Deliverable D7.2

BioSFerA Replication Pre-Feasibility Studies in at least 3 EU Countries

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Abbreviations

CAPEX	Capital Expenditures
DFBG	Dual Fluidized Bed Gasification
EU	European Union
IEA	International Energy Agency
LCA	Life Cycle analysis
LCC	Life Cycle costing
MSP	Minimum Selling Price
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
OPEX	Operating Expenses
SAF	Sustainable Aviation Fuel
sCBA	Social Cost Benefit analysis
sLCA	Social Life Cycle analysis
TAGs	Triglycerides
TCI	Total Capital Investment
TEA	Techno-economic assessment
UCOs	Used Cooking Oils
WP	Work Package

Contents

Executive Summary

This deliverable is part of Task 7.1 “Techno-economic assessment (TEA)” whose aim is to evaluate the techno-economics of the full-scale operation of BioSFerA process.

The aim of this deliverable is to carry out three replication pre-feasibility studies in three different EU countries (Greece, Italy, and Spain) to assess their effects on the economic performance of BioSFerA process. At this aim the Capex included in deliverable D7.1- “BioSFerA Techno-Economical Assessment” has been used for the three studies, while the Opex has been evaluated based on the boundary conditions of each country. It is pointed out that, concerning the boundary conditions, some parameters are common for the three studies (thermal input, plant lifetime, operating hours), whereas other parameters are specific for each country (feedstock cost, electricity price, yearly average salary).

The three studies have been focused on the *Microbial oil scenario* which is revealed as the most commercially attractive business-case scenario, and the most ‘realistic’ market-wise choice from the assessment carried out in deliverable D7.1. From the financial analysis, it has been concluded that the Minimum Oil Selling Price (MOSP) is the most suitable indicator for the financial evaluation.

An analysis concerning the estimated MOSP for the BioSFerA replication in four different countries, Greece, Italy, Spain, and Finland was carried out (data regarding Finland have been taken from deliverable D7.1). The MOSP range obtained from the BioSFerA replication in four different countries was 1.29-1.43 €/l. Some sensitivity analyses have been performed to evaluate the impact of different economic parameters and operational aspects on the MOSP formation. The Total Capital Investment (TCI) and the feedstock costs are the main cost-drivers of the process. Moreover, a comparative analysis to check the effect of the oil selling price on the net present value and on the discounted payback period of the three replication studies has been carried out.

Finally, a comparison between the average European price of typical HEFA/HVO feedstocks (Used Cooking Oils & vegetable oils) and the calculated MOSP of BioSFerA microbial oil has been made. The initial estimations showed that the BioSFerA microbial oil seems more expensive than the majority of the primary renewable oils. However, the simultaneous aimed decarbonization of multiple transport sectors based on advanced biofuels (e.g. aviation, maritime) and the scarcity of cheap feedstock (e.g. Used Cooking Oils – UCOs) is expected to bring to the fore the necessity for additional advanced sustainable oils, such as the microbial oil. Moreover, ongoing research and development efforts related to Biomass-to-Liquid (BtL) pathways are expected to reduce the production costs and upgrade the financial competitiveness of such concepts towards the large-scale availability of low-carbon liquid fuels.

1 Introduction

1.1 Overview of BioSFerA project

BioSFerA aims to develop cost-effective technology aimed at producing sustainable aviation and maritime fuels. This technology foresees the production of syngas through gasification of biogenic residues and wastes. Syngas is fermented to produce bio-based triacylglycerides (TAGs). Through TAGs hydrotreatment biofuels are produced. The overall process can be separated into three different phases: the thermochemical phase, the biotechnological phase and the thermocatalytic phase.

The thermochemical phase, where the syngas stream is produced and purified, is based on the Dual Fluidized Bed Gasification (DFBG) unit, followed by a catalytic reformer and proper syngas conditioning (contaminants reduction). The biotechnological phase, where the syngas stream is converted into TAGs which are medium (C14) and long (C16-18) fatty acids, includes the double-stage syngas fermentation (syngas → acetic acid → lipids/TAGs) and the subsequent lipids purification system. Finally, the thermocatalytic phase foresees the hydrotreatment activities where lipids (TAGs) are converted into drop-in liquid fuels (jet- and bunker-like biofuels) as shown in the figure below.

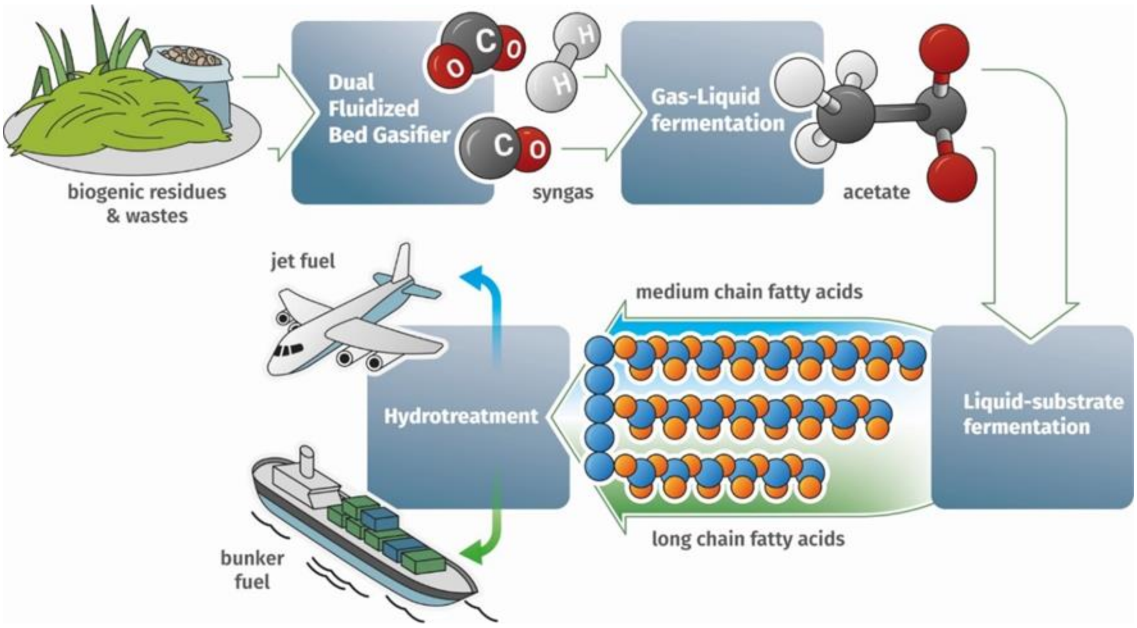


Figure 1. The BioSFerA concept [1]

1.2 Scope of work

This deliverable belongs to Task 7.1 – "Techno-economic assessment (TEA)" included in the WP7-"Sustainability (techno-economic, environmental, social) and Health & Safety issues".
The aim of Task 7.1 is to evaluate the techno-economics of the full-scale operation of BioSFerA process analysing the full BioSFerA Value Chain and cost/competitor/potential supplier of each value chain step from a technical (performances) and economic (cost) point of view. Total investment costs, discounted pay-back period and biofuel production costs are evaluated with the support of the theoretical and experimental activities carried out in the project.

The aim of this deliverable is to make three replication pre-feasibility studies in three different EU countries (Greece, Italy, and Spain) to assess their effects on the economic performance of BioSFerA process. It is worth mentioning that the capital costs reported in deliverable D7.1- “BioSFerA Techno-Economical Assessment” have been used for the pre-feasibility studies of the three countries, while the operational costs are adapted according to each country’s boundary conditions.

It is pointed out that the relationships between Task 7.1 and other tasks of BioSFerA project are essential, in particular with tasks of Work Package (WP) 2, 6 and 7 as shown in the following figure:

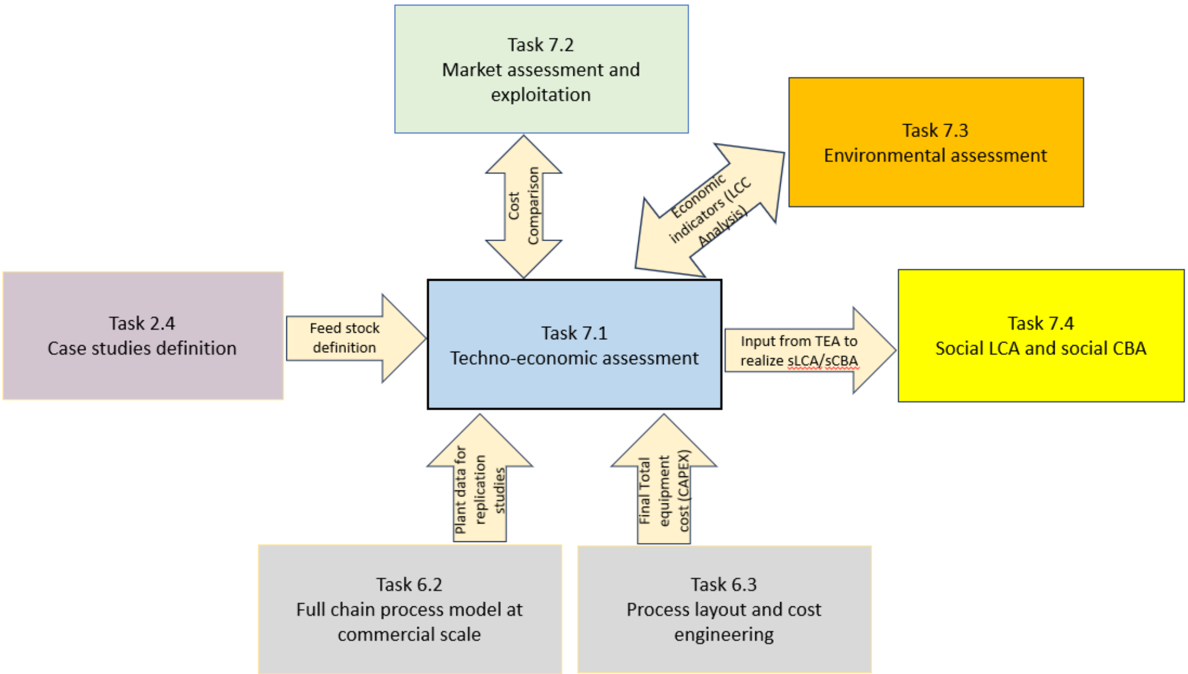


Figure 2. Relationships between the tasks of WP2, WP6 and WP7

In particular, the above relationships concern:

- Task 2.4 and deliverable D2.4 “Determination of the main input parameters for the case studies”, where the three feedstocks, to use in the 3 pre-feasibility studies (olive prunings for Greece, wheat straw for Italy, vineyard prunings for Spain) have been defined;
- Task 6.2 and deliverable D6.2” Results of full-chain process simulations”, including the description of the BioSFerA concept and the full-scale heat and mass balances of the overall process;
- Task 6.3 and deliverable D6.3 “Process layout and cost engineering of the BioSFerA refinery plant”, where the industrial layout of the BioSFerA concept has been defined and design rules for component sizing have been provided.
- Task 7.2 and deliverable D7.3 “BioSFerA market and competitor assessment”, where a market analysis is performed for the aviation/maritime current biofuel trends;
- Task 7.3 and deliverable D7.6 “BioSFerA LCC assessment”, where the main economic indicators extracted by LCC analysis are strictly connected with T7.1 techno-economic assessment;
- Task 7.4 and deliverable D7.7 “Report on sLCA and sCBA”, where input coming from T7.1 techno-economic assessment are used for preparing the sLCA and sCBA.

This deliverable is composed by the following sections:

- Section 1 is dedicated to the introduction, including a brief overview of the BioSFerA concept and the scope of work;
- Section 2 describes the methodological approach used for the drafting of the deliverable;

- Section 3 provides an overview of biorefineries status, and an assessment of feedstock costs, electricity prices, and salary in the three countries on which the pre-feasibility studies are focused (Greece, Italy and Spain);
- Section 4 provides the three replication/pre-feasibility studies and a comparison between market price of typical green oils and price of microbial oil;
- Section 5 draws the conclusions;
- Section 6 includes the references used;
- Appendix A shows the discounted cash flow analyses for the three studies.

It is worth mentioning that in deliverable D7.1“BioSFerA techno-economical assessment”, three different business case scenarios, related to Finland, were carried out to assess the techno-economic aspects of each scenario. Specifically, the following three scenarios:

- Jet fuel scenario;
- Marine fuel scenario;
- Microbial oil scenario.

The assessment of the three scenarios revealed that the most commercially attractive scenario is the Microbial oil scenario. In fact, it is the most attractive business case presenting the highest potential in terms of **minimization of the payback period** and **maximization of the Net Present Value** as shown in the figures below.

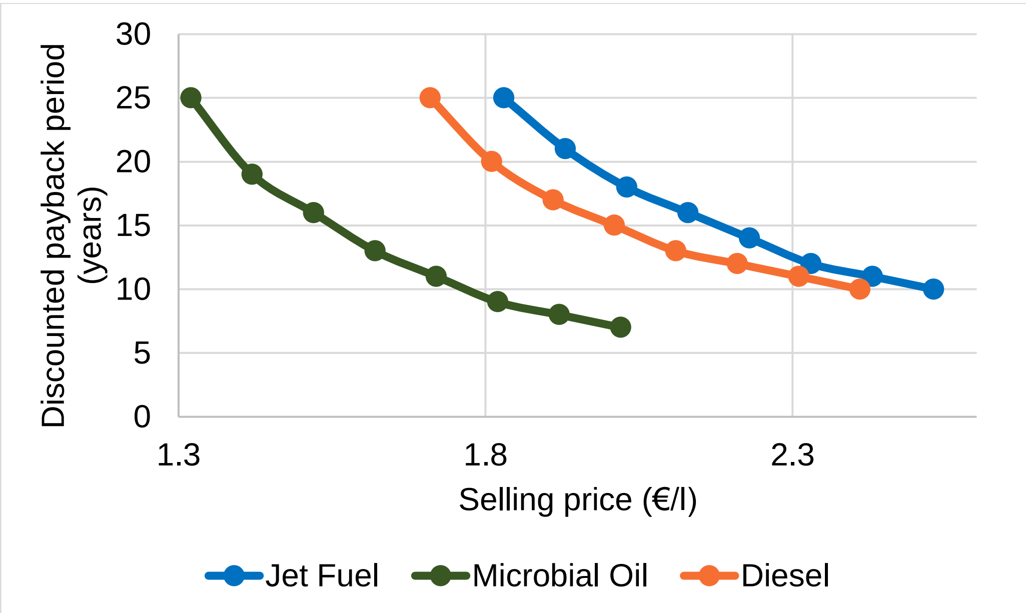


Figure 3. Discounted Payback Period vs Selling Price for the Finnish case study [21]

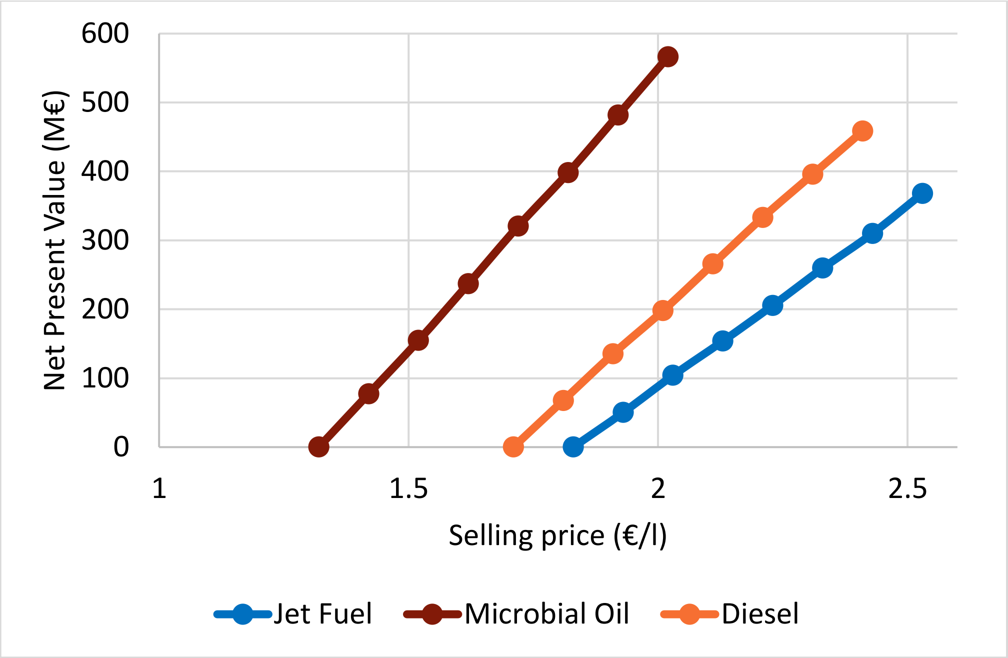


Figure 4. Net Present Value vs Selling Price for the Finnish case study [21]

It is also the only case that enables the exploitation of the existing refining infrastructure of each country and seems the most 'realistic' market-wise choice. The microbial oil scenario envisages the establishment of a BioSFerA plant that reaches the production of purified TAGs and feeds the existing refineries with 'green oil' (microbial oil) for hydrotreatment. It is highlighted that this aspect implies not only the avoidance of the construction costs for a new refinery but also the exploitation of the large existing refining infrastructure and knowledge. Therefore, one scenario, the Microbial Oil scenario, has been used in Section 4 for the three replication studies related to Greece, Italy, and Spain.

2 Methodological approach

The Methodology followed for the preparation of this deliverable includes the analysis of the submitted deliverables concerning the BioSFerA concept including the main technical and economic data and information. Specifically, the techno-economic assessment (TEA) has been applied to three replication pre-feasibility studies concerning Greece, Italy, and Spain.

The following submitted deliverables have been investigated:

- Deliverable D2.4 “Determination of the main input parameters for the case studies”, where the three feedstocks, olive prunings for Greece, wheat straw for Italy, and vineyard prunings for Spain, were defined in detail. Moreover, the identification of the location, for each country, that can guarantee the feedstock availability, and the average feedstock price (€/t) were carried out in deliverable D2.4;
- Deliverable D6.2 “Results of full-chain process simulations”, including the description of the BioSFerA concept and the description of the three parts of the overall process, thermochemical, biotechnological and thermocatalytic part;
- Deliverable D6.3, submitted in January 2024, provides useful data and information regarding both the technical details of the equipment of BioSFerA concept and the final total capital investment (TCI).

An overview of biorefineries’ status in the three countries, including the main characteristics of the existing plants, has been provided. Moreover, an assessment of the feedstock prices, electricity prices, and salaries has been made.

Finally, based on the techno-economic assessment methodology given by CERTH, three replication pre-feasibility studies, focused on the “**Microbial oil scenario**”, have been prepared. CERTH applied this methodology in deliverable D7.1 where a techno-economic assessment, regarding Finland focused on the three scenarios mentioned in Section 1.2, was carried out.

It is worth mentioning that the starting point for the preparation of the three replication pre-feasibility studies has been the identification of the boundary conditions for each country as shown in Section 4.

3 Overview of biorefinery status and assessment of feedstock cost, electricity price and salary in Greece, Italy and Spain

The aim of this section is twofold:

- to provide, through desk research, an overview of the existing biorefineries status in the three countries;
- to assess and update the feedstock costs, electricity price, and salary included in deliverable D2.4.

The sources of consulted documents, useful for the preparation of this section, are shown in Section 6- References- at the end of this deliverable.

Biorefineries definition

As regards biorefineries, there exist several definitions of biorefinery and biorefining. The preference for one over the other often depends on the context. A biorefinery can be defined as a framework or a structure in which biomass is utilized in an optimal manner to produce multiple products and tries to be self-sustaining and not harmful to the environment. A biorefinery is a refinery that converts biomass to energy and other beneficial byproducts (such as chemicals).

Two widely used definitions are formulated by IEA and NREL, respectively. For example, the International Energy Agency Bioenergy Task 42 defined biorefining as "the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat)". NREL Biomass Research gives the following definition of a biorefinery: “a biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass.”

As refineries, biorefineries can provide multiple chemicals by fractioning an initial raw material (biomass) into multiple intermediates (carbohydrates, proteins, triglycerides) that can be further converted into value-added products.

Feedstock costs, electricity price, and salary

As regards feedstock costs, electricity price, and salary, more details for each of the three countries are included in sections below.

3.1 Greece

3.1.1 Current status of biorefineries

Greece ranks thirteenth [15] in terms of the total number of biorefineries (37 installations) in EU, regardless of their production capacities. The largest contribution is made by liquid biofuels (51%). These are followed by pulp and paper production facilities (35%), and bio-based chemical production facilities (19%) according to the data provided in the Joint Research Centre (JCR) database of the European Commission [16].

According to the updated NECP (National Energy & Climate Plan), conventional liquid biofuels are already used in Greece in the form of biodiesel (with a mandatory blending quota of 7% v/v in road transport oil) and bioethanol (with a mandatory blending quota of 5% v/v in gasoline). Biodiesel is almost entirely produced in Greece with energy crops (rapeseed, sunflower, soya, cotton seed) and lately UCOs (Used Cooking Oils). Bioethanol is produced by fermentation of sugars/starch canals (sugar beet, sugar cane, cereals, maize) and is imported. The production/consumption of conventional liquid biofuels is not further developed in order not to create a problem in the supply of food/feed, in line with EU policy. The above limit on conventional biofuels as percentage of transport fuels is maintained at 1.7% throughout the energy aftermarket, indicating a gradual reduction in their production in absolute terms. There is currently no production of advanced liquid biofuels in Greece. However, the contribution of advanced biofuels is expected to reach 2.4% of transport fuels by 2030 and 17% by 2040.

Some key biofuel plants in Greece are provided below:

- The first domestic biodiesel production plant, operated by Hellenic Biopetroleum Industrial and Commercial S.A. at Kilkis, with an annual production capacity of 40,000 tons, started operating in December 2005.
  A second biodiesel production plant, operated by VERT OIL S.A. in Thessaloniki, with an annual production capacity of 25,000 tons entered production in July 2006.
  A third plant, operated by Pavlos N. Pettas Industrial and Commercial S.A., with an annual production capacity of 50,000 tons, and the same start production date.
  A fourth plant, with an annual production capacity of 200,000 tons, by Agroinvest S.A. at Fthiotida, central Greece started production in November 2006.
  A fifth one with an annual production capacity of 80,000 tons, by Elinoil S.A. at Volos started operation on December 2006 [2];
- A biodiesel plant with an annual capacity of 100,000 tons, built on the site of the VIOHALCO Group's SOVEL plant at Almiro in Magnisia. The investment involves the creation of a vegetable oils refinery with a capacity of 300 tons per day, a glycerin distillation plant, a biodiesel transesterification plant and ancillary installations (steam generators, biological treatment, etc.).
  In this plant are involved the following companies: Hellenic Petroleum, Viohalco s.a., Hellenic Fabrics S.A., Prima Holding S.A. [3];
- Installation of a Biodiesel production plant which has been operational since April 2023. It uses vegetable oil extracted from the seeds of the cotton plant, a low-quality oil not intended for human consumption, which represents a waste of production for the customer. The entire plant is developed in two separate special boxes, 12 meters each: in the first one, there are four reactors to produce Biodiesel, while in the second one, there is the control room and the methanol distillation area. Currently, the plant has a production capacity ranging from 23,000 to 27,000 litres/day and supplies the product according to the parameters required by the European standard in EN14214. [4];
- Integration of new equipment to produce hydrotreated vegetable oil (HVO) into the Thessaloniki refinery of Hellenic Petroleum in Greece. The expected annual production capacity is 22,000 tons of biofuel [5] and the plant is going to start operation by 2026.

3.1.2 Feedstock cost, electricity price and salary

In this section, the feedstock cost, the electricity price, and salary are shown.

Feedstock cost

As regards the feedstock cost it is worth mentioning that feedstock for Greece is "olive prunings" as shown in Deliverable D2.4- "Determination of the main input parameters for the case studies", section 2.2. In particular, the area of Peloponnese was chosen to form the selected region for the Greek case study as shown in D2.4. This region presents remarkable olive prunings capacities that offer flexibility and feedstock assurance locally.

Feedstock costs (collection and transportation) have been taken from deliverable D2.4, where these costs were estimated through the BIORAISE platform [6]. Specifically, the following costs have been extracted:

- Collection cost: 38 €/t;
- Transportation cost: 15 €/t.

Therefore, the feedstock cost is **53 €/t** as shown in the following table:

Table 1. The Case Study of Greece

Case (Country)	Greece
Feedstock	Olive prunings
Region	Peloponnese
Average collection cost (€/t)	38
Average transport cost (€/t)	15
Estimated average feedstock cost (€/t)	**53**

Electricity price

As regards the electricity price for Greece, the industry electricity price (average last 5 years) was set at 0.12 €/kWh [**7**].

Salary

The average salary in Greece for the chemical industry is about 22,000.00 € [**8**].

3.2 Italy

3.2.1 Current status of biorefineries

Italy ranks fourth [15] in terms of the total number of biorefineries (209 installations), regardless of their production capacities. The largest contribution is made by pulp and paper production facilities (57%). These are followed by bio-based chemical production facilities (27%) and liquid biofuels (10%) according to the data provided in the Joint Research Centre (JCR) database of the European Commission [16].

According to the updated NECP (National Energy & Climate Plan) in Italy, **conventional liquid biofuels**, like biodiesel and bioethanol, are currently used predominantly for road transport.
In Italy, biodiesel is primarily produced from rapeseed (40%), soybean (30%), and palm oil (25%), with the remaining portion coming from recycled vegetable oils, sunflower oil, and animal fats.
Notably, Italian biodiesel production relies heavily on imported raw materials, with rapeseed oil imported from other EU countries and soybean oil either imported from the EU or domestically produced from imported beans. Bioethanol is mainly produced from crops like wheat, maize, sugar beet, barley, and rye.

It is highlighted that, from 1 January 2024, the share of bioliquids produced from palm oil, empty palm oil fruit bundles and fatty acids resulting from the treatment of palm oil fruits must be reduced, unless they are certified as having a low indirect land-use change (ILUC) risk.
Liquid biofuels, specifically biodiesel and bioethanol, are currently used in Italy in various ways. Italy was the first EU Member State to mandate the use of advanced liquid biofuels, with requirements for gasoline and diesel to contain a minimum percentage of advanced biofuel. The country has been actively involved in advanced biofuels demonstrations and research projects, such as Eni's plans to convert its Venice refinery into a "green refinery" producing HVO using an innovative process.

As regards the **advanced biofuels**, it is planned to exceed the specific target laid down in the RED III Directive of 5.5% by 2030, by updating the incentive mechanisms provided for advanced biomethane and other advanced biofuels (by Ministerial Decree of 2 March 2018, Ministerial Decree of 15 September 2022 and Ministerial Decree of 16 March 2023) until a target of around 10% is reached.

There are some refineries that have been converted in biorefineries, specifically refineries of ENI S.p.A., the leader operator in refining and marketing of petroleum products in Italy, Versalis, an ENI's chemical company, and Novamont, a chemical company.

Main ENI's biorefineries are in Gela (Sicily region) and Porto Marghera (Veneto region). Gela is the most advanced biorefinery in Europe, a plant capable of transforming practically any raw material of biological origin into biofuel. Moreover, as regards Versalis, there is a plant at Crescentino (Piedmont region) where advanced bioethanol is produced. Concerning Novamont, there is a plant at Bottrighe di Adria.

Gela biorefinery – ENI [9]

Opened in August 2019, the biorefinery has a processing capacity of up to 750,000 tons a year and will be able to treat increasing quantities of used vegetable oil, animal fat, algae and by-products to produce high-quality biofuels.

The bio-refinery in Gela produces quality **biofuel** (HVO - Hydrotreated Vegetable Oil) from raw materials of organic origin. The plant can use second generation (unconventional) feedstocks for up to 100% of its processing capacity and has a high level of operational flexibility.

The process is based on ENI proprietary Eco-fining technology. Production started in 2019 and in the first phase certified palm oil was used. Since October 2022, ahead of the current regulations, the supply of this product has been definitively ended and today ENI only uses oils from crops that do not compete with the food chain, such as castor, cotton or croton. These are also produced by agri-hubs that ENI have established in African countries that involve local farmers in development programs. Among the other raw materials, ENI uses cooking oil (UCO) and waste from some types of agro-food processing. The Gela refinery is also fundamental to produce sustainable aviation fuels (SAFs) because it produces the bio-components that are sent to the Livorno refinery and distilled to obtain Eni Biojet, which can be used in blends with conventional jet fuel.

Porto Marghera biorefinery – ENI [10]

Porto Marghera was the first ENI's biorefinery realized by converting old plants thanks to technologies developed by ENI Research Centers.

The biorefinery has a processing capacity of up to 350,000 tons a year and will be able to treat increasing quantities of used vegetable oil, animal fat, algae and by-products to produce high-quality biofuels. The Porto Marghera biorefinery produces quality biofuels (HVO-Hydrotreated Vegetable Oil) from raw materials of biogenic origin. At the time of its inauguration in 2014, it was the first example in the world of the complete conversion of a traditional refinery into a biorefinery. The process is based on proprietary Eco-fining technology. In the first phase, ENI used certified palm oil as a starting filler. Since October 2022, ahead of current legislation, the supply of this product has been definitively concluded and today ENI only uses waste and residues from the processing of vegetable oils, used frying oil, animal fats and vegetable oils from the crops that Eni is being developed in Africa, in degraded lands unsuitable for food production and with little need for water. These are also produced thanks to the activation of agri-hubs in African countries which involve local farmers in development programs. Other raw materials used by ENI are "used cooking oil (UCO)" and waste from some agri-food processing.

Crescentino – Versalis [11]

The plant, which was acquired in 2018, has been overhauled thanks to major investments and has started the production of advanced bioethanol, in compliance with the European legislation for the development of renewable energy RED II, as it is derived from raw materials that do not interfere with the food chain. The bioethanol, produced using Proesa technology, one of the world's most innovative industrial-scale biomass chemistry technologies, is ISCC-EU[1] certified and will be used to formulate gasoline with a renewable component.

The plant is capable of processing 200,000 tons of biomass per year, with a maximum production capacity of approximately 25,000 tons of bioethanol per year.

The Versalis plant at Crescentino is an example of sustainable initiative and circularity: its energy supply is self-sustaining due to the production of renewable electricity and steam from the thermoelectric power plant, which is fed with short supply chain biomass and the lignin co-produced by the process.

Bottrighe di Adria – Novamont [12]

Mater-Biotech was created by Novamont from the industrial reconversion of an abandoned production site. The company carries out research, development, and production of chemical intermediates, obtained from renewable raw materials.

The plant is a starting point for subsequent integrations upstream and downstream of Novamont production process and represents a fundamental development of the Novamont biorefinery model, integrating already consolidated chemical processes with industrial biotechnologies.
Mater-Biotech represents the first dedicated industrial plant worldwide capable of producing butanediol (1,4 BDO) directly from sugars through a fermentation process. Bio butanediol has a carbon footprint 50% lower than traditional BDO. Launched in 2016, the plant has a production capacity of 30,000 tons per year and was designed to reuse the by-products for the energy needs of the plant itself, thus optimizing the life cycle of the entire process.

The 1,4 BDO produced by Mater-Biotech is used as a renewable building block to produce Novamont bioplastics. It makes the production of the fourth generation of MATER-BI possible, significantly increasing its content of renewable raw materials (going from around 35% to over 60% for the grades intended for film production) and further reducing emissions of greenhouse gases (10-15% lower carbon footprint).

3.2.2 Feedstock cost, electricity price and salary

In this section, the feedstock cost, electricity price and salary are shown.

Feedstock cost

As regards the feedstock cost it is worth mentioning that feedstock for Italy is "straw-derived fuel biomass" as shown in Deliverable D2.4 - "Determination of the main input parameters for the case

[1] ISCC-EU: Certification system referring to the EU Directive 2009/28/EC (RED Directive) and its recent revision 2018/2001/EU, also known as RED II (Renewable Energy Directive), which sets out the necessary and specific requirements for biofuel producers, with the ultimate aim of ensuring their sustainability.

studies", section 2.3. In particular, the sub-regions of Udine, Venezia and Pordenone were chosen to form the selected region for the Italian case study as shown in D2.4. This region presents remarkable straw capacities that offer flexibility and feedstock assurance locally.

Feedstock costs (collection and transportation) have been taken from deliverable D2.4, where these costs were estimated through the BIORAISE platform [6]. Specifically, the following costs have been extracted:

- Collection cost: 30 €/t;
- Transportation cost: 13 €/t.

Therefore, the feedstock cost is **43 €/t** as shown in the following table:

Table 2. The Case Study of Italy

Case (Country)	Italy
Feedstock	Straw
Region	Friuli Venezia Giulia (Udine)
Average collection cost (€/t)	30
Average transport cost (€/t)	13
Estimated average feedstock cost (€/t)	**43**

Electricity price

As regards the electricity price for Italy, the industry electricity price is 0.14 €/kWh for annual consumption of 70,000 MWh/y ÷ 150,000 MWh/y [13].

Salary

The average salary in Italy for the chemical industry is about 29,000.00 € [14].

3.3 Spain

3.3.1 Current status of biorefineries

Spain ranks seventh [15] in terms of the total number of biorefineries (108 installations), regardless of their production capacities. The largest contribution is made by pulp and paper production facilities (43%), mainly located in the Basque Country, Aragon and Catalonia. These are followed by bio-based chemical production facilities (28%) and liquid biofuels (18%), more evenly distributed according to the data provided in the Joint Research Centre (JCR) database of the European Commission [16].

According to the updated NECP (National Energy & Climate Plan), conventional liquid biofuels, like biodiesel and bioethanol, are already used in Spain. The biofuel sector in Spain is influenced by regulatory developments and demand for conventional fuels.
Bioethanol consumed and produced in Spain is mainly derived from corn, with a small percentage produced from wine alcohol obtained from winemaking residues. Biodiesel is primarily produced from grains. Additionally, a limited amount of wheat has also been used to produce bioethanol in certain plants. Spain has been actively involved in the production and use of both **conventional** and **advanced liquid biofuels**.

The revision of the Renewable Energy Directive establishes an overall objective for renewables in transport of 14% by 2030. Furthermore, specific objectives for advanced biofuels have been set for 2022 (0.2%), 2025 (1%) and 2030 (3.5%).

To achieve the objectives for consumption of advanced biofuel, advanced biofuel production must be boosted, as it is still very low. This is due, in some cases, to the limited availability of some of the raw materials required and, in others, to the lack of technological maturity of some of the manufacturing processes involved in producing this type of biofuel.
The country's advanced biofuels production capacity includes Hydrogenated Vegetable Oil (HVO) co-processing by petrol companies. These advanced biofuels have shown promising results, reducing CO_2 emissions significantly compared to conventional fuels and contributing to the decarbonization of heavy transport. It is highlighted that the transport sector is a key focus area, aiming to reduce fuel consumption through policies like increasing the use of advanced biofuels, renewing the vehicle fleet, and introducing electric vehicles.
As regards the bioethanol production, the main relevant plants are: [17]

- The plant of the company Ecocarburantes Españoles S.A. located in Cartagena (Region of Murcia) started the operation in the year 2000. It produces, in a continuous process, 150,000 m^3 of bioethanol per year. Bioethanol is used by companies in the oil sector as raw material for the manufacture of ETBE (Ethyl TerButyl Ether), a fuel additive in vehicles powered by unleaded gasoline;
- The raw materials used in the process are cereals (wheat and barley) and alcohols of wine origin, produced domestically. It is worth mentioning that 300,000 t/year of cereal are consumed;
- From them, bioethanol, dehydrated ethyl alcohol, is obtained in a process that generates DDGS (Distilled Dried Grain Soluble) and CO2 as economically recoverable by-products, destined for the manufacture of animal feed and strontium chemistry, respectively;
- The plant's facilities are completed with a 22 MW natural gas-fired cogeneration plant, which supplies electricity, steam and hot water to the bioethanol manufacturing process and exports surplus electricity production to the grid;
- Another plant, property of Bioethanol Galicia S.A., Texeiro, located in La Coruna, started the operation in the year 2002. It produces 176,000 m^3 of bioethanol per year. Bioethanol is used to produce ETBE (Ethyl TerButyl Ether), a fuel additive in vehicles powered by unleaded gasoline. It is highlighted that 340,000 t/year of cereal are consumed;
- Another plant, Biocarburantes de Castilla y Leon, located in Babilafuente (Salamanca) started the operation in the year 2006. It produces 200,000 m^3 of bioethanol per year. This plant was the first of its kind in the world with the possibility of producing bioethanol from biomass, from cereal straw, with Enzymatic Hydrolysis technology. It is pointed out that 585,000 t/year of cereal are consumed;
- Another plant is located in San Roque (Cádiz). It is a biodiesel plant in an area adjacent to Cepsa´s Gibraltar Refinery and produces 200,000 t per year of biodiesel. The plant started the operation in 2008 and consume about 200,000 t of vegetable oils (rape, soy, and palm) per year;
- A bioethanol plant, located in Alcázar de San Juan (Ciudad Real), started the operation in the year 2006. It produces around 33,000 t of bioethanol per year, after its expansion in May 2009 from the initial 26,000 t. The raw material used in production is raw alcohols from the auction of alcohols of wine origin that the EU Intervention Agencies carry out to regulate the sector.

3.3.2 Feedstock cost, electricity price and salary

In this section the feedstock cost, electricity price and salary are shown.

Feedstock cost

As regards the feedstock cost it is worth mentioning that feedstock for Spain is “woody prunings” as shown in Deliverable D2.4 - “Determination of the main input parameters for the case studies”, section

2.4. In particular, the sub-regions of Granada, Almeria, and Murcia were chosen to form the selected region for the Spain case study as shown in D2.4. These regions present remarkable woody (olive/vineyard/orchards) prunings capacities that offer flexibility and feedstock assurance locally.

Feedstock costs (collection and transportation) have been taken from deliverable D2.4, where these costs were estimated through the BIORAISE platform [6]. Specifically, the following costs have been extracted:

- Collection cost: 45 €/t;
- Transportation cost: 14 €/t.

Therefore, the feedstock cost is **59 €/t** as shown in the following table:

Table 3. The Case Study of Spain

Case (Country)	Spain
Feedstock	Woody prunings
Region	**Granada,** Almeria, and Murcia
Average collection cost (€/t)	45
Average transport cost (€/t)	14
Estimated average feedstock cost (€/t)	**59**

Electricity price

As regards the electricity price for Spain, the industry electricity price is 0.13 €/kWh [18].

Salary

The average salary in Spain for the chemical industry is about 29,000.00 € [19]

4 Three replication pre-feasibility studies

As shown in section 1.2, the three replication pre-feasibility studies are focused on the "**Microbial oil scenario".**

The three pre-feasibility studies are based on data and information provided by deliverables D6.2 and D6.3 where the required components of BioSFerA concept, the design rules for component sizing and the final total capital investment (TCI), used as input in the TEA, have been defined.

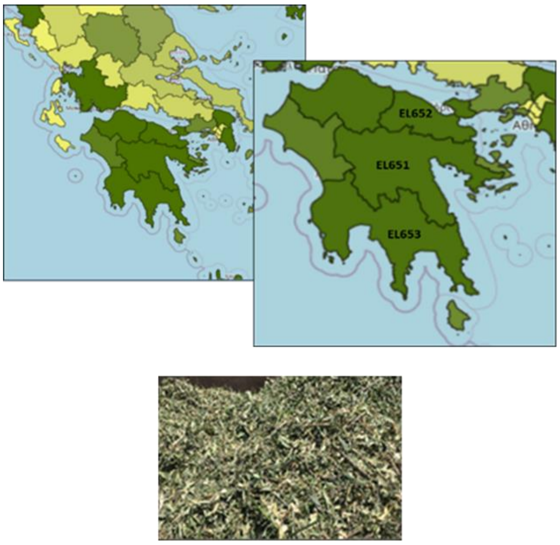
It is worth mentioning that TEA methodology and CapEx & OpEx estimations are included in deliverable D7.1. Specifically, the capital costs reported in D7.1 have been used for the feasibility studies of the three countries, while the operational costs have been adapted according to each country's "boundary conditions" which are the starting point for the preparation of the three replication pre-feasibility studies as shown in sections below. Another important starting point is the mass balance of each country shown here below:

- Greece: 302,205 t/year (olive pruning) that allows the production of 49,054 t/year microbial oil;
- Italy: 365,896 t/year (wheat straw) that allows the production of 46,909 t/year microbial oil;
- Spain: 334,534 t/year (woody pruning) that allows the production of 46,920 t/year microbial oil.

4.1 Pre-feasibility replication study for Greece

As regards the Greek replication study, the relevant inputs from Deliverable D2.4 'Determination of the main input parameters for the case studies' were adopted [20]. In particular, the potential establishment of a commercial 200 MWth BioSFerA plant based on olive prunings as feedstock in the area of Peloponnese is replicated. Most boundary conditions for the financial assessment are set as common for all the replication studies, while the feedstock cost, electricity price, and average annual salary are adjusted to the specifications of the country.

The following figure shows the proposed area, feedstock, and boundary conditions for the Greek replication study.



Greece boundary conditions	
Thermal input	200 MWth
Plant lifetime	25 years
On-stream factor	85% (7446 h)
Feedstock cost (**olive prunings**)	53 €/tn
Electricity price (business)	0.12 €/kWh
Average annual salary	22000 €/year
Discount rate	6%
Tax rate	0%
Construction period	2 years (40% 1st year, 60% 2nd year)
Cellular biomass (as by-product)	700 €/tn

Figure 5. Proposed area, feedstock, and boundary conditions for the Greek replication study

The discounted cash flow rate of return methodology is applied for the economic analysis. A cash flow analysis is performed in Microsoft Excel based on the estimated capital and operating costs. The Minimum Oil Selling Price (MOSP) has been elected as the most suitable indicator for the initial financial evaluation of the concept. The MOSP is obtained by iterating the microbial oil product cost to obtain a Net Present Value equal to zero at a specific discount rate. An annual revenue stream is considered from the selling of cellular biomass (yeast biomass) as a valuable by-product. Yeast biomass, as derived from TAGs purification, can be utilized in various ways such as fertilizers, animal feed or for the enhancement of biogas production.

The Total Capital Investment (TCI) is assumed equal to 526,592,000 M€ for all the replication studies, as presented in Deliverable D7.1 - 'BioSFerA Techno-Economical Assessment' [21]. The annual operating costs are transformed according to the Heat & Mass balances of the Greek replication study, the main elements of which are presented in Table 4. Table 5 provide an overview of the annual operational financial streams that take part in the cash flow analysis of the Greek replication study.

Table 4. Feedstock/production capacity for the Greek replication study

Parameter	Value
Feedstock requirements (olive prunings)	302,205 t/year
Produced microbial oil (purified TAGs)	49,054 t/year
Produced cellular biomass (by-product)	8,711 t/year

Table 5. Annual operating costs for the Greek replication study

Parameter	Value
Feedstock costs	16,016,936 €/year
Electricity	7,148,160 €/year
Salary (100 employees)	2,200,000 €/year
Maintenance	9,574,400 €/year
Nutrients & chemicals	1,054,532 €/year
Property Insurance	3,351,040 €/year
Solvent make-up	2,959,338 €/year
Wastewater discharge	1,858,164 €/year
Total annual operating costs	**44,162,570 €/year**

Assuming a net present value equal to zero at the end of the plant lifetime, the computed baseline value for the MOSP of the Greek replication study is 1.29 €/l. The detailed cash flow analysis is shown in Appendix A (Table A.1.). A sensitivity analysis was performed to evaluate the impact of different economic parameters and operational aspects on the formation of Greek MOSP.

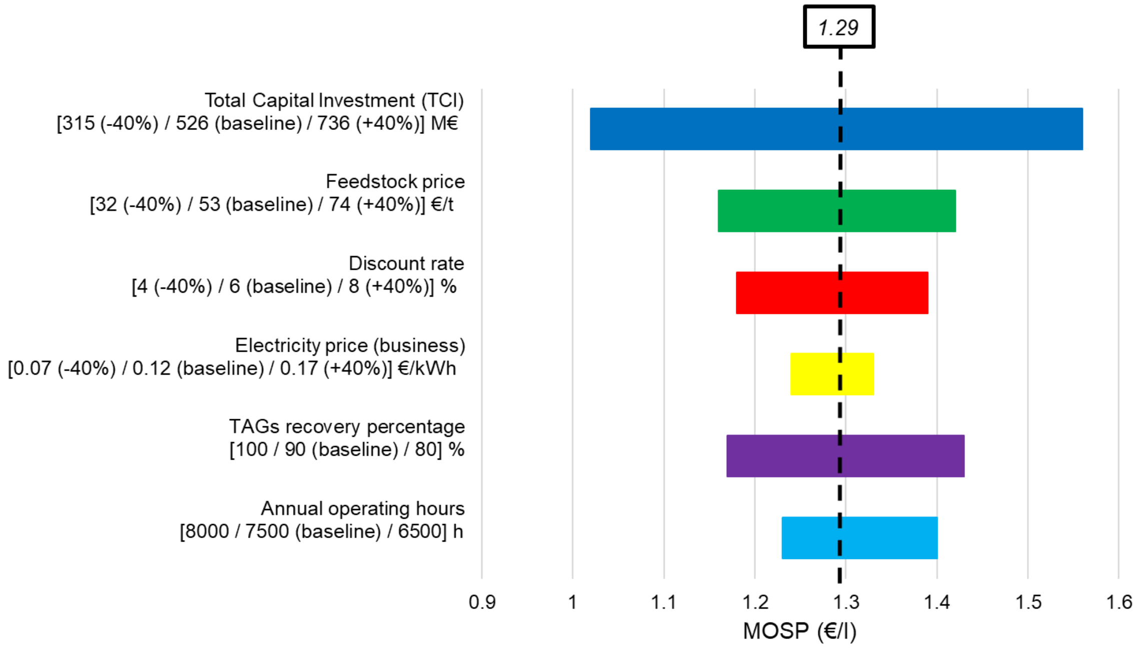


Figure 6. MOSP sensitivity analysis for the Greek replication study

As already mentioned in Deliverable D7.1, TCI and feedstock costs are the main cost drivers of the process. A combination of reduced capital and feedstock costs seems necessary for the achievement of a MOSP value close to 1 €/l. Moreover, ensuring high oil (TAGs) recovery percentages is critical for the financial competitiveness of the concept. Finally, an additional sensitivity analysis was performed to observe the effect of the microbial oil selling price on the discounted payback period and the net present value of the replication study.

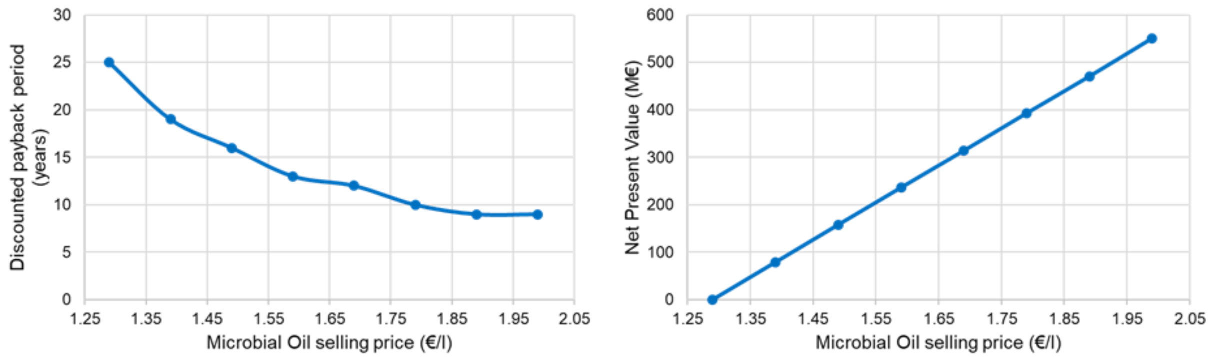
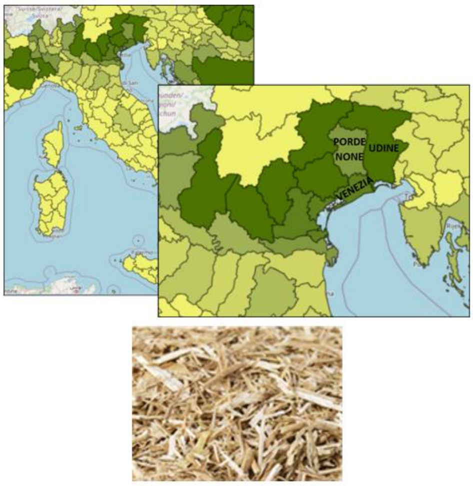


Figure 7. Discounted payback period and net present value evolution in relation to the microbial oil selling price for the Greek replication study

The MOSP of 1.29 €/l corresponds to a net present value equal to zero and a discounted payback period equal to the plant lifetime (25 years). A microbial oil selling price of over 1.75 €/l seems essential for the security of a discounted payback period of less than 10 years, while a selling price of around 2 €/l seems able to lead to net present values of around 500 M€.

4.2 Pre-feasibility replication study for Italy

As regards the Italian replication study, it was adopted the relevant input from Deliverable D2.4 - 'Determination of the main input parameters for the case studies' [20]. In particular, the potential establishment of a commercial 200 MWth BioSFerA plant based on straw as feedstock in the Friuli Venezia Giulia region (Udine) is replicated. Most boundary conditions for the financial assessment are set as common for all the replication studies, while the feedstock cost, electricity price, and average annual salary are adjusted to the specifications of the country. The following figure shows the proposed area, feedstock, and boundary conditions for the Italian replication study.



Italy boundary conditions	
Thermal input	200 MWth
Plant lifetime	25 years
On-stream factor	85% (7446 h)
Feedstock cost (**straw**)	43 €/tn
Electricity price (business)	0.14 €/kWh
Average annual salary	29000 €/year
Discount rate	6%
Tax rate	0%
Construction period	2 years (40% 1st year, 60% 2nd year)
Cellular biomass (as by-product)	700 €/t

Figure 8. Proposed area, feedstock, and boundary conditions for the Italian replication study

The discounted cash flow rate of return methodology is applied for the economic analysis. A cash flow analysis is performed in Microsoft Excel based on the estimated capital and operating costs. The Minimum Oil Selling Price (MOSP) has been elected as the most suitable indicator for the initial financial evaluation of the concept. The MOSP is obtained by iterating the microbial oil product cost to obtain a Net Present Value equal to zero at a specific discount rate. An annual revenue stream is considered from the selling of cellular biomass (yeast biomass) as a valuable by-product. Yeast biomass, as derived from TAGs purification, can be utilized in various ways such as fertilizers, animal feed or for the enhancement of biogas production.

The Total Capital Investment (TCI) is assumed equal to 526,592,000 M€ for all the replication studies, as presented in Deliverable D7.1-'BioSFerA Techno-Economical Assessment' [21]. The annual operating costs are transformed according to the Heat & Mass balances of the Italian replication study, the main elements of which are presented in Table 6. Table 7 provides an overview of the annual operational financial streams that take part in the cash flow analysis of the Italian replication study.

Table 6. Feedstock/production capacity for the Italian replication study

Parameter	Value
Feedstock requirements (straw)	365,896 t/year
Produced microbial oil (purified TAGs)	46,909 t/year
Produced cellular biomass (by-product)	8,705 t/year

Table 7. Annual operating costs for the Italian replication study

Parameter	Value
Feedstock costs	15,733,546 €/year
Electricity	8,339,520 €/year
Salary (100 employees)	2,900,000 €/year
Maintenance	9,574,400 €/year
Nutrients & chemicals	1,054,532 €/year
Property Insurance	3,351,040 €/year
Solvent make-up	2,959,338 €/year
Wastewater discharge	1,858,164 €/year
Total annual operating costs	**45,770,542 €/year**

Assuming a net present value equal to zero at the end of the plant lifetime, the computed baseline value for the MOSP of the Italian replication study is 1.37 €/l. The detailed cash flow analysis is shown in Appendix A (Table A.2.). A sensitivity analysis was performed to evaluate the impact of different economic parameters and operational aspects on the formation of Italian MOSP.

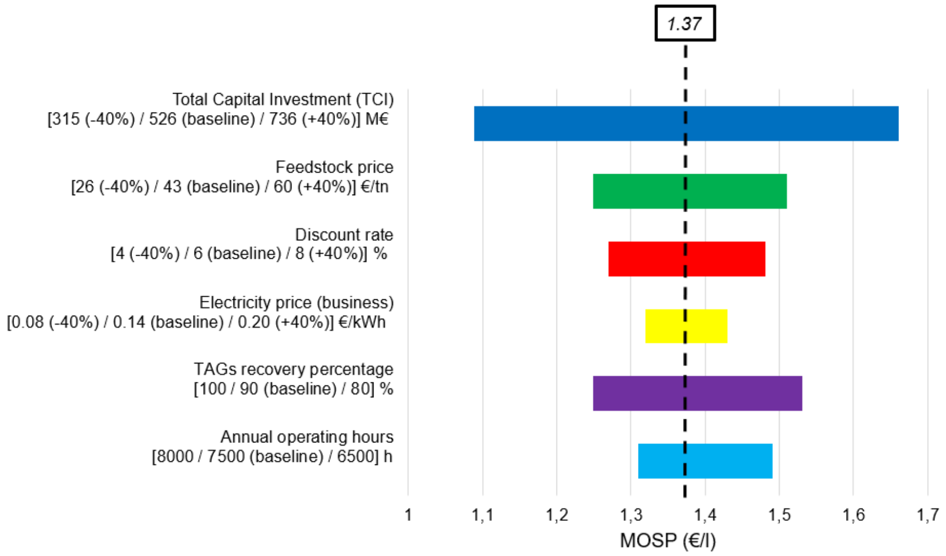


Figure 9. MOSP sensitivity analysis for the Italian replication study

As already mentioned, TCI and feedstock costs are the main cost drivers of the process. The higher baseline electricity price of Italy is translated to slightly larger impact of this parameter on the formation of MOSP compared to Greece, but the inherent low electricity requirements of the concept are still evident. Finally, an additional sensitivity analysis was performed to observe the effect of the microbial oil selling price on the discounted payback period and the net present value of the replication study.

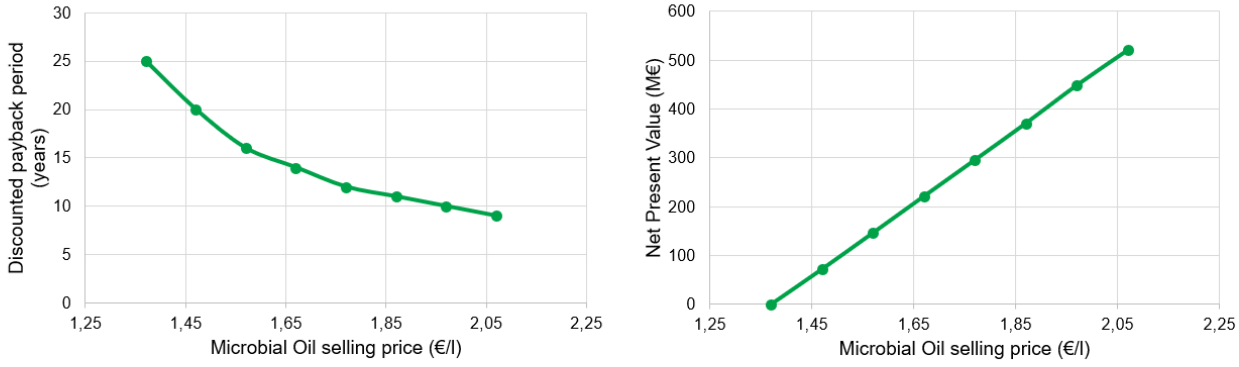


Figure 10. Discounted payback period and net present value evolution in relation to the microbial oil selling price for the Italian replication study

The MOSP of 1.37 €/l corresponds to a net present value equal to zero and a discounted payback period equal to the plant lifetime (25 years). A microbial oil selling price of over 1.85 €/l seems essential for the security of a discounted payback period of less than 10 years, while a selling price around 2.05 €/l seems able to lead to net present values of around 500 M€.

4.3 Pre-feasibility/replication study for Spain

As regards the Spanish replication study, it was adopted the relevant input from Deliverable D2.4 ‘Determination of the main input parameters for the case studies’ [20]. In particular, the potential establishment of a commercial 200 MWth BioSFerA plant based on woody prunings as feedstock in the region of **Granada,** Almeria, and Murcia is replicated. Most boundary conditions for the financial assessment are set as common for all the replication studies, while the feedstock cost, electricity price, and average annual salary are adjusted to the specifications of the country.

The following figure shows the proposed area, feedstock and boundary conditions for the Spanish replication study.

Spain boundary conditions	
Thermal input	200 MWth
Plant lifetime	25 years
On-stream factor	85% (7446 h)
Feedstock cost (**woody prunings**)	59 €/tn
Electricity price (business)	0.13 €/kWh
Average annual salary	29000 €/year
Discount rate	6%
Tax rate	0%
Construction period	2 years (40% 1st year, 60% 2nd year)
Cellular biomass (as by-product)*	700 €/t

Figure 11. Proposed area, feedstock, and boundary conditions for the Spanish replication study

The discounted cash flow rate of return methodology is applied for the economic analysis. A cash flow analysis is performed in Microsoft Excel based on the estimated capital and operating costs. The Minimum Oil Selling Price (MOSP) has been elected as the most suitable indicator for the initial financial evaluation of the concept. The MOSP is obtained by iterating the microbial oil product cost to obtain a Net Present Value equal to zero at a specific discount rate. An annual revenue stream is considered from the selling of cellular biomass (yeast biomass) as valuable by-product. Yeast biomass, as derived from TAGs purification, can be utilized in various ways such as fertilizers, animal feed or for the enhancement of biogas production.

The Total Capital Investment (TCI) is assumed equal to 526,592,000 M€ for all the replication studies, as presented in Deliverable D7.1 - ‘BioSFerA Techno-Economical Assessment’ [21]. The annual operating costs are transformed according to the Heat & Mass balances of the Spanish replication study, the main elements of which are presented in Table 8. Table 9 provides an overview of the annual operational financial streams that take part in the cash flow analysis of the Spanish replication study.

Table 8. Feedstock/production capacity for the Spanish replication study

Parameter	Value
Feedstock requirements (woody prunings)	334,534 t/year
Produced microbial oil (purified TAGs)	46,920 t/year
Produced cellular biomass (by-product)	8,672 t/year

Table 9. Annual operating costs for the Spanish replication study

Parameter	Value
Feedstock costs	19,737,499 €/year
Electricity	7,743,840 €/year
Salary (100 employees)	2,900,000 €/year
Maintenance	9,574,400 €/year
Nutrients & chemicals	1,054,532 €/year
Property Insurance	3,351,040 €/year
Solvent make-up	2,959,338 €/year
Wastewater discharge	1,858,164 €/year
Total annual operating costs	**49,178,814 €/year**

Assuming a net present value equal to zero at the end of the plant lifetime, the computed baseline value for the MOSP of the Spanish replication study is 1.43 €/l. The detailed cash flow analysis is shown in Appendix A (Table A.3.). A sensitivity analysis was performed to evaluate the impact of different economic parameters and operational aspects on the formation of Spanish MOSP.

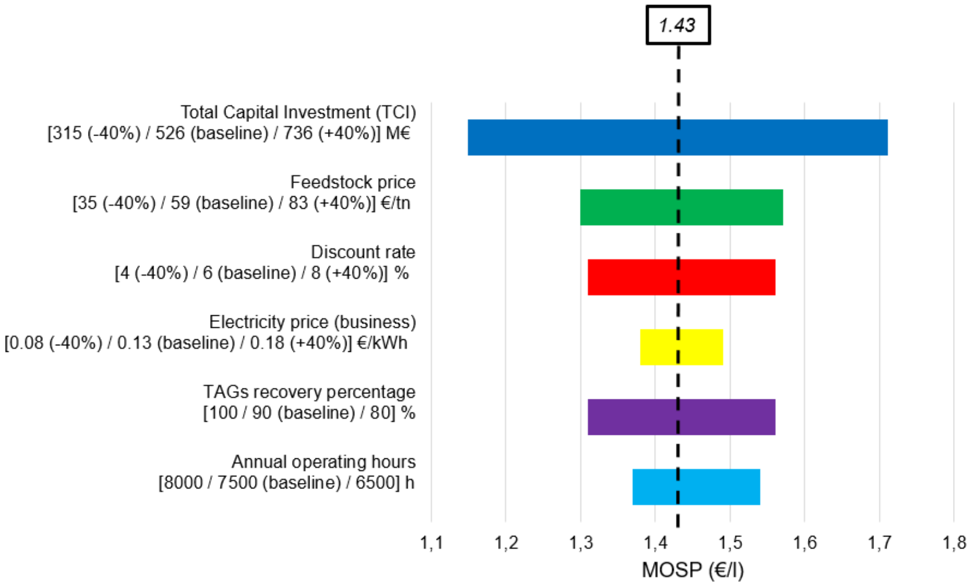


Figure 12. MOSP sensitivity analysis for the Spanish replication study

As expected, a similar sensitivity analysis diagram is generated for Spain with slightly different boundaries, since the MOSP baseline of 1.43 €/l is the highest of the three scenarios. Finally, an additional sensitivity analysis was performed to observe the effect of the microbial oil selling price on the discounted payback period and net present value of the replication study.

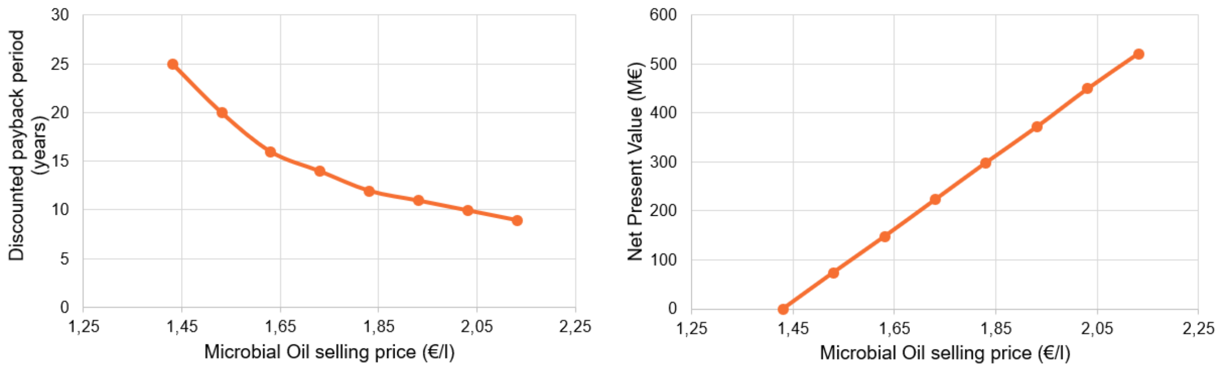


Figure 13. Discounted payback period and net present value evolution in relation to the microbial oil selling price for the Spanish replication study

The MOSP of 1.43 €/l corresponds to a net present value equal to zero and a discounted payback period equal to the plant lifetime (25 years). A microbial oil selling price of over 1.92 €/l seems essential for the security of a discounted payback period less than 10 years, while a selling price of around 2.10 €/l seems able to lead to a net present value around 500 M€.

4.4 Comparative analysis for the replication studies

In this section a comparative analysis, based on the main outcomes coming from the three replication pre-feasibility studies, has been carried out.

Specifically, the comparative analysis has been focused on the discounted payback period and Net Present Value vs Microbial oil selling price for the three countries as shown in the following two figures:

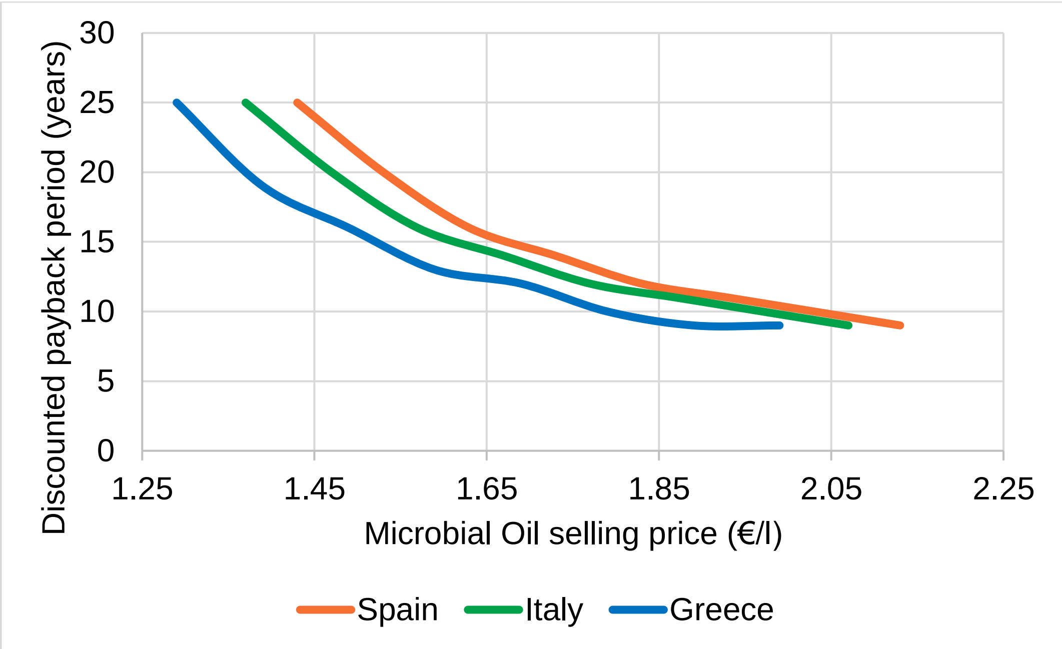


Figure 14. Discounted payback period vs Microbial oil selling price for the three countries

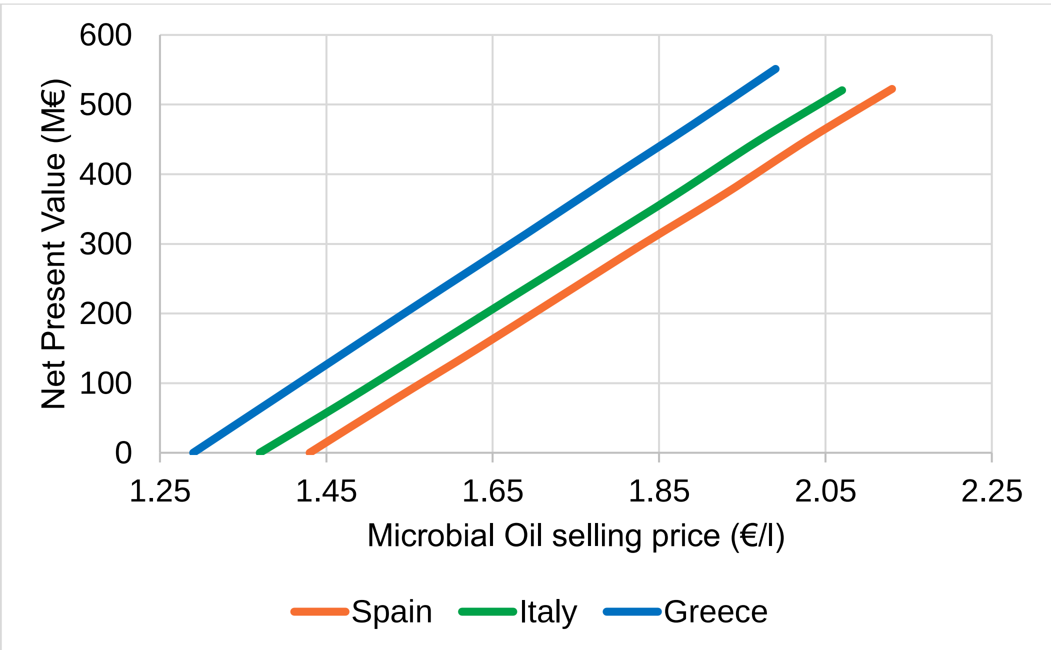


Figure 15. Net Present Value vs Microbial oil selling price for the three countries

From the previous two figures the following points are highlighted:

- Similar performance indicators (e.g.: Discounted payback period and Net Present Value) for the three Mediterranean replication pre-feasibility studies have been used. Among the three studies, Greek scenario comes up with slightly better numbers as shown below:
- The lower price of assumed straw feedstock (Italy) is matched by the more efficient mass balance of the concept with woody prunings (Greece and Spain), resulting in similar estimated MOSPs for all three scenarios.
- Microbial oil selling prices: MOSP over 1.5 €/l is a prerequisite for all three replication studies to obtain a discounted payback period less than 15 years.

The following figure provides an insight of the estimated MOSPs for four countries: Greece, Italy, Spain, and Finland. Data regarding Finland column have been taken from deliverable D7.1.

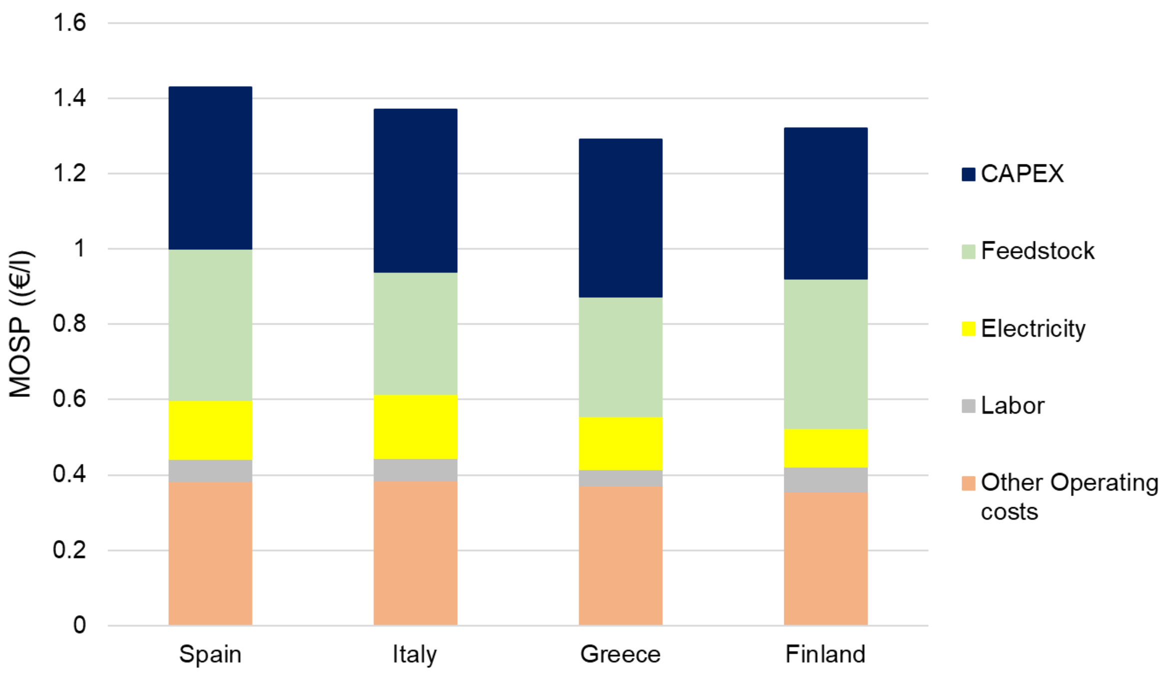


Figure 16. Estimated MOSP cost breakdown for the BioSFerA replication in four different countries

This figure revealed the following main points:

- As regards Finland, its mature and active biomass market implies higher feedstock costs (mainly due to market supply and demand), and lowest electricity price, whereas in the other three Mediterranean countries feedstock is cheaper, and electricity prices are higher as shown in the following table.
- CAPEX, feedstock costs and the other inevitable fixed operating costs (e.g.: maintenance, property insurance, etc.) are the financial regulators of the Minimum Oil Selling price value for all countries.
- The MOSP range obtained from the BioSFerA replication in four different countries is rather narrow, in the range 1.29-1.43 €/l. This implies that the concept can be applied similarly in different regions due to the feedstock flexibility and the inherent mild electricity requirements.

All the investigated replication studies in an aggregated form are presented in Table 10.

Table 10. BioSFerA replication studies in numbers

Parameter	Greece	Italy	Spain	Finland
Feedstock quantity (t/y)	302,205 (olive prunings)	365,896 (straw)	334,534 (woody prunings)	301,295 (crushed bark)
Microbial oil quantity (t/y)	49,054	46,909	46,920	50,395
Feedstock cost (€/t)	53	43	59	70
Electricity price (€/kWh)	0.12	0.14	0.13	0.09
MOSP (€/L)	1.29	1.37	1.43	1.32

4.5 Market price of typical green oils vs MOSP of microbial oil

This section is focused on the comparison between the market price of typical green oils, as UCOs (Used Cooking Oils), other conventional vegetable oils as sunflower oil, soybean oil, rapeseed oil, palm oil that are currently used in refineries to feed the hydrotreatment unit, and the Minimum Oil Selling Price (MOSP) of BioSFerA microbial oil.

4.5.1 Comparison between UCOs and microbial oil prices

A range for the European UCOs price has been found through desk research. Specifically, from this research the following prices range for Used Cooking Oils has been identified:

UCOs: 0.482 €/liter [22] ÷ 0.841 €/liter [23], where these data have been calculated respectively as follows:

- UCO data from [22] equal to 530 €/t = 0.530 €/kg = 0.482 €/liter, considering that 1kg of UCO is equal to 1.1 liter of UCO;
- UCO data from [23] equal to 925 €/t = 0.925 €/kg = 0.841 €/liter, considering that 1kg of UCO is equal to 1.1 liter of UCO.

The calculated MOSP prices of the microbial oil for the three countries are:

- Greece: 1.29 €/l;
- Italy: 1.37 €/l;
- Spain: 1.43 €/l;
- Finland: 1.32 €/l;

Therefore, the comparison between the Used Cooking Oils prices and the MOSP of the four countries revealed that the calculated MOSP prices are 50-70% higher than the identified UCOs European price.

4.5.2 Comparison between conventional vegetable oils and microbial oil prices

Prices regarding conventional vegetable oils have been found through desk research. Specifically, from this research the following prices have been identified for sunflower oil, soybean oil, rapeseed oil, and palm oil. These prices are subject to fluctuations based on market conditions and factors affecting production and demand.

Starting from current prices of conventional vegetable oils in $/t:

- Sunflower oil: 910 $/t; [24];
- Soybean oil: 915 $/t; [24];
- Rapeseed oil: 987.71 $/t; [25];
- Palm oil: 930 $/t [24].

considering the following density for each vegetable oil:

- Sunflower oil: 0.919 kg/l;
- Soybean oil: 0.920 kg/l;
- Rapeseed oil: 0.920 kg/l;
- Palm oil: 0.914 kg/l.

and a conversion $/€ where: 1$=0.910 €, the following prices have been calculated:

- Sunflower oil: 0.761 €/l;
- Soybean oil: 0.766 €/l;
- Rapeseed oil: 0.827 €/l;
- Palm oil: 0.774 €/l.

Also, in this case the comparison between the conventional vegetable oils prices and the estimated MOSP of the microbial oil of the four countries revealed that the MOSP prices are higher than the conventional vegetable oils prices.

To sum up, the initial estimations showed that the BioSFerA microbial oil seems more expensive than the majority of the primary renewable oils. However, the target of decisively decarbonizing several transport sectors with advanced biofuels and the lack of cheap appropriate feedstock (e.g. UCOs) is expected to highlight the need for additional sustainable input refinery streams, such as the microbial oil. Furthermore, it is anticipated that continuous research efforts related to Biomass-to-Liquid (BtL) plants would reduce the production costs and upgrade the financial viability of such concepts.

5 Conclusions

The aim of this deliverable is to carry out three replication pre-feasibility studies in three different EU countries (Greece, Italy, and Spain) to assess their effects on the economic performance of BioSFerA process. It is highlighted that the base case study (Finland) has been deployed in detail within Deliverable D7.1 - “BioSFerA Techno-Economical Assessment”. The capital costs reported in D7.1 have been adopted for the replication of all pre-feasibility studies, while the operational costs have been adapted according to each country’s boundary conditions that are the starting point for the preparation of the three pre-feasibility studies.

Most of the boundary conditions for the financial assessment are common for the three replication studies (e.g.: thermal input, plant lifetime, operating hours), while feedstock cost, electricity price, and average yearly salary have been adjusted to the specifications of each country. Specifically, the feedstock cost, electricity price, and salary included in deliverable D2.4 - “Determination of the main input parameters for the case studies”, have been considered and, in some cases (electricity price and salary), updated in this deliverable. Moreover, an assessment of the current status of biorefineries in the three countries has been carried out.

It is worth mentioning that, from the evaluation of three different scenarios (jet fuel scenario, marine fuel scenario, microbial oil scenario) carried out in deliverable D7.1, the *Microbial oil scenario was* revealed as the most commercially attractive business case, since it is the only case that enables the exploitation of the existing refining infrastructure of each country and seems the most ‘realistic’ market-wise choice. Therefore, the three studies concerning Greece, Italy, and Spain have been implemented through microbial oil scenarios.

A cash flow analysis has been performed based on the estimated capital and operating costs. The Minimum Oil Selling Price (MOSP) has been elected as the most suitable indicator for the initial financial evaluation of the concept. Calculated MOSPs for Greece, Italy, Spain, and Finland (data regarding Finland from D7.1) are 1.29 €/l, 1.37 €/l, 1.43 €/l. and 1.32 €/l, respectively. The MOSP range obtained from the BioSFerA replication in four different countries is rather narrow, in the range 1.29-1.43 €/l. This implies that the concept can be applied similarly in different regions due to feedstock flexibility and the inherent mild electricity requirements. Total Capital Investment and feedstock costs are the main cost drivers of the process. A combination of reduced capital and feedstock costs would pave the way for the achievement of a MOSP value close to 1 €/l, which can be a breakthrough for the financial competitiveness of microbial oil. Moreover, a comparative analysis was performed to observe the effect of the microbial oil selling price on the discounted payback period and the net present value of the replication studies. Greek scenario comes up with slightly better numbers. However, microbial oil selling prices over 1.5 €/l for all replication studies seem essential for the securement of a discounted payback period less than 15 years.

The initial estimations showed that the BioSFerA microbial oil seems more expensive than the majority of the traditional renewable oils (i.e. UCOs, vegetable oils). However, the need for additional renewable input refinery streams (oils) towards the decarbonization of several transport sectors (e.g. aviation, maritime) and the scarcity of inexpensive suitable feedstock (e.g. UCOs) are expected to form the conditions for the exploitation of advanced sustainable oils (such as the BioSFerA microbial oil). Furthermore, it is anticipated that the ongoing research activities related to BtL plants will reduce the productions costs and upgrade the performance and financial viability of such concepts in the future.

Finally, it is worth mentioning, that the scenarios described within this deliverable can by no means be considered as optimized. The present study can act as an initial attempt to replicate and assess the financial feasibility of the BioSFerA concept in targeted countries under different feedstock types and boundary conditions.

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Appendix A

Table A.1. Discounted cash flow analysis - Greek replication study

Year	Total Capital Investment (TCI)	Income (Microobial Oil+ Cellular biomass)	Operational Expenses	Cash flow	Discount factor	Net Present Values	Discounted payback
-1	€ 210,636,800.00			-€ 210,636,800.00	1.00	-€ 210,636,800.00	
0	€ 315,955,200.00			-€ 315,955,200.00	1.00	-€ 315,955,200.00	
1		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.94	€ 38,861,852.83	(€ 487,730,147.17)
2		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.89	€ 36,662,125.31	(€ 451,068,021.86)
3		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.84	€ 34,586,910.67	(€ 416,481,111.20)
4		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.79	€ 32,629,161.01	(€ 383,851,950.19)
5		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.75	€ 30,782,227.37	(€ 353,069,722.82)
6		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.70	€ 29,039,837.14	(€ 324,029,885.68)
7		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.67	€ 27,396,072.77	(€ 296,633,812.91)
8		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.63	€ 25,845,351.67	(€ 270,788,461.24)
9		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.59	€ 24,382,407.24	(€ 246,406,054.00)
10		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.56	€ 23,002,270.98	(€ 223,403,783.02)
11		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.53	€ 21,700,255.64	(€ 201,703,527.38)
12		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.50	€ 20,471,939.28	(€ 181,231,588.10)
13		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.47	€ 19,313,150.27	(€ 161,918,437.83)
14		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.44	€ 18,219,953.08	(€ 143,698,484.75)
15		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.42	€ 17,188,634.98	(€ 126,509,849.77)
16		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.39	€ 16,215,693.38	(€ 110,294,156.39)
17		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.37	€ 15,297,823.94	(€ 94,996,332.45)
18		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.35	€ 14,431,909.38	(€ 80,564,423.07)
19		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.33	€ 13,615,008.8S	(€ 66,949,414.22)
20		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.31	€ 12,844,347.97	(€ 54,105,066.24)
21		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.29	€ 12,117,309.41	(€ 41,987,756.84)
22		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.28	€ 11,431,423.97	(€ 30,556,332.87)
23		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.26	€ 10,784,362.23	(€ 19,771,970.63)
24		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.25	€ 10,173,926.64	(€ 9,598,044.00)
25		€ 85,356,134.45	€ 44,162,570.46	€ 41,193,564.00	0.23	€ 9,598,044.00	**€ 0.00**
					NPV	**€ 0.00**	***MOSP = 1.29 €/l***

Table A.2. Discounted cash flow analysis - Italian replication study

Year	Total Capital Investment (TCI)	Income (Microbial Oil + Cellular Biomass)	Operational Expenses	Cash Flow	Discount factor	Net Present Values	Discounted payback
-1	€ 210,636,800.00			-€ 210,636,800.00	1.00	€ -210,636,800.00	
0	€ 315,955,200.00			-€ 315,955,200.00	1.00	-€ 315,955,200.00	
1		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.94	€ 38,861,852.83	(€ 487,730,147.17)
2		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.89	€ 36,662,125.31	(€ 451,068,021.86)
3		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.84	€ 34,586,910.67	(€ 416,481,111.20)
4		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.79	€ 32,629,161.01	(€ 383,851,950.19)
5		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.75	€ 30,782,227.37	(€ 353,851,950.19)
6		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.70	€ 29,039,837.14	(€ 324,029,885.68)
7		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.67	€ 27,396,072.77	(€ 296,633,812.91)
8		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.63	€ 25,845,351.67	(€ 270,788,461.24)
9		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.59	€ 24,382,407.24	(€ 246,406,054.00)
10		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.56	€ 23,002,270.98	(€ 223,403,783.02)
11		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.53	€ 21,700,255.64	(€ 201,703,527.38)
12		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.50	€ 20,471,939.28	(€ 181,231,588.10)
13		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.47	€ 19,313,150.27	(€ 161,918,437.83)
14		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.44	€ 18,219,953.08	(€ 143,698,484.75)
15		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.42	€ 17,188,634.98	(€ 126,509,849.77)
16		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.39	€ 16,215,693.38	(€ 110,294,156.39)
17		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.37	€ 15,297,823.94	(€ 94,996.332.45)
18		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.35	€ 14,431,909.38	(€ 80,564,423.07)
19		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.33	€ 13,615,008.85	(€ 66,949,414.22)
20		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.31	€ 12,844,347,97	(€ 54,105,066.24)
21		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.29	€ 12,117,309.41	(€ 41,987,756.84)
22		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.28	€ 11.431,423,97	(€ 30,556,332.871)
23		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.26	€ 10,784,362,23	(€ 19,771,970.63)
24		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	0.25	€ 10,173,926.64	(€ 9.598.044.00)
25		€ 86,964,105.65	€ 45,770,541.65	€ 41,193,564.00	*0.23*	€ 9.598.044.00	**€0.00**
					NPV	**€ 0.00**	***MOSP = 1.37 €/l***

Table A.3. Discounted cash flow analysis - Spanish replication study

Year	Total Capital Investment (TCI)	Income (Microbial Oil + Cellular biomass)	Operational Expenses	Cash flow	Discount Factor	Net Present Values	Discounted Payback
-1	€ 210,636,800.00			-€ 210,636,800.00	1.00	-€ 210,636,800.00	
0	€315,955,200.00			-€ 315,955,200.00	1.00	-€315,955,200.00	
1		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.94	€ 38,861,852.83	(€ 487,790,147.17)
2		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.89	€ 36,662,125.31	(€ 451,068.021.86)
3		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.84	€ 34,586,910.67	(€ 416,481,111.20)
4		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.79	€ 32,629,161.01	(€ 383,851,950.19)
5		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0,75	€ 30,782,22.37	(€ 353,069,722.82)
6		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.70	€ 29,039,837.14	(€ 324,029,885.68)
7		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.67	€ 27,396,072.77	(€ 296,633,812.91)
8		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.63	€ 25,845,351.67	(€ 270,788,461.24)
9		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.59	€ 24,382,407.24	(€ 246,406,054.00)
10		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0,56	€ 23,002,270.98	(€ 223,403,783.03)
11		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.53	€ 21,700,155.64	(€ 201,703,527.39)
12		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.50	€ 20,471,939.28	(€ 181,231,588.10)
13		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.47	€ 19,313,150.27	(€ 161.918.07.84)
14		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.44	€ 18,219,953.08	(€ 143.698.484.75)
15		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.42	€ 17,188,634.98	(€ 126,509.849.77)
16		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.39	€ 16,215,693.38	(€110,294,156.38)
17		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.37	€ 15,297,823.94	(€ 94,996,332.45)
18		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.35	€ 14,431,909.38	(€ 80,564,423.07)
19		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.33	€ 13,615,008.85	(€ 66,949,414.22)
20		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.31	€ 12,844,347.97	(€ 54,105,066.24)
21		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.29	€ 12,117,308.41	(€ 41,987,756.84)
22		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.28	€ 11,431,423.97	(€ 41,987,756.84)
23		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.26	€ 10,784,362.23	(€ 30,556.332.87)
24		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.25	€10,173,926.64	(€ 19,771,970.63)
25		€ 90,372,378.12	€49,178,814.12	€ 41,193,564.00	0.23	€ 9,598,044.00	**€0.00**
					NPV	**0.00**	**MOSP = 1.43 €/l**