profound negative impact on one of the factors are omitted. The three scenarios vary in terms of the locations for biocrude and biofuel production. This part explores the advantages and drawbacks of the following three value chain scenarios. Base scenarios are used, in which the three scenarios are simplified to be able to choose between them.

Value chain scenarios

There are three options on how to structure the biofuel producing value chain from olive residues in Andalusia. In all three value chain scenarios, Crude Olive Pomace (COP) is produced by primary mills, which is used to produce biocrude by HTL. The biocrude is subsequently upgraded to biofuel that is sold to bunkering companies in the Port of Gibraltar. Figures 14, 15 and 16 show the different value chain options to valorise COP into biofuel. Three different routes can be taken. Scenario 1) biocrude is made from COP through HTL by existing secondary mills, after which the San Roque biofuel refinery upgrades the biocrude to biofuel. Scenario 2) a centralised HTL biorefinery is built which produces biocrude. This biocrude is then valorised into biofuel by the San Roque upgrading facility. Scenario 3) the centralised HTL biorefinery produces biocrude and upgrades it into biofuel itself. All Scenarios end in selling the biofuel to bunkering companies in the Port of Gibraltar.

Scenario 1 - Base

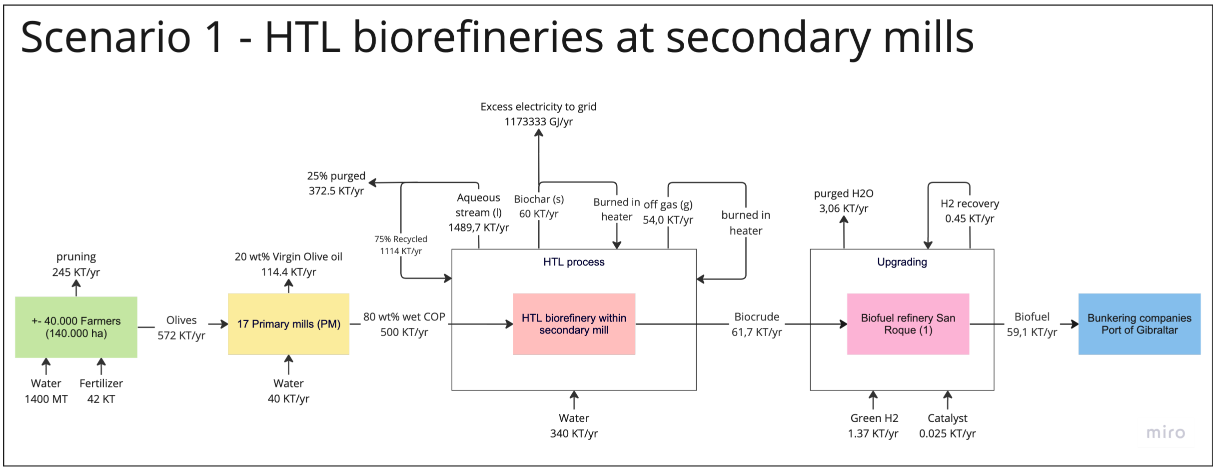

Figure 14: Value chain scenarios for producing biofuel out of COP. Figure 11 shows the block scheme of scenario 1 in which COP is valorised into biocrude through HTL in a secondary mill and upgraded to biofuel in the San Roque upgrading facility.

Figure 14 shows the block scheme of scenario 1, in which the production of biocrude by HTL is done at the largest secondary mill in Jaén, called San Miguel Arcángel in Villanueva del Arzobispo. This secondary mill alone produces 24% of the total market share of COP. This village is close to Ubéda, which is the geographical centre of Jaén. This facility has been chosen, since it can be assumed if the implementation of a new technology does not generate profit at the largest facility, this new value chain will not generate a profit anywhere else either. The San Miguel Arcángel secondary mill has the capacity to handle 500.000 tons of COP per year. Biocrude is then upgraded by the existing upgrading facility in San Roque. This upgrading facility upgrades biocrude with H_2 to 59,1 KT biofuel per year. The maritime biofuel is sold to bunkering companies in the port of Gibraltar, responsible for supplying the end-user ships with maritime (bio)fuel).

This figure shows the scenario in which the HTL by-product biochar is burned to generate the heat needed for the HTL process. Excess electricity is produced, which is sold to the grid. Transport is kept the same as the current value chain as much as possible. This means the primary mills stay responsible for transporting COP in their own trucks to the HTL biorefinery secondary mills. Further, a COP price of 25 €/ton is used in this base scenario. Currently, COP is supplied for 0-8 €/ton by the primary mills. The amount of feedstock and generated by-products for the production of COP were calculated based on the maximum capacity of the secondary mill to produce biocrude out of COP. These amounts are needed to analyse the impact of this scenario on economic, environmental, social and technical aspects. Since transport is the main cost of COP, primary mills within a 30km boundary will supply COP to the secondary mill (Cardoza, 2021).

Based on a list of all 87 primary mills in Jaén, their locations and COP production capacities it was found the 17 primary mills that are the most close-by would be needed to supply the secondary mill with enough COP. However, 8 of these primary mills are further away than 30km by road. The distances between these secondary mills and the secondary mill range from 35 to 40 km by road. Based on the amount of olives needed for these primary mills to produce COP, it was calculated 140.000 hectares are needed with an average olive production rate of 4086 kg/ha (Fernández-Lobato et al., 2021). Since on average olive farmers own 3.5 ha of olive groves, this new value chain would impact 40.000 olive farmers, out of a total of 200.000 farmers in Jaén, delivering olives to the 17 primary mills.

Scenario 2 – Base

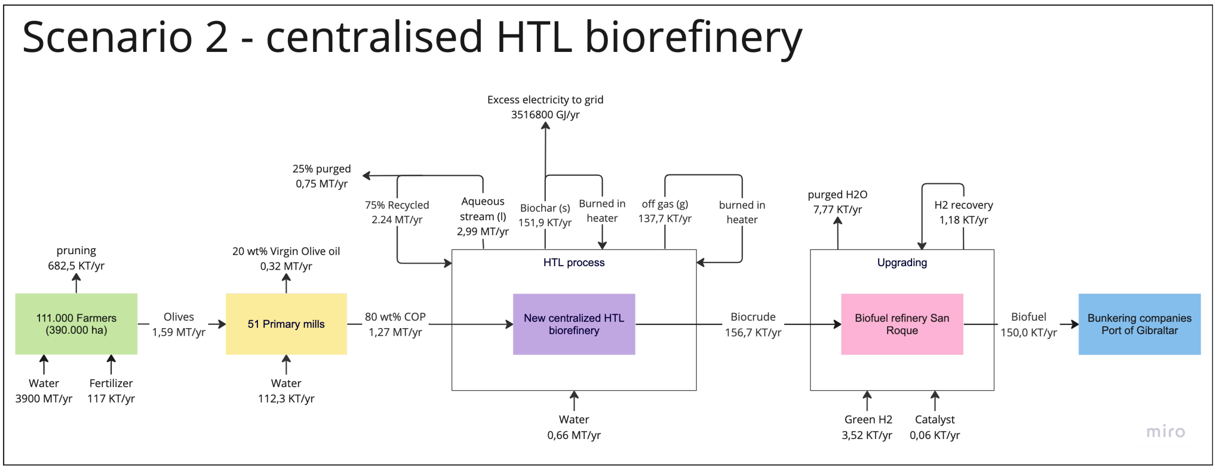

Figure 15: Value chain scenarios for producing biofuel out of COP. Figure 12 shows the block scheme of scenario 2, in which COP is valorised into biocrude in a new centralised HTL biorefinery and upgraded to biofuel in the San Roque upgrading facility.

Figure 15 shows the block scheme of scenario 2 in which biocrude is produced by a new centralised HTL biorefinery located in Úbeda, which is the geographical centre of Jaén. Biocrude is then upgraded by the existing upgrading facility in San Roque. This upgrading facility upgrades biocrude with H_2 to 150 KT biofuel per year. The maritime biofuel is sold to bunkering companies in the port of Gibraltar, responsible for supplying the end-user ships with maritime (bio)fuel). In this base scenario it is assumed the by-product biochar is burned to generate the heat needed for the HTL process. The excess electricity is sold back to the grid. Transport is kept the same as much as much as possible compared to the current value chain, which means the primary mills themselves are responsible for transporting COP to the new HTL biorefinery in Úbeda. Further, a COP price of 25 €/ton is used in this base scenario. Currently, COP is supplied for 0-8 €/ton by the primary mills.

Using an output of 156,7 KT/yr of biocrude, the feedstock needed and (by-)products generated were calculated. The impact of the new centralised HTL biorefinery was calculated based on its expected output of 156,7 KT biocrude/yr. This means 1,27 MT COP is needed per year, out of the total available amount of COP in Jaén of 2,05 MT/yr. It was found that based on their production capacity and location, 51 primary mills out of the total of 87 in Jaén are needed to supply the new centralised facility with sufficient COP. In total, these primary mills need 1,59 MT olives per year to produce at full capacity, which are grown on 390.000 ha with an average olive production rate of 4086 kg/ha (Fernández-Lobato et al., 2021). Since on average olive farmers own 3.5 ha of olive groves, this new value chain would impact 111.000 olive farmers, out of a total of 200.000 farmers in Jaén.

Scenario 3 – Base

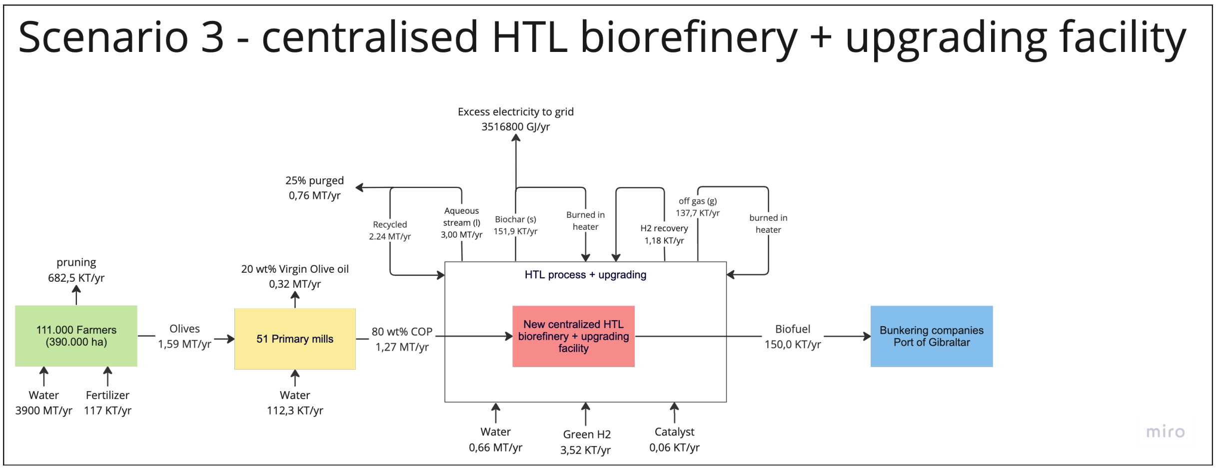

Figure 16: Value chain scenarios for producing biofuel out of COP. Figure 13 shows the block scheme of scenario 3, in which a new centralised HTL biorefinery produces biocrude and upgrades it to biofuel.

In scenario 3 biocrude is produced by a new centralised HTL biorefinery located in Úbeda, as in scenario 2. However, in scenario 3 the biocrude is not transported to the port of Gibralter to be upgraded by the San Roque refinery. The upgrading of biocrude to biofuel is done by the new biorefinery itself, as shown in the block scheme in Figure 16. The maritime biofuel is sold to bunkering companies in the port of Gibraltar responsible for supplying the end-user ships with maritime (bio)fuel). In this base scenario it is assumed the by-product biochar is burned to generate the heat needed for the HTL process. The excess electricity is sold back to the grid. Transport is kept the same as much as possible compared to the current value chain, which means the primary mills themselves are responsible for transporting COP to the new HTL biorefinery in Úbeda. Further, a COP price of 25 €/ton is used in this base scenario. It is assumed the HTL biorefinery and upgrading facility has the same output of biocrude as in scenario 2, which is 156,7 KT biocrude per year and this biocrude is upgraded with H_2 with the same efficiency as the biofuel refinery in San Roque. The impact of the new centralised HTL biorefinery was calculated based on its expected output of 150 KT biofuel per year. This means the same amount of COP, olives and farmers supplying the olives are needed as in scenario 2.

6. First-tier evaluation

In this chapter the first-tier evaluation is performed, using the base scenarios described in chapter 5. The first-tier evaluation is used to qualitatively compare the three previously described scenarios on their economic, environmental, social and technical impacts. This is done based on a set of KPI's set up by Dransfeld (2023), as described in the Methodology selection in chapter 3.

KPI selection

The KPI's used are based on previous work done by Maitland (2023), who based the selection of technical and economic KPI's on Kibira (2018). Environmental KPI's were chosen by using an International Organization of Standardization (ISO) standard proposing classification based on Areas of Protection (AoPs) and subsequent impact categories that KPI's are assigned to (International Organization for Standardization (ISO), 2006). Social evaluation KPI's were chosen based on a methodology proposed by the United Nations Development Programme (UNDP) (Traverso et al., 2021).

Dransfeld (2023) refined these KPI's from design variables and design constraints, as these are not considered outputs of the processes and assigned weights to this KPI selection using an analytical hierarchy process (AHP) (Brunelli, 2015). This process is used to evaluate the relative importance of each KPI based on expert input and determining their priority in a sustainability assessment of the marine biofuel value chain. The expert input consisted of 4 context specific experts for the Spain case study and 4 non-context specific experts. The list of interviewed experts and their ranking of the different aspects of the value chain according to priority is showed in Appendix B. Table 10 in the Methodology chapter shows Dransfeld's original list of KPI's.

First-tier Pugh matrix

The three scenarios were ranked per KPI based on quantitative calculations. Here the worst performing scenario was given 0 points, the scenario performing neither the best or worst was given 0,5 points and the best performing scenario was given 1 point. KPI's where all three scenarios performed the same, 0 points were given to all scenarios.

By multiplying the points given to the scenario with the weight given to the KPI, summing up the total score of that scenario within one of the four aspects and multiplying that score with the weight given to that aspect, it can be compared which scenario performed best within one aspect. By summing up the weighted scores for all four aspects in Table 3, it was found scenario 2 performed best.

Table 3: First tier of two-tier evaluation. Relative comparison between scenario 1 (sc1), scenario 2 (sc2) and scenario 3 (sc3) based on weighted economic, environmental, social and technical KPI's set up by Dransfeld (2023).

ASPECT	AREA of INTEREST	IMPACT CATEGORY	KPIs	UNIT of KPI	Weight	Sc1	Sc2	Sc3
Economic	Process	Feedstock/ Biomass	Biomass Pre-Processing costs	€/tbiomass	0,119	0	0	0
0,205			Feedstock Pre-Processing costs	€/tfeedstock	0,138	0	0	0
		HTL	Total investment	€	0,088	1	0,5	0,5
			Operational costs	€/tbio-crude	0,057	0,5	0,5	0
		Marine Biofuel	Min. fuel selling price	€/tbio-oil	0,214	0	1	0,5
		Overall Process	Transportation costs	€/year	0,047	1	0	0
			Levelized costs of energy	€/Unit of Energy	0,14	0,5	1	1
			Rate of Return	%/year	0,131	0	0	0
			Pay Back time	Years	0,066	0	0	0
Environmental	Ecosystem Health	Climate Change	GHG emissions harvesting	(mg CO2, N20, CH4, NO)/MJMBF	0,018	0	0	0
0,444			GHG emissions transport	(mg CO2, N20, CH4, NOx)/MJMBF	0,032	1	0	0
			GHG emissions conversion	(mg CO2, N20, CH4, NO)/MJMBF	0,045	0,5	1	0
			GHG emissions biofuel combustion	(mg CO2, N20, CH4, NO)/MJMBF	0,026	0	0	0
			Global warming potential	Kg CO2 eq.	0,103	1	0	0
		Eutrophication	Freshwater eutrophication (waste water disposal)	Mg PO4 eq./MJMBF	0,083	0	1	0,5
		Acidicification potential	Soil acidification	Mg SO2 eq./MJMBF	0,115	0	1	0,5
	Human Health	Human toxic effects	Particulate Matter (PM) emission	microg PM/ MJMBF	0,144	0,5	1	0
			Regulated toxic gas emission	(mg CO, THC, NOx)/ MJMBF	0,24	0,5	1	0
	Man Made environment	Land Transformation	Soil erosion	tsoil/ha impacted by soil erosion	0,048	0	0	0
			Biodiversity	plants/ha	0,145	0	0	0
Social	Workers	Working Hours	Number of overtime worked by employees	Billable h /total h logged by employee	0,041	0	0	0
0,141		Equal Opportunity	Gender Gap Index	Value woman /total value indicator (per country)	0,101	0	0	0
		Sexual Harassment	Number of sexual harassment cases reported to the organization	Cases /year	0,044	0	0	0
	Local Community	Local Employment	Unemployment Statistics	Unemployed /labor force -->#jobs added	0,162	0	0,5	1
		Rural Development	Rural abandonment statistics	Population decline in %	0,116	0	1	0,5
	Value Chain Actors	Wealth Distribution	Gini Index	Area between Lorenz curve and line of equality (A)/A +total area under line equality =%	0,258	0	0	0
	Society	Contribution to economic development	Contribution to GDP	Gross profit in €	0,062	0	0,5	1
		Poverty Alleviation	Multidimensional Poverty Index	Number of people living below poverty line/total population	0,046	0	0	0
	Consumer	Feedback Mechanisms	Customer satisfaction score	e.g. Complaints /year	0,046	0	0	0
		Transparency	company rating in sustainability indices	Rankings vs other companies /value chains .	0,046	0	0	0
technical	Process	Biomass	Ultimate Analysis	C,H,N,O,S (wt%)	0,136	0	0	0
0,21			Proximate Analysis	Moisture, volatile matter, ash, fixed C (wt%)	0,174	0	0	0
		Biocrude	Ultimate Analysis	C,H,N,O,S (wt%)	0,119	0	0	0
			Proximate Analysis	Moisture, volatile matter, ash, fixed C (wt%)	0,071	0	0	0
		Marine Biofuel	Proximate Analysis	Moisture, volatile matter, ash, fixed C (wt%)	0,1	0	0	0
			Annual Production	tMBF/year	0,065	0	1	1
			Physical properties	Ns/m^2	0,085	0	0	0
		Overall process	Overall Process Yield	(tMBF/year)/(tons biomass/year)*100	0,141	0	1	1
			Energy Efficiency	(MJ out/MJ in)*100	0,109	0	1	0,5

Table 3 shows the results of the first-tier evaluation. Scenario 2 performed the best overall with a relative weight of 0,473 compared to scenario 3 with a weight of 0,218 and scenario 1 with a weight of 0,220. Scenario 2 performed best overall, because it performed best on the economic, environmental, and technical aspects. Scenario 2 performed especially well compared to scenario 1 and 3 on the environmental aspect, which was found to be the most important aspect by the experts assigning the weights to the KPI's. The environmental aspect was given a weight of 44,4%, compared to the technical aspect with a weight of 21%, the economic aspect with a weight of 20,5% and lastly the social aspect was given a weight of 14,1%.

Economic aspect

Scenario 2 performed best on the economic aspect, as the production process is made more efficient by scaling up. This results in lower operational costs, MFSP (Minimum Fuel Selling Price) and more excess electricity generated than in scenario 1. This same effect applies to scenario 3, but due to the addition of the upgrading process, this scenario performs less on the total investment needed and the MFSP than scenario 2. Scenario 2 has the lowest MFSP since it is assumed when the upgrading process is done at the San Roque refinery only the operational costs will increase the MFSP. For scenario 3 the fixed capital investments needed to perform the upgrading process within the new HTL biorefinery will add to the MFSP as well, resulting in a higher minimum biofuel price. As the MFSP was found to be the most important KPI within the economic aspect, scenario 2 performs the best in this case. Feedstock pre-processing costs concern the COP price, as this is the feedstock needed for the HTL process. While this price is assumed to be 25 €/ton COP for all three scenarios, scenario 1 will be impacted the most by this increase in COP price as secondary mills receive COP for free in the current value chain. Scenarios 2 and 3 are less impacted by this COP price due to economies of scale. Scenario 3 directly produces valuable biofuel, instead of the intermediate product biocrude and will be the least impacted. Biomass pre-processing costs are made up of the cost of obtaining a ton of olives, which is assumed to be the same for all three scenarios. The rate of return and payback time are the same for all three scenarios as well, as the MFSP is based on a payback time of 15 years for all three scenarios, making the rate of return equal as well.

Environmental aspect

KPI's that were found to be the same for all three scenarios were GHG emissions of harvesting per MJ of MBF (Marine BioFuel), GHG emissions of biofuel combustion per MJ of MBF, soil erosion and biodiversity. Within the environmental aspect, the KPI's concerning local environmental impacts, such as soil acidification and regulated toxic gas emissions were found to be more important than global environmental impacts by the interviewed experts, such as conversion GHG emissions. Therefore, the location of the production facility is of great importance on its local environmental effects. Scenario 2 and 3 concerns an HTL biorefinery in the centrally located Úbeda, which is shown in Figure 12 be located away from the main olive tree fields. Comparatively, production in the secondary mill in the more rural Villanueva del Arzobispo in scenario 1 in the middle of the main olive tree fields and next to Sierras de Cazorla natural park is expected to have more local environmental effects. Production in scenario 3 will be in the same location as scenario 2, but also involves the upgrading process of the biocrude into biofuel. An additional production process is expected to increase local environmental effects of the facility, especially since upgrading is a polluting process. Refineries performing the upgrading process are a major source of air pollutants, including toxic metals, particulates, and many types of gases (nitrogen oxides, sulfur oxides, methane, carbon monoxide, benzenes, and others). Many of these gases contribute to the formation of ozone pollution and are causing the climate to warm due to the greenhouse effect (Abediyi, 2022). The emissions cause scenario 3 to perform the worst on the GHG emissions conversion, PM emission and regulated toxic gas emission KPI's. Therefore, scenario 2 scores best on local environmental effects, highly influencing the outcome of the scenario weightages. Scenario 1 performed best on the GHG emissions transport and global warming potential KPI's, since this scenario has the shortest transport routes, and it is assumed transport is the main contributor of the global warming potential of the scenarios.

Social aspect

The social aspect was found to be the least important by expert opinion, contributing little to the overall score. As Dransfeld (2023) edited the KPI's set up by Maitland (2023) to contain only quantifiable KPI's that are not impacted by policies, most social KPI's were found to either consist of company specific numbers such as the number of overtime worked by employees or the customer satisfaction score or were found to consist of country-wide statistics. Therefore, the three scenarios could not be compared on these KPI's, causing them to be left out of the equation. The impact of the jobs created through unemployment per region affected could be measured. Scenario 1 performed best on this KPI, as it would attribute to local jobs being created, instead of province-wide jobs created in scenario 2 and 3. Scenario 3 outperforms scenario 2, as the addition of the upgrading process equates to more jobs created. Scenario 1 is most impacted by rural abandonment, as it needs the local workforce. Scenario 3 needs a larger workforce than scenario 2 and is impacted more by rural abandonment than scenario 2. The contribution to GDP of Spain is the largest for scenario 3 as it involves the largest process.

Technical aspect

Since it is assumed the three scenarios use and produce biomass, biocrude and marine biofuel with the same composition, the ultimate and proximate analysis and physical properties of these products are all the same. Scenarios 2 and 3 have a higher annual production of MBF per year and higher overall process yield due to increased efficiency due to upscaling than scenario 1. However, Scenario 2 performs best on the technical aspect since it has the highest energy efficiency. This is due to the largest amount of excess electricity being generated, without the need for additional energy for the upgrading process as in scenario 3.

Alternative KPI's

The previous KPI selection was based on expert opinions, but not on the opinions of the smallholders themselves. The aim of the business case is to create an inclusive business case based on the LINK methodology, which focuses on inclusion of and engaging and empowering small holder farms. This aim does not correspond with the expert opinions in which the social aspect accounts for only 14,1% of the final weightages. This discrepancy may be explained by most of these experts being part of large companies or institutions, such as the shipping company Boskalis or the University of Jaén. The San Roque farmer cooperative SCA San Roque consists of farmers and ranks the environmental aspect last and the economic aspect of the value chain first. This can be explained by the farmers wanting above all to earn more money, as many of them struggle to earn enough from selling olive oil. The social aspect focuses on these personal economic effects, such as rural abandonment, unemployment, and poverty, which are important for smallholder inclusion.

Further, it was found half of the social KPI's could not be known or were found to be the same for all three scenarios and taken out of the equation. Therefore, less points could be awarded within the social aspect, negatively affecting its total contribution to the final weightages. To this end alternative social KPI's were set up, that do differ between the three scenarios, based on the subcategories selected by Maitland (2023). For wealth distribution the description used by Maitland (2023) was used instead of Dransfeld's (2023) description, which measures wealth distribution through the country-wide distribution of income Gini index.

Table 4: list of alternative social KPI's and their descriptions, weightages, and grading.

Alternative social KPI's	Description		sc1	sc2	sc3
Cultural heritage	Respect of organization towards local cultural heritage and recognition that all community members have the right to pursue their cultural development.	0,11111111	1	0	0
Community engagement/inclusion smallholders	Assesses whether an organization includes community stakeholders in relevant decision-making processes. Also considers extent to which the organization engages with the community in general.	0,11111111	1	0	0
Local employment	Assesses the role of an organization in directly or indirectly affecting local employment	0,11111111	1	0,5	0,5
Wealth distribution	Assesses the extent to which the value is distributed in an equitable way to all actors of the value chain.	0,11111111	1	0	1
Supplier relationships	Organization should consider potential impacts or consequences of its procurement and purchasing decisions on other organizations and act to avoid or minimize negative impacts. Relationship between the suppliers (the farmers) and the rest of supply chain is crucial for efficient employment of the Biohub.	0,11111111	1	0,5	0,5
Unemployment statistics	Unemployed /labour force.	0,11111111	1	0,5	0,5
Rural abandonment statistics	The development of rural areas in Jaén. Population decline in %.	0,11111111	0	0	0
Contribution to GDP	Assesses to what extent the organization contributes to economic development of the society. Contribution to GDP in €.	0,11111111	0	0,5	1
Poverty alleviation	measuring the presence or not of proactive activities, such as strategies, action plans, investment, to reduce the poverty of the society.	0,11111111	1	0	0,5

The alternative social KPI's in Table 4 were compared based on their descriptions. Since no expert interviews were done to assess the relative weights of these social KPI's, they were all given equal weights. Since the HTL biorefinery in scenario 1 is in a more rural area than in scenarios 2 and 3, it performs better on the alternative social KPI's. This is because the three scenarios cannot be compared when the KPI's measure country-wide effects, such as measuring wealth distribution by the Gini index, which measures the country-wide distribution of income. The alternative KPI's focus more on local effects, causing scenario 1 to perform the best comparatively. Even when using the alternative social KPI's where scenario 1 performs best, scenario 2 outperforms scenario 1, since the social aspect attributes only 14,1% to the final score. Therefore, the effect of assigning all four aspects equal weights was examined in Table 6, using both Dransfeld's as well as the alternative social KPI's.

The three scenarios were also compared on only the economic, environmental and social aspects. The technical aspect is the same on all accounts for all three scenarios, except for the amount of biofuel produced and the energy efficiency, which are already incorporated into the levelized costs of energy and the minimal fuel selling price in the economic aspect. As the Triple Bottom Line literature used only considers the three P's: people, planet and profit and not the technical aspect, the effect of giving equal weights to these three aspects was calculated as well.

Table 5: final values of normal, alt social KPI's, 4 aspects equally important (+alt social) and only 3P's (+alt social).

Relative weights	Scenario 1	Scenario 2	Scenario 3
Basis	0,12	0,46	0,28
Basis: Alternative social KPI's	0,23	0,48	0,31
4 aspects with equal weights	0,22	0,35	0,2
4 aspects with equal weights: Alternative social KPI's	0,4	0,37	0,26
3 P's with equal weights	0,26	0,41	0,25
3 P's with equal weights: Alternative social KPI's	0,5	0,43	0,33

Table 6 shows the relative weights between scenario 1, 2 and 3. Basis stands for the comparison of the scenarios based on the four aspects weighted based on expert opinion. Alternative social KPI's means instead of Dransfeld's social KPI's, the list of alternative social KPI's in Table 4 have been used. 4 aspects with equal weights means the four aspects are weighed equally, instead of based on expert opinion, and 3 P's with equal weights means only the economic, environmental and social aspects were considered with equal weights.

Since the local environmental effects have a large influence on the results, scenario 2 performs best in the basis comparison, irrespective of the alternative social KPI's. When giving the four aspects equal weights scenario 2 still performs best. This is because Dransfeld's social and technical KPI's are the same for all scenarios for five out of ten social KPI's and seven out of nine technical KPI's. Therefore, the social and technical aspects count very little to the final weightages compared to the environmental aspect in which scenario 2 outperforms the other two scenarios. Using the alternative social KPI's when the four aspects have equal weights therefore has a large impact on the relative weights of the scenarios, as scenario 1 performs best in this case. When the technical aspect is taken out and the remaining three aspects are given equal weights, scenario 2 still performs the best. This is because only three of Dransfeld's social KPI's could be filled in. Therefore, the environmental aspect is very important for the final result. By using the alternative social KPI's when giving the economic, environmental and social aspect equal weights, scenario 1 outperforms the other two scenarios. The result of scenarios 1 and 2 outperforming scenario 3 on all iterations of the first-tier evaluation is used in the following chapter on the second-tier evaluation.

7. Second-tier evaluation

This chapter will go into detail on the different ways the value chain scenarios 1 and 2 can be implemented, as scenario 3 did not emerge as the best scenario in any of the previous first-tier calculations. First, it is considered which implementation choices are considered in the second-tier evaluation. Next, the second-tier evaluation for scenarios 1 and 2 is performed by comparing the chosen implementation choices on the Triple Bottom Line areas by comparing their economic, environmental, and social impact. Finally, these comparisons were used to choose between the value chain implementations. Chapter 8 incorporates these decisions in a Linked Business Model for the value chain.

Implementation choices

First, it is considered which value chain implementation choices are assessed on their economic, environmental, and social impacts.

Pruning

Whilst for scenario 1 using pruning as well as COP to produce biocrude would be feasible due to the relative proximity of the farmers to the secondary mill, this option is not considered in this thesis due to its complexity. Pruning has the potential to significantly increase biocrude production while not being as dependent on the size of the olive harvest, transport from the farmers to the secondary mill, different composition compared to COP, storage, low value but high volume and the cleaning and chipping needed of the pruning makes for a difficult feedstock to implement in the value chain. Due to this implementing a value chain using only COP to produce biocrude is more feasible at first. Incorporating pruning as an additional feedstock may be implemented after proof of concept of the new COP value chain.

Biochar

A variation on scenario 1 that impacts the olive farmers is the option to recycle the HTL by-product biochar. In the base scenario biochar is used to generate the heat needed for the HTL process. In this case the secondary mill is energy self-sufficient and even produces a surplus of electricity, which can be sold back to the grid. Biochar can be used as soil amendment by olive farmers to reduce soil erosion by improved soil structure and improving drainage and aeration. Further, it enhances nutrient and water retention and contributes to carbon sequestration (Tsolis & Barouchas, 2023). Farmers are unlikely to organise transport themselves to obtain the biochar themselves and it likely is too expensive to use a transport company to deliver the biochar to the individual farmers. However, it is possible for the primary mills to buy and transport biochar from the secondary mill. The farmers need to pick up the biochar from the primary mill, which is much closer by than the secondary mill. When the biochar is sold to the primary mills, natural gas needs to be bought to be able to heat the HTL process as electrical heaters are not suitable. This means the secondary mill will be dependent on nearby facilities selling natural gas to power their biocrude production, including the risk on rising natural gas prices. Selling biochar as soil amendment is also considered for scenario 2.

Transportation

Transport is a key factor as it ensures the continuous provision of the feedstock and product between all stakeholders. Risks concerning transportation include delay, damage, contamination or even loss of feedstock or product. These supply chain risks are a vulnerability for the business; a liability even (Todd, 2017). The state of the feedstock or product and the distance between the stakeholders determines the type of transportation. Since transportation is an expensive part of a value chain, managing transport for a supply chain with multiple different stakeholders is an important element. It is important to consider what is the most suited transportation strategy and to have a clear supply chain management strategy, to ensure the continuous supply of feedstock, which was found to be one of the struggles of an inclusive bio-based value chain. Transportation needs to be in place for the delivery of biomass produced by farmers (olives and pruning), COP and biocrude. Table 6 shows the different transport options available. Transport option 1 stays closest to the current value chain, in which the farmers are responsible for olive transport, primary mills responsible for COP transport and biocrude transport is done by a transport company. In transport option 2, the farmers stay responsible for olive transport, but COP and biocrude transport is done by an overarching transport company. In transport option 3 all transport is handled by a single transport company.

Table 6: Transport options to organise olive, COP and biocrude transport.

Transport option	Olives	COP	Biocrude
1	Farmers	Primary mills	Transport company
2	Farmers	Transport company	
3	Transport company		

Olive transport

The farmers produce biomass in the form of olives, which needs to be transported to the primary mill. The olive transport to the primary mills is now done by the farmers themselves by truck. The farmers carry the costs and risks. Transport by truck is the most economic option for smaller distances; the costs are more expensive as the distances increase (Zafar, 2021). While in theory a transport company could take over olive transport, this is deemed an unlikely scenario. Field work has found the farmers are hesitant to change, therefore, using transport option 3 to organise olive transport is not considered in the second tier evaluation.

Crude Olive Pomace (COP) transport

As of now COP is transported by the primary mills to the secondary mills. The primary mills carry out and pay for transport by truck, carry the risks and give away for free or sometimes even pay the secondary mills for the disposal of the toxic by-product COP. The contracts for supplying olive pomace to the secondary industry are mostly yearly contracts, in which the price is determined based on the amount of residual oil left in the pomace. When secondary mills implement HTL technology to make biocrude out of COP, this transport infrastructure may stay in place, as in transport option 1 in Table 6. However, a requirement of an inclusive business case is the equitable divide of risks, costs and benefits between those in the value chain. Therefore, in the new value chain, the primary mills should benefit from the delivering the COP to the secondary mills, as they carry the costs and risks as well. This is realised by having the secondary mills pay a fair price for the COP they receive. The transport costs are still paid for by the primary mills, regardless of if they do it themselves or not. Transport costs will be calculated through a fixed price per tonne COP delivered in addition to a price per km travelled, based on the price of using a transport company, as shown in Appendix C.1. Another option is to have the biocrude transport company be responsible for COP transport as well, which is shown as transport option 2 in Table 6. While the transport of a low-value product like COP will not generate a high profit for a transport company, transporting the higher-value biocrude will offset this. When a transport company is used the primary mills pay the same amount for transport as well, but in return they do not have the responsibility of organising transport anymore.

Biocrude transport

Biocrude is produced either at the secondary mills or at a centralised HTL biorefinery. This is a liquid product that needs to be transported to the San Roque refinery at the port of Gibraltar. There is no existing transport infrastructure in place to transport the biocrude from the secondary mills to the San Roque refinery. Trucks will most likely stay the most economic option. Even though transport by truck gets more expensive when the distances increase, the product that is being transported is a dense liquid, which means less trucks are needed. Additionally, biocrude is a valuable product that is made with a steady supply. Therefore, it is easier, but also more important to organise reliable and safe transport for this easily flammable product. Other options such as pipelines or train transport are not considered in the second-tier evaluation.

When the choice is made to work with one overarching organisation that provides transport along the entire value chain, the type of transportation contract needs to be agreed on, these are called incoterms. Incoterms are an international standard that establishes the rights and duties of both the buyer and the seller (International Trade Administration, 2020). Here the transportation company sells a service, which the next stakeholder in the value chain buys. In this case-study, an incoterm is required that places a lot of responsibility on the transportation organization. This should result in the organization doing everything in its power to deliver on time and therefore ensure a continuous feedstock. This also takes away the responsibility of the stakeholders, giving them less pressure and more incentive to be part of this value chain. To this end the incoterm Delivery Duty Paid (DDP) may be applicable, as the seller is fully responsible for the costs and duration of the transport, until the product is safely delivered at the destination and can be accessed by the buyer (Maersk, 2023). From all possible incoterms, DDP is highest in cost, yet the risks are at the lowest (Schenk, 2021). Because it creates a more effective transportation system, the costs are paid back by efficiency easily. DDP is the assumed incoterm used when a transportation company is used. In the second tier evaluation the transportation choice is between the primary mills organising transport themselves as in transport option 1 and the transport company needed for biocrude transport organising COP transport as well as in transport option 2 in Table 6.

Pricing and contracts

Pricing agreements and contracts are needed for every part of the value chain, from the sale of COP to the HTL biorefinery, the sale of biocrude to the upgrading facility and the transport of these products, pruning and biochar. In the current value chain COP is sold by the cooperatives to the secondary industry using one-year contracts. However, the COP price is now either close or even below zero, while the intention of the inclusive new value chain is to increase the income of the cooperative and thereby the farmers. Additionally, the reliability of the farmer’s income should be improved. Thus, contracting for a longer period of time would be beneficial to this end. This will also ensure feedstock availability for the HTL biorefinery. A downside is that due to unpredictable harvest yields the amount of COP will fluctuate. Biofuel prices have been shown to fluctuate as well, which means COP and biocrude may be worth less or more depending on the year or time period (Declerck et al., 2022). To ensure a reliable income for the farmers and to uncomplicate the calculations a fixed COP price is assumed in the second-tier evaluation. Different COP prices are used to calculate impact in the second-tier evaluation. As the expenses calculations on the different scenarios were performed by calculating the MFSP at which the processing plant has a payback time of 15 years, different levels of biocrude pricing are not considered in the second-tier evaluation.

Second-tier evaluation matrix

Next, the three different implementation options described previously for scenario 1 and 2 will be compared based on the Triple Bottom Line by assessing their economic, environmental, and social impact. As in none of the cases in Table 7 scenario 3 is the better option over scenario 1 and 2, the second-tier evaluation was not performed for scenario 3. Table 7 describes the value chain implementation choices for scenario 1 and 2 that are used in the second-tier evaluation matrix.

Table 7: Choices for the implementation of the value chain of scenario 1 and 2.

Area	Abbreviation	Decision	Economic impact	Environmental impact	Social impact
Biochar	BC1	Biochar is burned at secondary mill biorefinery	Excess electricity is sold to the grid	All biochar is burned, which is more than is needed to heat the HTL process releasing biogenic carbon and producing excess electricity	Farmers use artificial fertilisers
	BC2	Biochar is sold to primary mills, which distribute it as soil amendment to farmers	Buying natural gas to heat the HTL process	+ The carbon in the biochar is sequestered. - Biochar needs to be transported - Only the needed amount of natural gas is burned	Biochar can be used to combat soil erosion, which may improve olive yields
Transport	TR1	COP transport is still being done by primary mills	Primary mills pay for transport	Transport is done by every primary mill itself	Less efficient transport means more work
	TR2	COP transport is done by a transport company	Transport company needs to be paid for, which is reflected In the COP price.	COP transport is combined in large trucks	More efficient transport by a transport company means rural jobs are lost
Price	PR1	25 euros/ton COP	Base price	COP price does not have an environmental impact	Primary mills get 25 euros per ton COP instead of -8 to 0euros/ton COP
	PR2	50 euros/ton COP	2 times base price for feedstock	COP price does not have an environmental impact	Primary mills get 50 euros per ton COP instead of -8 to 0euros/ton COP
	PR3	75 euros/ton COP	3 times base price for feedstock	COP price does not have an environmental impact	Primary mills get 75 euros per ton COP instead of -8 to 0 euros/ton COP
	PR4	100 euros/ton COP	4 times base price for feedstock	COP price does not have an environmental impact	Primary mills get 100 euros per ton COP instead of -8 to 0 euros/ton COP

Table 7 shows the comparative impact of the economic, environmental and social factors on the choices between biochar use, transport and COP price. The threshold was set to see which choices have an undesirable effect on one of the factors. The comparison is made between the base scenario and an alternative way to manage biochar use, transport, and COP pricing. The base scenario consists of BC1, TR1 and PR1. When the effect of BC2 is measured for example, this uses the base scenario described in chapter 5 in Value Chain Scenarios of TR1 and PR1 and only changes the biochar use from BC1 to BC2. The economic, environmental, and social impacts of the biochar, transport and pricing decisions were calculated using the impacts described in Table 7.

Quantifiable factors and thresholds

The economic, environmental, and social comparisons are performed based on quantifiable factors as seen in Table 8. For the economic aspect the ratio of the Minimum Fuel Selling Price (MFSP) of the biofuel to MGO (Marine Gasoil) was used. MGO is used as a comparison, since due to new legislation in 2020, large shipping vessels need to use fuels with less than 0.5% sulphur content. MGO is a fuel that consists of distillates and has a low sulphur content. Currently, most drop-in biofuels are approximately 1,65 times more expensive than MGO (Brown et al., 2020). Meanwhile, drop-in biofuels are approximately 2 times more expensive than fossil fuels. (Kargbo, 2021). Therefore, the minimum biofuel selling price to MGO price ratio threshold has been set at 2,0. The MFSP to MGO price ratio is increased when additional costs are made, such as buying natural gas to heat the HTL process instead of burning the by-product biochar, making the biofuel more expensive.

The environmental impact of the value chain decisions was measured in tons CO_2 per year reduced or increased compared to the base scenario. The social impact of the value chain decisions was measured on a social impact scale ranging from negative five to positive five. This rating is based on a quantifiable factor, namely the monetary impact of the value chain implementation decision the workers in the surrounding area, such as the olive farmers, truck drivers and primary mill and HTL biorefinery staff. For instance, when transport jobs are taken away due to the increased efficiency of using an overarching transport company instead of individual primary mills, this has a negative social impact. However, when the price of COP is increased from the base scenario level of 25 €/ton to 100 €/ton this has a large positive social impact by increasing the primary mill's and farmer's profits. This quantifiable financial factor has been chosen to assess the social impact of these decisions, because from the expert opinion survey resulted that the farmer-led cooperative SCA San Roque rated the economic aspect of the value chain as the most important, as seen in Appendix B. The interviews performed by Heijdens (2022) also showed the importance of the farmers' financial concerns. The values for the MFSP:MGO ratio in Tables 8 and 9 were calculated using the financial overviews of the three scenarios in Appendix D. The environmental and social impact calculations are shown in Appendix C.2.

Value chain implementation decisions

Scenario 1

Table 8: Second tier of two-tier evaluation for scenario 1. Relative comparisons between the choices for biochar use (BC1 or BC2), COP transport (TR1 or TR2) and COP price (PR1, PR2, PR3 or PR4).

Aspect	Factor	Threshold	BC1	BC2	TR1	TR2	PR1	PR2	PR3	PR4
Economics	MFSP:MGO price ratio	MFSP:MGO price ratio lower than 2	1,358	1,34	1,358	1,358	1,358	1,599	1,841	2,083
Environment	Ton CO_2/yr reduced or increased compared to other option	Increase of tons CO_2/yr emitted: value is lower than 0	0	-170863	0	-107,8	0	0	0	0
Social	Impact scale: -5 = negative, 0 = no impact, 5 = positive	Negative social impact: any value below 0	0	5	3	-3	2	3	4	5

From Table 8 follows that using biochar as soil amendment (BC2) is overall more preferable than burning it to heat the HTL process (BC1). Selling biochar has a positive financial impact on the secondary mill HTL biorefinery, as a profit is made on selling the biochar even when natural gas needs to be bought to heat the HTL process instead. Using biochar as soil amendment also has a positive environmental effect. This is due to the storage of carbon in biochar, which is called carbon sequestering. The carbon emissions of burning natural gas to heat the HTL process and biochar transport are very small in comparison to the effect of carbon sequestering. Using biochar as soil amendment also has a positive effect on the rural population's financial situation. When biochar is used as soil amendment, this contributes to jobs in transport, storage at the primary mill and adding the biochar to the olive groves. Due to the large positive economic and environmental effects and more positive social effect than burning the biochar, using biochar as soil amendment will be implemented in the linked Business Model Canvas.

From Table 8 follows that COP transport by the primary mills (TR1) compared to COP transport by a transport company (TR2) has no effect on the MFSP, as the primary mills are assumed to pay for transport in both cases, as explained in Chapter 7: COP transport. While using a transport company (TR2) improves transport efficiency and thus reduces carbon emissions, this improved efficiency also impacts the number of trucks and truck drivers needed. Therefore, using the more efficient transport company reduces the number of jobs in rural areas, which has a negative social impact. As the threshold for social impact is any negative effect, COP transport done by the primary mills themselves is the choice that does not cross any of the three thresholds. Thus, transport organized by the primary mills is chosen to be implemented in the linked Business Model Canvas.

Since a higher COP price will add to the profit made by the primary mills and thus the profit made by the olive farmers, this will positively affect the social impact. Since a COP price of 75 €/ton (PR3) stays under the economic threshold of a MFSP:MGO price ratio below 2, has no environmental impact and has an increased positive social impact, this was found to be the most beneficial price point. However, when using PR3 in the financial overview in Appendix D, the secondary mill HTL biorefinery was not found to barely make a profit, as further explained in the Chapter 8 analysis. Therefore, PR2 was implemented in the Linked Business Model in Chapter 8.

Scenario 2

Table 9 shows the economic, environmental, and social impacts of the value chain choices on biochar use, transport and COP price for scenario 2. The value chain implementation decisions were compared on the same factors and thresholds as for scenario 1.

Table 9: Second tier of two-tier evaluation for scenario 2. Relative comparisons between the choices for biochar use (BC1 or BC2), COP transport (TR1 or TR2) and COP price (PR1, PR2, PR3 or PR4).

Aspect	Factor	Threshold	BC1	BC2	TR1	TR2	PR1	PR2	PR3	PR4
Economics	MFSP:MGO price ratio	MFSP:MGO price ratio lower than 2	1,008	0,918	1,008	1,008	1,008	1,25	1,492	1,733
Environment	Ton CO_2/yr reduced or increased compared to other option	Increase of tons CO_2/yr emitted: value is lower than 0	0	-457303	0	-70,5	0	0	0	0
Social	Impact scale: -5 = negative, 0 = no impact, 5 = positive	Negative social impact: any value below 0	0	5	5	-5	2	3	4	5

From Table 9 it shows that for scenario 2 it is more beneficial to sell biochar as soil amendment (BC2) than to burn it (BC1). Because the off gas produced during the HTL process is already sufficient to heat the HTL process, the biochar is not needed for heat generation and can be sold as soil amendment, contributing to carbon sequestering, combating soil erosion, and adding biochar handling jobs in the region. This is because of scaling up the process compared to scenario 1. Due to the positive economic, environmental, and social impact compared to simply burning the biochar, it is chosen to implement biochar as soil amendment in the linked Business Model Canvas.

Table 9 shows that COP transport by the primary mills (TR1) is more beneficial overall than using a transport company (TR2). As the primary mills pay for transport regardless of whether they or a transport company organises transport, this has no effect on the MFSP because of this. While a transport company can merge deliveries and use larger trucks, making transport more efficient, employing a transport company has a negative social impact, since a centrally organized transport company will need less truck drivers due to this increased efficiency. Since using a transport company has a negative social impact, this option exceeds the threshold set for this aspect and is not regarded as the most beneficial option, regardless of the little amount of carbon emission savings. Thus, transport organized by the primary mills is chosen to be implemented in the Business Model Canvas.

For scenario 2 it was found from Table 9 that a COP price of 100 €/ton (PR4) stays below the financial threshold of a MFSP:MGO ratio of 2,0. Aditionally, a higher COP price has the most beneficial social impact by increasing the primary mill and farmer's profits the most and has no environmental impact. However, when using PR4 in the financial overview in Appendix D, the secondary mill HTL biorefinery was found to make a loss, as further explained in the Chapter 8 analysis. Therefore, PR3 was implemented in the Linked Business Model in Chapter 8.

8. Business Model Canvas (BMC)

This chapter will show the economic linked Business Model, Environmental Life Cycle BMC and Social Stakeholder BMC based on the VCM and the value chain implementation choices made based on the two-tier evaluation. As BMC's show a rapid picture of that stakeholder's business model for analysis, they are subsequently used to discuss bottlenecks, financial imbalances and to identify areas for innovation or improvement (Lundy et al., 2012). More detailed descriptions of how to fill the nine economic BMC areas can be found in Appendix A. More detailed Economic Linked Business Models, Environmental Life Cycle BMC's and Social Stakeholder BMC's for scenario 1 and 2 are included in Appendix E.1 and E.2.

The economic, environmental and social BMC analysis were used to find financial imbalances and value chain implementation improvements. These improvements were implemented in the following final overview in Figure 17 of the value chains of scenario 1 and 2.

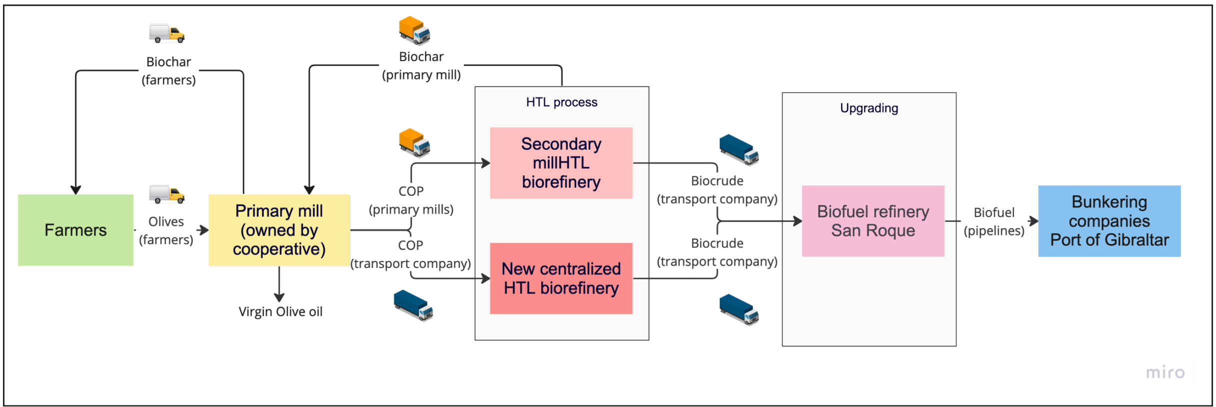

Figure 17: Scenario 1 and 2 value chain overview of transport methods of the main products.

Economic Linked Business Model

The economic Linked Business Model is made up of one BMC per stakeholder for the economic BMC's, in which the previous stakeholder's customer is the next one's supplier.Four different BMCs will reflect the business case per stakeholder: the farmers, the primary mill, the secondary mill HTL biorefineries and the upgrading facility. Together they make up a linked Business Model. Additionally, an Environmental Life Cycle and Social stakeholder BMC were made based on the Triple Bottom Line. From Table 8 and 9 follows using BC2, TR1 and PR2 for scenario 1 and BC2, TR1 and PR3 for scenario 2 are the most beneficial choices based on economic, environmental, and social factors.

Economic BMC Farmers analysis

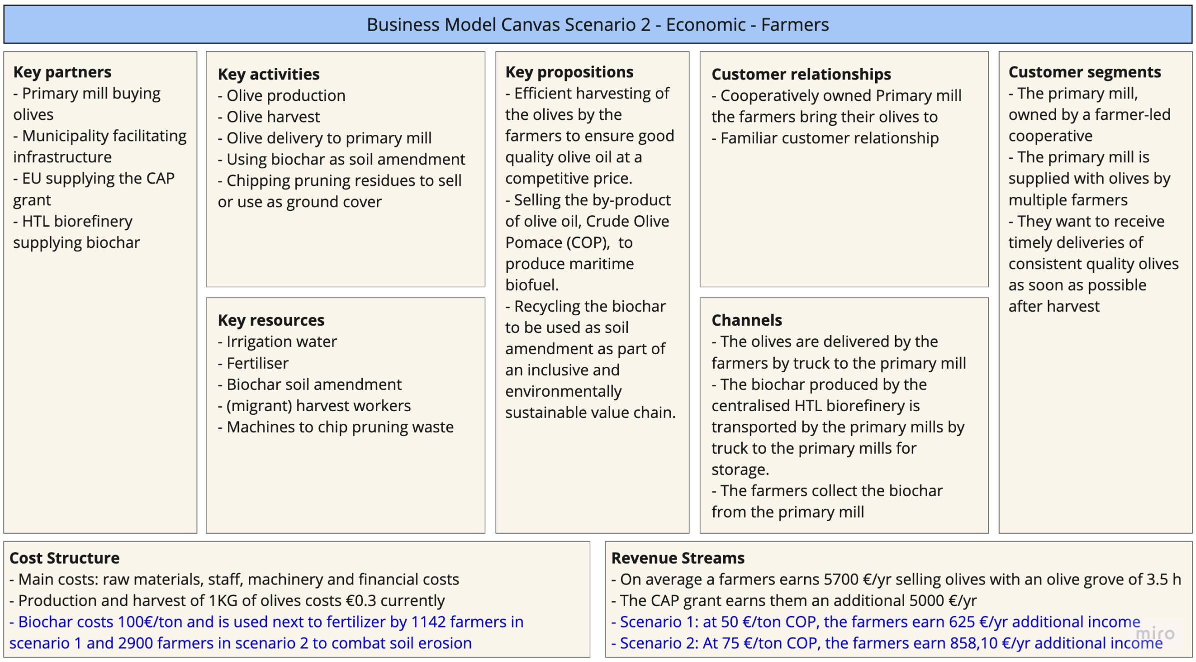

Figure 18: Business Model Canvas from the farmer's perspective.

From Heijdens' (2022) work it was found olive farmers are very concerned with their financial livelihood. Therefore, their cost structure and revenue streams in the new value chain need to be evaluated. It was found that a farmers with an average olive grove size of 3,5 ha only earns 5700€/yr by selling olives. Therefore, the addition of the EU CAP grant at 5000€/yr for this olive grove size has a large impact on the farmer's revenue stream. Meanwhile, for both scenario 1 and 2 it was found the increased COP price adds little additional income, as the farmers earn only 625€/yr in scenario 1 and 858,10€/yr in scenario 2, even when it is assumed all COP profits go directly to the farmers, instead of the primary mill. The price of the raw materials needed such as fertiliser and biochar have a significant impact on the farmer's cost structure. A price of 100 €/ton biochar is used in the Linked Business Model. This is in addition to the average fertiliser import price of around 550 €/ton in 2022 in Spain, as biochar is used alongside fertiliser (IndexBox Inc., 2023). With the low profit margins of farmers the cost of biochar will significantly add to their cost structure. Carbon credits could be used to lower the biochar price for the cooperatives.

However, using biochar as soil amendment impacts a low number of farmers. When an average of 15 ton biochar is applied per ha as recommended by Gao et al., (2021), this equates to the secondary mill HTL biorefinery being able to supply 4000 ha with an effective amount of biochar. With an average olive grove size of 3,5 ha, this impacts 1142 farmers in the region (Heijdens, 2022). This equates to only 2,86% out of the 40.000 farmers supplying the olives needed to produce sufficient COP for the HTL process. In scenario 2, the addition of 15 ton biochar/ha can only be used by 2900 farmers, or 2,61% of the total 390.000 farmers supplying COP in the value chain. With an average primary mill size of around 2300 farmers, this biochar would only have to be transported to the closest primary mill, which could distribute the biochar to their olive farmers. The biochar could be picked up by this primary mill itself. Biochar has a positive effect on soil erosion when as little as 5 ton/ha is applied, which triples the number of impacted farmers benefiting from biochar use (Martos et al, 2019).

Economic BMC Primary mill analysis

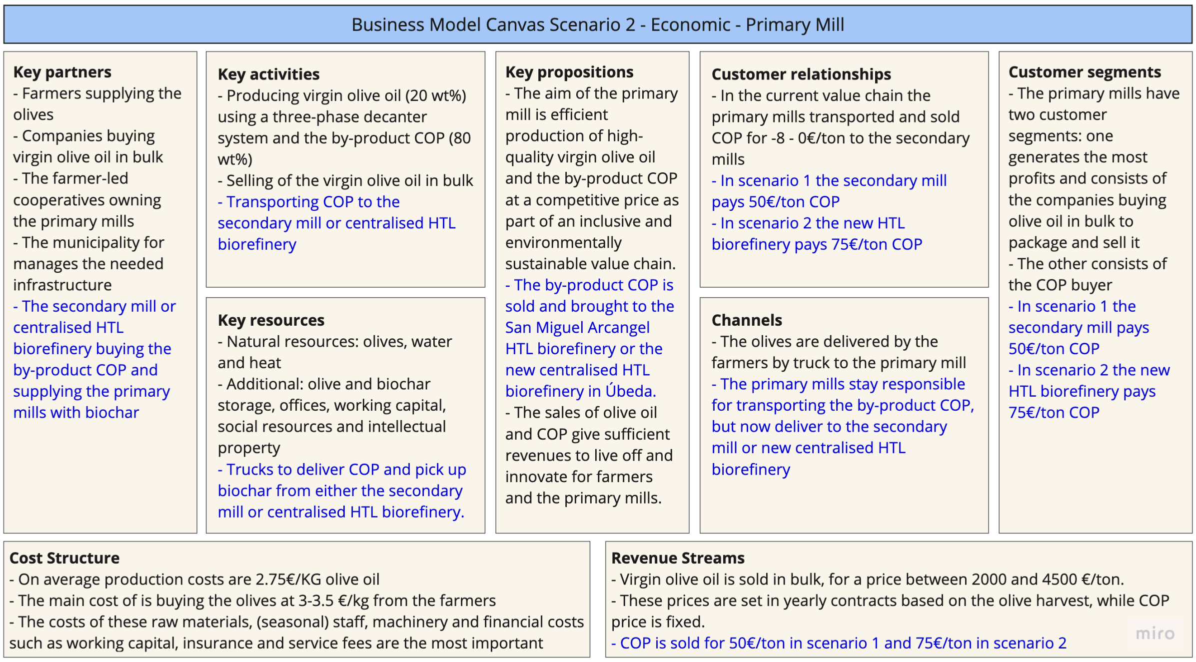

Figure 19: Business Model Canvas from the primary mill's perspective.

In the new value chain, one of the main differences for the primary mills is selling COP for 50 or 75€/ton in scenario 1 and 2 respectively. This increased price from -8 to 0 €/ton earns a primary mill in scenario 1 an additional 1.47 M€/yr, when it is assumed, the primary mills do not turn out these COP profits to the farmers. This is an additional income next to the sale of virgin olive oil, which was worth around 5000 €/ton in 2023, earning a primary mill on average 33.6 M€/year (International Olive Council, 2023). The increased COP price only increases the primary mills profits by 4,4%. A COP price of 75 €/ton in scenario 2 earns a primary mill an additional 1.9 M€/yr, increasing their profits by 6%. However, since COP is produced at the farmer-owned primary mills through cooperatives, it is more likely most of the COP profits will be used to pay for transport and to invest in the primary mills themselves. Especially since it is likely that the secondary mill HTL biorefinery will expert COP of a certain quality, as for example the water content is very important for the HTL process. It was found in Chapter 7 that COP transport by the primary mills was the most beneficial for both scenarios. However, in scenario 2 the average distance from the 51 closest primary mills to Úbeda is 41,2 km, but the furthest away primary mill is as far away as 67,7 km. The primary mills located further away from the centre of Jaén are disadvantaged in this new value chain due to the increased transport costs. Additionally, they also carry more risks and responsibilities when transporting COP almost twice the distance of the current value chain. Complicated transport by the primary mills also means the HTL biorefinery runs the risk of not receiving enough COP. Therefore, the assumption the primary mills continue to pay for transport in the new value chain, regardless of the primary mills or a transport company organising transport, does not go up for scenario 2. Due to the changed transport routes in scenario 2 it is deemed more equitable to organise transport payment as is usually done in value chains, by having the receiver pay for transport in this case. When the HTL biorefinery organises and pays for COP transport, it will be easier and more efficient to use a transport company. This way the transport company is responsible for the load, primary mill contacts and getting enough COP to the HTL biorefinery.

Economic BMC HTL biorefinery analysis

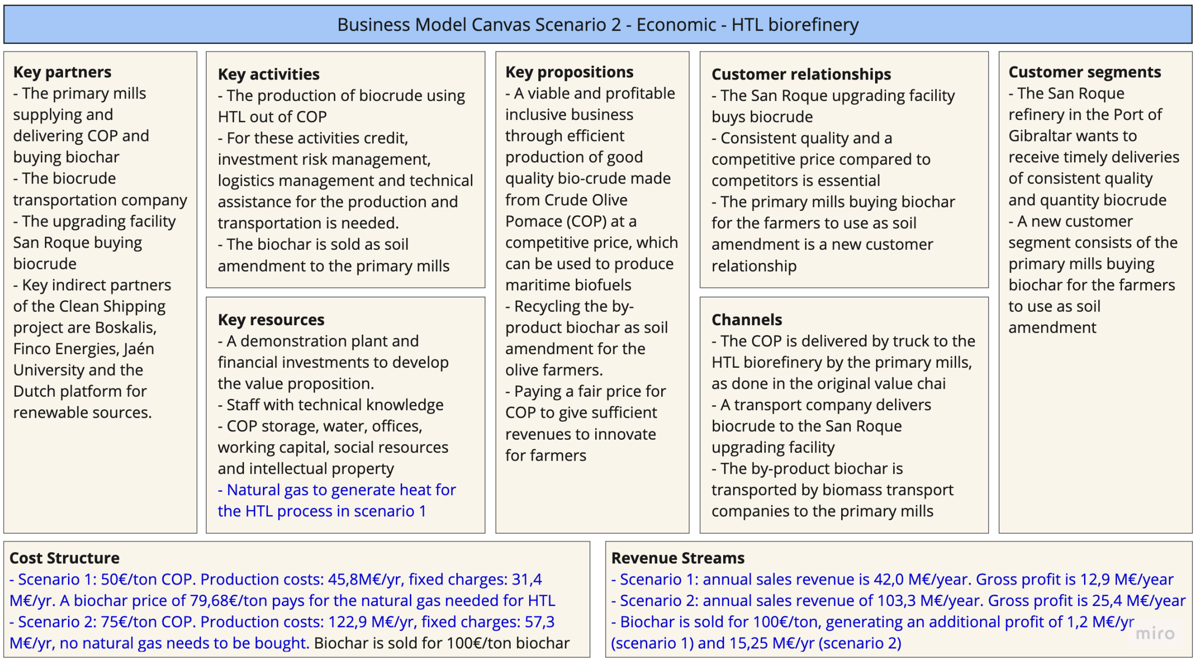

Figure 20: Business Model Canvas from the HTL biorefinery's perspective.

The HTL biorefinery in scenarios 1 and 2 are impacted by a higher COP price. Only a COP price of 25, 50 or 75€/ton keeps the minimum biofuel selling price to MGO price ratio under 2,0 in scenario 1. However, at 75€/ton barely a profit is being made by the secondary mill biorefinery at a gross profit of only 1,5 M€/year. A COP price of 50 €/ton results in a MFSP 1,6 times MGO price and a gross profit of 12,9 M€/year. Due to scaling up the process in scenario 2, the MFSP to MGO ratio stays below the 2,0 mark even with a COP price of 100 €/ton. This means the factory can raise their biocrude price significantly to make the payback time of the factory shorter than its 15 year lifespan, generating a profit. While a COP price of 100 €/ton stays below the MFSP to MGO ratio threshold of 2,0 and has the most beneficial social impact by increasing the primary mill and farmer's profits the most, a negative gross profit of -3,7 M€/year is made. When a COP price of 75 €/ton is used, the MFSP is 1,5 times the MGO price, giving the HTL biorefinery leeway to increase the MFSP to shorten the payback time and ensures a yearly gross profit of 24,4 M€ is made.

Selling biochar was implemented in the linked business model as it has a positive financial impact. While natural gas needs to be bought to heat the HTL process instead, this expense is compensated by selling the biochar for 80 €/ton. When biochar is sold for the low biochar price of 100 €/ton, 20 €/ton profit is made, which equates to 1,2 M€/year additional income for the secondary mill HTL biorefinery. This adds only 2,6% additional profit on the annual sales revenue, when correcting for the 0,1 M€/year that would have been earned on selling the excess electricity. Table 9 shows that for scenario 2 it is more beneficial to sell biochar as soil amendment than to burn it. This is because the off gas produced in during the HTL process is already sufficient to heat the process due to the effect of scaling up the process compared to scenario 1. Selling biochar for a price as low as 100 €/ton, which earns the HTL biorefinery 15,25 M€/yr since no natural gas needs to be bought to heat the HTL process in scenario 2. This is a significant additional profit, as the HTL biorefinery has an annual sales revenue of 134,5 M€/yr. Selling biochar for 100 €/ton will increase these profits by 11,3%. Currently, biochar price ranges between 50 and 20.000 €/ton due to differences in quality and origins. The minimum biochar price produced through conventional pyrolysis, a process that can also be used to produce biofuels, is between 436 and 863 €/ton, making 100 €/ton biochar a conservative price point (Haeldermans, et al. 2020). Using an average price of 550€/ton, an additional profit of 33 M€/year could be made. The secondary mill also receives added responsibilities and risks when selling biochar, instead of simply burning it. Therefore, the secondary mill is only liable to sell their biochar when they get a sufficiently high price for it to counteract these risks. This may be done through raising the price of biochar. Carbon credits may be used to lower the price for the primary mills.

Economic BMC Upgrading facility analysis

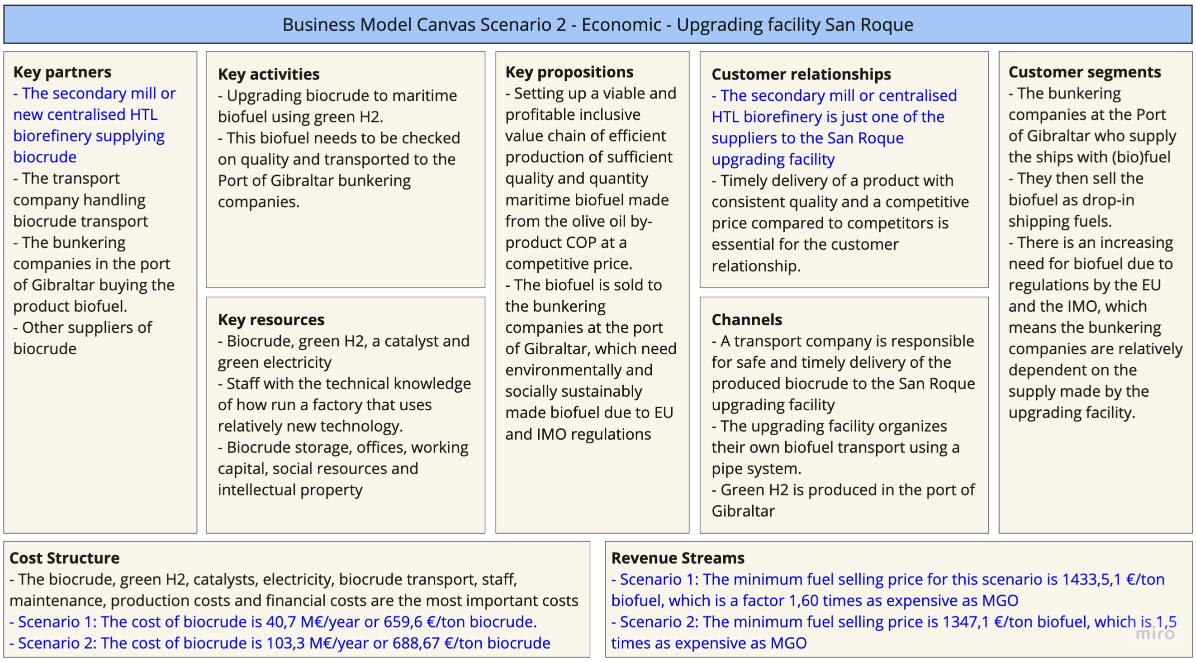

Figure 21: Business Model Canvas from the upgrading facility's perspective.

The San Roque upgrading facility is affected relatively little by the new value chain, as it already refines biocrude to biofuel. This makes the HTL biorefinery customer relationship and biocrude cost important factors. The larger scale of scenario 2 compared to scenario 1 means this value chain can deliver more biocrude, resulting in a stronger negotiation position as a supplier in scenario 2. Further, the lower biocrude price in scenario compared to scenario 1 due to scale up is more favourable.

Environmental Life Cycle BMC analysis

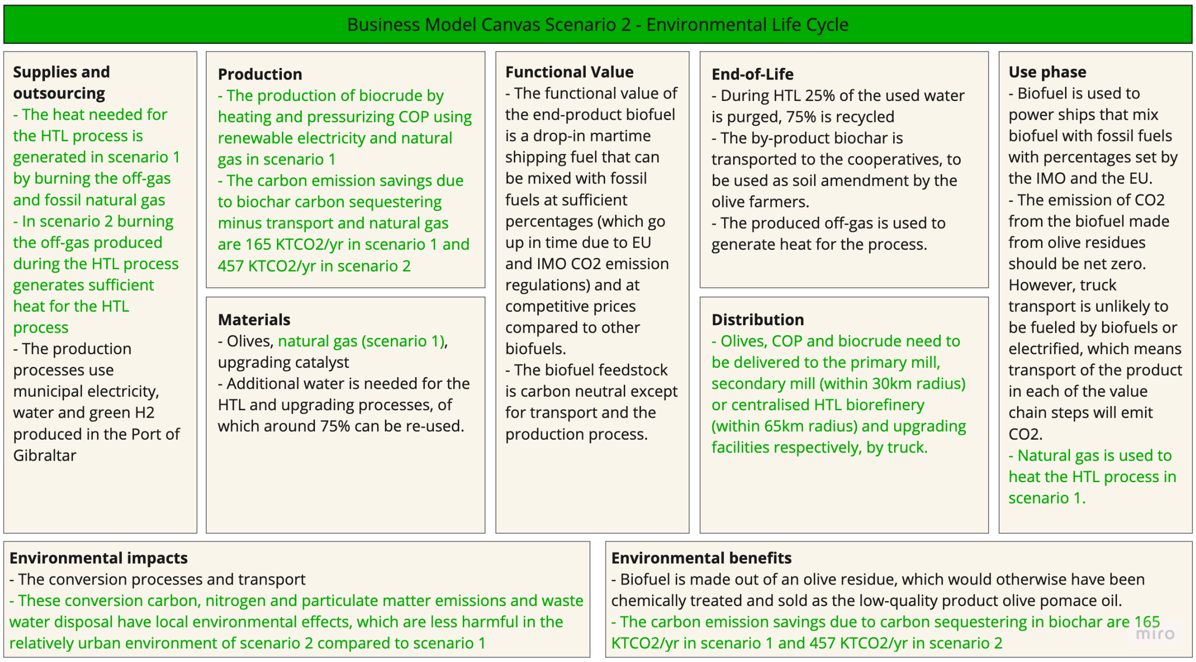

Figure 22: Environmental Life Cycle BMC.

From the first-tier evaluation in Chapter 6 it was found scenario 2 has less local environmental impact than scenario 1 due to its location. Additionally, due to economies of scale the by-product biochar or additional natural gas is not needed to generate heat for the HTL process, burning the by-product off-gas is sufficient in scenario 2. When biochar is used as soil amendment by farmers, the carbon in the biochar is sequestered, which has a positive environmental effect. Burning biochar seems to add to carbon emissions. However, just as with biofuels this carbon is stored each year in the olives used to produce COP, which is needed produce biocrude and its by-product biochar. Therefore, the carbon emission is simultaneously being stored in the new harvest, making the burning of biochar carbon neutral. Additionally, this process produces an excess of electricity, which can be powered back to the grid. However, the carbon neutrality of biomass burning is debatable, since biomass as has been found to release more carbon dioxide per unit of energy than coal, oil or gas, as the higher amount of carbon in reacts to form CO_2, while a higher proportion of hydrogen in oil and gas causes them to form H_2O alongside CO_2 (Stephanopoulos, 2022). Thus, burning biomass is not carbon neutral when comparing it to using gas to heat the HTL process in scenario 1, or solely burning biochar to generate excess electricity in scenario 2, while carbon sequestering adds to actively lowering the carbon emissions of the value chain.

Social Stakeholder BMC analysis

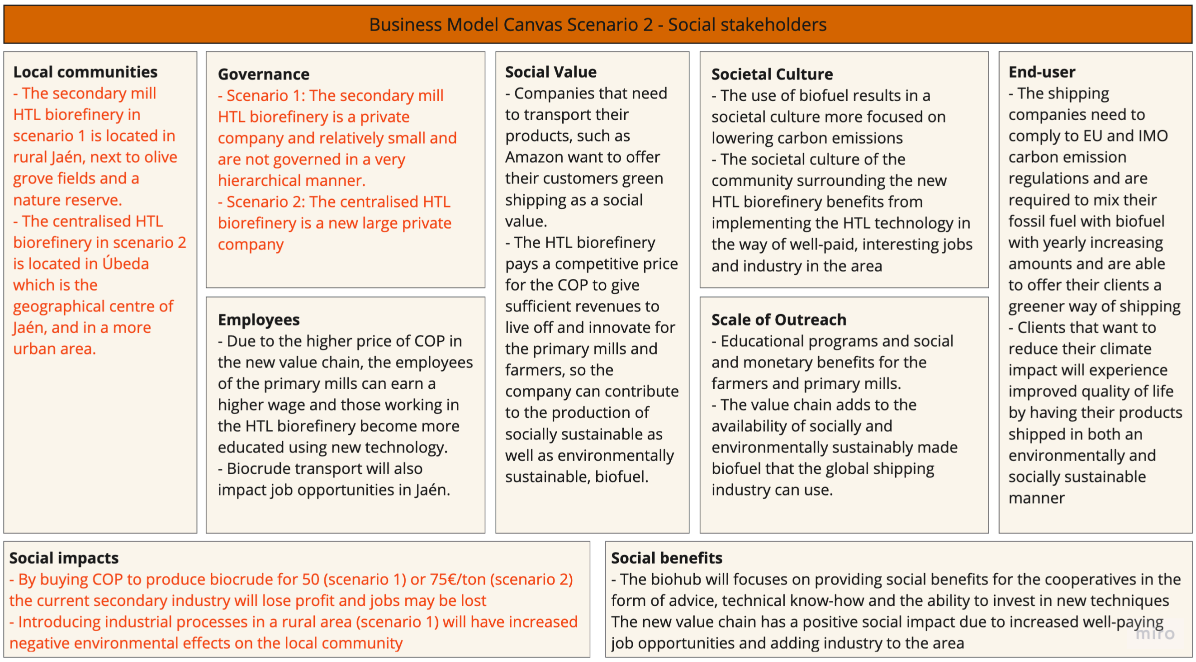

Figure 23: Social Stakeholders BMC.

Using biochar as soil amendment has a positive effect on the rural population's financial situation. 2143 trucks in scenario 1 and 5425 trucks in scenario 2 each carrying 28 tonnes of biochar are needed annually. When biochar is used as soil amendment, this contributes to jobs in transport, organisation within the primary mill and adding the biochar to the olive groves. Further, using biochar as soil amendment is beneficial on the social aspect, since farmers can combat soil erosion and improve their olive yields, which has a positive financial impact. A negative aspect of using recycling biochar is the added responsibilities for the farmers due to having to hire more people, organising transport and the financial responsibility of paying for the biochar at the risk of not profiting financially from using biochar. Generally, farmers are hesitant to change, and olive farmers are no exception as has been found from field study. Therefore, the use of biochar needs to have proven benefits that counteract the additional risks and responsibilities. This could be proven by setting up a pilot at one or multiple farmers.

The main social downside of using a transport company for COP transport is the profound impact this will have on the primary mills and their employees. As of now, the primary mills own trucks to transport COP themselves. As COP transport is organised per primary mill and transported in smaller trucks than a single transport company would use, this lower efficiency results in more jobs in the rural area around these primary mills. Due to the high unemployment and rural migration this is an unwelcome effect. While a transport company would still need truck drivers, the increased efficiency means less drivers are needed and they will mainly be employed from the region around the secondary mill HTL biorefinery, instead of around the many primary mills. When the HTL biorefinery organises and pays for COP transport, it will be easier and more efficient to use a transport company. This way the transport company is responsible for the load, primary mill contacts and getting enough COP to the HTL biorefinery. This does mean the loss of transport trucks in the primary mill regions, which is a negative effect that should be considered.

While pruning is not implemented due to its complexity in this linked Business Model, it is important to note that after proof of concept of the COP value chain, the use of pruning in the HTL process may prove to be profitable for the farmers in scenario 1. Diversification of biomass sources has the benefit of being able to produce biocrude even in the case of a bad harvest (Ferrari, 2023). The use of pruning will be increasingly difficult to employ full-scale in scenario 2 due to the central location of the HTL biorefinery, further away from the primary mills.

9. Discussion

In this chapter, the results of the Value Chain Map (VCM), two-tier evaluation and Business Model Canvasses (BMC's) are discussed, which were performed to answer the research question: *"How to create a viable business case using an inclusive business model for the production of maritime biofuels from olive residues in Jaén, Spain."*

Value Chain Map (VCM)

The LINK methodology to create an inclusive business case starts by using the VCM tool, which aims to define the stakeholders, their relationships and the flow of products and services. Finally, a VCM is made in which these (in)direct stakeholders, product flows and external factors are visualised. However, by using the VCM previously made by Lans (2022), this map is less detailed than the previous descriptions of all stakeholders, technologies and products as not all information was available at that time.

Two-tier evaluation

The VCM tool information was used in the two-tier evaluation of the three scenarios and subsequent value chain implementation decisions. In the first-tier evaluation economic, environmental, social and technical KPIs (Key Performance Indicators) set up by Dransfeld (2023) based on previous work done by Maitland (2023) and expert opinion were used in a Pugh matrix as the criteria to choose between the three possible value chain scenarios. However, it was found many of these KPIs were not applicable to choosing between different value chain scenarios of not-yet existing companies within the same country. This was especially true for the social and technical KPIs. A reason for this is that the refinements Dransfeld (2023) performed on Maitland's (2023) KPIs removed design constraints or design variable KPI's. As three different varieties of the same value chain were compared in this analysis, the three scenarios are inherently design variables of each other.

Another discrepancy was the comparative weightages of the four aspects, as the social aspect was found by expert opinion to be only worth 14,1% of the final score (Dransfeld, 2023). This low weight does not correspond with the aim of this thesis of creating an inclusive business case, which focuses on the impact of the new value chain on the smallholder olive farmers. A reason for this discrepancy may be that expert opinions were used, instead of the small holders themselves. However, the farmer led cooperative SCA San Roque was one of the experts as well. SCA San Roque found the economic aspect of the value chain to be the most important. This may be interpreted as the economic impact of the value chain on the cooperatives and thus farmers, instead of on the HTL biorefinery. This aligns with Heijdens' (2022) interviews, in which many farmers said to be concerned about their profits from olive farming being too low. Therefore, improving smallholder profits was found to be an important social impact, which was not incorporated in the aspect and KPI weightages.

Due to more than half of all social and technical KPI's not being applicable for the comparison between the three scenarios, the technical aspect was taken out, alternative social KPI's based on design variables set up by Maitland (2023) were used and the economic, environmental, and alternative social aspects were given equal weights. By giving all three aspects equal weights, the three scenarios can be compared based on which aspect they perform best on. When choosing the best value chain based on economics or environmental impact, scenario 2 performs the best. However, when choosing the best value chain based on its social aspect, scenario 1 performs the best. This shows the dilemma inherent of implementing a viable inclusive value chain, as a viable value chain is often measured on its economic and environmental sustainability, whilst an inclusive value chain is measured on its small holder impact.

Second-tier evaluation

The economic factor used compared the effect of the implementation decision on the MFSP to MGO price ratio. However, for both scenarios it was found that increasing COP price to a MFSP:MGO price ratio just below the threshold set at 2,0, the HTL biorefinery would be not or only barely have a positive gross profit due to the feedstock costs being too high. As having a positive gross profit is essential to create a viable business case, a lower COP price was chosen to be implemented in the Business Model Canvasses. This shows that only looking at the effect of a decision on the MFSP:MGO price ratio does not consider whether this results in an economically viable business case.

The environmental factor chosen to compare the impact of an implementation decision was the tons of emitted CO_2/yr reduced or increased. However, this measurement method only focused on the increase or reduction of the global GHG emissions. While this was found to be an important environmental KPI by the experts, summing up the local environmental impact KPI's resulted in a higher weight and thus higher importance, as shown in Table 3. These local effects were separately described in the analysis of the Environmental Life Cycle BMC. In addition, only carbon emissions were used to assess environmental impact, whilst excess nitrogen emissions and other toxic gas and particulate matter emissions also have a profound negative impact on biological diversity, human health and climate (Stevens, 2019).

The social factor utilized to gauge the social impact of an implementation decision involved a social impact scale ranging from -5 to 5. This scale assessed the financial impact on workers in the region to facilitate comparison of the effects of four different COP prices. However, instead of quantifying the financial impact of all decisions, the impact scale was employed to comparatively evaluate the decisions' financial impact on the rural community.

Business Model Canvas (BMC)

The LINK methodology Business Model Canvas was used to create an economic Linked Business Model of the four value chain stakeholders and an Environmental Life Cycle and Social Stakeholder BMC, to analyse the value chain's economic, environmental and social impact (Lundy et al., 2012). This analysis was meant to show the businesses risks, financial imbalances and find areas for improvement, but it was found that this summary was not able to show the complexity of the stakeholder's business case and the widespread impact the new value chain has on their livelihood. An additional SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis or an advantages/disadvantages list could significantly add to finding and visualising the stakeholder's risks, weak and strong points.

When looking at the strong and weak points of the Linked Business Model, Environmental Life Cycle BMC and Social Stakeholder BMC some unexpected results were found. Interestingly, from the economic BMC's it was found that while the increased COP prices in the new value chain were meant to benefit the smallholders by increasing their income and to make them more resilient against the fluctuating olive oil prices as described in the VCM, this is only true to certain extent. In scenario 1 and 2 the farmers only receive an additional 625 or 858 €/yr, on an average income of 10.000 €/yr from selling olives and the EU CAP grant, in the event all COP profits go the farmers. Raising this COP price was found to make the secondary mill HTL biorefinery and new centralised HTL biorefinery concepts not economically viable. These additional COP profits do come without any additional risks and responsibilities for the farmers. Realistically speaking, it is more likely these COP profits will go to the primary mills. In scenario 1 they remain responsible and pay for COP transport and as water content of COP is very important for the HTL process it can be assumed the additional COP profits will pay for transport and process innovation, instead of to the farmers. Therefore, a higher COP price due to the implementation of this new value chain adds very little to nothing to the farmer's yearly profits, causing them to remain dependent on the fluctuating olive oil price and the EU's CAP grant for their income.

Conversely, while it was assumed in the base scenarios in Chapter 5 that it would be the easiest, most cost-efficient to burn the by-product biochar to heat the HTL process, this was found not to be the case. Selling biochar for a price below market value whilst having to buy natural gas instead to heat the HTL process in scenario 1, this still adds to the HTL biorefinery's profits. Thus, selling biochar as soil amendment significantly adds to creating an economically viable HTL biorefinery and also adds to reducing the effect of soil erosion to close-by farmers and reduces carbon emissions through carbon sequestering.

It should be considered, however, that this analysis has been done on the largest secondary mill in Jaén, called San Miguel Arcángel in Villanueva del Arzobispo, producing 24% of the total market share of COP. As it was reasoned that in the case this value chain would not be profitable at the largest secondary mill, due to economies of scale it also would not be profitable at smaller secondary mills. By comparing the profitability of scenario 1 with the 2,5 times larger production of biocrude in scenario 2, it follows that economies of scale have a large impact on the profitability of a production facility. As the second largest secondary mill is already 1,5 times smaller than the San Miguel Arcángel secondary mill, it can be assumed that the implementation of a HTL biorefinery in smaller secondary mills will be significantly less profitable due to economies of scale.

Finally, the environmental and social impact of the new value chains for scenarios 1 and 2 were considered in BMC's. It is difficult to assess all environmental and social impacts of a new value chain. Both scenarios have negative and positive environmental and social effects. For instance, whilst the scenario 2 HTL biorefinery is located in a more urban area, away from nature reserves and produces more biochar which carbon can be sequestered, this does mean a completely new, very large production facility will be built in this area compared to only adjusting the existing facility in scenario 1. Similarly, building a new large production facility in scenario 2 will add more jobs than the smaller scale production in scenario 1, but these jobs will not be located in rural Jaén, in which unemployment and poverty is a problem. The BMC analysis therefore shows the complexity of introducing a new value chain, in which all options have economic, environmental, and social advantages and disadvantages. In this case it was found that while scenario 2 appeared to perform best on the environmental and economic aspects, scenario 1 performed the best on the social aspect as found from the first-tier evaluation. As the aim of this thesis was to create a viable inclusive business case using the LINK methodology this result shows the dilemma of creating an economically and environmentally viable but also inclusive business case, since these values were found to be mutually exclusive in this case.

Therefore, when choosing a value chain scenario and deciding how to choose between implementation decisions, it should be carefully considered which value takes precedence over the others and who is making this choice. Different stakeholders, such as the farmers or HTL biorefinery investors are bound to give importance to different values. Interestingly, it was found that in this value chain the focus of the interviewed experts as well as the interviewed farmers by Heijdens (2023) was on the environmental impact and profitability of the new value chain. This does not correspond with the definition of an inclusive value chain used in this thesis, which focused more on the farmers having a say in dividing the risks, responsibilities, and benefits.

10. Conclusion

The methodology used in this thesis, including the Value Chain Map (VCM), two-tier evaluation, and Business Model Canvasses (BMCs), provided valuable insights into the complexities of creating a viable inclusive business case. The VCM allowed for a comprehensive understanding of stakeholder relationships and product flows. The two-tier evaluation was used to choose between biocrude production either at the largest secondary mill in Jaén, San Miguel Arcángel (scenario 1) or at a new centralised biorefinery in Úbeda (scenario 2) or introducing a refinery in the centralised HTL biorefinery (scenario 3) and to choose which value chain implementation choices would be implemented in the BMCs. It was found that different value chain scenarios and implementation decisions have a profound impact on stakeholders' economic, environmental, and social aspects. This assessment revealed challenges in comparing value chain scenarios, particularly when assessing the social aspect, which is crucial for inclusivity. The Business Model Canvasses showed an overview of the economic, environmental, and social impacts of the scenario 1 and 2 value chains, highlighting trade-offs and complexities inherent in value chain decisions.

Key findings indicate that while economic and environmental considerations often take precedence in value chain decision-making, social impacts, particularly those affecting smallholders, must not be overlooked. The thesis uncovered discrepancies between expert opinions and the needs of smallholder farmers, underscoring the importance of including diverse perspectives in decision-making processes. Moreover, the analysis revealed the significance of local environmental impacts and the need for holistic assessments beyond carbon emissions.

Economically, biocrude production shows promise, but the distribution of profits and responsibilities raises questions about the true inclusivity of the business model. While increasing COP prices may seem beneficial to smallholders, the reality may be different, with profits potentially accruing elsewhere in the value chain. Additionally, the analysis underscored the role of economies of scale to obtain an economically profitable business case, which implies implementation of the production of biocrude at smaller secondary mills than the San Miguel Arcángel secondary mill will be significantly less profitable. Social impacts, including job creation and community well-being, further complicate value chain decisions, requiring careful balancing of competing priorities.

In conclusion, this thesis contributes to our understanding of setting up an inclusive business model in the context of maritime biofuel production from olive residues in Jaén, Spain. It underscores the importance of integrating economic, environmental, and social considerations into decision-making processes to ensure the creation of economically viable and inclusive value chains. Future research should focus on choosing between scenario 1 or 2 and applying the next key tool of the LINK methodology: the New Business Model (NBM) principles. As this tool is used to evaluate to what extent a business relationship with a formal buyer is inclusive of small-scale producers and concrete actions are defined to improve inclusivity for smallholder farmers, it is recommended future research this tool is used to assess the final Linked Business Model for scenario 1 or 2 on smallholder inclusivity.

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Appendices

Appendix A

Block #1: Customers
Without customers no business can survive. Therefore, it is important to understand the wants and needs of the customer or customer segments the businesses provide for to determine how to best satisfy these wants and needs. However, for small-holder farmers the end-consumers are often unknown, which is why investing time to understand their needs and preferences is even more important. Customers are grouped into segments if their needs justify a distinct product or service, they are reached through different distribution channels, they require different types of relationships, they have substantially different profitability or they are willing to pay for different products or services. Customers are defined here by the types of people or businesses the company will (in)directly target. There may be multiple customer types, which can be ranked by importance.

Block #2: Value Proposition
The value proposition is the reason why customers choose the products or service of one business over another. Therefore, the value proposition and cost management structures underpin the success of any business model. The value proposition for each customer or customer segment is identified by considering the problem or need that the product or service satisfies. In the context of small holder inclusion, business models beyond a mere economic value are needed. The value proposition should offer a solid combination of economic, social and environmental value to both downstream (whom you sell to) and upstream (whom you buy from) actors.

When creating an inclusive business model, it is important to not just show the value proposition from the customer's perspective, but to show the producer's point of view as well. Inclusive business models should be responsive to the realities of smallholder production as well as to market demands. For modern agri-food chains, almost all value propositions for buyers are built on high standards for food quality and safety, year-round availability, and, sometimes, lower prices, communicated to consumers through brands. The client-facing value proposition focuses on the assurance of supply, safety and quality of products that tell a story and support the brand. It needs to be considered what creates value for a buyer, such as quality of supply, reliable supply, certificates and standards, competitive price, reliable quality, transparency of processes. The farmer-facing value proposition focuses on what products, strategies, activities or purchasing practices can promote small-holder inclusion and staying the preferred buyer. For a smallholder, stable and consistent demand, provision of supplies, training and technical assistance, financial services, contracts and market information create value.

Block #3: Channels
The term channels describes the ways the business reaches and interfaces with its customers. When the business is a production facility or deals with agricultural products, the sales channel is often equivalent to the logistics supply chain, transferring the product between the producer and the final customer or between the farmer and the producer.

Block #4: Customer Relationships
This block refers to the type of relationship the business wants to establish with each customer (segment) to deliver the product or value proposition. For these relationships the type of channel, the consistency, and the cost of maintaining the communication as well as the potential to differentiate the company through a distinct customer relationship or customer service must be considered.

Block #5: Revenue Streams
A company's revenue stream is made up of a value proposition that reaches a customer (segment) through a certain channel supported by a distinct type of relationship. The revenue stream is what the customer pays for the product or service. Fixed or dynamic pricing mechanisms may be employed in a business model. Fixed pricing describes predefined prices based on static variables, while dynamic pricing describes prices that change based on market conditions.

Block #6: Key Resources
Key resources of an organisation can be physical, intellectual property, financial or human knowledge-based or social and are essential to create and sustain the value proposition, deliver it to the market, establish customer relationships and generate income. Any non-essential resources of an organisation will not be included here.

Block #7: Key Activities
An organisation's key activities are crucial for the business to successfully function. Key activities may be production, processing, marketing, producer networks or quality assurance. Like key resources, they are required to create and sustain a Value Proposition, reach markets, maintain customer relationships, and generate income.

Block #8: Key Partners
Most business models need a support network of key partners to be able to operate. These may be direct or indirect partners. Direct partners are those with whom the company operates its core business model, while indirect partners are those who support or facilitate the development of the business model.

Block #9: Cost Structure
The business model's cost structure describes the costs incurred for the creation and delivery of a value proposition, maintaining customer relationships, and generating income. These costs can be determined by identifying the key resources and key activities and may depend on the volume of goods or services produced (variable costs) or may remain the same (fixed costs). Economies of scale are costs advantages that a business enjoys as its output expands, while economies of scope are cost advantages due to a larger scope of operations. However, as major challenge in applying a business model approach to small holder agriculture is the general lack of cost data, specifically at farm level. This gap can be solved by organising farmer focus groups to map costs or timelines to convert activities to cash value.

KEY PARTNERS

- Who are our Key Partners?
- Who are our key suppliers?
- Which Key Resources are we acquiring from partners?
- Which Key Activities do partners perform?
- Are our partners satisfied with our goods or service?
- How dependent is our business on our partner's support?

KEY ACTIVITIES

- What Key Activities do our Value Propositions require?...our distribution channels?...our customer relationships?...our revenue streams?
- In what part of the chain are the key activities carried out?
- Who is responsible for these activities? What are the risks and incentives involved?

KEY RESOURCES

- What Key Resources do our Value Propositions require?
- Our Distribution Channels?
- Customer Relationships?
- Revenue Streams?
- How are the key resources available to all actors in the chain?
- How are these resources allocated and distributed?
- Who assumes the risk for the procurement of these resources?
- What are the rewards attached to these risks?

VALUE PROPOSITION

- What value does the company deliver to the customer?
- Which customer need is this satisfying?
- What bundles of products and services are we offering to each customer segment?
- Which one of our customer's problems are we helping to solve?

CUSTOMER RELATIONSHIPS

- Does our business manage customer relationships?
- What type of relationship does each of our Customer Segments expect us to establish and maintain with them?
- Which ones have we established?
- How are they integrated with the rest of our business model?
- How costly are they?
- Do we spend too much effort on relationships with unprofitable customers?
- Could we invest in more profitable customers?

CHANNELS

- Through which Channels is the product or service delivered?
- Through which Channels is the value proposition communicated?
- How are our Channels integrated?
- Which ones work best?
- Which ones are most cost-efficient?
- How are we integrating them with customer routines?

CUSTOMER SEGMENTS

- Who are the customers or customer segments?
- For whom are we creating value? Who do we sell our products to or services to?
- Who are our most important customers or customer groups?
- Can we identify our customers' needs?
- How do we respond to our customer's needs?
- Describe the relationship with our customers?
- How do we go about acquiring new customers?

COST STRUCTURE

- What are the most important costs inherent in our business model?
- Which Key Resources are most expensive? How much do they cost?
- Which Key Activities are most expensive? How much do they cost?
- How much does it cost to maintain the value proposition?

REVENUE STREAM

- For what value are our customers really willing to pay?
- How do we create income? For what do they currently pay?
- How are they currently paying?
- How would they prefer to pay?
- How much does each Revenue Stream contribute to overall revenues?
- How stable is our income stream?

Figure 24: BMC overview of the 9 blocks and their corresponding key questions.

By filling these 9 blocks, the BMC key questions can be answered:

1. How does my organization or business function?
2. Is the existing business model viable? What change(s) could improve the overall performance of my organisation?
3. What are the strengths and weaknesses of the existing business model?
4. What external influences impact positively and negatively on the business model?
5. Is the buyers's business model open to the inclusion of small-scale producers as providers?
6. Does the buyer's business model contain a double-facing value proposition (i.e., both towards their customers and towards their providers)?
7. Does the producer organisation's current model make it attractive as a business partner for a formal buyer?

Appendix B

Table 10: Expert opinion survey results at first-tier aspect level.

Name of the organization and field of expertise	Rank the different Aspects of the value chain according to priority: environmental	Rank the different Aspects of the value chain according to priority: social	Rank the different Aspects of the value chain according to priority: technical	Rank the different Aspects of the value chain according to priority: economical
Dutch Platform Renewable Fuels	1	2	3	4
Technology research institute	3	4	1	2
Boskalis	1	2	3	4
University of Jaén	1	4	3	2
University of Aveiro and agro-industrial waste valorization	1	2	3	4
UNIVERSIDAD DE JAÉN INVESTIGADOR POSTDOCTORAL	1	3	4	2
SCA SAN ROQUE	4	3	2	1
FincoEnergies	1	4	2	3

Appendix C.1

Calculations Pugh matrix first-tier evaluation.

Table 11: Quantitative comparison in pugh matrix first-tier evaluation.

ASPECT	KPIs	scenario 1	scenario 2	scenario 3	sc1	sc2	sc3	Sources
Economic	Biomass Pre-Processing costs	0	0	0	around 3 eur/kg	around 3 eur/kg	around 3 eur/kg	https://www.internationaloliveoil.org/wp-content/uploads/2019/11/INTERNATIONAL-OLIVE-OIL-PRODUCTION-COSTS-STUDY-.pdf
	Feedstock Pre-Processing costs	0	0,5	1	0.03	0.03	0.03 euro/kilo	https://www.internationaloliveoil.org/wp-content/uploads/2019/11/INTERNATIONAL-OLIVE-OIL-PRODUCTION-COSTS-STUDY-.pdf
	Total investment	1	0,5	0	176,8 M euros	318,2 M euro	367,5 M euro	Appendix D
	Operational costs	0	1	1	77,3 M euros	145,9 M euro	166,0 Meuro	Appendix D
	Min. fuel selling price	0	1	0,5	1215,1 eur/ton	902,4 euro/ton	1104,6 eur/ton	Appendix D
	Transportation costs	1	0	0	0	2,4 million euros/yr	2,4 million euros	Appendix C
	Levelized costs of energy	0,5	1	1	0,1 M eur/yr profit	0,2 Meur/yr	0,2 Meur/yr	Appendix D
	Rate of Return	0	0	0	0	0	0	Appendix D
	Pay Back time	0	0	0	15 years	15 years	15 years	Appendix D
Environmental	GHG emissions harvesting	0	0	0	0	0	0	Same
	GHG emissions transport	1	0	0	1,15 KT/yr	3,24 KT/yr	3,45 KT/yr	Appendix C
	GHG emissions conversion	0,5	1	0	0	0	0	Same

	GHG emissions biofuel combustion	0	0	0	0	0	0	Same
	Global warming potential	1	0	0	41,4 KTCO2/yr	100,5 KTCO2/yr	100,5 KTCO2/yr	Appendix C
	Freshwater eutrophication (waste water disposal)	0	1	0,5	same but location affects impact			Same
	Soil acidification	0	1	0,5	same but location affects impact			Same
	Particulate Matter (PM) emission	0,5	1	0	same but location affects impact			Same
	Regulated toxic gas emission	0,5	1	0	same but location affects impact			Same
	Soil erosion	0	0	0	same			Same
	Biodiversity	0	0	0	same			Same
Social	Number of overtime worked by employees	0	0	0	0	0	0	No data
	Gender Gap Index	0	0	0	0	0	0	Same
	Number of sexual harassment cases reported to the organization	0	0	0	0	0	0	No data
	Unemployment Statistics	1	0	0,5	20 workers	50 workers	60 workers	Appendix C
	Rural abandonment statistics	0	1	0,5	highest impact	least impact	need more workers than sc2	#workers/region size
	Gini Index	0	0	0	0	0	0	Same
	Contribution to GDP	0	0,5	1	23,2 Meur/yr	68,3 Meur/yr	93,4 Meur/yr	Appendix D
	Multidimensional Poverty Index	0	0	0	0	0	0	Same
	Customer satisfaction score	0	0	0	0	0	0	No data
	company rating in sustainability indices	0	0	0	0	0	0	No data
technical	Ultimate Analysis	0	0	0	0	0	0	Same
	Proximate Analysis	0	0	0	0	0	0	Same
	Ultimate Analysis	0	0	0	0	0	0	Same
	Proximate Analysis	0	0	0	0	0	0	Same
	Proximate Analysis	0	0	0	0	0	0	Same
	Annual Production	0	1	1	59,1 KT/yr	143,6 KT/yr	143,6 KT/yr	Chapter 5
	Physical properties	0	0	0	0	0	0	Same
	Overall Process Yield	0	1	1	0	0	0	Scaling up is more efficient
	Energy Efficiency	0	1	0,5	1173333	3516800	3516800	Excess energy produced Chapter 5

Table 11 shows the economic, environmental, social and technical KPI's set up by Dransfeld (2023), the ratings of the three scenarios and the quantitative numbers these ratings are based on. These numbers were calculated with the following calculations:

Economic
Transport cost, with number of tonnes COP based on Chapter 5 calculations and number of km based on the distance of the 51 closest primary mills to Úbeda.

Scenario 1: COP transport is done by primary mills, no costs for secondary mill HTL biorefinery.
Scenario 2 and 3: COP transport from 51 primary mills within a 65 km radius of Úbeda.

Equation 2: COP Transport cost equation.

$$Transport\ cost = 12€ * 1269572{,}927\ tonCOP + 0{,}27€ * 9008031\ km = 2{,}4\ M€$$

Environmental:

GHG emissions transport:

TRANSPORT SC1		1071480	KM IN TOTAL/YR
		1157868000	gco2 emitted per year
		360	gco2/km 18 tonne truck
SC2 AND 3		3242891160	gco2/yr

SC3 H2 TRANSPORT	UBEDA TO PORT OF GIBRALTAR	390	KM
		780	km round trip
	H2 needed	3330000	kg H2/year
		1300	kg H2/truck
		2561,538462	trucks needed
		2562	trucks needed
		1998360	km per year
		105	gco2/km
		209827800	gco2/year
		209827,8	
		209,8278	
		0,2098278	
	sc3 COP +H2 transport	3,45271896	

H2 emissions per truck: https://hydrogeneurope.eu/wp-content/uploads/2021/11/Tech-Overview_Hydrogen-Transport-Distribution.pdf

Co2 emissions per km: https://8billiontrees.com/carbon-offsets-credits/carbon-ecological-footprint-calculators/truck-co2-emissions-per-km-calculator/

Global Warming Potential:

sc1	**biofuel production per year**	**59078552,24**	**kg**
	GHG emission sc1	0,7	kg co2/kg fuel
	total GHG emissions/yr	41354986,57	kg co2 per year produced
sc2 and 3	biofuel production per year	143600000	
	total GHG emissions/yr	100520000	

Social

Unemployment statistics is measured by the number of workers needed for a scenario 1, 2 or 3 HTL biorefinery.

WAGES AND SALARIES

SC1	Operators per Shift, HTL	#	6	
	Shifts per Day	#	3	
	Hours per Shift	#	8	
			144	hours worked per day
	average salary factory worker spain		10	euros/hr
			1440	euros/day spent on salaries
			525600	euros/yr spent on salaries
			0,5256	
			18	employees
			20	2 extra employees to cover for worker benefits and vacation
SC2	Operators per Shift, HTL		15	
2,54 TIMES AS MUCH FEEDSTOCK GOING IN	Shifts per Day	#	3	
	Hours per Shift	#	8	
			360	
	average salary factory worker spain		10	
			3600	
			1314000	
			1,314	M euros/yr spent on salaries
			45	employees
			50	employees to cover for worker benefits and vacation
SC3	sc2 plus upgrading	2 workers per shift extra, 5 shifts assumed	10 extra employees	
			60 employees in total sc3	

extra employees to cover for worker benefits and vacation:
https://www.sciencedirect.com/science/article/pii/S0959652619327118?via%3Dihub#tbl5

Extra employees upgrading process:
https://pure.tudelft.nl/ws/portalfiles/portal/89384351/1_s2.0_S0960148117306080_main.pdf

Appendix C.2

Calculations Pugh matrix second-tier evaluation.

Scenario 1				
social	social impact	see comments		
economics	MFSP	Via "expenses_full_no upgrading" tab in excel "TEA pomace final Siva"		
	Transport	TR1: transport done by primary mill is free		
		TR2: transport done by transport company needs to be paid for		
		17858	trucks needed in total	
		30	km round trip	
		500000	ton COP to be transported	
	Truck transport, fixed	ton	12	
	Truck transport, variable	0,27	ton/km	
		6144649,8	euros in total/yr	
		6,1446498	mil euros/yr	
	BC2	energy needed	MJ	21513 MJ needed per hour
				172104000 MJ/year needed
			GJ	172104,00
		Natural gas, per GJ	GJ	27,78 euro
				4781049,12 euro
		BC1 and BC2 are the same, since with a price of 79,68 euros/ton biochar you raise the 4,78 million euros you pay for natural gas		79,68 euro/ton biochar
				100,00 euro/ton biochar assumed
				20,32 euro/ton biochar profit, when natural gas expenses are taken into account
				1218950,88 euro/yr profit on selling biochar
	pricing	changing COP price in "expenses_full_no upgrading" sheet TEA pomace final siva excel		
environment	**BC1 or BC2: Gas transport calculations**	https://www.degruyter.com/document/doi/10.1515/eng-2021-0096/html#:~:text=At%20present%2C%20LNG%20trucks%20produce,level%20of%200.044%20kg%2Ftkm.		
	Transport & burning natural gas CO2 emissions			
		amount	units	sources
		41,7	MJ/m3	https://www.rvo.nl/sites/default/files/2014/03/GTS%20brief%2017%20jan%202011.pdf
		172104000	MJ/year needed	
		4127194,245	m3 LNG needed/yr	
burning LNG		2,2	kg CO2/m^3 of natural gas	
		9079827,338	kg CO2/year by burning natural gas	
		9079,827338	ton co2/yr burning	
CO2 sequestering		3000	kgco2 seqestered/ton biochar	

	60000	ton biochar/yr		
	180000000	kg co2 sequestered/yr		
	180000	ton co2/yr		
	170920,1727	ton co2/yr sequestered - burning LNG		
Transport biochar	60000	ton biochar/yr		
	2142,857143	trucks	max truck size is 44 tonne truck with payload of 28 tonnes	https://coloradosun.com/2023/04/07/biochar-carbon-capture-climate-change/#:~:text=How%20much%20carbon%20is%20locked,of%20scientists%20combating%20climate%20change.
	2143	trucks needed/yr		
	30	km trip from secondary mill to each primary mill		
	880	gco2/km for 44 tonne truck		
	64290	km in total to transport all biochar from sec mill to 17 primary mills		
	56575200	gco2/yr		
	56575,2	kgco2/yr		
	56,5752	ton co2/yr		
	170863,5975	seq - burning - transport		

Tr1 or TR2 calculations	comparing CO2 emissions less efficient transport by primary mills versus done by transport company.			
assumptions:	pomace transport is done by diesel trucks of 7.5-16 metric tons	https://www.mdpi.com/2077-0472/13/6/1192		
	7.5-tonne truck (payload of around 3.5 tonnes)	> used by smallest primary mills		
	18-tonne rigid truck (payload of around 10 tonnes)	> used by bigger primary mills		https://www.returnloads.net/how-to-price-haulage-work/
	all trucks need to drive 30 km to secondary mill			
	scenarios master with production per primary mill is used -->	500.000	tons in total	
TR2:	transport company only uses biggest trucks	17857,14286	trucks needed	48,92367906
	max truck size is 44 tonne truck with payload of 28 tonnes			
TR1:	assume only 10 ton trucks are used	53605	trucks needed in total	146,8630137
	see scenarios master excel for calculation			-
emissions	20 gco2/km /ton vehicle weight	file:///Users/fiona/Downloads/TNO-2016-R10449%20(1).pdf		
TR2	44 tonne truck with 28 tonne payload			
	880	gco2/km for 44 tonne truck		
	17858	trucks needed in total		
	30	km trip		
	471451200	gco2 emitted per year		
	471451,2	kg co2 emitted per year		
TR1	18 tonne truck with 10 tonne payload			
	360	gco2/km for 18 tonne truck		
	53605	trucks needed in total		
	30	km round trip		
	578934000	gco2 emitted per year		
	578934	kg co2 emitted per year		
	578,934	ton co2/yr		
Co2 emissions reduction by using transport company:				
TR2-TR1	-107482,8	kg co2 emitted per year		

PR1 or PR2	pricing --> no influence on CO2 emissions because ships need to use certain amount of biofuel bc of regulations

	Scenario 2					
	social	social impact	see comments			
economics	Pricing	COP price				
	Transport	TR1: transport done by primary mill is free				
		TR2: transport done by transport company needs to be paid for				
km/yr			16,511	Mil euros/yr		
	Biochar	off-gas supplies enough energy to heat the HTL process				
		biochar does not need to be burned and is a by-product that can be sold.				
		100	euro/ton biochar?		biochar price of $280 ($2,512) per metric ton.	https://link.springer.com/article/10.1007/s10668-023-03984-6
		15250000	euro/yr profit from sales biochar		Biochar prices are after all varying over a wide range between 50 and more than 20,000 €/tonne	https://www.sciencedirect.com/science/article/pii/S0960852420313559
		15,25	M eur/yr profit biochar			
Environment	BC1 or BC2	off-gas supplies enough energy to heat the HTL process				
		biochar does not need to be burned --> only off-gas is burned to generate heat				
		Small amount of excess electricity is produced --> off-gas will be burned off in both cases				
	BC1	Still burning biochar to generate excess electricity				
Co2 sequestering		3000	kgco2 seqestered/ton biochar			
		151900	ton biochar/yr			
		455700000	kg co2 sequestered/yr			
		455700	ton co2/yr			
transport biochar						
		5425	trucks	max truck size is 44 tonne truck	https://coloradosun.com/2023/04/07/biochar-carbon-capture-climate-change/#:~:text=How%20much%20carbon%20is%20locked,of%20scientists%20combating%20climate%20change.	

			with payload of 28 tonnes
	5425	trucks	
	40,9	km between primary mill and ubeda	
	221882,5	km per year	
	195256600	gco2/yr	
	195256,6	kgco2/yr	
	195,2566	ton co2/yr on biochar transport	
	455504,7434	sequestering - transport co2 emissions	

environment	pricing	no effect		
	Transport	TR1	4729145,3	km/yr see "distances crude scenarios master" excel
			360	gco2/km for 18 tonne truck
			1702492308	gco2/yr
			1702492,308	kg co2/yr
			1702,492308	ton co2/yr
		TR2	880	gco2/km for 44 tonne truck (can transport 28 tonnes)
			1269572,927	tonnes total/yr
			45341,89024	trucks needed per year
			40,9	km between primary mill and ubeda
			1854483,311	km per year
			1631945314	gco2/yr
			1631945,314	kg co2/yr
			1631,945314	ton co2/yr
		TR2-TR1	-70,54699437	ton co2/yr saved by using transport company

Appendix D

Financial analysis scenario 1, 2 and 3.

Table 12: Financial analysis scenario 1 with COP price of 25€/ton.

Fixed Capital Investments, including	M EUR	176,8
Direct Capital Costs, including	**M EUR**	*108,3*
Total Purchased Equipment Cost	**M EUR**	**43,3**
of which, Feedstock Handling & Prep	**M EUR**	0,0
of which, Oil Production	**M EUR**	26,5
of which, hydrotreatment	**M EUR**	0,0
of which, Cogeneration	**M EUR**	16,8
Installation Costs	**M EUR**	**65,0**
Indirect Costs	**M EUR**	*36,8*
Contractor's Fee	**M EUR**	*10,0*
Contingency	**M EUR**	*21,7*
Working Capital	**M EUR**	**8,4**
Start-up Costs	**M EUR**	**17,68**
TOTAL CAPITAL INVESTMENT	**M EUR**	***202,9***
LOCATION ADJUSTED CAPEX	**M EUR**	***182,6***
Direct Production Costs, including		**34,3**
Variable costs	*M EUR/year*	*17,6*
of which, feedstock	M EUR/year	11,4
of which, hydrogen	M EUR/year	0,0
of which, wastewater treatment	M EUR/year	0,2
of which, gas cleaning	M EUR/year	4,3
of which, ash disposal	M EUR/year	1,55
of which, catalysts	M EUR/year	0,00
of which, natural gas	M EUR/year	0,0
of which, water	M EUR/year	0,0
Labor Related Costs	*M EUR/year*	*0,86*
of which, direct wage and benefits	M EUR/year	0,58
of which, supervision, supplies, assistance	M EUR/year	0,29
Maintenance	*M EUR/year*	*15,9*
Plant Overhead	**M EUR/year**	**0,6**
Contingency	**M EUR/year**	**6,9**
Fixed Charges, including	**M EUR/year**	**31,4**
Local Taxes	*M EUR/year*	*2,4*
Insurance	*M EUR/year*	*2,2*
Depreciation	*M EUR/year*	*26,8*
Total General Expenses	**M EUR/year**	**4,2**
TOTAL OPERATING COSTS (Annual)	***M EUR/YEAR***	***77,4***
Annual Salues Revenue	**M EUR/year**	**42,0**
of which Biocrude	M EUR/year	40,7
of which biochar	M EUR/year	0,0
of which Electricity	M EUR/year	0,1
Gross Profit	**M EUR/year**	**24,4**
Earninngs Before Tax	**M EUR/year**	**-35,5**
Minimum Fuel Selling Price	**EUR/ton**	**1217,2**
MFSP: VLSFO Price Ratio		1,901900253
MFSP: MGO Price Ratio		1,360018058

Table 13: Financial analysis scenario 2 with COP price of 25€/ton.

Fixed Capital Investments, including	M EUR	318,2
Direct Capital Costs, including	**M EUR**	*195,0*
Total Purchased Equipment Cost	**M EUR**	**78,0**
of which, Feedstock Handling & Prep	**M EUR**	0,0
of which, Oil Production	**M EUR**	45,8
of which, hydrotreatment	**M EUR**	0,0
of which, Cogeneration	**M EUR**	32,2
Installation Costs	**M EUR**	**117,0**
Indirect Costs	**M EUR**	*66,3*

Contractor's Fee	**M EUR**	*17,9*
Contingency	**M EUR**	*39,0*
Working Capital	**M EUR**	**23,8**
Start-up Costs	**M EUR**	**31,82**
TOTAL CAPITAL INVESTMENT	**M EUR**	***373,8***
LOCATION ADJUSTED CAPEX	**M EUR**	***336,4***
Direct Production Costs, including		**64,7**
Variable costs	*M EUR/year*	*35,2*
of which, feedstock	M EUR/year	29,1
of which, hydrogen	M EUR/year	0,0
of which, wastewater treatment	M EUR/year	0,2
of which, gas cleaning	M EUR/year	4,3
of which, ash disposal	M EUR/year	1,55
of which, catalysts	M EUR/year	0,00
of which, natural gas	M EUR/year	0,0
of which, water	M EUR/year	0,0
Labor Related Costs	*M EUR/year*	*0,86*
of which, direct wage and benefits	M EUR/year	0,58
of which, supervision, supplies, assistance	M EUR/year	0,29
Maintenance	*M EUR/year*	*28,6*
Plant Overhead	**M EUR/year**	**0,6**
Contingency	**M EUR/year**	**12,9**
Fixed Charges, including	**M EUR/year**	**57,7**
Local Taxes	*M EUR/year*	*4,3*
Insurance	*M EUR/year*	*4,0*
Depreciation	*M EUR/year*	*49,4*
Total General Expenses	**M EUR/year**	**11,9**
TOTAL OPERATING COSTS (Annual)	***M EUR/YEAR***	***147,8***
Annual Salues Revenue	**M EUR/year**	**118,8**
of which Biocrude	M EUR/year	103,3
of which biochar	M EUR/year	15,3
of which Electricity	M EUR/year	0,2
Gross Profit	**M EUR/year**	**83,6**
Earninngs Before Tax	**M EUR/year**	**-29,0**
Minimum Fuel Selling Price	**EUR/ton**	**914,6**
MFSP: VLSFO Price Ratio		1,429122537
MFSP:MGO price ratio		1,021942373

Table 14: Financial analysis scenario 3 with COP price of 25€/ton.

Fixed Capital Investments, including	M EUR	367,5
Direct Capital Costs, including	**M EUR**	*225,2*
Total Purchased Equipment Cost	**M EUR**	**90,1**
of which, Feedstock Handling & Prep	**M EUR**	0,0
of which, Oil Production	**M EUR**	45,8
of which, hydrotreatment	**M EUR**	12,1
of which, Cogeneration	**M EUR**	32,2
Installation Costs	**M EUR**	**135,1**
Indirect Costs	**M EUR**	*76,6*
Contractor's Fee	**M EUR**	*20,7*
Contingency	**M EUR**	*45,0*
Working Capital	**M EUR**	**26,9**
Start-up Costs	**M EUR**	**36,75**
TOTAL CAPITAL INVESTMENT	**M EUR**	***431,1***
LOCATION ADJUSTED CAPEX	**M EUR**	***388,0***
Direct Production Costs, including		**75,0**
Variable costs	*M EUR/year*	*41,1*
of which, feedstock	M EUR/year	29,1
of which, hydrogen	M EUR/year	0,0
of which, wastewater treatment	M EUR/year	0,2
of which, gas cleaning	M EUR/year	4,3
of which, ash disposal	M EUR/year	1,55
of which, catalysts	M EUR/year	5,89
of which, natural gas	M EUR/year	0,0
of which, water	M EUR/year	0,0
Labor Related Costs	*M EUR/year*	*0,86*

of which, direct wage and benefits	M EUR/year	0,58
of which, supervision, supplies, assistance	M EUR/year	0,29
Maintenance	*M EUR/year*	*33,1*
Plant Overhead	**M EUR/year**	**0,6**
Contingency	**M EUR/year**	**15,0**
Fixed Charges, including	**M EUR/year**	**61,8**
Local Taxes	*M EUR/year*	*5,0*
Insurance	*M EUR/year*	*3,3*
Depreciation	*M EUR/year*	*53,6*
Total General Expenses	**M EUR/year**	**13,5**
TOTAL OPERATING COSTS (Annual)	***M EUR/YEAR***	***166,0***
Annual Salues Revenue	**M EUR/year**	**134,5**
of which Biofuel	M EUR/year	134,3
of which biochar	M EUR/year	0,0
of which Electricity	M EUR/year	0,2
Gross Profit	**M EUR/year**	**93,4**
Earninngs Before Tax	**M EUR/year**	**-31,4**
Minimum Fuel Selling Price	**EUR/ton**	**1104,6**
MFSP: MGO Price Ratio		1,23414109

Appendix E.1

More detailed Economic, Environmental Life Cycle and Social Stakeholder Business Model Canvasses for scenario 1.

Business Model Canvas Scenario 1 - Economic - Farmers

Key partners
Key direct partners of the farmers are the primary mill, the cooperative buying the olives and the municipality for managing the needed infrastructure, such as water for irrigation. For many farmers a key financial partner is the EU due to the CAP (Common Agricultural Policy) grant given to olive farmers based on their productivity. Since the biochar produced by the secondary mill is not burned, a new key partner is the secondary mill HTL biorefinery supplying the cooperatives with biochar, which the farmers can use as soil amendment

Key activities
The farmers in Jaén produce olives, which are brought to a close-by primary mill, where the produced olive oil is sold in bulk. The pruning residues are chipped and sold or used as ground cover. During the HTL process the by-product biochar can be recycled and transported back to the olive farmers to be used as soil amendment to counter soil erosion and improve water retention.

Key resources
The farmers often irrigate their olive groves; therefore, water is a natural key resource for the farmers. During the 3-month harvest period family and seasonal (migrant) workers are needed to collect the olives. Olive groves in flat areas need machinery to chip the pruning waste so it can be used as ground cover sold locally or to a biomass electricity plant. Further, fertilizer and biochar soil amendment from the HTL biorefinery is needed due to soil erosion.

Value proposition
Efficient harvesting of the olives by the farmers to ensure good quality olive oil at a competitive price. A by-product of olive oil is Crude Olive Pomace (COP), which is used to produce biocrude at a secondary mill. This biocrude is upgraded tothe valuable product maritime biofuel. Therefore, the farmer-owned primary mills now get 50€/ton COP instead of 0-8€/ton COP, ensuring the farmers get a fair revenue for their production of olives to live off and innovate. The bunkering companies at the port of Gibraltar and the shipping companies need environmentally and socially sustainably made biofuel due to EU and IMO regulations. Recycling the biochar as soil amendment satisfies the want for an inclusive and environmentally sustainable value chain by the end-users.

Customer relationships
Since the farmers sell their olives exclusively to a primary mill owned by cooperatives, customer relationships are essential. Since the farmers lead the cooperatives themselves, this customer relationship is very familiar and aimed at the farmer's best interests.

Channels
The olives are delivered by the farmers by truck to the primary mill, as done in the original value chain. After chipping, when the olive tree pruning is not used locally or as ground cover. it is brought to biomass electricity plants within a 30km radius by biomass transport companies. The biochar produced by the secondary mill HTL biorefinery is transported by the primary mills by truck to the primary mills for storage. The farmers then organize their own biochar transport to collect it.

Customer segments
The customer of the farmers is the primary mill, owned by a farmer-led cooperative. They want to receive timely deliveries of consistent quality olives as soon as possible after harvest. The farmers have just one customer segment, the primary mill. The primary mill is supplied with olives by multiple farmers, however. Therefore, the farmers should make sure to keep good relations with the primary mill as they are dependent on them for the olive oil production and sale.

Cost Structure
The Farmers need to pay for fertiliser and the municipality for irrigation water. The costs of these raw materials, staff, machinery and financial costs such as working capital, insurance and service fees are the most important costs. Biochar is used next to fertilizer by around 1100 farmers to combat soil erosion. It costs the farmers around 30 cents to produce and harvest a kilo of olives currently, excluding biochar costs. A price of 100 €/ton is used in this value chain and could be lowered by selling carbon credits.

Revenue Streams
The farmers earn a profit on the sale of their olives. Additional income for many farmers comes from the EU's CAP grant of 5000 €/yr on average. The average extra virgin olive oil price in Jaén can be as low as 2000 €/ton or as high as 4500 €/ton. On average a farmers earns 5700 €/yr selling olives with an olive grove of 3.5 ha. The farmer-owned primary mills earn 50 €/ton COP, which translates to 625 euro/yr additional income per farmer, without taking into account COP transport costs.

Figure 25: Economic BMC Scenario 1 farmers. Business Model Canvas of scenario 1 from the farmer's perspective.

Business Model Canvas Scenario 1 - Economic - Primary Mill

Key partners
Key direct partners of the primary mill are the farmers supplying the olives, the companies buying virgin olive oil in bulk, the cooperatives which own the primary mills and the secondary mill HTL biorefinery buying their by-product COP to make biocrude and supplying the primary mills with biochar. Another key partner of the primary mills is the municipality for managing the needed infrastructure, such as the water and power needed for the three-phase decanter. In the current value chain COP transport is done by the primary mills themselves.

Key activities
The primary mills use olives to produce virgin olive oil (20 wt%) using a three-phase decanter system and the by-product COP (80 wt%). The virgin olive oil is sold in bulk by the cooperatives who own the primary mills, while the COP is brought to a secondary mill with HTL technology by the primary mills themselves where it is converted into biocrude.

Key resources
Olives, water and heat are natural key resources needed for the production of virgin olive oil for the primary mills. Furthermore, storage, offices, working capital and social resources along with intellectual property such as rules and standards are needed. Since the primary mills deliver COP to the HTL biorefinery at the secondary mill, they also need trucks as a key resource.

Value proposition
The primary mills sell virgin olive oil in bulk to companies who package and sell it. Their by-product COP is sold and brought to a HTL biorefinery secondary mill. The aim of the primary mill is efficient production of high-quality virgin olive oil and the by-product COP at a competitive price as part of an inclusive and environmentally sustainable value chain. The sales of olive oil and COP give sufficient revenues to live off and innovate for farmers and the primary mills. The bunkering companies at the port of Gibraltar and the shipping companies need environmentally and socially sustainably made biofuel due to EU and IMO regulations.

Customer relationships
The primary mills have a pre-existing customer relationship with the secondary mills, as in the previous value chain they transported and sold their waste stream of COP for 0-8€/ton to the secondary mills. In the new value chain, the secondary mills need to pay 50€/ton for the COP, which means this new customer relationship should be carefully managed.

Channels
The feedstock olives are delivered by the farmers by truck to the primary mill, as done in the original value chain. The primary mills stay responsible for transporting the product COP to the secondary mills by truck.

Customer segments
The primary mills have two customer segments: one generates the most profits and consists of the companies buying olive oil in bulk to package and sell it. The other consists of the secondary mills paying for the by-product of olive oil production, COP, to make biocrude out of it. By increasing COP price to 50€/ton an additional revenue is made from selling COP, where it used to cost primary mills money deliver COP to the secondary mills.

Cost Structure
On average it costs 2.75€ to produce 1kg of olive oil in Spain. The main cost of the primary mill is buying the olives at 3-3.5 €/kg from the farmers. The primary mill needs to pay the municipality for the water needed to produce olive oil. The costs of these raw materials, (seasonal) staff, machinery and financial costs such as working capital, insurance and service fees are the most important costs.

Revenue Streams
The primary mill's main profit comes from selling virgin olive oil in bulk, for a price between 2000 and 4500 €/ton. Additional income will come from selling COP for 50€/ton to the secondary mills. This price is based on maintaining an acceptable minimum biofuel selling price, while increasing the farmer's profits. A good harvest means a high amount of olive oil can be made, which drives the olive and olive oil prices down. These prices are set in yearly contracts based on the olive harvest, while COP price is fixed.

Figure 26: Economic BMC Scenario 1 primary mill. Business Model Canvas of scenario 1 from the primary mill's perspective.

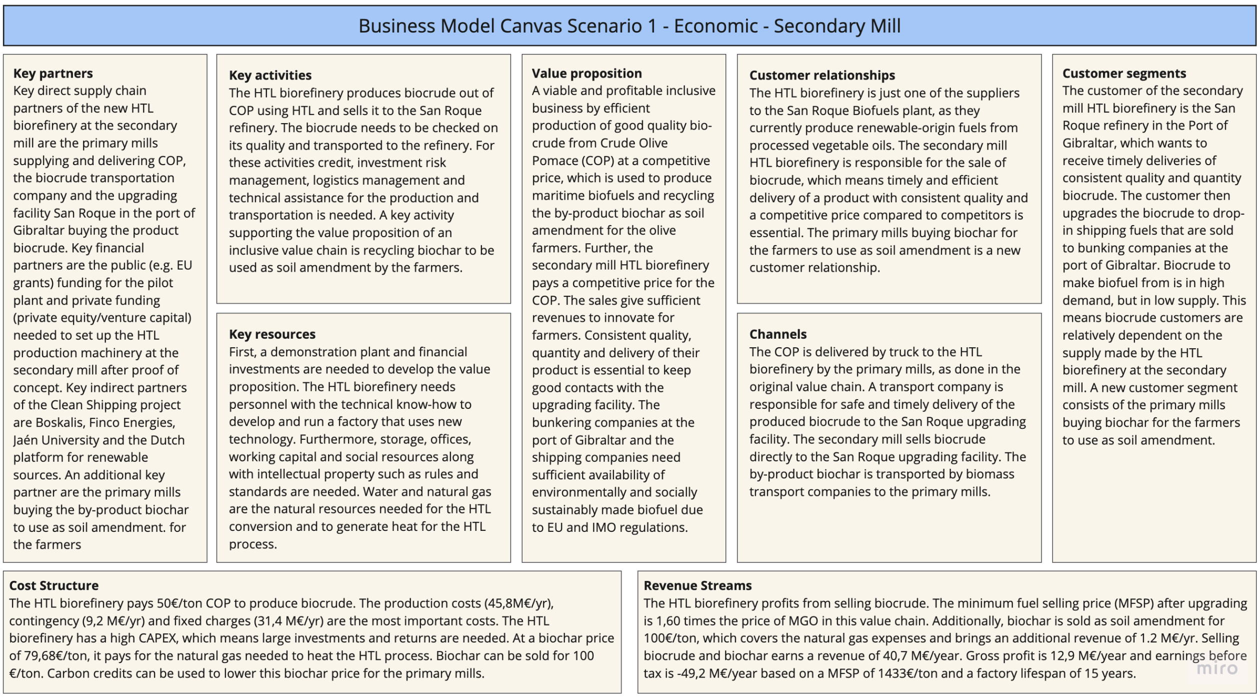

Figure 27: Economic BMC Scenario 1 secondary mill. Business Model Canvas of scenario 1 from the secondary mill's perspective.

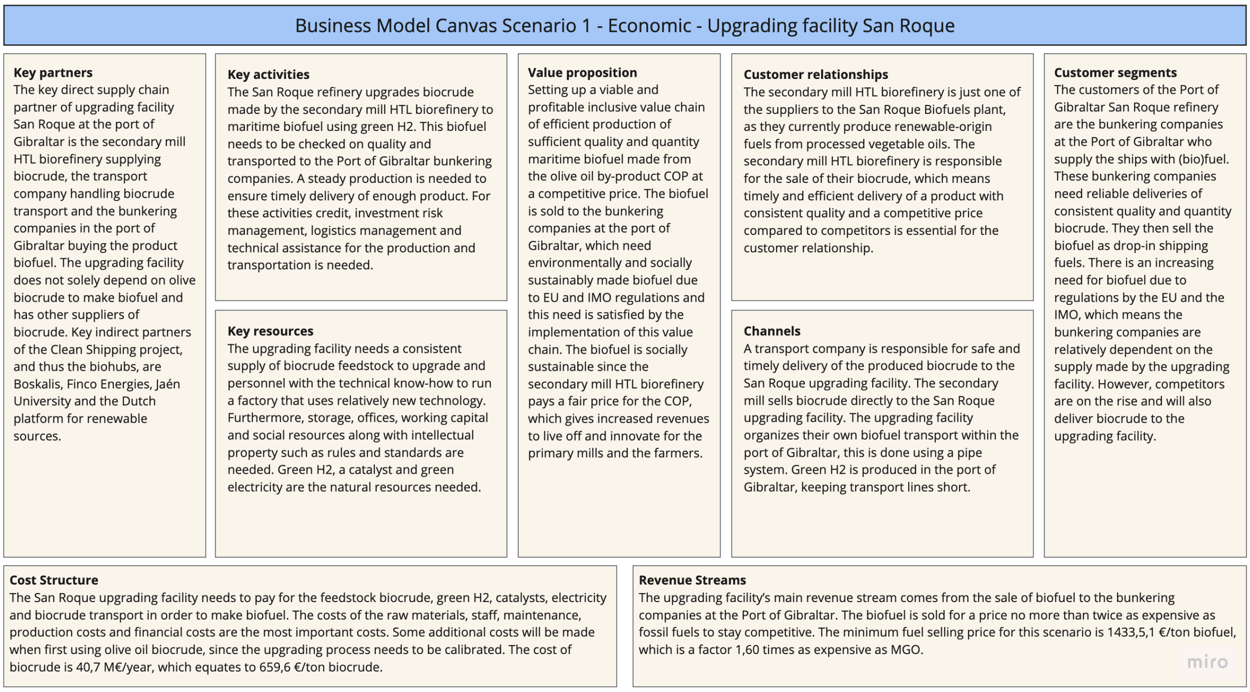

Figure 28: Economic BMC Scenario 1 Upgrading facility San Roque. Business Model Canvas of scenario 1 from the upgrading facility's perspective.

Business Model Canvas Scenario 1 - Environmental Life Cycle

Supplies and outsourcing
The main environmental impact of the production of feedstocks in the value chain is due to truck transport of olives, COP and biocrude, alongside the heat needed for the HTL process in the secondary mill. This is generated by burning natural gas, since the biochar is recycled as soil amendment. The production of olives, COP and biocrude uses municipal electricity and water. The green H2 needed for the upgrading process is produced in the Port of Gibraltar and transported by pipeline to the upgrading facility in San Roque, saving truck carbon emissions.

Production
The secondary mill HTL biorefinery produces biocrude by heating and pressurizing COP. The electricity needed to pressurize the COP comes from renewable sources. The heat needed for the HTL process is generated by burning the off-gas and natural gas, since biochar is used as soil amendment instead of used to heat the HTL process. The carbon emissions from burning natural gas and biochar transport is 165 KT CO2 less than burning biochar due to the effects of carbon sequestering in biochar.

Materials
Since the biofuel is made from a residue of the olive oil production, this is a sustainable resource with a net zero carbon footprint, except for transport and the production process. Even though a feedstock with high water content is used, additional water is needed for the HTL process, of which 75% can be re-used. Further, catalysts are used to make the HTL and upgrading processes more efficient, reducing environmental impact. However, they often contain heavy metals and should be disposed of correctly.

Functional Value
The functional value of the end-product biofuel is a drop-in marine shipping fuel that can be mixed with fossil fuels at sufficient percentages (which go up in time due to EU and IMO CO2 emission regulations) and at competitive prices compared to other biofuels. Since an olive oil residue, COP, is used to produce biocrude and subsequently biofuel, the biofuel feedstock is carbon neutral except for transport and the production process. This gives the shipping companies a high-quality biofuel they can mix with fossil fuels.

End-of-Life
During the HTL process 25% of the used water is purged, while 75% is recycled in the process. The by-product biochar is transported to the cooperatives, to be used as soil amendment by the olive farmers. The produced off-gas is used to generate heat for the process. During the upgrading process a small amount of water and negligible amounts of H2S and NH3 are produced due to the reaction of the oxygen atoms with the hydrogen. These by-products are purged.

Distribution
olives, COP and biocrude need to be delivered to the primary mill, secondary mill HTL biorefinery and upgrading facilities respectively, by truck. COP is produced at 87 primary mills in Jaén, of which 17 primary mills within a 30 km radius deliver to the secondary mill HTL biorefinery. The further a lower in density product needs to be transported, the more CO2 emissions are made. By producing biocrude at secondary mills the lower in usable weight COP needs to travel the least distance, generating the least carbon emissions.

Use phase
The final product in the value chain is biofuel. Biocrude is used to produce biofuel through upgrading. For this, green H2 is needed. This is produced in Andalusia through electrolysis powered on renewable energy such as wind or solar enegy. This process also consumes renewable energy. The biofuel is used to power large ships that mix biofuel with fossil fuels with percentages set by the IMO and the EU. The emission of CO2 from the biofuel made from olive residues should be net zero. However, truck transport is unlikely to be fueled by biofuels or electrified, which means transport of the product in each of the value chain steps will emit CO2. Further, natural gas is used to heat the HTL process.

Environmental impacts
The conversion processes and transport are the most polluting factors in the value chain. When the biochar is sold and used as soil amendment by farmers, this contributes to combating soil erosion. The carbon emissions from burning natural gas instead of biochar and biochar transport is 165 KT CO2 less than burning biochar due to the effects of carbon sequestering in biochar. These conversion carbon, nitrogen and particulate matter emissions and waste water disposal are all local environmental effects.

Environmental benefits
Biofuel is made out of an olive residue, which would otherwise have been chemically treated and sold as the low-quality product olive pomace oil. By using different catalysts during the HTL and upgrading processes, higher quality biocrude and biofuel may be produced, but this may result in a lower yield and thus generating more by-products. Environmental impact can be reduced by limiting transportation, efficient production, recycling and using different techniques or catalysts.

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Figure 29: Environmental Life Cycle BMC Scenario 1.

Business Model Canvas Scenario 1 - Social stakeholders

Local communities
The secondary mill HTL biorefinery is located in rural Jaén, next to olive grove fields and a nature reserve. In the current value chain the community surrounding the secondary industry experience hinder due to the smell of the open pond storage of COP. By closing off the ponds to keep the water content high, which means less water needs to be added to the HTL process, this hinder will disappear. The local communities of the farmers in Jaén will be positively impacted by the new value chain through increased income due to increased COP price. Biocrude production at a secondary mill benefits the surrounding communities by new job opportunities in biocrude transport and working in the secondary mill.

Governance
The secondary mill HTL biorefinery is a private company, which formerly produced pomace olive oil. The secondary mills are relatively small and are not governed in a very hierarchical manner. The company should be highly transparent through public reports that present economic, environmental and social performance.

Employees
Due to the higher price of COP in the new value chain, the employees of the primary and secondary mills can earn a higher wage and those working in the HTL biorefinery secondary mill become more educated using new technology. Biocrude transport will also impact job opportunities in Jaén. COP transport will be done by the primary mills themselves, instead of by a transport company. This is less efficient, but means truck drivers will not lose their jobs.

Social Value
The bunkering companies at the port of Gibraltar want environmentally and socially sustainably made biofuel due to EU and IMO regulations for carbon emissions. Companies that need to transport their products, such as Amazon want to offer their customers green shipping as a social value. The secondary mill HTL biorefinery pays a competitive price for the COP to give sufficient revenues to live off and innovate for the primary mills and farmers, so the company can contribute to the production of socially sustainable as well as environmentally sustainable, biofuel.

Societal Culture
The biohub supports a communal culture, by supporting the cooperatives and thus the farmers by improving their profits. By working together, benefits and risks are more equitably distributed. The use of biofuel results in a societal culture more focused on lowering carbon emissions. The societal culture of the communities surrounding the secondary mills benefit from implementing the HTL technology in the way of well-paid, interesting jobs and industry in the area.

Scale of Outreach
The introduction of the biohub means the scale of outreach is not only large in distance (from the entire province of Jaén to the port of Gibraltar), but also in depth. This is done through educational programs and social and monetary benefits for the farmers and primary mills. Further, the value chain adds to the availability of socially and environmentally sustainably made biofuel that the global shipping industry can use.

End-user
The final product in the value chain is biofuel. The end-users of this biofuel are the shipping companies buying biofuel from bunkering companies. These end-users need to comply to EU and IMO carbon emission regulations and are required to mix their fossil fuel with biofuel with yearly increasing amounts and are able to offer their clients a greener way of shipping. Clients that want to reduce their climate impact will experience improved quality of life by having their products shipped in both an environmentally and socially sustainable manner.

Social impacts
By buying COP to produce biocrude for 50 €/ton, instead of the 0-8 €/ton the secondary industry is currently paying, the secondary industry will have the incentive to increase COP price. The current secondary industry will lose profit and jobs may be lost in this sector. Further, introducing industrial processes in a local area will increase truck transport and have negative environmental effects, which will impact the local community.

Social benefits
The biohub is part of an inclusive value chain, which means it is focused on improving the lives of the farmers as well as their profits and the environment. The biohub will also focus on providing social benefits for the cooperatives themselves in the form of advice, technical know-how and the ability to invest in new techniques. The new value chain has a positive social impact due to increased well-paying job opportunities and adding industry to the rural area increasing rural development.

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Figure 30: Social stakeholders BMC Scenario 1.

Appendix E.2

More detailed Economic, Environmental Life Cycle and Social Stakeholder Business Model Canvasses for scenario 2.

Business Model Canvas Scenario 2 - Economic - Farmers

Key partners
Key direct partners of the farmers are the primary mill, the cooperative buying the olives and the municipality for managing the needed infrastructure, such as water for irrigation. For many farmers a key financial partner is the EU due to the CAP (Common Agricultural Policy) grant given to olive farmers based on their productivity. Since the biochar produced by the secondary mill is not burned, a new key partner is the new centralised HTL biorefinery supplying the cooperatives with biochar, which the farmers can use as soil amendment

Key activities
The farmers in Jaén produce olives, which are brought to a close-by primary mill, where the produced olive oil is sold in bulk. During the HTL process the by-product biochar can be recycled and transported back to the olive farmers to be used as soil amendment to counter soil erosion and improve water retention, instead of being burned to generate heat for the HTL process. The pruning residues are chipped and sold or used as ground cover.

Key resources
The farmers often need irrigation for their olive groves; therefore, water is a natural key resource for the farmers. Further, fertilizer and biochar soil amendment from the HTL biorefinery is needed due to soil erosion. During the 3-month harvest period family and seasonal (migrant) workers are needed to collect the olives. Olive groves in flat areas need machinery to chip the pruning waste so it can be used as ground cover or transported off the fields and sold locally or to a biomass electricity plant.

Key propositions
Efficient harvesting of the olives by the farmers to ensure good quality olive oil at a competitive price. A by-product of olive oil is Crude Olive Pomace (COP), which is used to produce biocrude at a new centralised HTL biorefinery This biocrude is upgraded to the valuable product maritime biofuel. Therefore, the farmer-owned primary mills now get 100€/ton COP instead of 0-8€/ton COP, ensuring the farmers get a fair revenue for their production of olives to live off and innovate. The bunkering companies at the port of Gibraltar and the shipping companies need environmentally and socially sustainably made biofuel due to EU and IMO regulations. Recycling the biochar to be used as soil amendment satisfies the need for an inclusive and environmentally

Customer relationships
Since the farmers sell their olives exclusively to a primary mill owned by cooperatives, customer relationships are essential. Since the farmers lead the cooperatives themselves, this customer relationship is very familiar and aimed at the farmer's best interests.

Channels
The olives are delivered by the farmers by truck to the primary mill, as done in the original value chain. After chipping, when the olive tree pruning is not used locally or as ground cover. it is brought to biomass electricity plants within a 30km radius by biomass transport companies. The biochar produced by the centralised HTL biorefinery is transported by the primary mills by truck to the primary mills for storage. The farmers then organize their own biochar transport to collect it.

Customer segments
The customer of the farmers is the primary mill, owned by a farmer-led cooperative. They want to receive timely deliveries of consistent quality olives as soon as possible after harvest. The farmers have just one customer segment, the primary mill. The primary mill is supplied with olives by multiple farmers, however. Therefore, the farmers should make sure to keep good relations with the primary mill as they are dependent on them for the olive oil production and sale.

Cost Structure
The Farmers need to pay the municipality for irrigation water and fertiliser. The costs of these raw materials, staff, machinery and financial costs such as working capital, insurance and service fees are the most important costs. Biochar is used next to fertilizer by around 2900 farmers to combat soil erosion. It costs the farmers around 30 cents to produce and harvest a kilo of olives currently, excluding biochar. A price of 100 €/ton is used in this value chain and could be lowered by selling carbon credits.

Revenue Streams
The farmers earn a profit on the sale of their olives, based on the harvest. Additional income for many farmers comes from the EU's CAP grant. The average extra virgin olive oil price in Jaén can be as low as 2000 €/ton or as high as 4500 €/ton. On average a farmers earns 5700 €/yr selling olives with an olive grove of 3.5 ha, while the CAP grant earns them an additional 5000 €/yr. The farmer-owned primary mills earn 100 €/ton COP, which translates to 1250 €/yr additional income per farmer.

Figure 31: Economic BMC Scenario 2 farmers. Business Model Canvas of scenario 1 from the farmer's perspective.

Business Model Canvas Scenario 2 - Economic - Primary Mill

Key partners
Key direct partners of the primary mill are the farmers supplying the olives, the companies buying virgin olive oil in bulk, the cooperatives which own the primary mills and the centralised HTL biorefinery buying their by-product COP to make biocrude and supplying the primary mills with biochar. Another key partner of the primary mills is the municipality for managing the needed infrastructure, such as the water and power needed for the three-phase decanter. In the current value chain COP transport is done by the primary mills themselves.

Key activities
The primary mills use olives to produce virgin olive oil (20 wt%) using a three-phase decanter system and the by-product COP (80 wt%). The virgin olive oil is sold in bulk by the cooperatives who own the primary mills, while the COP is brought to a centralised HTL biorefinery by the primary mills themselves where COP is converted into biocrude.

Key resources
Olives, water and heat are natural key resources needed for the production of virgin olive oil for the primary mills. Furthermore, storage, offices, working capital and social resources along with intellectual property such as rules and standards are needed. Since the primary mills deliver COP to the HTL biorefinery, they also need trucks as a key resource.

Key propositions
The primary mills sell virgin olive oil in bulk to companies who package and sell it. Their by-product COP is sold and brought to a new centralised HTL biorefinery in Úbeda. The aim of the primary mill is efficient production of high-quality virgin olive oil and the by-product COP at a competitive price as part of an inclusive and environmentally sustainable value chain. The sales of olive oil and COP give sufficient revenues to live off and innovate for farmers and the primary mills. The bunkering companies at the port of Gibraltar and the shipping companies need environmentally and socially sustainably made biofuel due to EU and IMO regulations. This biofuel can be made and supplied by the production of COP, which can be used to produce biocrude, out of which biofuel is made.

Customer relationships
The primary mills have a pre-existing customer relationship with the secondary mills, as in the previous value chain they transported and sold their waste stream of COP for 0-8€/ton to the secondary mills. In the new value chain, the secondary mills pay 100€/ton for the COP, which means this new customer relationship should be carefully managed.

Channels
The feedstock olives are delivered by the farmers by truck to the primary mill, as done in the original value chain. The primary mills stay responsible for transporting the by-product COP, but now deliver to the new centralised HTL biorefinery, instead of the relatively close-by secondary mills.

Customer segments
The primary mills have two customer segments: one generates the most profits and consists of the companies buying olive oil in bulk to package and sell it. The other consists of the secondary mills paying for the by-product of olive oil production, COP, to make biocrude out of it. By increasing COP price to 100€/ton an additional revenue is made from selling COP, where it used to cost primary mills money deliver COP to the secondary mills.

Cost Structure
On average it costs 2.75€ to produce 1kg of olive oil in Spain. The main cost of the primary mill is buying the olives at 3-3.5 €/kg from the farmers. The primary mill needs to pay the municipality for the water needed to produce olive oil. The costs of these raw materials, (seasonal) staff, machinery and financial costs such as working capital, insurance and service fees are the most important costs.

Revenue Streams
The primary mill's main profit comes from selling virgin olive oil in bulk, for a price between 2000 and 4500 €/ton. Additional income will come from selling COP for 100€/ton to the secondary mills. This price is based on maintaining an acceptable minimum biofuel selling price, while increasing the farmer's profits. A good harvest means a high amount of olive oil can be made, which drives the olive and olive oil prices down. These prices are set in yearly contracts based on the olive harvest, while COP price is fixed.

Figure 32: Economic BMC Scenario 2 primary mill. Business Model Canvas of scenario 1 from the primary mill's perspective.

Business Model Canvas Scenario 2 - Economic - HTL biorefinery

Key partners
Key direct supply chain partners of the new HTL biorefinery are the primary mills supplying and delivering COP, the biocrude transportation company and the upgrading facility San Roque in the port of Gibraltar buying the product: biocrude. Key financial partners are the public (e.g. EU grants) funding for the pilot plant and private funding (private equity/venture capital) needed to set up the HTL biorefinery after proof of concept. Key indirect partners of the Clean Shipping project are Boskalis, Finco Energies, Jaén University and the Dutch platform for renewable sources. An additional key partner are the primary mills buying the by-product biochar to use as soil amendment for the farmers

Key activities
The centralised HTL biorefinery produces biocrude out of COP using HTL and sells it to the San Roque refinery. The biocrude needs to be checked on its quality and transported to the refinery. For these activities credit, investment risk management, logistics management and technical assistance for the production and transportation is needed. A key activity supporting the value proposition of an inclusive value chain is recycling biochar to be used as soil amendment by the farmers.

Key resources
First, a demonstration plant and financial investments are needed to develop the value proposition. The HTL biorefinery needs personnel with the technical know-how to develop and run a factory that uses new technology. Furthermore, storage, offices, working capital and social resources along with intellectual property such as rules and standards are needed. Water is the natural resource needed for the HTL conversion, the heat for the HTL process is generated by burning the off-gas.

Key propositions
A viable and profitable inclusive business by efficient production of good quality bio-crude from Crude Olive Pomace (COP) at a competitive price, which is used to produce maritime biofuels and recycling the by-product biochar as soil amendment for the olive farmers. Further, the secondary mill HTL biorefinery pays a competitive price for the COP. The sales give sufficient revenues to innovate for farmers. Further, consistent quality, quantity and delivery of biocrude is essential to keep good contacts with the upgrading facility. The bunkering companies at the port of Gibraltar and the shipping companies need sufficient availability of environmentally and socially sustainably made biofuel due to EU and IMO regulations.

Customer relationships
The HTL biorefinery is just one of the suppliers to the San Roque Biofuels plant, as they currently produce renewable-origin fuels from processed vegetable oils. The HTL biorefinery is responsible for the sale of biocrude, which means timely and efficient delivery of a product with consistent quality and a competitive price compared to competitors is essential. The primary mills buying biochar for the farmers to use as soil amendment is a new customer relationship.

Channels
The COP is delivered by truck to the HTL biorefinery by the primary mills, as done in the original value chain. A transport company is responsible for safe and timely delivery of the produced biocrude to the San Roque upgrading facility. The secondary mill sells biocrude directly to the San Roque upgrading facility. The by-product biochar is transported by biomass transport companies to the primary mills. As 51 out of 87 primary mills in Jaén need to supply sufficient COP to the HTL biorefinery, maintaining supplier relationships is essential.

Customer segments
The customer of the new centralised HTL biorefinery is the San Roque refinery in the Port of Gibraltar, which wants to receive timely deliveries of consistent quality and quantity biocrude. The customer then upgrades the biocrude to drop-in shipping fuels that are sold to bunking companies at the port of Gibraltar. Biocrude to make biofuel from is in high demand, but in low supply. This means biocrude customers are relatively dependent on the supply made by the HTL biorefinery. A new customer segment consists of the primary mills buying biochar for the farmers to use as soil amendment.

Cost Structure
The HTL biorefinery pays 75€/ton COP to produce biocrude. The production costs (122,9 M€/yr), contingency (24,6 M€/yr) and fixed charges (57,3 M€/yr) are the most important costs. The HTL biorefinery has a high CAPEX, which means large investments and returns. The off-gas is capable of generating enough heat for the HTL process, no natural gas needs to be bought. The biochar is sold for 100€/ton biochar. Carbon credits can be used to lower this biochar price for the primary mills.

Revenue Streams
The HTL biorefinery profits from the sales price of the produced biocrude. The minimum biofuel selling price after upgrading is 1,5 times the price of MGO in this value chain. Additionally, biochar is sold as soil amendment for 100€/ton, generating an additional profit of 15,25 M€/yr. Selling biocrude earns a revenue of 103,3 M€/year. Gross profit is 25,4 M€/year and earnings before tax is -98,8 M€/yr based on a MFSP of 1347€/ton and a factory lifespan of 15 years.

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Figure 33: Economic BMC Scenario 2 HTL biorefinery. Business Model Canvas of scenario 1 from the HTL biorefinery's perspective.

Business Model Canvas Scenario 2 - Economic - Upgrading facility San Roque

Key partners
The key direct supply chain partner of upgrading facility San Roque at the port of Gibraltar is the new centralised HTL biorefinery supplying biocrude, the transport company handling biocrude transport and the bunkering companies in the port of Gibraltar buying the product biofuel. The upgrading facility does not solely depend on olive biocrude to make biofuel and has other suppliers of biocrude. Key indirect partners of the Clean Shipping project, and thus the biohubs, are Boskalis, Finco Energies, Jaén University and the Dutch platform for renewable sources.

Key activities
The San Roque refinery upgrades biocrude made by the secondary mill HTL biorefinery to maritime biofuel using green H2. This biofuel needs to be checked on quality and transported to the Port of Gibraltar bunkering companies. A steady production is needed to ensure timely delivery of enough product. For these activities credit, investment risk management, logistics management and technical assistance for the production and transportation is needed.

Key resources
The upgrading facility needs a consistent supply of biocrude feedstock to upgrade and personnel with the technical know-how to run a factory that uses relatively new technology. Furthermore, storage, offices, working capital and social resources along with intellectual property such as rules and standards are needed. Green H2, a catalyst and green electricity are the natural resources needed.

Key propositions
Setting up a viable and profitable inclusive value chain of efficient production of sufficient quality and quantity maritime biofuel made from the olive oil by-product COP at a competitive price. The biofuel is sold to the bunkering companies at the port of Gibraltar, which need environmentally and socially sustainably made biofuel due to EU and IMO regulations and this need is satisfied by the implementation of this value chain. The biofuel is socially sustainable since the HTL biorefinery pays a fair price for the COP, which gives increased revenues to live off and innovate for the primary mills and the farmers.

Customer relationships
The centralised HTL biorefinery is just one of the suppliers to the San Roque Biofuels plant, as they currently produce renewable-origin fuels from processed vegetable oils. The HTL biorefinery is responsible for the sale of their biocrude, which means timely and efficient delivery of a product with consistent quality and a competitive price compared to competitors is essential for the customer relationship.

Channels
A transport company is responsible for safe and timely delivery of the produced biocrude to the San Roque upgrading facility. The upgrading facility organizes their own biofuel transport within the port of Gibraltar, this is done using a pipe system. Green H2 is produced in the port of Gibraltar, keeping transport lines short.

Customer segments
The customers of the Port of Gibraltar San Roque refinery are the bunkering companies at the Port of Gibraltar who supply the ships with (bio)fuel. These bunkering companies need reliable deliveries of consistent quality and quantity biocrude. They then sell the biofuel as drop-in shipping fuels. There is an increasing need for biofuel due to regulations by the EU and the IMO, which means the bunkering companies are relatively dependent on the supply made by the upgrading facility. However, competitors are on the rise and will also deliver biocrude to the upgrading facility.

Cost Structure
The San Roque upgrading facility needs to pay for the feedstock biocrude, green H2, catalysts, electricity and biocrude transport in order to make biofuel. The costs of the raw materials, staff, maintenance production costs and financial costs are the most important costs. Some additional costs will be made when upgrading the olive oil biocrude is first being implemented, since the upgrading process needs to be calibrated. The cost of biocrude is 103,3 M€/year, which equates to 688,67 €/ton biocrude.

Revenue Streams
The upgrading facility's main revenue stream comes from the sale of biofuel to the bunkering companies at the Port of Gibraltar. The biofuel is sold for a price no more than twice as expensive as fossil fuels to stay competitive. The minimum fuel selling price for this scenario is 1347,1 €/ton biofuel, which is 1,5 times as expensive as MGO.

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Figure 34: Economic BMC Scenario 2 Upgrading facility San Roque. Business Model Canvas of scenario 1 from the upgrading facility's perspective.

Business Model Canvas Scenario 2 - Environmental Life Cycle

Supplies and outsourcing
The main environmental impact of the production of feedstocks in the value chain is due to truck transport of olives, COP and biocrude, alongside the heat needed for the HTL process in the secondary mill. This is generated by burning the off-gas producing during the HTL process. The production of olives, COP and biocrude uses municipal electricity and water. The green H2 needed for the upgrading process is produced in the Port of Gibraltar and transported by pipeline to the upgrading facility in San Roque, saving truck carbon emissions.

Production
The secondary mill HTL biorefinery produces biocrude by heating and pressurizing COP. The electricity needed to pressurize the COP comes from renewable sources. The heat needed for the HTL process is generated by burning the off-gas, during which excess electricity is produced. The carbon emission savings due to carbon sequestering in biochar are 457 KTCO2/yr, whilst taking biochar transport emissions into account.

Materials
Since the biofuel is made from a residue of the olive oil production, this is a sustainable resource with a net zero carbon footprint, except for transport and the production process. Even though a feedstock with high water content is used, additional water is needed for the HTL process, of which 75% can be re-used. Further, catalysts are used to make the HTL and upgrading processes more efficient, reducing environmental impact. However, they often contain heavy metals and should be disposed of correctly.

Functional Value
The functional value of the end-product biofuel is a drop-in martime shipping fuel that can be mixed with fossil fuels at sufficient percentages (which go up in time due to EU and IMO CO2 emission regulations) and at competitive prices compared to other biofuels. Since an olive oil residue, COP, is used to produce biocrude and subsequently biofuel, the biofuel feedstock is carbon neutral except for transport and the production process. This gives the shipping companies a high-quality biofuel they can mix with fossil fuels.

End-of-Life
During the HTL process 25% of the used water is purged, while 75% is recycled in the process. The by-product biochar is transported to the cooperatives, to be used as soil amendment by the olive farmers. The produced off-gas is used to generate heat for the process. During the upgrading process a small amount of water and negligible amounts of H2S and NH3 are produced due to the reaction of the oxygen atoms with the hydrogen. These by-products are purged.

Distribution
olives, COP and biocrude need to be delivered to the primary mill, secondary mill HTL biorefinery and upgrading facilities respectively, by truck. COP is produced at 87 primary mills in Jaén, of which 51 primary mills within a 45 km radius deliver to the centralised HTL biorefinery. The further a lower in density product needs to be transported, the more CO2 emissions are made.

Use phase
The final product in the value chain is biofuel. Biocrude is used to produce biofuel through upgrading. For this, green H2 is needed. This is produced in Andalusia through electrolysis powered on renewable energy such as wind or solar enegy. This process also consumes renewable energy. The biofuel is used to power large ships that mix biofuel with fossil fuels with percentages set by the IMO and the EU. The emission of CO2 from the biofuel made from olive residues should be net zero. However, truck transport is unlikely to be fueled by biofuels or electrified, which means transport of the product in each of the value chain steps will emit CO2. Further, natural gas is used to heat the HTL process.

Environmental impacts
The conversion processes and transport are the most polluting factors in the value chain. When the biochar is sold and used as soil amendment by farmers, this contributes to combating soil erosion. The carbon emission savings due to carbon sequestering in biochar are 455 KTCO2/yr. These conversion carbon, nitrogen and particulate matter emissions and waste water disposal are all local environmental effects, which are less harmful in the relatively urban environment of Úbeda.

Environmental benefits
Biofuel is made out of an olive residue, which would otherwise have been chemically treated and sold as the low-quality product olive pomace oil. By using different catalysts during the HTL and upgrading processes, higher quality biocrude and biofuel may be produced, but this may result in a lower yield and thus generating more by-products. Environmental impact can be reduced by limiting transportation, efficient production, recycling and using different techniques or catalysts.

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Figure 35: Environmental Life Cycle BMC Scenario 2.

Business Model Canvas Scenario 2 - Social stakeholders

Local communities
The centralised HTL biorefinery is located in Úbeda which is the geographical centre of Jaén, and in a more urban area. In the current value chain the community surrounding the secondary industry experience hinder due to the smell of the open pond storage of COP and the close-by olive groves and nature reserve are impacted by carbon and nitrogen emissions. By placing the HTL biorefinery in the more urban Úbeda, this effect is lessened. The local communities of the farmers in Jaén will be positively impacted by the new value chain through increased income due to the increased COP price. Biocrude production at a large HTL biorefinery benefits the surrounding urban community by new job opportunities in biocrude transport and working in the production facility.

Governance
The centralised HTL biorefinery is a new private company. As it will handle a large amount of feedstock per year, the factory and its profits should me managed carefully. The company should be highly transparent through public reports that present economic, environmental and social performance.

Employees
Due to the higher price of COP in the new value chain, the employees of the primary mills can earn a higher wage and those working in the HTL biorefinery become more educated using new technology. Biocrude transport will also impact job opportunities in Jaén. COP transport will be done by the primary mills themselves, instead of by a transport company. This is less efficient, but means truck drivers will not lose their jobs.

Social Value
The bunkering companies at the port of Gibraltar want environmentally and socially sustainably made biofuel due to EU and IMO regulations for carbon emissions. Companies that need to transport their products, such as Amazon want to offer their customers green shipping as a social value. The HTL biorefinery pays a competitive price for the COP to give sufficient revenues to live off and innovate for the primary mills and farmers, so the company can contribute to the production of socially sustainable as well as environmentally sustainable, biofuel.

Societal Culture
The biohub supports a communal culture, by supporting the cooperatives and thus the farmers through improving their profits. By working together, benefits and risks are more equitably distributed. The use of biofuel results in a societal culture more focused on lowering carbon emissions. The societal culture of the community surrounding the new HTL biorefinery benefits from implementing the HTL technology in the way of well-paid, interesting jobs and industry in the area.

Scale of Outreach
The introduction of the biohub means the scale of outreach is not only large in distance (from the entire province of Jaén to the port of Gibraltar), but also in depth. This is done through educational programs and social and monetary benefits for the farmers and primary mills. Further, the value chain adds to the availability of socially and environmentally sustainably made biofuel that the global shipping industry can use.

End-user
The final product in the value chain is biofuel. The end-users of this biofuel are the shipping companies buying biofuel from bunkering companies. These end-users need to comply to EU and IMO carbon emission regulations and are required to mix their fossil fuel with biofuel with yearly increasing amounts and are able to offer their clients a greener way of shipping. Clients that want to reduce their climate impact will experience improved quality of life by having their products shipped in both an environmentally and socially sustainable manner.

Social impacts
By buying COP to produce biocrude for 75€/ton, instead of the 0-8 €/ton the secondary industry is currently paying, the secondary industry will need to increase their COP price. The current secondary industry will lose profit and jobs may be lost in this sector. Further, introducing industrial processes in a local area will increase truck transport and have negative environmental effects, which will impact the local community.

Social benefits
The biohub is part of an inclusive value chain, which means it is focused on improving the lives of the farmers as well as their profits and the environment. The biohub will also focus on providing social benefits for the cooperatives themselves in the form of advice, technical know-how and the ability to invest in new techniques. The new value chain has a positive social impact due to increased well-paying job opportunities and adding industry to the area.

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Figure 36: Social stakeholders BMC Scenario 2.