Sustainability and certification for aviation biofuels

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Abstract

With the rapid growth and increased consumption of biofuels worldwide, and the multitude of policy decisions supporting this expansion, growing concerns about the biofuels sustainability have arisen. Therefore, the European project "ITAKA", aiming at supporting the development of aviation biofuels in an economically, socially, and environmentally sustainable manner has devoted considerable effort to take sustainability into account, in a quantitative and qualitative manner. More precisely, a robust assessment of a lifecycle greenhouse gas (GHG) calculation for the produced bio jet fuel have been set up, using the RSB EU RED methodology. This pathway includes feedstock production, feedstock processing, biofuel production, biofuel distillation, and all transport steps involved. A significant reduction in GHG emissions (up to 66%) has been demonstrated.

I. INTRODUCTION

In the last decade, the world has seen the production of biofuels increase roughly fivefold [1], as proven by the case of ethanol for instance (Figure 1). In 2012, over 50% of Brazil's sugar cane crop and over 30% of United States of America corn were used for the production of ethanol, while in the European Union (EU), biodiesel production used almost 80% of the EU vegetable oil production [2]. With the air transportation sector growing substantially (and expected to continue to do so), and subsequent demand for liquid fuels for transport rising globally, the IEA assesses biofuels as one of the key technologies to reduce CO2 emissions and reduce dependency on liquid transport fuels, with up to 27% of the world transportation fuel provided by sustainable biofuels by 2050 [3].

With the rapid growth and increased consumption of biofuels worldwide, and the multitude of policy decisions supporting this expansion, growing concerns about the biofuels sustainability have arisen. Some of the most important policy drivers for biofuel uptake include climate change mitigation, fossil fuel dependence reduction, conservation of biodiversity and water, as well as agricultural and rural development. However, potential negative impacts of biofuel production were recognized early on. Such impacts can be direct, occurring within the boundary or in the vicinity of biofuel operations, or indirect, triggered by market reactions to increased biofuel production.

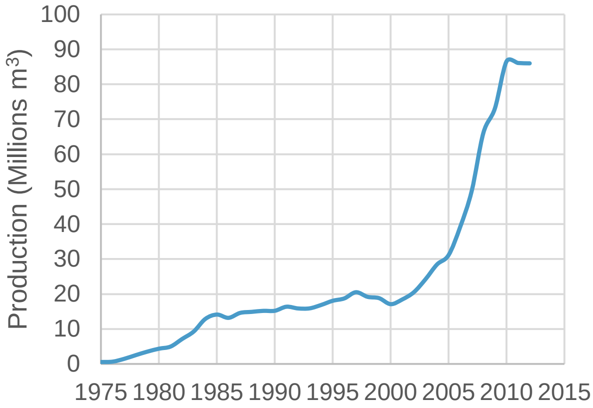

Figure 1 - World Fuel Ethanol Production, 1975-2012 Source: F.O. Licht and Earth Policy Institute [1]

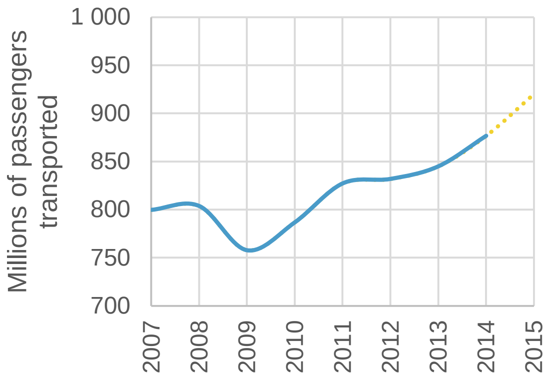

Figure 2 – Evolution of air passenger transport in the European Union [4]

The EU Advanced Biofuels Flightpath has set up the objective to achieve 2 million tons of sustainable biofuel per year in 2020 [5]. Therefore, the European project "ITAKA", aiming at supporting the development of aviation biofuels in an economically, socially, and environmentally sustainable manner has devoted considerable effort to take sustainability into account, in a quantitative and qualitative manner. More precisely, in addition to wide ranging research aiming at optimizing and consolidating the biofuel sustainability along the whole value chain, a robust assessment of a lifecycle greenhouse gas (GHG) calculation for the produced biojet fuel have been set up, using both the EU-RED and RSB criteria and methodologies. This pathway includes feedstock production, feedstock processing, biofuel production, biofuel distillation, and all transport steps involved. At the same time, it highlights gaps and improvement areas in the RSB-EU RED standard with the goal to strengthen it as an international standard for certification of biojet sustainability for all pathways and feedstock.
Such a complete assessment has already been carried out for other biofuel feedstock, such as Jatropha [6], however not within a full sectorial value. In addition, to the author's knowledge, it is the first time it has been carried out for Camelina sativas.

II. SUSTAINABILITY

Sustainability standards
A strategy to achieve sustainability includes the need for certification systems. The development of robust certification schemes is essential in the process of sustainably converting biomass feedstock to biofuel. It requires an objective identification and assessment of existing systems for biomass production and conversion, followed by measures to improve them. Certification procedures need to be applicable at both global and local level, and should be applicable not only by large conglomerates but also by small farmers.

Compliance with sustainability criteria applies to all links of the biofuel supply/production chain, from production to distribution, and they are often mandatory to either receive public support or to count towards national renewable energy targets in the European Union (EU). One way to demonstrate compliance is to participate in voluntary schemes recognized by the EU, and confirmed by an independent and properly authorized certification body. Various biofuel certification systems exist, and each possess different strength and thoroughness, though they should all be in line with the sustainability criteria of the Renewable Energy Directive (2009/28/EC, RED, [7]) which are also stated in the Fuel Quality Directive (2009/30/EC, [8]). The recognition is based on RED Article

18 (4-6) and refers to proving compliance of RED Article 17 (2) and RED Annex V on GHG emission saving. The sustainability criteria for biofuels in RED imposes a minimum GHG emission savings of 35% for old installations (in operation in 2008), 50% reduction in 2017 and up to 60% GHG reduction in 2018 for new installations (Art. 17.2).

The Roundtable on Sustainable Biomaterials (RSB) is an independent and global multistakeholder coalition originated in Switzerland. It developed a standard for sustainable biofuel production covering the entire chain of production of the biofuel, from feedstock production to final biofuel blending. The RSB standard covers 12 Principles & Criteria, one of which is greenhouse gas (GHG) emissions. The RSB standard was recognized by the European Commission to be in compliance with the requirements of the EU Renewable Energy Directive (RED) in 2010. The RSB RED-compliant standard is termed the "RSB-EU RED Standard" and it includes its own implementation of the EU RED GHG calculation methodology for biofuels. Emissions are allocated towards products and co-products at each processing step. Allocation is done differently for the RSB and RSB-EU RED methodologies, which constitutes the main difference between both methodologies. The RSB methodology carries out an allocation based on economic value of products and co-products; the EU-RED methodology follows an allocation based on lower heating value (LHV), i.e., based on energy content.

As described in the chapter Methodology below, the following analysis is based on the RSB methodology, and using the RSB GHG calculation tool (“RSB GHG Tool”, [9]), which conducts calculations according to the RSB’s implementation of the EU RED methodology (“RSB-EU RED methodology”, [10]).

Compliance

In order to comply with the GHG Principle of the RSB-EU RED Standard, an operator must meet both the RSB and the EU RED requirements. To meet the RSB requirements, GHG emissions should be calculated according to the RSB methodology using the RSB GHG tool and meet the targeted reduction requirements, i.e., both the RSB GHG reduction threshold (50%) for the final blender, and the GHG reduction threshold with respect to the fossil fuel baseline determined by the RSB, namely 90 gCO2-eq/MJ-fuel. To meet the EU RED requirements, GHG emissions should be calculated according to the RSB-EU RED methodology, which is the adaptation of the EU RED GHG calculation methodology made by the RSB (and which was recognized by the EU when the RSB EU RED Standard was recognized in 2011). The targeted requirements are as follows: on the one hand, it should meet the EU-RED GHG reduction threshold for the final blender, which is currently 35% reduction with respect to the fossil fuel baseline given in the EU RED, namely 83.8 gCO2-eq/MJ-fuel. It is to be noted that this reduction threshold increases to 50% after 2017 and the FP7 requirements for ITAKA encourage a reduction of 60%.

Various methodology to assess GHG emissions

Dozens of systems exist to ensure socio-economic sustainability along the whole supply chain, including aspects such as land use, agricultural practices, competition with food, energy efficiency and GHG emissions, life cycle analysis (LCA), etc. Among them, nineteen have been officially recognized by the European Union to be in compliance with the sustainability criteria for biofuels. The RSB-EU RED scheme is one of those scheme. It is important to highlight that each system relies on its own methodology, standardized database of values to be used in the calculations, and have different allocation of co-products (as is the case between RSB and EU RED). This will tend to give slightly different numerical results. Nevertheless, the trend achieved is similar independently of the tool used; therefore, one should consider the general tendency given by the numbers rather than looking at the absolute value itself.

III. METHODOLOGY

Overview of the biokerosene production process

As part of the ITAKA project, Camelina sativa is produced in Spain. After the harvest, the Camelina grains are transported from the field to a cleaning facility in Albacete, Spain. Once cleaned, the grain is crushed and pressed into oil. The crushing facility is located in Cuenca, Spain, therefore, another step of transport is necessary between the cleaning and pressing steps. With the oil ready to be transformed into biokerosene, Camelina oil heads towards Finland to reach the transformation refinery. This entails a first transport step by truck to reach the cost, in Valencia, and a second transport step by transoceanic freight ship to reach the refining facility in Porvoo, Finland. Camelina is there converted into biokerosene. Finally, it is transported where it will be use, i.e. in the Oslo airport in Norway.

GHG emissions within the ITAKA project were calculated using both the RSB GHG methodology, and the RSB EU RED GHG methodology. Both methodologies are integrated in the RSB GHG Tool, an online GHG calculator that allows operators to enter data and perform calculations relevant to their operations (http://rsb.org/ghgcalc/). Operators must enter all chemical, material and energy usage data relevant to their scope of operation. They must also enter the GHG intensity of their feedstock, which they obtain from the immediately upstream operator. In such a way, the cumulative GHG emissions are calculated through the chain of production of the biofuel.

GHG emissions related to indirect land use change (ILUC) are not taken into account in either methodology. To better understand the steps and their respective environmental impact, it is useful to separate the whole system into independent activities referred as the value chain [11]. While usually used in economic calculations to optimize profit margins, it is also useful to fully assess a logistics system with successive steps. Based on the value chain developed in the previous paragraph, GHG emissions calculations have been carried out on the whole Camelina value chain.

Two main pathways have been assessed and compared in this article.

First, a real production from a Camelina batch grown and harvesting during the ITAKA project. Compared to the slender overview of the steps described previously, it includes some steps which are specific to the research carried out within the project. For instance, in this “real production batch”, an oil cleaning step has been added. The Camelina oil is pre-treated to ensure that it meets the quality requirements of the biokerosene production process, following a physicochemical process of degumming and dewaxing. Quality tests later revealed that the oil already met the necessary quality standards after the crushing step, therefore, this step is not necessary in the long run. This scenario is called “real production”.

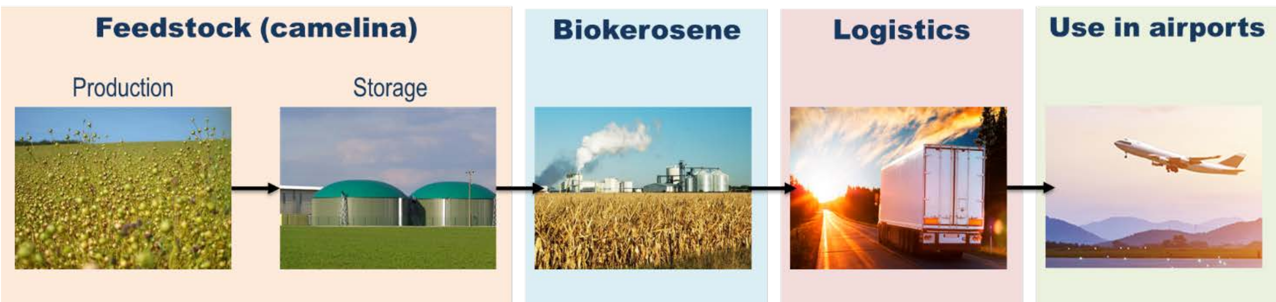

Figure 3 – Overview of the main steps of the process

In a second step, results achieved within the project have been compared with a baseline scenario, which has been tailored to better represent what a “typical” or mature scenario would look like. It reflects a typical mature process throughout all the steps, and in this sense, results achieved would be closer to what would be achieved should the process be maintained in the long run. Only the necessary steps are kept (for instance the oil cleaning step is not included since it has been proven to be unnecessary), transport is optimized between all the steps, and oil pressing is improved given the fact that the current oil pressing facility is old and sub-efficient. This scenario is called “mature scenario”.

IV. RESULTS

The GHG emission calculation results are summarized in the Table 1 below. The table shows the cumulative emissions throughout the whole chain of production of the biofuel, as the emission impacts from each step are added. Cumulative GHG emissions are given in kilograms of carbon dioxide equivalent per kilogram of main product at the end of each processing step (kg-CO2eq/kg-main product). For instance, the GHG intensity at the feedstock production stage refers to the Camelina oil product, and the units are in kgCO2-eq/kg-Camelina oil. The final lifecycle GHG emissions are given in grams of CO2-equivalent per megajoule of finished biokerosene (gCO2eq/MJ-fuel). Emissions in these units are then compared to the fossil fuel baseline.

From Table 1, one can see that the use of biofuels according to the process set-up within the ITAKA project can yield significant GHG emissions reduction with regard to the fossil fuel baseline of 83.80 gCO2eq/MJ-fuel, as stated in the Renewable Energy Directive. The real production batches harvested within the project produce results comprised between 56% reduction and 61% reduction (this batch is not described in this article). An optimization of the different steps gives an even higher reduction, of 66% reduction. This is in line with the FP7 encouragement towards a 60% emission decrease.

A step-by-step segmentation analysis of the kerosene production value chain is proposed in Figure 4 below. From this figure, it is clear that three steps concentrate most of the total GHG emissions, i.e. feedstock production, oil pressing and oil refining to biokerosene. All other steps are comparatively negligible, and most of the efforts to optimize the GHG emissions reduction should be concentrated on those three steps.

Table 1 – Results from the two scenarios regarding GHG emissions reduction with regard to the RED fossil fuel baseline

	Real production	**Mature scenario**
Cumulative GHG emissions (gCO_2eq/MJ)	36.82	28.08
RED fossil fuel reference (gCO_2eq/MJ-fuel)	83.80	83.80
Reduction with respect to baseline (%)	56% (>50% threshold)	66% (>60% threshold)

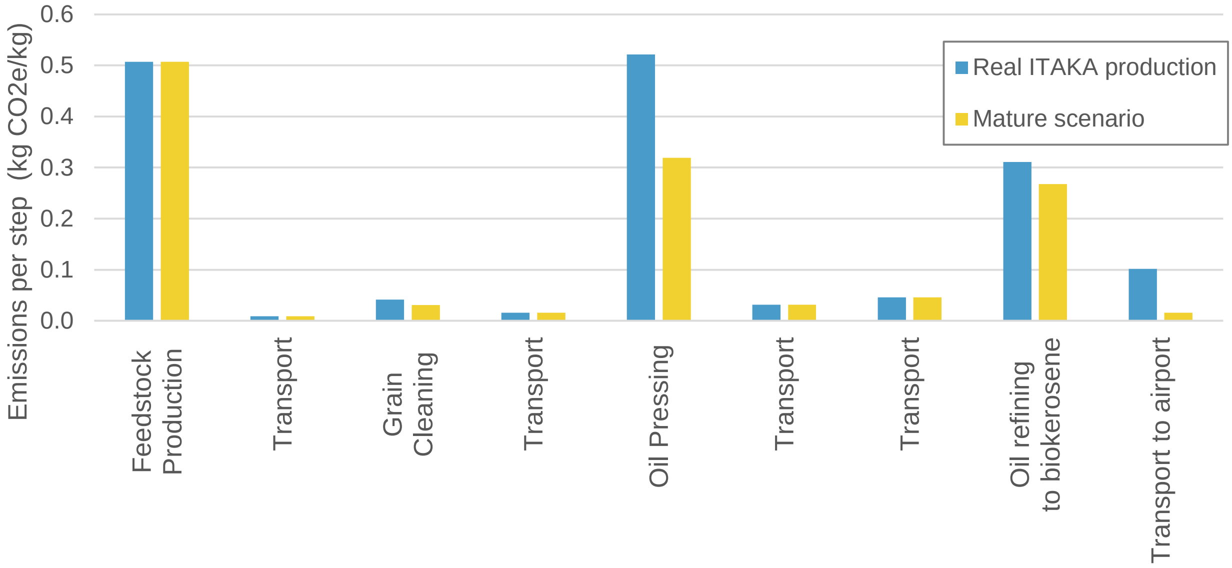

Figure 4 – Breakdown of the GHG emission per step

A more detailed overview of the main factors explaining the GHG emissions values is given in Figure 5 below, which highlights within each of those three steps the main accountants towards GHG emissions. Values correspond to the real Camelina production scenario.

Camelina sativa is produced in a number of locations in Spain's semi-arid regions of Aragón and Castilla-La Mancha. Its production requires fossil fuels for sowing, tilling, application of chemicals, and harvesting. The main GHG emissions in this process step are mainly associated with the emission of N2O due to the application of nitrogen fertilizers (in the figure, called "Chemicals"). Emissions from chemical use include also ammonia, carbon dioxide, dinitrogen monoxide and nitrate. Other large sources of emissions include fossil fuel use for sowing, tilling, applying chemicals, and harvesting (in the figure, called "Mechanical Processing"), followed by the use of fertilizers. In contrast, pesticide production is a minor source of GHG emissions. Seed production is a relatively minor contributor to overall GHG emission from this step. While this step is among the main sources of lifecycle GHG emission, it is challenging to diminish substantially its associated GHG emissions. Indeed, although crop yield is expected to keep increasing (though optimization of the agronomic protocol), so will nitrogen fertilization. With the use of chemicals and fertilizers contributing to three quarters of the GHG emission, the total feedstock GHG contribution would remain relatively similar. Therefore, one could consider this production step close to its limit regarding remaining GHG emission potential until new camelina improved varieties are developed. Camelina Company España has initiated a camelina breeding program in 2013 that will deliver new improved camelina varieties in the short term. However, in the "mature scenario" described, this step has not been changed, and values for Camelina production have remained similar to those of "Real ITAKA production".

All emissions from seed crushing / grain pressing are associated with the consumption of fossil energy in the industrial cleaning process. In this case, the energy sources are grid electricity and heat from a co-generation plant as well as fuel, natural gas and biomass boilers. The crushing facility employed is 40 years old and not yet very energy efficient, therefore, it is one main avenue for GHG reduction in this value chain which can still be improved. Most other optimizations have already been carried out during the project.

Camelina oil is converted into biokerosene at a refining facility in Finland following the NEXBTL (Next Generation Biomass to Liquid) process. The NEXBTL process converts vegetable oils and animal fats to NEXBTL diesel or aviation fuels, bionaphtha, and biopropane. The product of NEXBTL is hydrotreated vegetable oil with properties similar to those of fossil fuels from a variety of raw materials. In the pretreatment unit, various chemicals and bleaching earths are used to remove unwanted residues and impurities from the feedstock. Used chemicals, bleaching earths and absorbed feedstock residues are then separated from the clean, pretreated feedstock. The residues leave the unit as separate waste streams. The pretreated feedstock is then processed in the NEXBTL unit. During the process, pressure and hydrogen are added to the feedstock, resulting in a mix of hydrocarbons, water, and CO_2. Water and CO_2 are separated from the mixture; the hydrocarbons are split into NEXBTL diesel, bionaphtha, and biopropane components. The figure below shows that chemicals (mainly hydrogen) and energy are the main sources of GHG emissions.

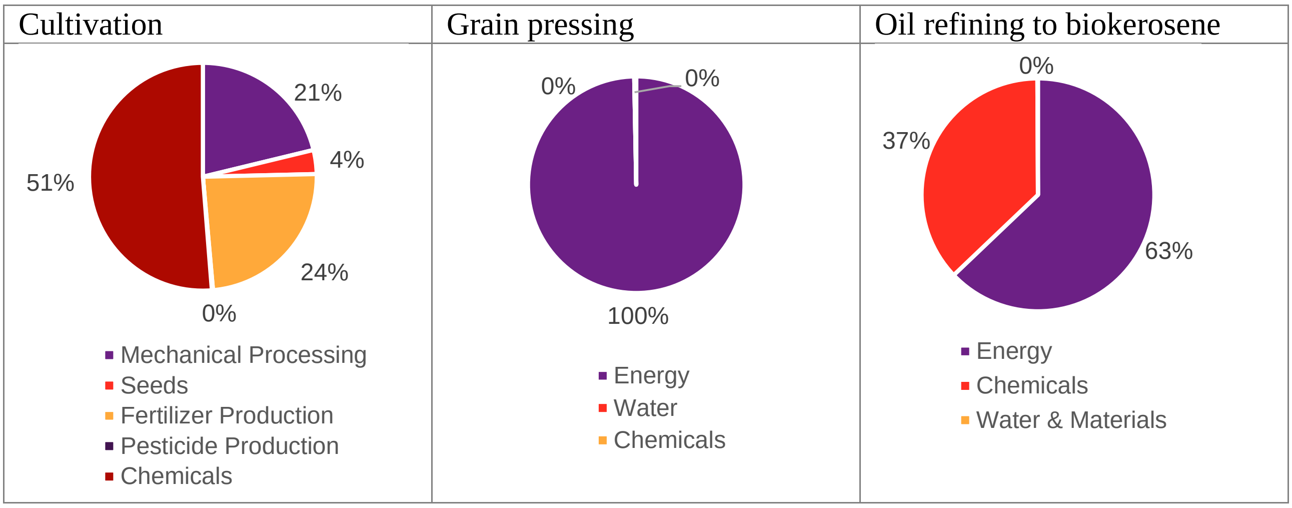

Figure 5 – Details about the most GHG-intensive steps, values of GHG emissions for the real ITAKA production batch

V. CONCLUSION

Biofuel sustainability is of growing concern with the steady increase in transport-related GHG emissions. It is necessary to ensure a sustainable production, conversion, and use. In order to guarantee this sustainability in the long-rum, it is necessary to promote global standards or socially, environmentally and economically sustainable production and conversion of biofuels, through transparent, credible, practical and affordable certification schemes. Nearly twenty of such schemes have been officially recognized by the European Union regarding biofuels.

Using the specific methodology of the RSB EU-RED scheme, we have clearly shown that a significant improvement in GHG emissions can be reached on the whole aviation fuel value chain. In terms of GHG emissions, the ITAKA pathway is currently at more than 50% GHG emission reduction compared to the fossil fuel reference (RSB EU-RED). A more mature process could lead to reduction above 66% GHG emission reduction (RSB EU-RED). While the feedstock production step is the most GHG intensive step, an increased yield would generally lead to a stronger use of nitrogen fertilization, which is greatly penalized as of GHG contribution. It is therefore expected that GHG emissions reduction from feedstock production will mainly come from new improved camelina varieties, with better nitrogen/yield efficiency. Therefore, especially the oil pressing step could be still improved and thus further decrease the reduction of 66%. This is summarized in Figure 6 below.

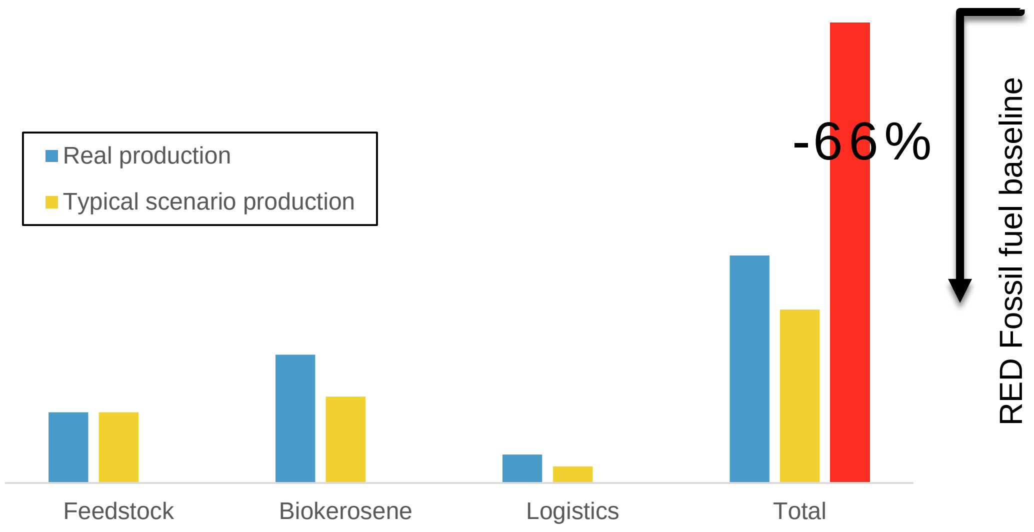

Figure 6 – Improvements with regards to the fossil fuel baseline

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ABBREVIATIONS

EU	European Union
GHG	Greenhouse Gas
ILUC	Indirect Land Use Impacts
ITAKA	Initiative Towards Sustainable Kerosene for Aviation
NEXBTL	Next Generation Biomass to Liquid, patented process for biofuel production
RED	Renewable Energy Directive
RSB	Roundtable on Sustainable Biomaterials