# Advanced Sustainable BIOfuels for Aviation

# **DeliverableD4.2**:
# Preliminary Environmental Assessment

**Consortium:**

| Acronym | Legal entity | Role |
|---|---|---|
| RE-CORD | CONSORZIO PER LA RICERCA E LA DIMOSTRAZIONE SULLE ENERGIE RINNOVABILI | CO |
| TRC | TOTAL RAFFINAGE CHIMIE SA | BEN |
| SKYNRG | SKYENERGY BV | BEN |
| TRF | TOTAL RAFFINAGE FRANCE | BEN |
| CENER | FUNDACION CENER-CIEMAT | BEN |
| ETA | ETA – Energia, Trasporti, Agricoltura Srl | BEN |
| CCE | CAMELINA COMPANY ESPANA S.L. | BEN |
| JRC | JOINT RESEARCH CENTRE – EUROPEAN COMMISSION | BEN |

*CO…Coordinator, BEN…Beneficiary*

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| | | |
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| **PRO** | Technical/economic progress report (internal work package reports indicating work status) | |
| **DEL** | Technical reports identified as deliverables in the Description of Work | **x** |
| **MoM** | Minutes of Meeting | |
| **MAN** | Procedures and user manuals | |
| **WOR** | Working document, issued as preparatory documents to a Technical report | |
| **INF** | Information and Notes | |

**Dissemination Level**

| | | |
|---|---|---|
| **PU** | Public | **x** |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
| **RE** | Restricted to a group specified by the Consortium (including the Commission Services) | |
| **CO** | Confidential, only for members of the Consortium (including the Commission Services) | |
| **CON** | Confidential, only for members of the Consortium | |

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Abbreviations

ASTM – American Society for Testing and Materials
CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation
EC – European Commission
EU – European Union
EU28 – Member States of the European Union
GWP_Global Warming Potential
GHG – Greenhouse Gas
HEFA – Hydro-processed Esters and Fatty Acids
HVO - Hydrogenated Vegetable Oil
LCA – Life Cycle Assessment
OEM's – Original Equipment Manufacturers
PoS – Proof of Sustainability
RED – Renewable Energy Directive
RED II- Renewable Energy Directive recast
RJF- Renewable Jet Fuel
RSB – Roundtable of Sustainable Biomaterials
SAF – Sustainable Aviation Fuel
SOC- Soil organic carbon
UCO-Used Cooking Oil
WtWa- well-to-wake

# Executive Summary

This document contains a preliminary life cycle assessment (LCA) for the production of sustainable aviation fuel (SAF) from *Camelina sativa* oil as main feedstock. The evaluation has assessed the full value chain of the biofuel including feedstock production, feedstock processing, biofuel production and use. This report is an intermediary progress report: the final lifecycle Green House Gases (GHG) emissions report (D4.4) will study other scenarios using feedstock such as Used Cooking Oil (UCO) and Camelina cultivation with biochar and COMBI (co-composted biochar in various blends) in order to produce bio jet and see the infuence of different value chains in the environmental performance.

Renewable fuels plays a key role into aviation sector to reduce greenhouse gases emissions and to introduce a sustainable fuel that can substitute the traditional jet fuel in order to mitigate the $CO_2$ emissions to face the global challenge of climate change (Chiaramonti et al., 2017). Camelina crop is a low-cost feedstock which is produced sustainably and converted into alternative jet fuel via the well-established Hydroprocessed esters and fatty acids (HEFA)-pathway (Core Jet, 2016). Besides Camelina crop has the potential to be grown in degraded land beign a non food competition crop. The end-product HEFA-SPK shows a considerable GHG reduction potential, which contributes to european renewable energy goals besides makes it a promising candidate for contributing to making commercial aviation more sustainable.

The LCA results for the Camelina HEFA pathway range between 73-87 % GHG emission saving with REDII fossil fuel comparator. This variability is due to different options defined in transport distances and biorefinery process for biojet.
It has to be taken into account that in calculation of this data a scenario has been defined where Camelina is cultivated in degraded land. If Camelina was to be cultivated in other type of area these emissions could be around 55% (CORSIA, 2019) or 64% (ITAKA, 2013) GHG emission saving.

# 1 Introduction

BIO4A is a Horizon 2020 project that will scale up the industrial production and the market uptake of sustainable aviation fuel, made from residual lipids.

Besides, it will also investigate the alternative supply of sustainable feedstocks by recovering EU MED marginal land for drought resistant crop production.

The project will test the entire value chain and logistic at industrial scale and it will assess the environmental performance of the overall process.

This preliminary environmental assessment constitutes part of the workplan for the environmental assessment of the whole BIO4A value chain. It is intended to be the first step in order to evaluate different sustainable alternatives for SAF production.

In this report it was studied the value chain of biojet fuel produced from Camelina crop in Spain. As it is a theoretical value chain based on how the final product is going to be produce and commercialized, different options for transportation and other key paramenters have been studied in order to assess its impact in the final result.

Therefore, the base case considers that Camelina seeds and oil are produced in Spain degraded land areas by Camelina Company España. Then oil is subsequently transferred to the Total company facility located in La Mède, Southern France, where it is transformed into biokerosene. The biokerosene is then either sent to Marseille Airport in France or Schipol airport in Netherlands.

As previously stated, this is a prelimanry environmental assessment, in the final deliverable other value chains will be studied, such as UCO which is currenly used to produce biojet or Camelina cultivation with biochar and COMBI, using data from agronomic experimental trials in the framework of BIO4A (WP2).

## 1.1 Environmental Life Cycle Assessment

In order to assess the impact that BIO4A project will have among the environment a LCA must be carried out. The results of this LCA will be compared with the environmental impacts of the fossil fuel production as defined in Renewable Energy Directive recast (RED II).

LCA is a methodological tool which aims to calculate the environmental impact of a product, process or system throughout its entire life cycle (from the raw material to its end of life). The methodology is based on the review and analysis of the inputs and outputs of the system to obtain, as a result, its potential environmental impact. The main aim of LCA is to establish strategies in order to mitigate these impacts.

As shown in Figure 1, the LCA of a product must consider the inputs and outputs of all the stages of the life cycle: beginning with the raw materials extraction, followed by the manufacturing of the components, the use of the product, and finally its recycling or disposal as a waste. The transport, storage, distribution and other activities between stages of the life cycle are included when having enough relevance. This type of life cycle it is commonly named “cradle to grave” perspective.

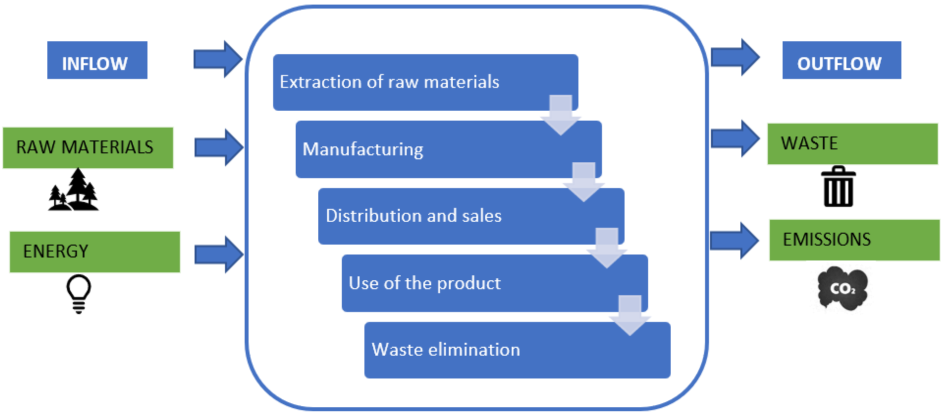


Figure **1** Steps to develop a LCA

# 2 BIO4A value chain

### 2.1.1 Camelina oil value chain

In general, it can be stated that Camelina is non-food competing crop, considering it a second-generation biofuel (Garraín, 2012) and with no or minor emissions due to land use changes (CoreJet, 2016). In addition it offers the possibility of reducing emissions of greenhouse gases. And in the case of obtaining biokerosene, it has already been tested with success in test flights of various commercial airlines. Its cultivation is tolerant to droughts and requires a lower consumption of fertilizers and herbicides. This helps to reduces production costs compared to other oilseeds and it is an excellent crop that can be grown in marginal lands, considering Low ILUC feedstock according to REDII.

There is a growing availability of arable land in the Mediterranean regions, as a consequence of the decline of cereal cropping systems and grain legume. This provides ample opportunities for performing successful feedstock production on unmanaged areas (Pulighe, 2019).

In this report it has been studied value chain for obtaining bio jet using Camelina oil as main feedstock grown in Spanish degraded land. The data used for crop practices have been facilitated from Camelina Company trials held in BIO4A project. Different options based on cultivation practices, biorefinery and end use airport has been studied, in order to define the optimized value chain. In Figure 2 it can be seen the studied value chain from feedstock production until final usage.

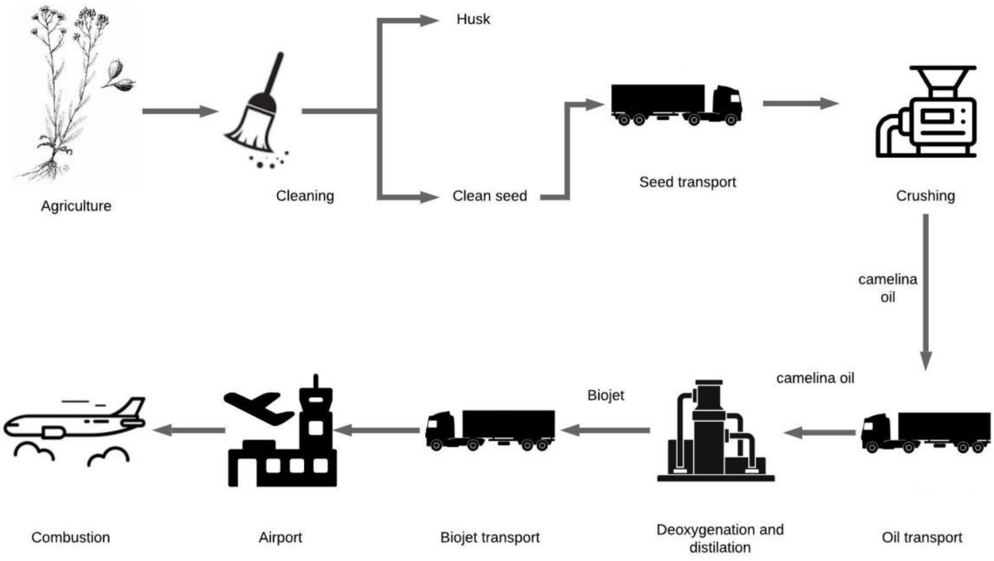


Figure 2 BIO4A value chain

As it can be seen in the figure above (Figure 2) after harvesting the Camelina seed, the following step is cleaning the seeds and preparing them for the oil extraction process, where they are crushed and pressed. If harvested correctly, drying the seeds is not necessary. Then the oil obtained from seed is transported to the biorefinery where after a deoxygenation and distillation process, the biojet is produced. Afterwards, this biojet is taken to the airport where it is combusted in the plane. There are different means of transport linked to the steps of value chain: road transport, barge or pipeline. These different options have been studied in order to reflect the value chain as close to real case as possible.
Additionally, Camelina oil production value chain has enabled producing other valuable by-products (Camelina husks and Camelina meal), which can be employed as high quality animal feed (Itaka, 2017).

**Camelina meal valorization**

Camelina meal or expeller is produced at the crushing facility, as a solid by-product of the oil extraction process. It is a raw material of great interest from a nutritional point of view, since there is no plant feedstock produced nationally in Spain with higher protein levels. Camelina meal could be commercialized targeting the animal feed industry.
It is expected that once the crop is fully established and there are large amounts of guaranteed product available on the market throughout the whole year, animal feed producers will be willing to pay for its nutritional value, which should be at least 10% more than rapeseed meal price. As this market in not yet established, this by-product is not considered in this study.

**Camelina husk valorization**

Camelina husks main destination is the animal feed industry too, due to its high fiber content. They have around 35% of fiber content which can be employed as raw material in ruminants animal feed. Camelina husk commercialization has been performed basically on the basis of its fiber content for the animal feed industry. Such price is however very dependent on the market prices and, most importantly, the availability of other source of fiber.

Consequently, the share of Camelina final product break down is the following:

- Camelina oil content: 38% of grain
- Camelina meal content: 62% of grain
- Camelina husks: 61% of total harvest

These values are taken into account for the calculations and to define allocation rules in the value chain.

### 2.1.2 SAF production process

HEFA is a high maturity level and commercially available conversion technology. Since its ASTM certification in 2011, HEFA has been successfully used in numerous airlines (CoreJet, 2016). The HEFA pathway consists of the hydroprocessing of lipid feedstocks to upgrade them to drop-in jet fuels (CORSIA, 2019). This process is the one chosen in BIO4A project to convert Camelina oil into biojet.

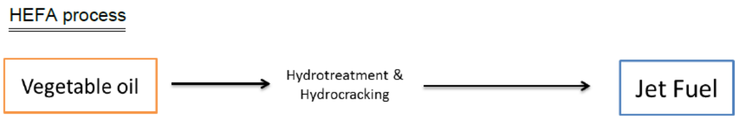


**Figure 3** HEFA process scheme
(Wilhelm, 2015)

At this stage of BIO4A project status, for the environmental assessment, primary data has not been used for SAF production since consolidated data was not available from process production. Whit the aim to have a preliminary representative result of the whole process, after discussion with BIO4A Consortium partners, it was decided to use data from sources which are considered to be robust enough to be employed in the LCA. So, it was decided to use REDII default values and data from ITAKA project (ITAKA, 2013). BIO4A project follows the path from ITAKA project, which supported the development of aviation biofuels in an economic and sustainable manner. Thus, these chosen values to be used as a reference for process production are the following:

- Data from RED: 16.3 g $CO_{2eq}$/MJ (EC, 2018). This value is reference data for rapeseed biodiesel production.
- Data from ITAKA: 6.9 g $CO_{2eq}$/MJ (ITAKA, 2016). This is the value was estimated for bio jet production in the framework of ITAKA project.

The LCA will be done using both data in different scenarios as it is considered more realistic to have these ranges of values for future comparison.

# 3 Environmental Assessment

## 3.1 Goal and Scope

### 3.1.1 Definition of goal and scope

The main goal of this environmental assessment is to estimate GHG emissions from BIO4 value chain. Moreover there are other benefits from this study:
- Evaluation of the environmental impacts of the biofuel obtained.
- Identify and evaluate the opportunities to reduce those environmental impacts throughout the life cycle, once the impacts of each phase of the process have been detected.
- Analyse the environmental benefits of the biofuel produced.

### 3.1.2 System boundaries

The boundaries specify the unit processes that will be considered in the studied analysis. The system boundaries are defined through the stages of the products' life cycle. It is essential to define where to stop tracking energy and material uses of upstream processes, otherwise the analysis would be endless, and the environmental impacts would be altered in the several processes studied. These boundaries shall be adapted to the potential accuracy that could be obtained from the available data.
In our assessment all the steps from cultivation of Camelina until its final use as biojet have been considered (Figure 2).
The assessment covered well-to-wake (WtWa) GHG emissions, expressed as $CO_{2eq}$. It includes emissions from feedstock cultivation, cleaning and crushing of the Camelina seed, conversion to Renewable Jet Fuel (RJF), combustion of the biojet, and all the transports involved in the entire life cycle. On the other hand different transport scenarios has been studied based on location of crop cultivation (ES or FR) and location of final use of biojet (FR or NL). These options have been considered in a sensitivity analysis in order to study the impact of these variables in the environmental assessment.

**Excluded stages from the analysis**.

The environmental burdens related to the manufacture of the machinery and the infrastructure used for the extraction, transfer and refining of Camelina oil have been excluded from the analysis. This is due to their short contribution to the global GHG emissions of the process. Similarly, environmental impacts related to the manufacture of agricultural machinery, transport vehicles, and facilities for the transformation of oil crops and used oils into biodiesel are excluded.

### 3.1.3 Functional Unit

The functional unit is the unit of measurement to which all the data relate. It allows the comparison among different systems, which are functionally equivalent, determining energy and mass flows in relation to its value.
The functional unit selected for the LCA results is grams of $CO_{2eq}$ per MJ of fuel produced ($gCO_2eq$/MJ SAF) and combusted in an aircraft engine (using the lower heating value for characterizing fuel energy content).

### 3.1.4 Allocation

When one system produces multiple products, great care must be taken in assigning each product an appropriate percentage of the environmental impacts from that system.

First, wherever possible, allocation will be avoided in this sustainability assessment by subdividing systems into sub-systems. So those sub-systems which do not result in the production of co-products can avoid undergoing allocation. According to ISO standard (ISO, 1997), system expansion (substitution) could be the second option. Where the allocation of impacts between different products must occur, this will be made according to ISO standards criteria.
In an attributional LCA, emissions must be allocated between products and co-products on the basis of their masses, energy contents, or economic value.

Emissions are allocated towards products and co-products at each processing step. In our case allocation is done based in RED methodology, which follows an allocation based energy content, i.e. on lower heating value (LHV).
The values which have been used for the different products have been provided by partners from Consortium and are the following:

| Product | LHV | Unit |
|---|---|---|
| **Camelina oil** | 37.03 | MJ/kg oil |
| **Camelina husk** | 17.07 | MJ/kg husk |
| **Camelina biojet** | 44.3 | MJ/kg biojet |

Table 1 HLV values for products of value chain

### 3.1.5 Assumptions

**Biogenic emissions**

Life-cycle GHG emission assessments generally assume biogenic carbon dioxide emissions to be fully offset by carbon sequestration during feedstock growth (de Jong, 2017).
As it is stated by (Rettenmaier, 2015) for biofuels the amount of $CO_2$ released into the atmosphere from direct biofuel combustion equals the amount of $CO_2$ that has been taken up by crops recently. This release of biogenic $CO_2$ is considered carbon neutral.
Besides as it is stated in article 13 of Annex V of RED cast emissions of the fuel in use (eu) shall be taken to be zero for biofuels and bioliquids.

**Soil emissions**

The model considers the direct and indirect emissions as well as the carbon sequestration in the soil. The direct emissions include $N_2O$ emission related to added nitrogen fertilizer, crop biomass added to the soil, nitrogen present in the soil and soil carbon changes (CORSIA, 2019). IPCC method was used in to estimate $N_2O$ emission as it is suggested by RED methodology.

**Degraded land bonus**

The GHG calculations also contain a bonus for use of degraded land of 29 g CO2eq/MJ biofuel. According to RED recast[1] this bonus can be allowed if evidence is provided that the land was not in use for agriculture or any other activity in January 2008 and falls into one of the categories severely degraded land (including such land that was formerly in agricultural use) or heavily contaminated land. Definition of severely degraded land as stated in Annex V of REDII includes land that for a significant period of time has been salinated, severely eroded or the organic matter content has been significantly lowered. Heavily contaminated land includes land that is unfit for the cultivation of food and feed due to soil contamination. The bonus can be used for a period of up to 20 years from the date of conversion of the land to agricultural use, provided there is a steady increase in carbon stock.

In Southern EU/MED Countries, there is strong evidence of irreversible desertification effects. Under these circumstances, loss of agricultural land directly corresponds to loss of organic carbon in the soil, as forest will not replace agricultural land due to the unfavourable climatic conditions. For instance, 20% of the territory in Spain is degraded

1
The bonus of 29 g $CO_2$eq/MJ shall be attributed if evidence is provided that the land:
(a) was not in use for agriculture or any other activity in January 2008; and
(b) is severely degraded land, including such land that was formerly in agricultural use.
The bonus of 29 g CO2eq/MJ shall apply for a period of up to 20 years from the date of conversion of the land to agricultural use, provided that a steady increase in carbon stocks as well as a sizable reduction in erosion phenomena for land falling under (b) are ensured.
9. Severely degraded land' means land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.

and an additional 1% is actively degrading, so a predictive/alert model has been developed for this purpose (Martínez-Valderrama, 2016)

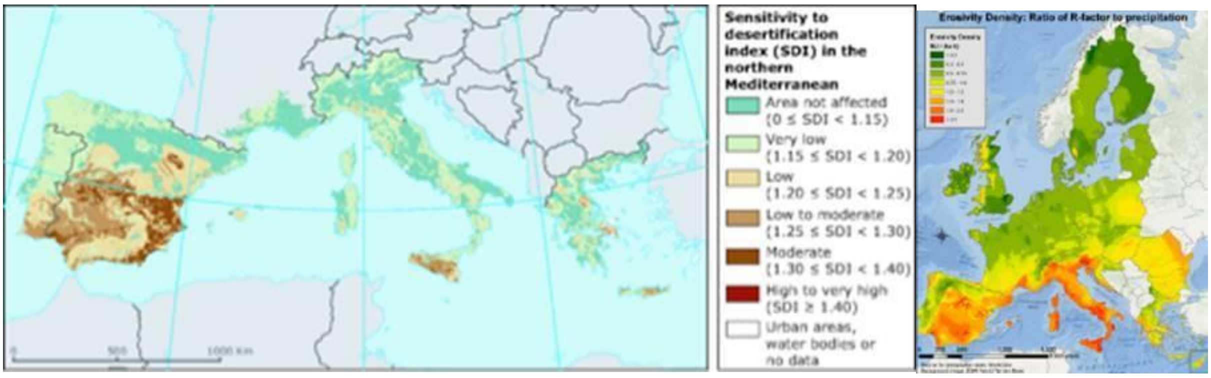


Figure 4 Desertification and Erosivity Index in the EU, focus on Southern EU (MED) region (EEA, 2017)

## Organic matter

Half the Spanish areas obtained a Soil organic carbon (SOC) value below 1%. The lowest SOC levels were associated with agricultural soils. The results herein highlight the potential land use change for SOC sequestration in Spanish soils (Rodriguez, 2016).

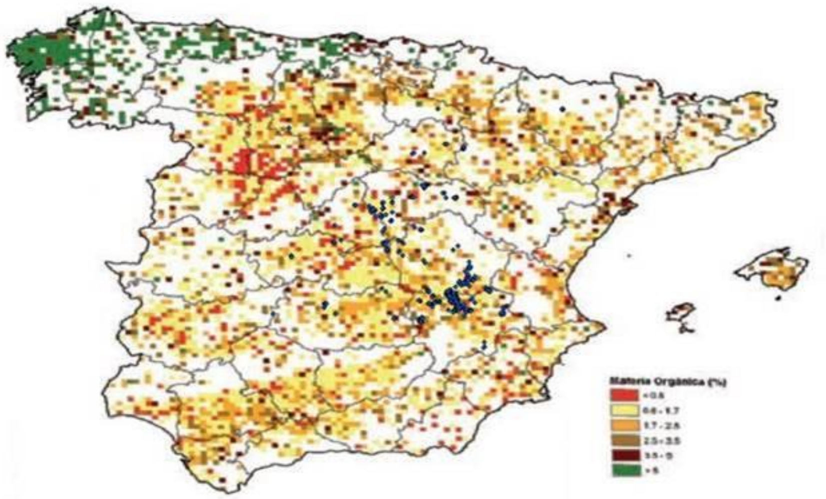


Figure **5** Map of Organic Matter content (%) in Spanish soils

In this report it is studied the scenario where Camelina is grown in the region of Toledo (Spain). The data used comes from experimental trial which have been carried out in the framework of BIO4A project. This area can be considered to fall into the category of degraded land. Therefore for this scenario it could be applied the 29 g CO2eq/Mj bonus for degraded land as stated in RED II.

## Eletricity mix

The energy consumed in the different operations of the BIO4A processes will have important implications on the overall impacts of the assessment. This means that datasets used to account for impacts from energy sources should be as transparent and accurate as possible
Taking into account La Méde biorefinery as the main step of the process, so the electricity supplied by the grid for the production processes have been considered to have impacts equal to the French average grid.
Besides for those steps which are held in Spain the electricity mix of Spain will be used. When electricity and/or heat are produced on site, specific data for the type of plant are used (e.g. a combined heat and power plant), its size, as well as the fuel (e.g. oil, natural gas, and biomass) is used for the assessment. This factor has been taken from Ecoinvent database v. 3.4

#### 3.1.6 Data quality requirements

Main data will be gathered from the BIO4A Consortium technology partners, with each partner(s) providing site-specific data for the stage of the process for which they are responsible. Data will be based on the most up-to-date pilot plant/installation of each stage of the BIO4A processes.

Secondary averaged data has been taken from databases in the public domain. The data collected was assessed by the Consortium partners to ensure consistency between sub-processes and that the entire BIO4A process has been captured. Regarding the time framework, this information is representative of current situation (average data from the last closest years).
Where data gaps remain on completion of the inventory (using all the available modelled and secondary data), such data has been substituted using surrogate data, for closely related processes, modified as necessary. All such deviations from process-specific have been transparently identified.
After defining the objective and the scope of the LCA, and before starting the inventory task, influential Camelina oil based biojet production papers were reviewed and the most important data sources were selected.
For processes where it was not possible to use primary data (stage of crushing and biojet conversion) data from relevant sources has been used such RED or data from contact with stakeholders. Furthermore, secondary data analyses allowed validating the primary data collected by comparing it with similar processes and studies. The carbon footprint results of the ITAKA and Core-Jet-Fuel projects, the predecessors to BIO4A, have been taken as guidance.

**<u>Cut-off criteria</u>**

Cut-off criteria allow a consistent approach to the exclusion of data that has, or is expected to have, only a very minor effect on the outcomes of an LCA study. This study aims to include as much data as possible relevant to the scope of the life-cycle. Therefore, all emissions that are expected to contribute more than 1% to the total GHG emissions have been included.

## 3.2 Life cycle Inventory (LCI)

The Life Cycle Inventory (LCI) is the LCA phase that involves the compilation and quantification of inputs and outputs for a given product system throughout its life cycle or for single processes. It is, generally, the most time-consuming phase. All the input and output flows should be related to the system boundaries and functional unit. Depending on time and availability, data can be collected in the field (linked to actual systems or operations), literature or databases. The type of data used in the analysis should be clearly indicated.

For each scenario, a detailed LCI, containing the mass and energy flows involved in BIO4A value chain have been compiled. Results from LCI are then used for the upstream and downstream characterization of impacts. Liquid, solid and gaseous emissions will be carefully evaluated and classified into impact categories in order to estimate Global Warming Potential (GWP) of the process.

## 3.3 Impact Assessment

The impact categories represent environmental issues of concern to which LCI results may be assigned. The impact categories selected in each LCA study have to describe the impacts caused by the products being considered or the product system being analysed.
The climate impact of SAF in this study is confined to the climate impact (de Jong, 2017) from wellmixed GHGs ($CO_2$, $CH_4$ and $N_2O$), as the primary rationale for SAF relies on reducing GHG emissions as it is related to transport mitigation policies such as RED.
In this study the ILCD 2011 Midpoint ( European Commission, 2012) method will be used in order to evaluate the environmental sustainability of the process. This method was released by the European Commission, Joint Research Centre in 2012. The impact category climate change assess the Global Warming Potential calculating the radiative forcing over a time horizon of 100 years. It follows IPCC 2007 method which accounts the following values:

- $CO_2$: 1 kg CO2eq/ kg
- $CH_4$: 25 kg CO2eq/ kg
- $N_2O$: 298 kg CO2eq/ kg

## 3.4 Methodology Assessment

RED and RED recast sets out the greenhouse gas emission calculation methodology for liquid, solid and gaseous biomass fuels and implements the EC's recommended methodology, as published in Annex V of RED (European Commission, 2009). RED takes an attributional life-cycle assessment approach to calculating GHG emissions, which is an estimate of the 'direct' GHG emissions associated with different bioenergy supply chains
All direct GHG emissions from the whole fuel chain must be included in the calculation, from cultivating or producing the feedstock, through any processing and transport steps to the use of the fuel. GHG emissions from the production of liquidid biomass fuels, before conversion into biofuels, are calculated according to the following formula:

$$E = eec + el + ep + etd + eu – esca – eccs – eccr$$

• E = total emissions from the production of the fuel before energy conversion
• eec = emissions from the extraction or cultivation of raw materials
• el = annualised emissions from carbon stock changes caused by land use change
• ep = emissions from processing
• etd = emissions from transport and distribution
• eu = emissions from the fuel in use
• esca = emission savings from soil carbon accumulation via improved agricultural management
• eccs/eccr = emission savings from carbon capture and geological storage/replacement
• Emissions from the manufacture of machinery and equipment are not included

Then GHG emission saving will be calculated based in the following formula:

$$Saving = (EF – EB)/EF$$

- EB = total emissions from the biofuel or bioliquid;
- EF = total emissions from the fossil fuel comparator.

Based on reference data from REDII (EC, 2018) the value used as fossil fuel comparator is the following 94 g $CO_{2\ eq}$/MJ fossil jet fuel. [2]

## 3.5 Calculation tool

In this table (Table 2) it is summarised the tools which have been used to develop the environmental assessment:

2
19.For biofuels, for the purposes of the calculation referred to in point 3, the fossil fuel comparator EF(t) shall be 94 g CO2eq/MJ

| | | |
|---|---|---|
| **Software** | *Simapro 9.1.0.7* | SimaPro is a professional tool to evaluate the environmental impacts of products, services and processes by the utilization of bibliographic databases. It will be used to assist the LCA modelling and link the reference flows with the LCI database, as well as LCI flows to the relevant characterization factors. This software allows the use of EcoInvent databases, which operating transparently so that all assumptions and supply-chains are visible |
| **Data base** | *Ecoinvent 3.4* | Ecoinvent is a database which counts with up to 10000 inputs from different data from sectors such as transport, energy, chemistry. It contains data at, national and international level. |
| **Calculation methodology** | *ILCD 2011* | This is one of the most used methods to evaluate at European level. It can evaluate up to 16 categories. In our case it has been evaluated Climate change category, which shows the result of the GHG emissions of the process |

Table 2 Tools used to develop LCA

### 3.6 Sensitivity Analysis

An analysis has been carried out in order to understand which inputs are substantial or negligible and which sub-processes carry most of the impacts. This allows improvement of the overall performance of the system. It also ensures that the most detailed data is collected for processes exerting the biggest impact on the system.
Given that the BIO4A process is at an early stage of development input data is likely to have a range of uncertainty. Therefore uncertainty analysis around key data ranges will be carried out, in order to determine how uncertainties in data and assumptions progress in the calculations and how they affect the reliability of the results.
Sensitivity analysis assesses how changes in data and methodological choices affect the results of the sustainability assessment. In terms of both the overall impact and the relative responsibility of inputs/outputs for the overall burden. The specific sensitivity analysis has been done to inputs which have a greater influence in GHG emissions during the process such as transportation distances and production process values.
Two different end use options were considered: use in Marseille airport (France) and use in Schiphol airport in the Netherlands. In both instances, the biojet is produced in La Méde facilities in France.
If final fuel is consumed in Schiphol, the transportation mode is by freigth with a distance of 1000km. In the case of La Méde finished fuel is transported by pipeline from La Méde to Marseille airport.
Transportation distances has been seen as a key parameter when evaluating environmental assessments. In this study it has been studied different transportation

distances related to crushing facility, cleaning step and final usage of biojet. The following options have been studied as shown in Table 3:

| Options | Distance (km) | | | |
|---|---|---|---|---|
| | Cultivation crop | Crushing facility | Biorefinery | Final Usage |
| 1 ES+ES+ FR+FR | 100 | 300 | 750 | 20 |
| 2 ES+ES+FR+NL | 100 | 300 | 750 | 1000 |
| 3 FR+FR+FR+FR | 100 | 300 | 100 | 20 |

Table 3 Transport distances studied

Besides it has also been studied another scenario where RED default value for transportation is used as a reference, this value is set as: 1 g CO2eq/MJ fuel.

| Transport | RED default values | Unit |
|---|---|---|
| | 1 | g CO2 eq/MJ |

Table 4 RED default value transport

All these options have been studied in a sensitivity analysis in order to see the influence of this variables in the final result.

# 4 Results

## 4.1 Biojet production from Camelina

As previously explained it has been studied several scenarios for Camelina value chain due to variability of data studied. These options are based in transport mode and distances, biorefinery production values and crop cultivation scenarios.
It has been defined those values based on its saving value taking as main reference fossil fuel baseline 94 g CO2/MJ fuel as defined in REDII.
All the results obtained for each case it is going to be discussed in the following section in order to define the best performance environmental option. In the table below (Table 5) it is summarised the data used what it is defined as base case. Scenario 1 has been defined as base case since the data used from cultivation stage has been extracted from trials held in the framewrok of BIO4A project.

| Case | Biorefinery data | | Transport distance |
| --- | --- | --- | --- |
| | RED II | ITAKA | |
| **Scenario 1** | 16,3 | 6,70 | Cultivation/Crushing ES+ Biorefinery FR+ Final use FR |

Table 5 Data used for the base case studied

The base case studied is the one where cultivation of Camelina is made in Spain and biorefinery and end use is Marseille airport in France.

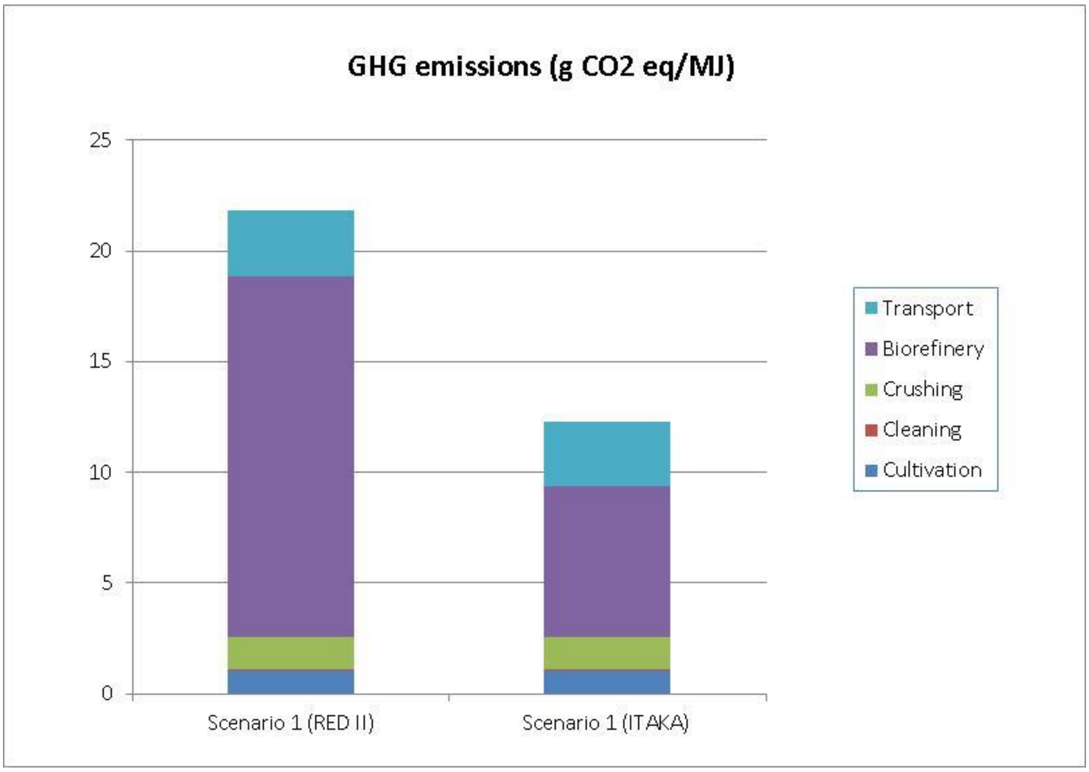


Figure **6** GHG emissions of base case

In this case it can be seen that biorefinery step and transport have the biggest contribution to GHG emissions, between 50 up to 70% of impact in both scenarios. This is associated to the great variability on the biorefinery process data from REDII value and ITAKA. Crushing and cultivation steps have an impact between 4% and 8% respect to total emissions. As it was previously mentioned in this base case it has been studied Camelina grown in Spanish degraded land. Therefore a bonus for degraded land use has been applied lowering the impact of cultivation step. In this scenario transport contributes to more than 10% emissions due to the distances between crushing and next steps biorefinery process and end use.

## 4.2 Sensitivity analysis

Sensitivity analysis is a mean of assessing the effect on model outputs (results) from a specified change in a single input variable. A sensitivity analysis has been conducted to determine the impact of the most sensitive parameters in the biojet value chain. This allows a specific description of how much variation in results would be expected from changing just that one input.
In our case a sensitivity analysis has been done to assess the influence of the most relevant factors on the results of the study:

- Biorefinery process
- Transport distances

All the results obtained for each case it is going to be discussed in the following section in order to define the best performance environmental option. In the following table (Table 6) it is summarised the different scenarios which have been studied for each case study:

| | Biorefinery data | | Transport distance |
|---|---|---|---|
| | **RED II** | **ITAKA** | |
| **Scenario 2** | 16,3 | 6,70 | Cultivation/Crushing ES+ Biorefinery FR+ Final use NL |
| **Scenario 3** | 16,3 | 6,70 | Cultivation/Crushing FR+ Biorefinery FR+ Final use FR |
| **Scenario 4** | 16,3 | 6,70 | RED Deafult value: 1 g CO2/MJ |

Table 6 Summary of the studied scenarios in the sensitivity analysis

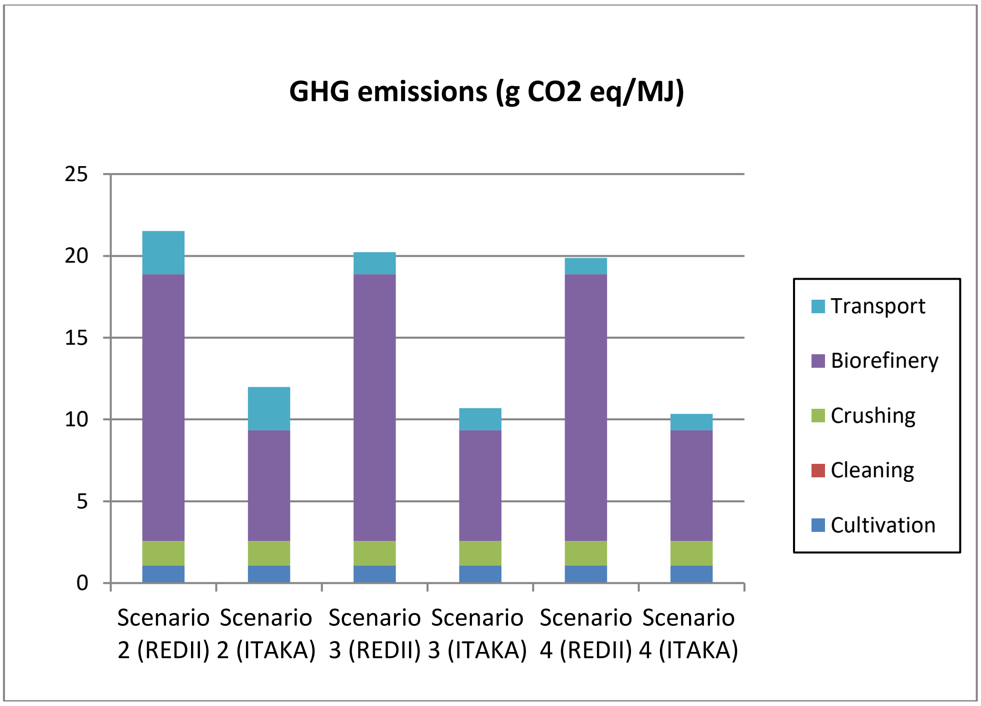

Figure **7** Results for steps of the scenarios studied

As it can be seen in Figure 7 results range between 10.7 to 21,83 g $CO_2$ eq/MJ jet fuel. These results are due to great variation of values both in the biorefinery step and transport distances. The scenario which has lower emissions is the one where the whole steps from value chain are carried out in France (Scenario 3), from crop cultivation until final usage of biojet in Marseille airport.

Results vary significantly depending on the conditions under which scenario is implemented. But it can be seen that biorefinery step is key parameter which has a significant impact on the process. In all scenarios emissions from cultivation are lowered up due to the fact that Camelina is grown in of degraded land areas. If the cultivation was done on another type of land, the overall result would be different. In general the overall GHG balance of cultivating Camelina is influenced by a variety input factors. Hereby, soil emissions resulting from nitrogen fertilizing ($N_2O$) are of special importance, as these have the highest GWP in the cultivation process counting for more than half of the total emissions in this process. In addition, fossil fuels consumed by farming machinery and by trucks transporting the feedstock to processing facilities also negatively impact the GHG balance of Camelina cultivation. In general, all of the emissions associated with the production of Camelina are influenced to a large degree by the efficiency of the cultivation process in terms of seed yield, especially when considering the sustainability of the end product. In this case, a strategy to lower emissions in this stage could be the use of more sustainable fertilizers, such as compost, biochar and COMBI. As previously explained in the next report it will be studied the effect of using bio char and COMBI in Camelina cultivation (WP2). Those results will be used for an environmental assessment of that value chain.

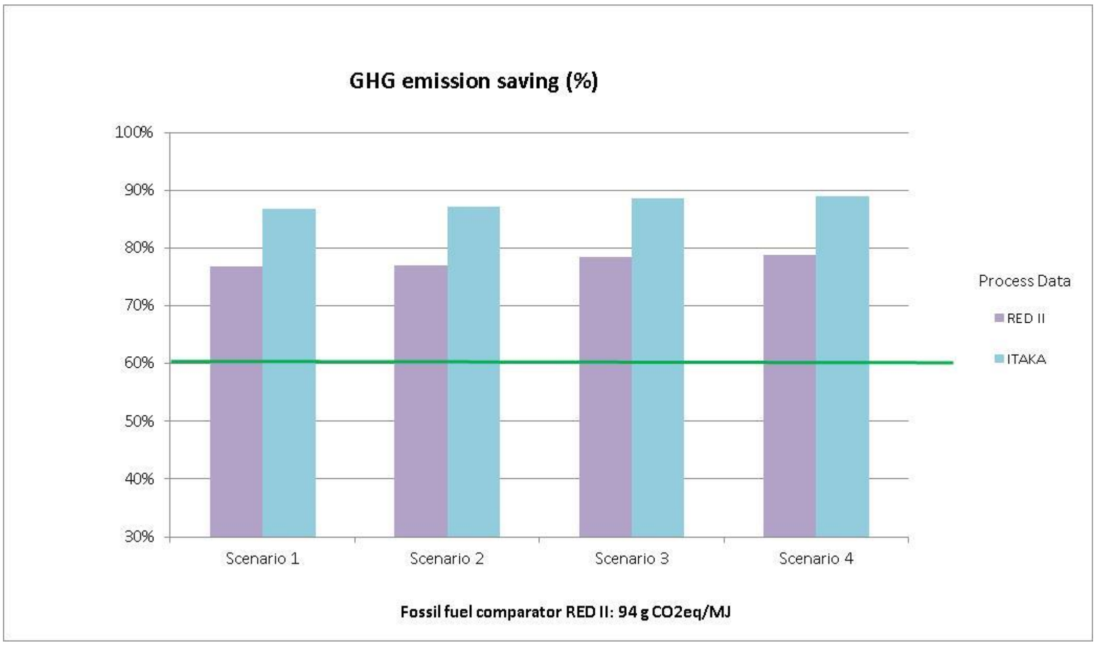


Figure **8** GHG emission saving (%) in the studied scenarios

In the figure it can be seen the result of GHG emission savings for all the studied scenarios. Overall, it appears that the production of 1 MJ of biojet under scenario 4 will have less greenhouses gas emissions compared to reference fossil fuel of REDII. Those values meet requirements for REDII saving as well as those defined for BIO4A project which established a minimum 60% GHG emission saving.
On the other hand if Camelina was cultivated in other type of land other than degraded land the estimated GHG emissions would be around 55-64% saving. This value depends on the scenario studied (CORSIA, 2019) (ITAKA, 2013), which would still meet emisson saving requirements for DERII and BIO4 project.
Those emissions from cultivation stage are related to practices such as fertilization and also related to low yields from cultivation. Improvements could be based on more sustainable fertilizations modes which could lower GHG emissions in this step, and therefore in the whole process.

# 5 Conclusions

These preliminary results show that Camelina value chain can meet REDII reduction requirements when it is cultivated in degrade land areas. Taking into account that Camelina could achieve GHG emission saving up to 73-87% depending on the scenario studied.
As with all emission estimates based on lifecycle accouning methods (CORSIA, 2019), it is important to remember this is based on methodological choices that it has been made, which have greater impact on final emission estimate. For example cultivation data from Camelina is based on experimental trials. If cultivated in large extensions, data related to cultivation practices and yields could be affected. Also as it has been seen biorefinery data has greater impact in the final result depending on choices made.
In summary it can be concluded that Camelina could be an option for bioenergy cultivation when harvested in degraded land, achieving substantial greenhouse gas emission mitigation.
Finally, in the next report it will be studied new approaches for feedstock. It will be evaluated Camelina cultivation practices using biochar and COMBI and other value chain such as UCO in order to produce biojet. The results of this environemtal assessment will be used for comparative purposes and to identify GHG emission reduction measures to improve the sustainability of the whole value chain.

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