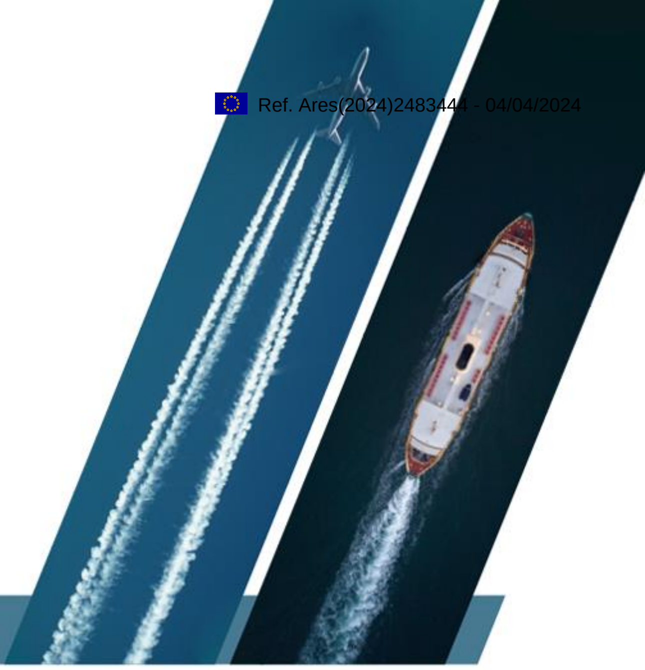

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Abbreviations

LCA	Life Cycle Assessment
S-LCA	Social Life Cycle Assessment
S-CBA	Social Cost-Benefit Analysis
ISO	International Organization for Standardization
RED	Renewable Energy Directive
RES	Renewable Energy Sources
EU	European Union
EU ETS	European Union's Emission Trading System
HHV	High Heating Value
HRJ	Hydroprocessed Renewable Jet
LHV	Low Heating Value
AtJ	Alcohol-to-Jet
FT	Fischer-Tropsch
HEFA	Hydroprocessed Esters and Fatty Acids
KPIs	Key Performance Indicators
TEA	Techno-Economical Assessment
SETAC	Society of Environmental Toxicology and Chemistry
UNEP	United Nations Environment Programme

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Executive Summary

Task 7.4, as part of the BioSFerA Project, embarked on a mission to conduct a Social Life Cycle Assessment (S-LCA) and Social Cost-Benefit Analysis (S-CBA). The aim was to identify, quantify, and effectively manage social impacts, providing a comprehensive societal perspective on the project's social viability.

The project task adhered to the ISO 14040/44 Standards and UNEP Guidelines for conducting the S-LCA. The importance of social group criteria was determined through expert questionnaires, leading to the identification of social impacts groups, and social criteria from stakeholders across participating countries. The S-CBA incorporated social considerations into the cost-benefit analysis, providing a framework for integrating 'wellbeing' impacts into the socio-economic benefits of alternative fuel solutions.

Case study scenarios were configured, focusing on different feedstocks (pellet, straw, pruning from vineyards and olives, and organic waste) and biorefinery locations in Finland, Italy, Spain, and Greece.

The project task successfully identified and quantified social impacts, aiding decision-makers in developing effective management strategies. The weight on the importance of social group criteria was found to be high or almost high across participating countries, with Health & Safety emerging as a very high importance factor. The survey revealed critical social hotspots within the impact categories that needed to be addressed.

The S-LCA results align with those reported in similar cases in relevant literature, indicating a significant Social Cost-Benefit gain in GHG emissions reduction. The project demonstrated several social benefits, including reduction in Greenhouse Gas Emissions, enhanced Energy Security, positive Economic Impacts, Job creation, and Health Benefits. However, it also highlighted social costs, such as Economic Costs associated with the initial investment and operating costs for collecting, transporting, and processing, as well as low Environmental Impact of biofuels.

In conclusion, the project task has made significant strides in understanding the social impacts of biofuel production, providing valuable insights for decision-makers, and contributing to the broader goal of sustainable and socially responsible biofuel production.

1 Introduction

Sustainable alternative fuels are essential for reducing the environmental impact of aviation and maritime industries, meeting regulatory requirements, enhancing energy security, promoting innovation, and improving economic and environmental sustainability. They play a crucial role in addressing the pressing global challenges of climate change and air quality while driving positive economic and technological developments.

Biofuels can make a significant contribution as alternative fuels for aviation and maritime industries. However, it's important to note that the contribution of biofuels to aviation and maritime industries depends on various factors, including the availability of sustainable feedstock, technological advancements, and the development of supply chains and infrastructure. Additionally, the sustainability of biofuels depends on responsible sourcing practices to prevent negative impacts on land use, biodiversity, and food security.

BioSFerA project aims to develop a cost-effective interdisciplinary technology to produce sustainable aviation and maritime fuels, utilizing non-food bio-based blends, by gassing biogenic residues and wastes into bio-based triacylglycerides (TAGs), to:

- Achieve a high conversion efficiency of biomass to biofuels, using a novel gasification and syngas fermentation process.
- Reduce the greenhouse gas emissions and the environmental impacts of biofuels production, compared to fossil fuels and conventional biofuels.
- Enhance the social and economic benefits of biofuels production, by creating new jobs, improving rural development, and increasing energy security.

1.1 A brief overview of the deliverable and its expected outcomes

To maximize the contribution of biofuels in aviation and maritime industries, it is essential, apart from responsible sourcing of feedstock, a holistic techno-economic assessment, market analysis, environmental assessment, social assessment and social cost-benefit analysis on a life cycle basis.

1.2 Questions and hypotheses that guide the task

The main research questions and hypotheses that guide the task are:

- What are the social and socio-economic impacts of the biofuels production from different types of biomass and biorefineries locations, compared to the conventional fossil fuels and biofuels?

- How can the social and socio-economic impacts of the biofuels production be measured and valued, using the S-LCA and S-CBA methodologies?
- How can the social and socio-economic impacts of the biofuels production be integrated into the sustainability assessment of the BioSFerA process, and inform the policy and decision making?

1.3 Aim and objectives of the present deliverable

Life cycle assessment (LCA) has generally been used to analyse the effects that a product or process will have on the environment. Results of an LCA study will let the involved stakeholders know which aspects of their new developed product or process are efficient, and where that efficiency can be improved to reduce environmental impacts: these inputs (coming from T7.3) and the inputs coming from TEA (T7.1) will be capitalized to perform the S-LCA and S-CBA analysis.

The Social Life cycle assessment (S-LCA) is complementing the environmental LCA and Life Cycle Costing methodologies by adding extra dimensions of impact analysis, offering valuable information for those who seek to produce or purchase responsibly and by contributing to the full assessment of goods and services within the context of sustainable development. Social welfare is considered one of the main development goals of research projects promoting alternative fuel solutions.

"Social Life Cycle Assessment" (S-LCA) and "Social Cost-Benefit Analysis" (S-CBA) are both methods used to evaluate the social impacts and benefits of products, projects, or policies. These approaches take into account various social factors and attempt to quantify their effects to aid decision-making and policy formulation.

Understanding and assessing what could improve or undermine well-being is a key element in developing sustainable fuel solutions, aiming at improving social and economic benefit while reducing both social and environmental impacts. Combining Social Life Cycle Assessment (S-LCA) and Social Cost-Benefit Analysis (S-CBA) studies into a united report is a comprehensive approach that can provide a holistic understanding of the social impacts and economic aspects of the BioSFerA project. Integrating S-LCA and S-CBA allows for a thorough examination of the project's life cycle and its implications on various social dimensions. Here's how you can approach the integration:

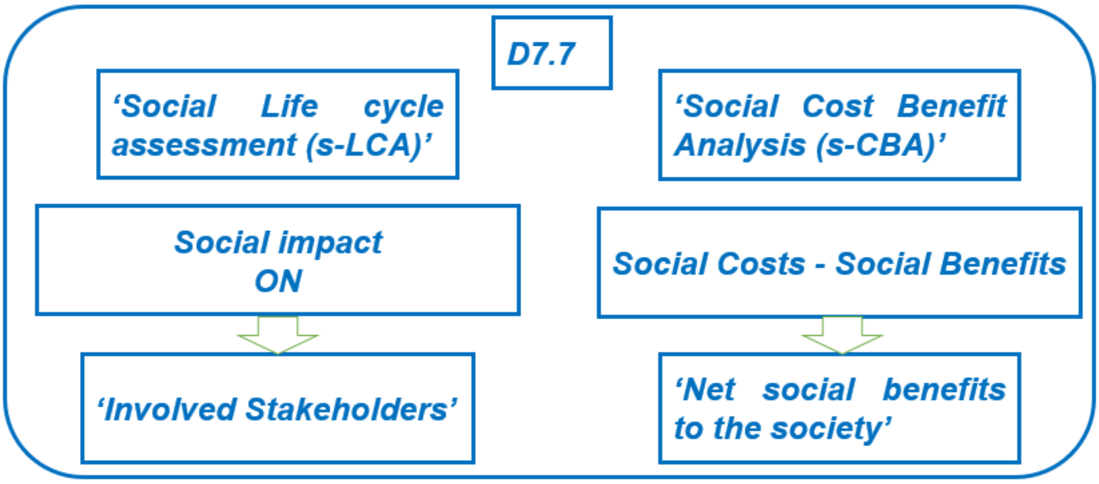

Figure 1 The Deliverable Structure

1.4 Structure of the Deliverable

The Deliverable is structured as follows:

- Chapter 2 briefly presents the theoretical framework of social assessment and social cost-benefit analysis
- In Chapter 3 the methodology is presented.
- Chapter 4 sets the boundaries of the system.
- Chapter 5 is devoted to the Social Life Cycle Assessment Criteria and Indicators
- Chapter 6 analyses the social costs and benefits
- Chapter 7 presents and discusses results.
- The report closes with the conclusions in chapter 8.

2 Brief theoretical framework of social assessment and social cost-benefit analysis

As every project, a biorefinery may affect people and their communities, so "Social Life Cycle Assessment" (S-LCA) and "Social Cost-Benefit Analysis" (S-CBA) can help an organization deliver its mission-critical services, engage its communities, and increase trust among stakeholders. S-LCA is a method that assesses the social and socio-economic impacts of a product throughout its life cycle, from raw material extraction to disposal (Mattioda et al., 2020). On the other hand, S-CBA is a method that compares the social costs and benefits of a project or policy, taking into account the externalities that are not reflected in the market price (Zhang et al., 2021). When considering the use of biofuels as marine and plane fuel, S-LCA can be used to assess the social impact of the entire life cycle of biofuels, including the social impact of the raw material extraction, processing, transportation, and use of biofuels. S-CBA can be used to compare the social costs and benefits of using biofuels as marine and plane fuel with those of using conventional fossil fuels, taking into account the externalities such as environmental effects.

2.1 Social Life Cycle Assessment

Social Life Cycle Assessment (S-LCA) is a powerful technique to assess and report about the social and socio-economic impacts and benefits of product life cycle from the extraction of the natural resources to the final disposal (Benoît-Norris et al., 2020a). It helps organizations to measure and manage social risks within their supply chains. The guidelines for S-LCA of products provide an adequate technical framework from which a larger group of stakeholders can engage to move towards social responsibility when assessing the life cycle of goods and services. S-LCA is important because it provides a comprehensive approach to evaluate the social impacts of products and services, which is essential for sustainable development.

According to the literature analysis conducted by (Ramos Huarachi et al., 2020), the prevailing patterns indicate a surge in interest in Social Life Cycle Assessment studies within the context of the bioeconomy. This observation suggests a mirroring of trends seen in broader sustainability science, with a notable resonance in the field of social sustainability. The authors further assert that, despite more than two decades of development, S-LCA is currently experiencing its most flourishing period. However, they also acknowledge that there is a considerable distance to cover before achieving the scientific maturity of this assessment methodology.

The S-LCA methodology will follow the ISO 14040 framework and the UNEP Guidelines for Social Life Cycle Assessment of Products, developed for different aspects of the environmental impact assessment and for each phase of the product's development.

In order to develop the social impact criteria, this study adopted the criteria provided by Society of Environmental Toxicology and Chemistry (SETAC)/United Nations Environment Programme (UNEP) Code of Practice (UNEP-SETAC 2009), supplemented by a survey, and reconciled by literature review. The criteria were grouped by (Manik et al., 2013) as: 1. Human Rights 2. Working Conditions 3. Cultural Heritage 4. Socio-economic Repercussion 5. Governance. Each criterion represents a different aspect of social sustainability, and together they provide a comprehensive framework for evaluation.

2.2 Social Cost-Benefit Analysis

Social Cost-Benefit Analysis (S-CBA) is a systematic and comprehensive approach used to evaluate the efficiency of a project from the perspective of the society as a whole. It involves identifying, measuring, and comparing all the costs and benefits of a project, policy, or decision. CBA is a compass in the decision-making process, guiding efforts toward interventions that not only align with the intended objectives but also offer the best returns on investment. It empowers policymakers and stakeholders to make data-driven choices, optimize resource allocation, and enhance the overall effectiveness of public interventions in the face of pressing challenges like climate change and development.

The economic evaluation of a project performed with the use of a Cost Benefit Analysis to assess whether a project or policy should be undertaken or not, could also be improved with use of complement methodologies to evaluate the welfare of the economic results. Social cost-benefit analysis (S-CBA) is an extension of the economic CBA, adjusted to take into account the full spectrum of costs and benefits (including social and environmental effects) accepted by society as a whole as a result of an intervention. In order to compare different types of costs and benefits with economic costs and benefits, they must first be converted in monetary values. The condition for a project or process to be undertaken is that the sum of economic, social and environmental benefits outweighs the sum of economic, social and environmental costs. The S-CBA used to evaluate the developed biofuels of the project will identify the targeted population who gain and (if there are any) those who lose, will identify the benefits and costs of the new alternative fuels allocated to time periods, will quantify the benefits and costs within ranges and will compare the estimated benefits with costs to a discounted common period. The S-CBA will incorporate social considerations into the cost–benefit analysis providing a framework for combining 'wellbeing' impacts into the socio-economic benefits of the alternative fuel solutions (From the GA).

Social cost-benefit analysis is much broader in scope than private cost-benefit analysis because it considers what constitutes valid measures of wellbeing, of costs and benefits it, taking into account the effect that projects have on all facets of society – on all citizens (van Kooten, 2013). The short answer is that economists measure costs and benefits as surpluses; the longer answer requires some elaboration. Social cost-benefit analysis assumes that everything of interest to the decision maker can somehow be measured in monetary terms (Bonner, 2022). Nevertheless, there will remain some things of importance to society that simply cannot be included in the money metric. Since these items are only important if they are somehow (directly or indirectly) affected by the project, these 'intangibles' must be evaluated or judged against the money metric. If the focus is on employment (which is not a true surplus) than any gain in employment that a policy or project brings about needs to be evaluated in terms of the net social loss, preferably measured in terms of the forgone opportunities per job created. If the focus is on CO_2 emissions, a project that reduces the amount of CO_2 in the atmosphere needs to be evaluated with respect to the change in a society's 'surpluses' (economic wellbeing broadly defined).

There are two principal approaches for the quantitative assessment of the costs and benefits to society to determine if an investment will have greater value for society than not making it: the Little-Mirrlees (L-M) Approach and the UNIDO Approach (Borad, 2021). The first approach is based on the concept of shadow pricing, while the second is a more recent development and is based on the concept of social opportunity cost. Shadow Price is the real economic price of projects, activities, goods, and services that have no market price or for which prices are difficult to estimate. It is the opportunity cost, i.e., what somebody had to give up when they made a choice. The shadow price is often defined by what somebody has to give up to gain an extra unit of that good. However, the value of a good or project when measured using the shadow price may differ from its value when measured using market prices. This is because the market may not have properly priced it in the first place. On the other hand, Opportunity Cost is a more general concept that refers to the value of the best alternative forgone, where a choice needs to be made between several mutually exclusive alternatives under conditions of scarcity. It's the value of the next best alternative use of the resources. While both terms refer to the cost of forgoing the next best alternative, shadow price is specifically used to estimate the real economic price of goods or projects that do not have a market price or are hard to value, whereas opportunity cost is a broader term used in decision-making processes to consider the cost of forgoing the next best alternative. Given that the BioSFerA project aims to develop a cost-effective interdisciplinary technology to produce sustainable aviation and maritime fuels, it might involve both types of situations. Therefore, a combination of both approaches could potentially be used, depending on the specific aspects being analysed.

By using these methods, it is possible to evaluate the social impact of biofuels as marine and plane fuel and make informed decisions that take into account the social, economic, and environmental aspects of the use of biofuels.

3 Methodology

3.1 Social Life Cycle Assessment

S-LCA complements the environmental focus of traditional Life Cycle Assessment (LCA) by evaluating social impacts such as worker's rights and conditions, local community impacts, socio-economic ripple effects, health and safety, and cultural heritage. The S-LCA process typically involves several key steps (Benoît-Norris et al., 2020b).

Social impacts in Social Life Cycle Assessment (S-LCA) are typically measured through a systematic process that involves the identification, prioritization, and evaluation of various social and socio-economic impact subcategories (Bouillass et al., 2021). Here’s a general process on how these impacts are measured:

- **Identification of Impact Subcategories**: The first step is to identify the relevant social impact subcategories that are applicable to the product or service being assessed. These subcategories can include aspects like workers’ rights and conditions, local community impacts, socio-economic ripple effects, health and safety, and cultural heritage.
- **Prioritization of Impact Subcategories**: Once the relevant subcategories have been identified, the next step is to prioritize them based on their significance. This can be done through a participatory approach involving all concerned stakeholders.
- **Selection of Indicators**: For each prioritized subcategory, specific social inventory indicators are selected. These indicators are used to measure the potential social impacts in a quantifiable way.
- **Data Collection**: Data is then collected for each of the selected indicators. This can involve a variety of methods, including surveys, interviews, and review of secondary data sources.
- **Evaluation of Social Impacts**: The collected data is then used to evaluate the social impacts associated with each stage of the product or service life cycle. This involves comparing the data against established benchmarks or standards.
- **Interpretation of Results**: Finally, the results are interpreted to provide insights into the social impacts of the product or service. This can involve identifying key areas of concern, evaluating the effectiveness of current social performance strategies, and making recommendations for improvement.

In the context of the BioSFerA project, the S-LCA would aim to assess the social impacts of producing biofuels for aviation and maritime sectors from different types of non-food biomass. The assessment would consider impacts on workers’ rights and conditions, local communities, socio-economic development, health and safety, and cultural heritage. To conduct a social cost-benefit analysis for the BioSFerA project, it is needed to assess the viability of the project for the public and not just for shareholders. It is also needed to identify and measure the economic as well as social costs and benefits of the project and investment. The results of the S-LCA can provide valuable insights into the social sustainability of the BioSFerA Project. They can help identify areas of concern, inform decision-making, and guide strategies to mitigate negative impacts and enhance positive impacts.

The project task adhered to the ISO 14040/44 Standards and UNEP Guidelines for conducting the S-LCA. The importance of social group criteria was determined through expert questionnaires, leading to the identification of social impacts groups, and social criteria from stakeholders across participating countries.

3.2 Social Cost-Benefit Analysis

The main objective of S-CBA is to guide decision-making towards options that maximize social welfare. In the context of the BioSFerA project, S-CBA can provide valuable insights into the social implications of producing sustainable aviation and maritime fuels using non-food bio-based blends. Here's a brief overview of the key components of S-CBA:

- **Identification of Costs and Benefits**: This involves identifying all the social costs and benefits associated with the project. In the case of BioSFerA, this could include the costs of setting up and operating the biorefineries, the benefits of job creation and economic stimulation, the environmental costs and benefits, and the potential health risks and benefits.
- **Measurement of Costs and Benefits**: Once the costs and benefits have been identified, the next step is to measure them. This can be challenging, especially when dealing with non-market goods such as environmental benefits or health risks. Various techniques can be used to assign monetary values to these costs and benefits, such as contingent valuation or damage cost assessment.
- **Comparison of Costs and Benefits**: The final step in S-CBA is to compare the total social costs with the total social benefits. If the benefits outweigh the costs, the project is considered socially desirable. If the costs outweigh the benefits, the project may need to be reconsidered or modified.
- **Sensitivity Analysis**: Given the uncertainties and assumptions involved in S-CBA, it's important to conduct a sensitivity analysis. This involves testing how the results of the S-CBA change with variations in key parameters or assumptions.

The S-CBA incorporated social considerations into the cost-benefit analysis, providing a framework for integrating 'wellbeing' impacts into the socio-economic benefits of alternative fuel solutions.

Case study scenarios were configured, focusing on different feedstocks (pellet, straw, pruning from vineyards and olives, and organic waste) and biorefinery locations in Finland, Italy, Spain, and Greece.

By carrying out a S-CBA, the BioSFerA project can ensure that it not only contributes to energy security and environmental sustainability but also maximizes social welfare. This holistic approach can help to build a more sustainable and inclusive bioeconomy.

3.3 Trade-offs and synergies between the environmental, social, and economic dimensions

The S-LCA follows the ISO 14040 framework and the UNEP Guidelines, and assesses the social impacts of the biofuels production along the life cycle stages, such as feedstock cultivation, transport, conversion, and end-use. The S-CBA incorporates social considerations into the cost–benefit analysis, and provides a framework for combining 'wellbeing' impacts into the socio-economic benefits of the alternative fuel solutions. The tasks will help to identify the trade-offs and synergies between the environmental, social, and economic dimensions of sustainability, and to provide recommendations for the BioSFerA Project and other stakeholders.

4 The BioSFerA case studies

The case studies are based on the hypothetical establishment of a 200 MWth plant, that corresponds to feedstock annual needs of *approximately* 250 kt/year (considering LHV of 20 MJ/kg and annual operational time of 6,000 h). Case study scenarios were configured, focusing on different feedstocks (pellet, straw, pruning from vineyards and olives, and organic waste) and biorefinery locations in four countries; **Finland**, **Greece**, **Italy** and **Spain**.

4.1 Functional Unit

The functional unit provides the reference to which the inputs and outputs of the systems are normalised.

4.2 Boundaries of system

The production of biofuel from non-food biomass involves several stages, each with its own potential hotspots or areas of concern. Here are some of them:

- **Feedstock Processing**: This involves the conversion of biomass into a usable form for biofuel production. Hotspots can include energy use and emissions from processing.
- **Biofuel Production**: This is the conversion of processed biomass into biofuel. Hotspots can include energy use, emissions from production processes, and waste generation.
- **Distribution and Use**: This involves the transportation and use of biofuels. Hotspots can include emissions from transportation and combustion.

Producing biofuel from non-food biomass such as pellet, straw, pruning (vineyard and olive), and organic waste can help mitigate some of these hotspots. For instance, using these types of biomass can reduce competition with food crops and may require less water and fertilizer. Moreover, using waste materials for biofuel production can contribute to waste management solutions.

However, it’s important to note that while these approaches can mitigate some of the hotspots, they also have their own set of challenges, such as the need for advanced technologies for biofuel production from these feedstocks. Therefore, a balanced and sustainable approach is needed in the development and use of biofuels.

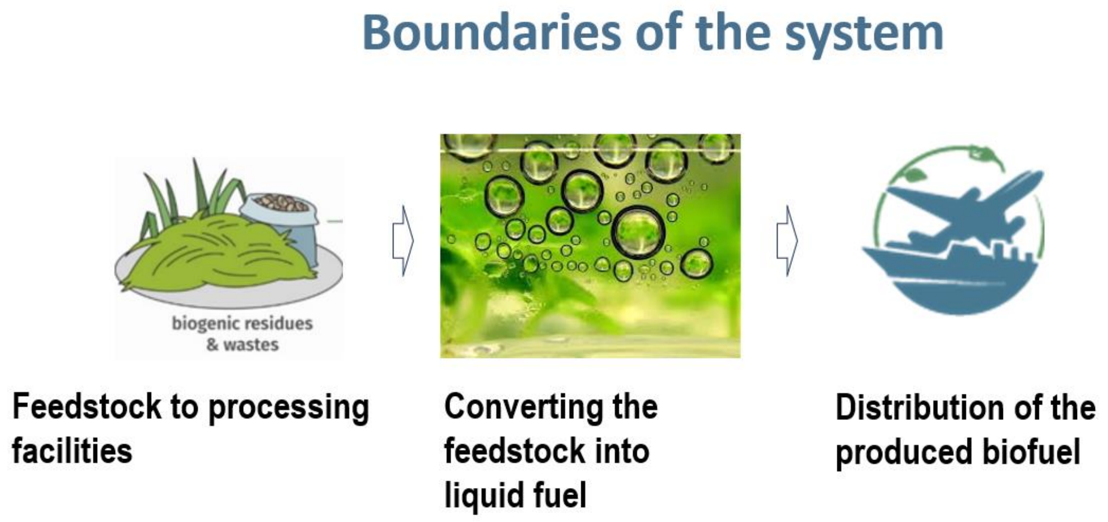

Figure 2 The boundaries of the system

(1) supply of each type of feedstock to processing facilities
(2) the process of converting the feedstock into liquid fuel.
(3) Distribution of the produced biofuel.

5 Social Life Cycle Assessment Criteria and Indicators

5.1 Defining the Social Sustainability Criteria

Sustainable alternative fuels are essential for reducing the environmental impact of aviation and maritime industries, meeting regulatory requirements, enhancing energy security, promoting innovation, and improving economic and environmental sustainability. They play a crucial role in addressing the pressing global challenges of climate change and air quality while driving positive economic and technological developments. Biofuels can make a significant contribution as alternative fuels for aviation and maritime industries. However, it's important to note that the contribution of biofuels to aviation and maritime industries depends on various factors, including the availability of sustainable feedstock, technological advancements, and the development of supply chains and infrastructure. Additionally, the sustainability of biofuels depends on responsible sourcing practices to prevent negative impacts on land use, biodiversity, and food security.

To maximize the contribution of biofuels in aviation and maritime industries, it is essential, apart from responsible sourcing of feedstock, a holistic techno-economic assessment, market analysis, environmental assessment, social assessment and social cost-benefit analysis on a life cycle basis. In order to develop the social impact criteria in this study, we adopted the criteria provided by Society of Environmental Toxicology and Chemistry (SETAC)/United Nations Environment Programme (UNEP) Code of Practice (UNEP-SETAC 2009), supplemented by a survey, and reconciled by literature review. The criteria groups used are: 1. Human Rights 2. Working Conditions 3. Cultural Heritage 4. Socio-economic Repercussion 5. Governance. Each criterion represents a different aspect of social sustainability, and together they provide a comprehensive framework for evaluation.

5.1.1 Human Rights

Human Rights aligns with the understanding that sustainable development extends beyond just environmental issues and includes the rights to life, health, food, water and sanitation (About Human Rights and the Environment, n.d.), (ESG (Environmental, Social, & Governance), n.d.). A safe, clean, healthy and sustainable environment is integral to the full enjoyment of a wide range of human rights, including apart of rights to life, health, food, water and sanitation, gender equality. action to reduce gender inequality and shift gender norms for improved health outcomes, calling on leaders in national governments, global health institutions, civil society organisations, academic settings, and the corporate sector to focus on health outcomes and engage actors across sectors to achieve them; reform the workplace and workforce to be more gender-equitable; fill gaps in data and eliminate gender bias in research; fund civil-society actors and social movements; and strengthen accountability mechanisms (Gupta et al., 2019).

5.1.2 Working Conditions

Working Conditions is in line with the understanding that social sustainability encompasses labor relations, fair wages, working hours, and the right to collective bargaining. World

Employment and Social Outlook 2024 report underscores the need for policy interventions focused on social justice to ensure a fair and sustainable global economic recovery (World Employment and Social Outlook, 2024). The quality of a company's relationships and engagement with its stakeholders is critical. Directly or indirectly, companies affect what happens to employees, workers in the value chain, customers and local communities, and it is important to manage impacts proactively. While it is the primary duty of governments to protect, respect, fulfil and progressively realize human rights, businesses can, and should, do their part. At a minimum, we expect businesses to undertake due diligence to avoid harming human rights and to address any adverse impacts on human rights that may be related to their activities (Social Sustainability | UN Global Compact, n.d.).

5.1.3 Cultural Heritage

Cultural Heritage aligns with the understanding that sustainability involves the impact of projects on the cultural heritage of the communities where they operate. Axelsson et al., (2013) conclude that it is possible to identify indicators and match them with verifier variables to support inclusion of social and cultural values in planning. There is, however, more work to do when it comes to the selection of indicators and verifier variables. To make this approach operational there is also a need for the final step, to identify target levels, such as those expressed in policies. This would then allow for social and cultural sustainability assessments. We argue that the use of maps to visualize the sustainability status will assist stakeholders in the process of defining indicators, verifier variables, and target levels.

5.1.4 Socio-economic Repercussion

Socio-economic Repercussion aligns with the understanding that social sustainability refers to the social and economic impacts of projects on local communities and the wider society. Almost all the initiatives share an approach that is strongly based on participation and involvement of communities, with specific focus on promoting the well-being of citizens. A participatory approach means involving communities in the definition of strategies, policies, initiatives, services and products, as well as in the definition of agreed objectives to secure a good life now and for future generations. This cooperation also facilitates exploitation of the interconnections between local entities (such as municipalities) committed to developing Sustainable Development Goals at local level (McGuinn et al., 2020).

5.1.5 Governance

Governance aligns with the understanding that good governance is crucial for the success and sustainability of projects. It's an oversight function that is aligned with the organization's governance model and encompasses the project life cycle (Matthews, 2019). In essence, good governance is crucial for the success and sustainability of projects as it provides direction, defines procedures and processes, and creates a framework for decision making (Alie, 2015). It enables greater transparency and visibility across the project landscape, ensuring that the project is well managed and that stakeholders are kept informed of progress[4] (What Is Governance?, n.d.).

Table 1 Social Sustainability Criteria

1. Human Rights
2. Working Conditions
3. Cultural Heritage
4. Socio-economic Repercussion
5. Governance

5.2 Indicators for the social assessment

5.2.1 Gender equity

Gender equity for biofuel producers refers to the fair treatment of all genders in the biofuel production industry. This involves ensuring equal access to opportunities, resources, and benefits, and eliminating discrimination based on gender. It's important to note that achieving gender equity in biofuel production can have significant social and economic benefits (Rossi & Lambrou, 2008). For instance, women are primary producers of biofuel worldwide, and their inclusion can lead to increased productivity and sustainability. However, there are also potential risks, such as discriminatory working conditions on plantations, that need to be addressed to ensure gender equity.

5.2.2 Occupational health and safety

Occupational health and safety for biofuel producers refers to the policies, procedures, and practices implemented to protect workers involved in the production of biofuels from hazards that could cause injury or illness. It is also necessary to assesses the impact of the biofuel industry on the health and safety of workers and local communities. It's important to note that these health and safety risks can be managed and mitigated through appropriate safety measures, regulatory compliance, worker training, and the use of safer materials and technologies. In the context of the BioSFerA project, occupational health and safety would involve assessing these potential hazards and implementing measures to mitigate them, thereby ensuring the safety and well-being of the workers involved in the project.

5.2.3 Work-life balance

Work-life balance for biofuel producers, like any other workers, refers to the equilibrium between their work responsibilities and their personal life. This includes managing their time and energy between work and other important aspects of their life such as family, leisure activities, and self-care. Biofuel production can sometimes require long or irregular hours, especially during certain seasons or in certain phases of a project. This could impact workers' ability to balance their work and personal life and lead to a high-stress job due to factors like meeting production targets or adhering to safety regulations.

Achieving a good work-life balance is important for maintaining worker satisfaction, health, and productivity. It's beneficial for both the workers and the organization as it can lead to increased job satisfaction, improved work performance, and reduced employee turnover.

5.2.4 Job Satisfaction and Engagement

In the context of the BioSFerA project, ensuring high levels of job satisfaction and engagement among biofuel producers could contribute to the project's success by promoting a motivated, productive, and stable workforce. Job Satisfaction refers to the level of contentment or fulfillment that biofuel producers receive from their work. It can be influenced by various factors such as the nature of the work itself, working conditions, pay, work-life balance, relationships with colleagues and superiors, and opportunities for career advancement (Richards, n.d.). Job Engagement refers to the level of commitment, involvement, and enthusiasm that biofuel producers have towards their work. Engaged employees are typically more passionate and motivated, which can lead to higher productivity and performance. Factors influencing job engagement can include the meaningfulness of the work, support from management, and a positive workplace culture. This goes beyond their daily duties to cover satisfaction with team members/managers, satisfaction with organizational policies, and the impact of their job on employees' personal lives.

5.2.5 Community Engagement

Community Engagement refers to the involvement of local communities in decision-making processes related to biofuel production and Community perceptions of the project.

5.2.6 Public Commitments to Sustainability Issues

Public Commitments to Sustainability Issues refers to the commitments made by the organization to address sustainability issues in biofuel production.

5.3 Grouping the indicators

Following the above discussion, and the KPIs from D2.1 the chosen indicators for assessment were listed under the corresponding group category:

Human Rights

- **Gender Equity**: Ensuring equal rights and opportunities for all genders is a fundamental human right.

Working Conditions

- **Health and Safety**: This refers to the measures and practices in place to ensure the safety and health of employees.
- **Work-Life Balance**: This pertains to the balance that an individual needs between time allocated for work and other aspects of life.
- **Job Satisfaction and Engagement**: This relates to how content and engaged an employee is with their job.

Cultural Heritage

- **Community Engagement**: This refers to the involvement of local communities in decision-making processes related to biofuel production1.

Socio-economic Repercussion

- **Direct/Indirect Jobs Creation**: This refers to the jobs created directly by the biofuel production and indirectly in supporting industries.
- **Local Employment**: This refers to the employment opportunities created for the local population.

Governance

- **Public Commitments to Sustainability Issues**: This refers to the commitments made by the organization to address sustainability issues in biofuel production.

6 Social Life Cycle Costs and Benefits for the BioSFerA project

Like in the cost-benefit analysis the sum of the social costs is deducted from the social benefits to get the net social benefit to the society.

social benefits - social costs = net social benefits to the society

6.1 The social benefits of biofuel production

Biofuels are derived from “energy crops” like wheat, corn, soybeans, and sugarcane, can be grown sustainably, and if every nation cultivates its own, biofuels could potentially become an inexhaustible resource. BioSFerA project proposed feedstock comes from different types of (non-food) biomass, such as pellet, straw, pruning (vineyard and olive) and organic waste contributing even more to sustainably.

6.1.1 Environmental benefits

Biofuels have the potential to significantly reduce greenhouse gas emissions. For instance, ethanol can cut these emissions by up to 65%, while biodiesel made from cooking oil can reduce them by as much as 87% compared to petroleum diesel. Biofuels emit less harmful carbon compared to standard diesel and are not only less flammable than fossil diesel, but they also offer superior lubricating properties, enhancing engine performance. Bio-based fuels are anticipated to provide an estimated 80% reduction in overall CO2 life cycle emissions compared to fossil fuels.

6.1.2 Lower Foreign Oil Dependence

Biofuels have been recognized as a potential solution to reduce dependence on foreign oil. Publications come from both sides of the Atlantic.

An article titled “9/11: using biofuels to reduce American dependence on foreign oil” discusses how the U.S. government has recognized the potential economic and security benefits of reducing the need to import petroleum fuels through the use of biofuels (Pond, 2011). The U.S. Energy Information Administration (EIA) states that there are potential national economic and security benefits when biofuel use reduces the need to import petroleum fuels (Biofuels and the Environment - U.S. Energy Information Administration (EIA), n.d.). A review published in the Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences discusses how biofuels are viewed widely as promising alternative transportation fuels to reduce dependence on petroleum-based fuels (Jeswani et al., 2020). An article on ThoughtCo mentions that since biofuels are derived from agricultural crops, they are inherently renewable and can be produced domestically, reducing dependence on unstable foreign sources of oil (What You Need to Know About Biofuels, n.d.). The U.S. Department of Energy also acknowledges that biofuels can help reduce dependence on foreign oil, thereby driving growth in local economies and increasing energy security (Energy Department Helping Lower Biofuel Costs for the Nation, n.d.).

The European Commission (EC) has recognized the potential of biofuels in reducing dependence on foreign oil. Here are some references that support this: The EC's official page on biofuels states that biofuels serve as a renewable alternative to fossil fuels in the EU's transport sector, helping to reduce greenhouse gas emissions and improve the EU's security of supply (Biofuels - European Commission, n.d.). An article titled "In focus: Reducing the EU's dependence on imported fossil fuels" discusses how the EU's energy policy has driven significant change in recent years, with a considerable drop in the most polluting fuels, as consumption has moved more towards natural gas and renewables (In Focus, n.d.). The EC's RePowerEU proposal aims to boost EU energy security and is an important step to reducing dependence on imported crude oil and ensuring stable domestic production of fuel (Vackeová & Noyon, 2022). An article titled "How much do biofuels reduce emissions?" mentions that the use of biofuels in transport is promoted as a means to tackle climate change, diversify energy sources, and secure energy supply. In addition, biofuels are considered as an option to contribute to the reduction of oil imports and oil dependence (How Much Do Biofuels Reduce Emissions?, n.d.).

6.1.3 Job creation

The construction and operation of a biorefinery that uses non-food biomass as feedstock can create a variety of jobs across different stages. These range from Research and Development, Design and Construction (Engineers and Technicians, Construction Workers), Feedstock Production and Collection (Agricultural Workers, Transportation Workers), Biorefinery Operation (Plant Operators, Maintenance Workers, Quality Control Inspectors), Sales and

Distribution. Local employment is a significant aspect of the social sustainability of biofuel production. It can contribute to the economic development of the local community by providing income opportunities and reducing unemployment. Furthermore, it can lead to the development of new skills and capacities within the community, which can have long-term benefits (Richards, n.d.).

Estimating the job creation from biofuel production projects is a complex task that depends on many factors, such as the type and source of feedstock, the technology and scale of conversion, the mode and sector of distribution and use, and the policy and market conditions. Different publications may use different methods, assumptions, and data sources to calculate the direct, indirect, and induced jobs that are associated with biofuel production and use. Therefore, the results may vary significantly across different studies and scenarios.

However, based on a range of publications that cover aspects of biofuel production, renewable energy, and sustainability, some general considerations can be drawn based on common trends and findings in the literature.

The AFTER-BIOCHEM project, funded by the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme, aims to create innovative and more sustainable value chains from non-food biomass feedstock to multiple high added-value products. The project foresees the creation of 60 direct jobs and up to 200 indirect jobs in manufacturing & construction/engineering sectors1(New Report Shows Advanced Biofuels Industry Can Create Jobs, Economic Growth, 2009). The U.S. Energy Information Administration (EIA) states that the U.S. bioindustry is expanding rapidly in response to the need for a near-term alternative to liquid petroleum fuels. The growth of the bioindustry is creating opportunities for workers with a wide range of skills (BIOENERGY TECHNOLOGIES OFFICE, 2013). The European Biomass Industry Association mentions that more than 90% of these jobs (approximately 840,000) will be in the bioenergy sector and 500,000 of them in the agricultural industry in order to provide primary biomass fuels (IRENA, 2017).

During the construction of biofuel production facilities, there is a temporary increase in job creation, mainly in the construction and engineering sectors. The number of jobs depends on the size and complexity of the facility, the location and availability of labor and materials, and the duration of the construction phase. According to one study (New Report Shows Advanced Biofuels Industry Can Create Jobs, Economic Growth, 2009), the construction of a cellulosic ethanol plant with a capacity of 50 million gallons per year could create about 210 direct jobs and 250 indirect and induced jobs during the construction phase, which lasts about 2 years.

During the operation and maintenance phase, there is a permanent increase in job creation, mainly in the agriculture and plant operation sectors. The number of jobs depends on the type and amount of feedstock, the technology and efficiency of conversion, the mode and distance of transportation, and the skill and training requirements of the workers. According to the same study, the operation and maintenance of a cellulosic ethanol plant with a capacity of 50 million gallons per year could create about 85 direct jobs and 120 indirect and induced jobs during the operation and maintenance phase, which lasts about 20 years.

During the advanced biofuel research and development phase, there is a potential increase in job creation, mainly in the scientific and technical sectors. The number of jobs depends on the level and direction of innovation, the availability and quality of human and financial resources, the collaboration and coordination among different actors and institutions, and the diffusion and adoption of new technologies and practices. According to another study (New Report Shows Advanced Biofuels Industry Can Create Jobs, Economic Growth, 2009), the advanced biofuel industry could create about 29,000 direct jobs and 94,000 indirect and induced jobs by 2016, and about 190,000 direct jobs and 383,000 indirect and induced jobs by 2022, assuming a steady growth of biofuel production and consumption under the Renewable Fuel Standard.

These are some general considerations based on common trends and findings in the literature on the job creation from biofuel production projects. These references highlight the potential of biofuels production from non-food biomass in creating jobs and stimulating economic growth.

The biorefineries of the case studies are based on the hypothetical establishment of a 200 MWth plant, that corresponds to feedstock annual needs of approximately 250 kt/year (considering LHV of 20 MJ/kg and annual operational time of 6,000 h). Based on the literature mentioned above, they are expected to employ around one hundred employees.

6.2 The social costs of biofuel production

The costs associated with biofuel production apart from the initial plant mainly are:

- Collection and Transportation: Cost of transportation and logistics for waste collection and fuel distribution.

- Processing: The processing costs for the biofuel production.

The costs have been presented in Deliverable D7.1: Techno-economical assessment.

While the costs associated with biofuel production are directly related to the production of biofuels, social costs take a broader view, considering the wider impacts of biofuel production and use on society.

The social costs for the production of biofuels for aviation and maritime sectors can be quite complex and multifaceted. They include both direct and indirect effects, as well as external effects. Direct effects can include the costs associated with the production process itself, such as labor and materials. Indirect effects can include the impacts on related industries or sectors, such as agriculture or transportation. External effects can include environmental impacts, such as air pollution.

Some potential social costs are:

- Competition for Resources: The use of these materials for biofuel production could potentially compete with other uses, such as composting or animal feed (Searchinger & Heimlich, 2015).
- Environmental Impact: While biofuels can help reduce greenhouse gas emissions, the production process can also have environmental impacts, as discussed in LCA (D2.1).
- Social Displacement: In some cases, large-scale biofuel production can lead to displacement of local communities, particularly in developing countries where land rights may be less secure. An article titled "Spatial scale and social impacts of biofuel production" highlights how the establishment of large-scale biofuels feedstock production can cause smallholders, tenants, and herders to lose access to productive land (Van der Horst & Vermeylen, 2011).
- Food Security: While these materials are not food crops, they often come from agricultural processes. Large-scale diversion of these resources to biofuel production could potentially impact food security (Biofuels - Energy System, n.d.).
- Job Displacement: While biofuel production can create jobs, it can also displace jobs in other sectors, particularly in traditional energy sectors1(Harvey & correspondent, 2022).
- Health Impact: The production process can have potential health impacts on local communities, particularly if it results in air or water pollution (Popp et al., 2016).

The biofuel production from non-food waste pellet, straw, pruning (vineyard and olive), and organic waste, due to the nature of the feedstock and the small size are not expected to have significant social costs.

6.3 Estimating the monetary values

Before contacting social cost-benefit analysis, it is necessary to estimate the monetary values of the factors assessed. Since most of the social costs and benefits are not distributed like the physical products or services, it is necessary to monetarize them.

6.3.1 Estimating the monetary value of GHG emissions

Putting a monetary value on greenhouse gas (GHG) emissions involves capturing the external costs of these emissions—the costs of emissions that the public pays for, such as damage to crops, health care costs from heat waves and droughts, and loss of property from flooding and sea level rise. These costs are tied to their sources through a price, usually in the form of a price on the carbon dioxide (CO_2) emitted (What Is Carbon Pricing?, n.d.).

To put a monetary value on the CO_2 reduction annually, one would need to consider various factors including the cost of damage caused by CO_2 emissions, the benefits of reducing these emissions, and the costs associated with alternative energy sources. This requires a comprehensive analysis involving environmental economics and possibly consulting with an expert in this field.

The monetary value per tonne of CO_2 reduction can vary significantly depending on the method of calculation and the specific context.

This price is often referred to as the "carbon price" or the "social cost of carbon," and it represents a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO_2e). It differs from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme).

The European Union's Emission Trading System (EU ETS) is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively (EU Emissions Trading System (EU ETS) - European Commission, n.d.). It is the world's first major carbon market and remains the biggest one.

The EU ETS operates on a ‘cap and trade’ principle, where a cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. This cap is reduced over time so that total emissions fall.

Companies receive or buy emission allowances, which they can trade with one another as needed. Each allowance gives the right to emit one tonne of CO_2 or the equivalent amount of another greenhouse gas.

The price of emissions allowances (EUA) traded on the EU ETS can vary. For instance, the price reached a record high of 100.34 euros per metric ton of CO_2 in February 2023 (EU-ETS Price 2022-2024, n.d.). Please note that these prices are subject to change based on supply and demand.

These values are used when the government and businesses weigh up the benefits and costs of acting on climate mitigation. Please note that these are just estimates and the actual value can vary based on a variety of factors. It’s also important to note that these values are subject to change as more research is conducted and our understanding of the impacts of CO_2 emissions evolves.

6.3.2 Estimating the monetary value of “Lower Foreign Oil Dependence”

Estimating the monetary value of “Lower Foreign Oil Dependence” as a social benefit from biofuel production is complex and depends on various factors. These factors include the price of oil, the amount of biofuel produced, the energy content of the biofuel relative to oil, and the economic impacts of oil imports.

One way to estimate this value is to consider the cost savings from reduced oil imports. For example, if biofuel production reduces oil imports by 1 million barrels per day, and the price of oil is $100 per barrel, then the savings would be $100 million per day. Over a year, this would amount to over $36 billion.

Another approach is to consider the broader economic impacts of reduced oil dependence. For instance, reducing oil imports can lead to improvements in the trade balance, which can have positive effects on the national economy. It can also reduce the economic risks associated with oil price volatility and supply disruptions.

6.3.3 Estimating the monetary value of job creation

The key to successful monetization of job creation is to clearly demonstrate the value created by the new jobs and to effectively communicate this value to stakeholders, including government agencies, investors, and the local community. Projects that create jobs and contribute to economic development can be more attractive to investors. These jobs can be quantified and monetized based on the wages and benefits paid to the employees (Employment Growth and the Establishment of Bio-Refineries in the EU, 2020). The Labor costs for every case scenario it has been estimated in Deliverable 7.1 of the project.

7 Analysis of the Results

7.1 Social Life Cycle Assessment Results

The importance of social group criteria was determined through expert questionnaires, leading to the weighting of social impacts groups. 15 experts answered the questionnaire, equally distributed among the participating countries. They were asked to weight the importance of each of the social group criteria (i.e. Human Rights, Working Conditions, Cultural Heritage, Socio-economic Reprecussion, and Governance), in a scale 1 to 10 (1 for the lowest).

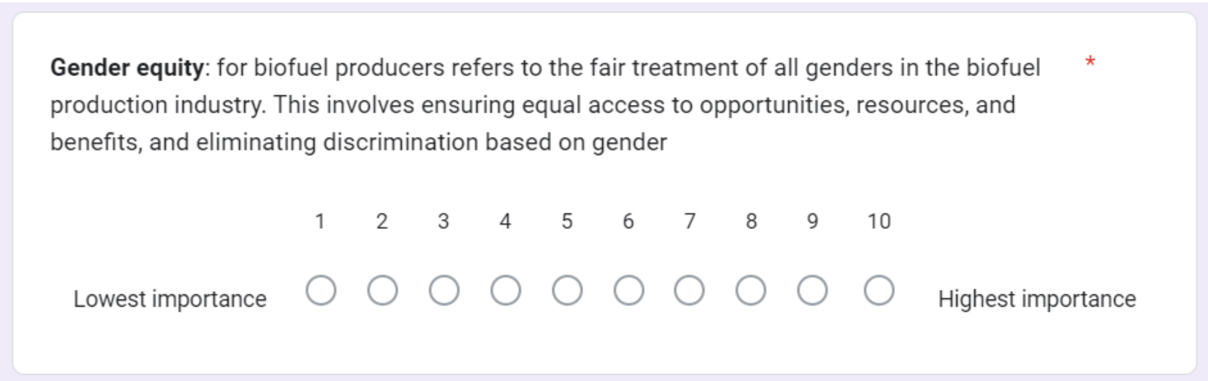

Figure 3 Sample question to weight the importance of each of the social group criteria.

Another similar questionnaire was circulated to evaluate the social indicators (**Error! Reference source not found.**) from stakeholders across participating countries. The social indicators were ranked in a scale 1 to 10 according to each relevance. 30 questionnaires were collected. Attention was taken to include all categories of stakeholders across participating countries.

7.1.1 Social Sustainability Criteria Weighting

Social impact group categories weighted by the experts are shown in Figure 4 Social group criteria weighted by country).

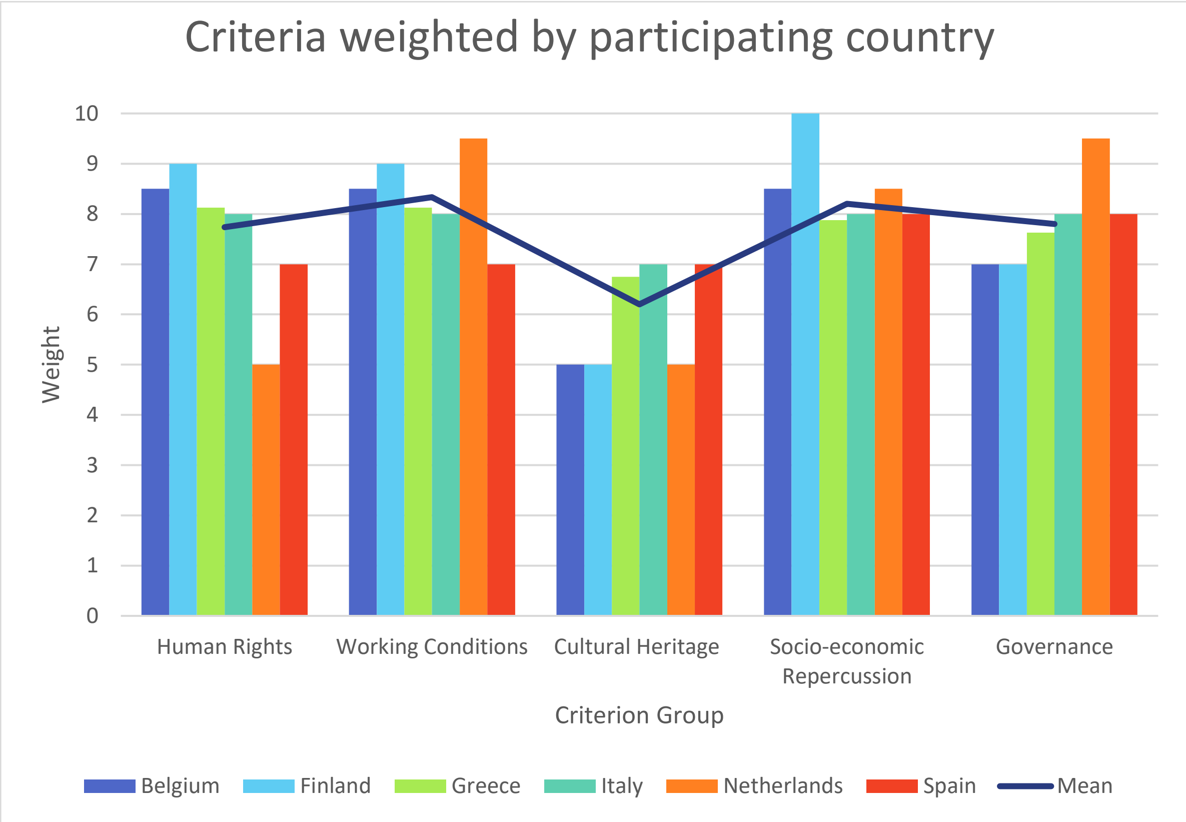

Figure 4 Social group criteria weighted by country

Social impact categories were weighted by experts according to their importance, using a 1-10 scale, (1 is the lowest importance and 10 the highest).

The mean social impact group categories weight is shown in Figure 6 Social criteria weighted. The weight on the importance of the social group criteria is almost similar within the project participating countries, and high, or almost high. The less weighted criterion is Cultural Heritage.

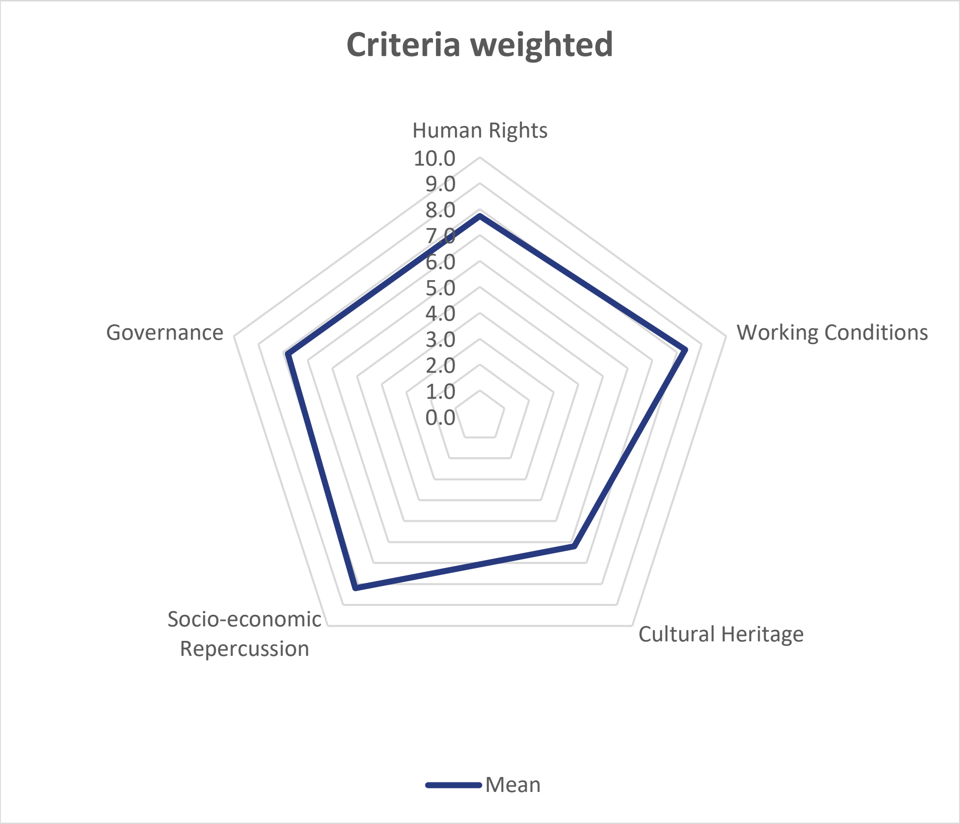

Figure 5 Mean social group criteria weighted

7.1.2 Social indicator assessment

The social indicators ranked in the collected questionnaires were weighted by multiplied by the corresponding social group criterion weight. The results are shown in Figure 6 Social criteria weighted). The survey revealed the critical social hotspots within the impact categories to be addressed through actions. The main found concern is Health and Safety. Attention is also needed in the Public commitment and Community Engagement.

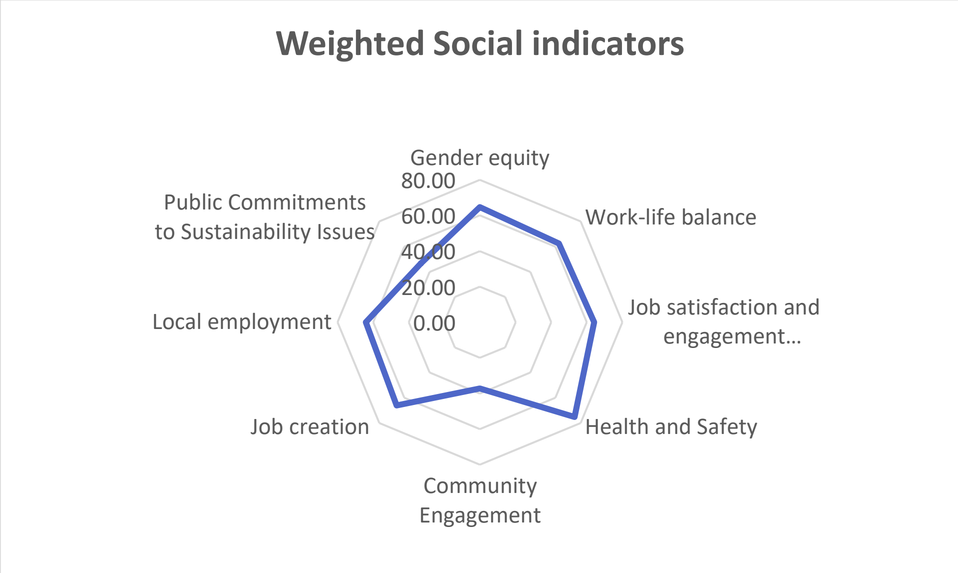

Figure 6 Social criteria weighted

7.2 Social Cost-Benefit Analysis Results

7.2.1 Environmental cost-benefit

The functional unit provides the reference to which the inputs and outputs of the systems are normalized (BioSFerA deliverable D7.5). Based on the RED II, the functional unit can be defined and quantified as follows (EU 2018): "*Greenhouse gas emissions from biofuels, E, in terms of grams of CO_2-equivalent per MJ of fuel, gCO_{2eq} /MJ*".
The GHG emission savings from bioethanol are calculated as (EU 2018):

$$SAVING = (E_{F(t)} - E_{B(t)}) / E_{F(t)} \quad (1)$$

where:
EB = total emissions from the biofuel in [g CO_{2eq}/MJ];
EF = total emissions from the fossil fuel comparator in [g CO_{2eq}/MJ].

In RED II (Annex V, part B in paragraph 19) referred that:
*"For biofuels used as transport fuels, the fossil fuel c EF(t) shall be **94 gCO_{2eq}/MJ."***

<u>**Cost estimation example:**</u>

From LCA results (Deliverable D7.5 T.3.2.I)

<u>Finnish Scenario</u>

The estimated total GHG emissions are approximately 21,167,631 kg CO2eq/a or 21,168 ton CO_2eq/a.

Using the price of emissions allowances (EUA) traded on the EU ETS 100.34 euros per metric ton of CO_2 in February 2023,

The monetarized value of GHG emissions for the production of biofuel is 2,123,960 euros.

Benefit:

Reduction in Greenhouse Gas Emissions

"For biofuels used as transport fuels, the fossil fuel comparator EF(t) shall be ***94 gCO_{2eq}/MJ."***
From LCA results, Finnish Scenario: 86% greenhouse gas emission savings compared to conventional route, so the reduction is: 151,197 - 21,168 =

Saved 130,030 ton CO_2eq/a

with monetarized value of GHG **emissions saved 13,047,183 euros.**

7.2.2 Environmental cost-benefit for the case studies

Repeating the calculations for the scenarios examined in D7.5 the monetarized "Reduction in Greenhouse Gas Emissions" cost-benefit from not using conventional fuel was deducted. The results are presented in Figure 7 The "Greenhouse Gas Emissions". It is obvious the benefit from not using conventional fuel (in monetarized GHG emissions) it is much greater than the cost (in monetarized GHG emissions) for the production of the biofuel.

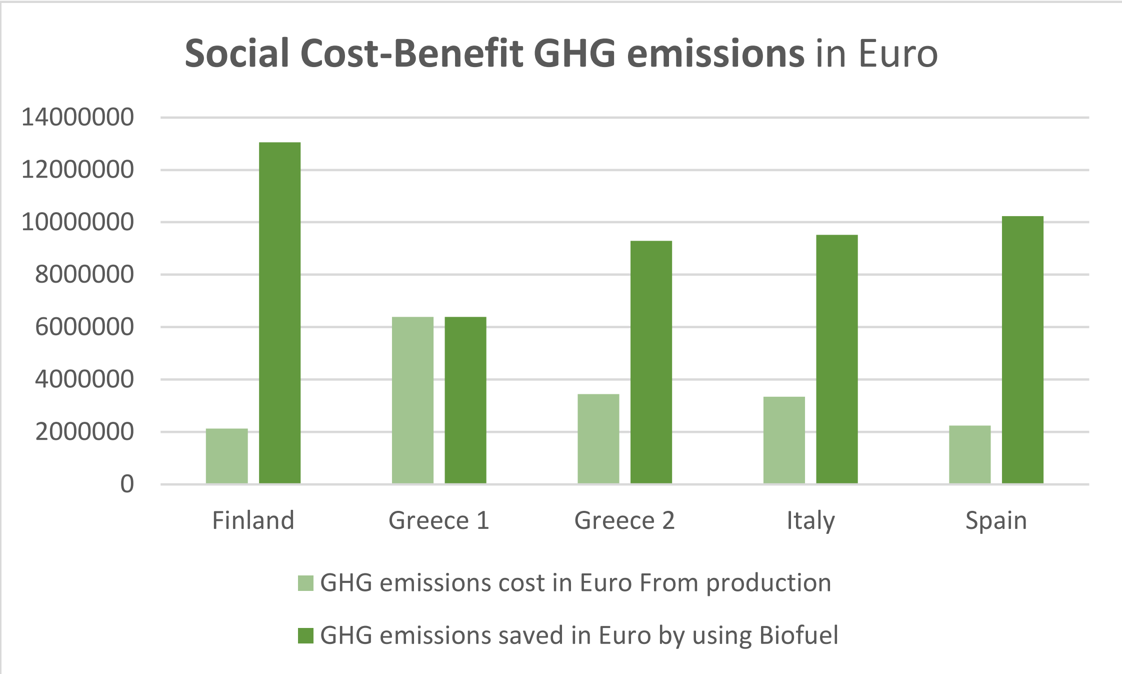

Figure 7 The "Greenhouse Gas Emissions"

8 Conclusions

BioSFerA Project focuses on producing biofuels for aviation and maritime sectors. In this context Task 7.4 has undertaken a critical mission: to assess the social viability of these alternative fuel solutions. Through a rigorous Social Life Cycle Assessment (S-LCA) and Social Cost-Benefit Analysis (S-CBA), the project has shed light on the multifaceted social impacts of biofuel production from non-food waste.

Utilizing the robust Social Life Cycle Assessment (S-LCA) method, this study evaluated the social impacts of a product's life cycle. The aim was to aid organizations in managing social risks within their supply chains and promoting social responsibility. The social impact criteria were developed in accordance with the SETAC/UNEP Code of Practice and were further refined through a survey and literature review. These criteria covered various social groups, including Human Rights, Working Conditions, Cultural Heritage, Socio-economic Repercussion, and Governance, thus providing a comprehensive evaluation framework. Each of these groups represents a unique facet of social sustainability, and specific indicators were chosen for assessment. For the Human Rights group, the focus was on ensuring Gender Equity, a fundamental human right. The Working Conditions group included measures and practices to ensure Health and Safety, Work-Life Balance, and Job Satisfaction and Engagement. The

Cultural Heritage group emphasized Community Engagement to ensure the involvement of local communities in decision-making processes. Lastly, the Governance group incorporated Public Commitments to address sustainability issues.

The conducted social cost-benefit analysis, assessed the project's viability from a public perspective, not just from the viewpoint of shareholders. This analysis identified and quantified the project's economic and social costs and benefits. The social benefits encompassed a reduction in emissions, improved energy security, positive economic impacts, job creation, and enhanced health outcomes. However, the analysis also factored in social costs, which included the initial investment and operational expenses. The project's findings, which are in line with existing literature, underscored a significant gain in Social Cost-Benefit, particularly in terms of reduced greenhouse gas emissions.

The BioSFerA Project's findings contribute to the broader discourse on sustainability and social responsibility of biofuel production. These insights can guide decision-makers in balancing the economic, environmental, and social aspects of biofuel development. This study demonstrates how combined analysis S-LCA and S-CBA provides a holistic perspective on the potential social impacts of introducing biofuel, allowing decision-makers to make informed choices that take into account both the benefits and costs for the affected community.

In conclusion, the BioSFerA Project underscores the complexity of biofuel production and the need for a balanced approach that considers the diverse impacts on society. This project serves as a stepping stone towards a more sustainable and socially responsible biofuel industry.

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