ITAKA

Collaborative Project

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D5.16 GHG Calculations

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Executive summary

This document contains preliminary GHG calculations along the chain of production of the biofuel, including feedstock production, feedstock processing, biofuel production, and all transport steps involved. The pathway is for camelina oil production in Spain and subsequent conversion in Finland by NESTE oil.

This draft report is an intermediary progress report. The final lifecycle GHG emissions report is due in 2015.

This draft report follows a previous preliminary GHG calculations report submitted on 5 April 2013 and addressed in this report as the “March 2013” calculations. The values have changed slightly, mostly due to the use of more accurate data (more measurements and fewer estimates).

The calculations have been conducted using the Roundtable on Sustainable Biomaterials (RSB) GHG calculation methodology as well as the RSB-EU RED methodology, which is the RSB implementation of the EU RED methodology. Note that this methodology does not address indirect land use change (ILUC) emissions.

Preliminary results show that the GHG intensity of the full value chain is as follows:

- **RSB-EU RED**: 33 gCO2eq/MJ-fuel, a 61% reduction with respect to the EU RED fossil fuel baseline of 83.8 gCO2eq/MJ. This value meets the 35% and 50% GHG emission reduction requirements of the EU RED, as well as the 60% reduction requirement of ITAKA.
- **RSB**: 41 gCO2eq/MJ-fuel, a 55% reduction with respect to the RSB fossil fuel baseline of 90 gCO2eq/MJ. This value meets the required 50% GHG reduction requirement with respect to the fossil fuel baseline of the RSB Standard; and

During the rest of the ITAKA project, the project partners will assess how GHG emissions can be improved throughout the supply chain.

For the RSB-EU RED calculation, all data inputs have been measured directly.

For the RSB calculation, some data (such as camelina meal and oil price relationships) have been estimated, as measured values are not available yet.

Also, an uncertainty assessment has not yet been conducted for the calculations herein presented; the number of significant digits has been arbitrarily selected as two. We anticipate to assess uncertainties in the future.

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Abbreviations

EU RED	*European Union Renewable Energy Directive*
RSB	*Roundtable on Sustainable Biomaterials*

1 Introduction

This report describes the draft GHG emissions associated with the full production chain of biokerosene (biofuel for aviation) from camelina oil.

Camelina seeds and oil are produced in Spain by Camelina Company España. The oil is subsequently transferred to the Neste Oil facility in Porvoo, Finland, where it is transformed into biokerosene. The biokerosene is then either sent to Schiphol Airport in the Netherlands (Option 1) or Alicante airport in Spain (Option 2).

The Roundtable on Sustainable Biomaterials (RSB) standard for sustainable biofuel production covers 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. As part of this principle, each operator along the chain of production of the biofuel is required to calculate the GHG emissions associated with their operations.

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".

The ITAKA project envisions that the entire chain of production of camelina biokerosene will be certified according to the RSB EU RED Standard. CCE received its RSB EU RED certificate in October 2013.

2 GHG 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:

1. Calculate GHG emissions according to the **RSB methodology**;
    - for the final blender, meet the RSB GHG reduction threshold (50%);
    - the GHG reduction threshold is with respect to the fossil fuel baseline determined by the RSB, namely 90 gCO2-eq/MJ-fuel.
2. Calculate GHG emissions 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);
    - for the final blender, meet the EU RED GHG reduction threshold: 35%, which increases to 50% after 2017; furthermore, the FP7 requirements for ITAKA encourage a reduction of 60%.
    - the GHG reduction threshold is with respect to the fossil fuel baseline given in the EU RED, namely 83.8 gCO2-eq/MJ-fuel.

GHG emissions were calculated by the operators participating in the chain of production of the biofuel, who will also be certified and audited according to the RSB EU RED Standard. For the purpose of this preliminary report, GHG emissions related to transport downstream from the grain crushing facility were calculated by EPFL.

3 Description of the process

The process, from feedstock production to final blending and distribution to airports, is described in the table below.

Table 1: Description of process

Production step	**Description**	**Operator responsible for RSB EU RED certification**
Feedstock Production	Camelina grain is grown in Spain and subsequently sent to a cleaning facility. Clean grain is then sent to the grain crushing facility, located in Cuenca, Spain. There is a transport step to the cleaning step and a transport step to the crushing step.	Camelina Company Espana (CCE)
Transport	Transport from camelina field to cleaning facility	CCE
Cleaning	The grain is cleaned.	CCE
Transport	Transport to crushing facility.	CCE
Feedstock Processing	Camelina grain is crushed in Cuenca, Spain. Camelina oil is produced as the main product, and camelina meal as the byproduct.	CCE
Transport	The oil is transported via truck to Valencia, Spain.	CLH
Transport	The oil is shipped via transoceanic freight ship to Porvoo, Finland.	Neste
Biofuel production	Camelina oil is converted into biokerosene at the Neste Oil refining facility in Porvoo, Finland.	Neste
Transport – Option 1	The biokerosene is transported via transoceanic freight ship from Porvoo, Finland to Rotterdam, Netherlands, where it is blended with jet-A (50/50). From the Rotterdam terminal, the biokerosene is transported to Schiphol airport via truck (2000 ton fuel; option a) or pipeline (2600 ton fuel; option b)	SkyNRG
Transport – Option 2	The biokerosene is transported via transoceanic freight ship from Porvoo, Finland to Cartagena, Spain, where it is blended with jet-A (10/90). From Cartagena, the blended fuel is transported via pipeline to Valencia airport.	SkyNRG

4 GHG emissions calculation

GHG emissions were calculated using two methodologies, namely:

- the RSB GHG methodology, and
- the RSB EU RED GHG methodology. This methodology is the RSB interpretation of the EU RED GHG calculation methodology and it was approved in the RSB EU RED Standard recognition process.

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.f2.htw-berlin.de/).

Operators must enter all chemical, material and energy usage data relevant to their scope of operation, as well as 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.

Some methodological differences result in slightly differing results between the RSB-EU RED and the RSB methodology. Allocation of GHG emissions to products and co-products is done differently (see below). Other sources of differences between both methodologies relates to emission factors used in the calculations. Hence, both methodologies tend to yield slightly different results.

GHG emissions related to indirect land use change (ILUC) are not taken into account in either methodology.

Allocation

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.

CCE performed laboratory analyses of all camelina products and by-products generated during the 2012/2013 campaign in order to determine LHV values for each of them, and used the measured values in the calculations.

RSB – EU RED methodology economic values have been based on both measured and actual data. Although CCE has records of camelina meal sales prices, camelina oil was not marketed in this agricultural campaign. CCE provided an assumption for camelina oil price in order to obtain a ratio for camelina oil/meal, and used this value in the calculation.

Different Transport and End Use Options

Two different end use options were considered: use in Valencia airport, Spain, and use in Schiphol airport in the Netherlands. In both instances, the final fuel is produced in Porvoo, Finland.

If final fuel is consumed in Schiphol, two different transport options exist: Under “Option a”, the finished fuel is transported by truck from Porvoo to Schiphol. Under “Option b”, the finished fuel is transported by pipeline from Porvoo to Schiphol.

5 Results and Discussion

The GHG emission calculation results are summarized in the table below. The table shows the cumulative emissions throughout the 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). 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 table also shows the contribution of each production step towards overall lifecycle GHG emissions (%of total emissions).

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 of the RSB and the EU RED. Final emissions are based on the transport scenario where fuel is shipped by truck to Schiphol airport. The choice of transport (pipeline or truck) and final use location (Valencia or Schiphol) has very small impacts on overall GHG emissions.

The required GHG reduction thresholds are also listed in the table, namely 50% for the RSB, and 35%, 50% or 60% for the EU RED.

Uncertainties and the use of significant digits

In the results displayed, we have used two significant digits. This choice is arbitrary. We have not calculated the uncertainties associated with the calculations presented in this report, though this is a recommended additional element for the final report.

Relative impact of production steps on lifecycle GHG emissions

The table below shows that camelina production and oil pressing are the largest contributors to lifecycle GHG emissions of the biofuel. Processing at the Neste Oil facility is also a large contributor. Therefore, for the purpose of GHG emissions minimization, abatement efforts should be concentrated on these processing steps.

Differences between Transport and End Use Options

If the final fuel is used and transported to Valencia airport instead of Schiphol, final transport emissions are about 1.4% higher. However, since transport only makes up for about 1% of total lifecycle emissions, it is almost inconsequential, from a GHG perspective, if the final fuel is consumed in Valencia or in Schiphol.

Similarly, the 2013 transport options from Porvoo to Schiphol (shipping by truck, Option a vs. piping, Option b) have very small impacts on the overall GHG emissions.

Note on allocation

While the EU RED GHG calculation allocates emissions between co-products based on lower heating value (LHV), the RSB GHG calculation allocates emissions based on economic value. In this report, the relative prices for camelina meal and oil have been indicated by CCE. Although CCE has records of camelina meal sales prices, camelina oil has not been marketed for this agricultural campaign. CCE has provided an assumption for camelina oil price in order to obtain a ratio for camelina oil/meal.. In the last year, soy oil has gone down in price, while soy meal has increased. This has brought closer RSB and EU RED calculation values. If the meal prices decrease and/or oil prices increase in the future, RSB and EU RED results will be even more different.

Total GHG Emissions

Final emissions are based on the transport scenario where fuel is shipped by truck to Schiphol airport.

Final GHG emissions were as follows:

- 1.8 kg-CO2eq/kg-biokerosene for the RSB methodology; and
- 1.4 kg-CO2eq/kg-biokerosene for RSB-EU RED methodology.

This value is then converted to a unit of energy basis using the Lower Heating Value of biokerosene, namely 44.3 MJ/kg-biokerosene, yielding the following results:

- RSB: 41 gCO2eq/MJ-fuel, a 55% reduction with respect to the RSB fossil fuel baseline of 90 gCO2eq/MJ. This value meets the required 50% GHG reduction requirement with respect to the fossil fuel baseline of the RSB Standard; and
- RSB-EU RED: 33 gCO2eq/MJ-fuel, a 61% reduction with respect to the EU RED fossil fuel baseline of 83.8 gCO2eq/MJ. This value meets the 35% and 50% GHG emission reduction requirements of the EU RED, as well as the 60% reduction requirement of ITAKA.

Table 2: Results

			Cumulative GHG emissions (kg CO2e/kg) March 2013 Calcs - Draft		Cumulative GHG emissions (kg CO2e/kg) Oct 2013 Calcs - Draft		%of total emissions	Difference March-Oct (< lower; = same; > higher)
Lifecycle Step	**Description**	**Final Product**	**RSB**	**RSB-EU RED**	**RSB**	**RSB-EU RED**	**RSB-EU RED**	
Feedstock Production	Camelina grain, Spain	Camelina grain	0.595	0.664	0.54	0.49	34%	<<
& Transport	Spain; truck 98 km	Camelina grain	0.611	0.676	0.55	0.50	1%	=
& Cleaning	Camelina grain, Spain	Camelina grain	0.672	0.728	0.69	0.55	4%	>
& Transport	Spain; truck	Camelina grain	0.693	0.743	0.71	0.57	1%	=
& Oil Pressing	Camelina grain, Spain	Camelina oil	1.300	1.169	1.3	1.1	34%	>>
& Transport	Spain (Cuenca-Valencia); truck 200 km	Camelina oil	1.324	1.188	1.3	1.1	2%	>
& Transport	Valencia-Porvoo (Finland); Ship; 2600 nm=4800 km	Camelina oil	1.376	1.230	1.4	1.1	3%	=
& Oil refining to biokerosene	Porvoo, Finland (Neste)	Camelina oil	1.768	1.538	1.8	1.4	20%	=
Option 1 - use at Schiphol								
& Transport	Porvoo - Rotterdam; ship; 970 nm=1800 km	Biokerosene	1.787	1.554	1.8	1.4		=
& Transport (Option a)	**Rotterdam-Schiphol; truck 60 km**	**Biokerosene**	**1.794**	**1.560**	**1.8**	**1.4**	1%	=
& Transport (Option b)	Rotterdam-Schiphol airport; pipeline 60km	Biokerosene	1.788	1.555	1.8	1.4		=
Option 2 - use at Alicante airport								
& Transport	Porvoo - Cartagena; ship (see above)	Biokerosene	1.819	1.580	1.8	1.5		=
& Transport	Cartagena-Alicante airport; pipeline 120 km	Biokerosene	1.821	1.582	1.8	1.5		=
Total (gCO2eq/MJ-fuel) 2013 Batch Opt. A			**41**	**35**	**41**	**33**	**100%**	
Fossil fuel reference (gCO2eq/MJ-fuel)			90.00	83.80	90.00	83.80		
Reduction with respect to baseline (%)			**55%**	**58%**	**55%**	**61%**		
35% Reduction threshold (gCO2eq/MJ-fuel)			NA	54.47	NA	54.47		
50% Reduction threshold (gCO2eq/MJ-fuel)			45.00	41.90	45.00	41.90		
60% Reduction threshold (gCO2eq/MJ-fuel)			NA	33.52	NA	33.52		

Figure 1 shows cumulative lifecycle GHG emissions throughout the production chain (the values are the same as those in Table 2). The figure shows that the feedstock production step (camelina cultivation) step adds significant GHG emissions to the biokerosene lifecycle, which was expected, given that this lifecycle step tends to be the most GHG intensive step in biofuel production, mainly dominated by the nitrous oxide emissions from fertilizer use. The oil crushing (pressing) step also adds significant emissions. The biofuel production step also results in important emissions, mainly associated with product loss due to the nature of the process.

The figure also shows the differences between the calculated values using the RSB vs. the RSB-EU RED methodology. The main reason for the disparities is the different allocation method followed, namely economic allocation for the RSB methodology and Lower Heating Value (LHV) for the EU RED methodology.

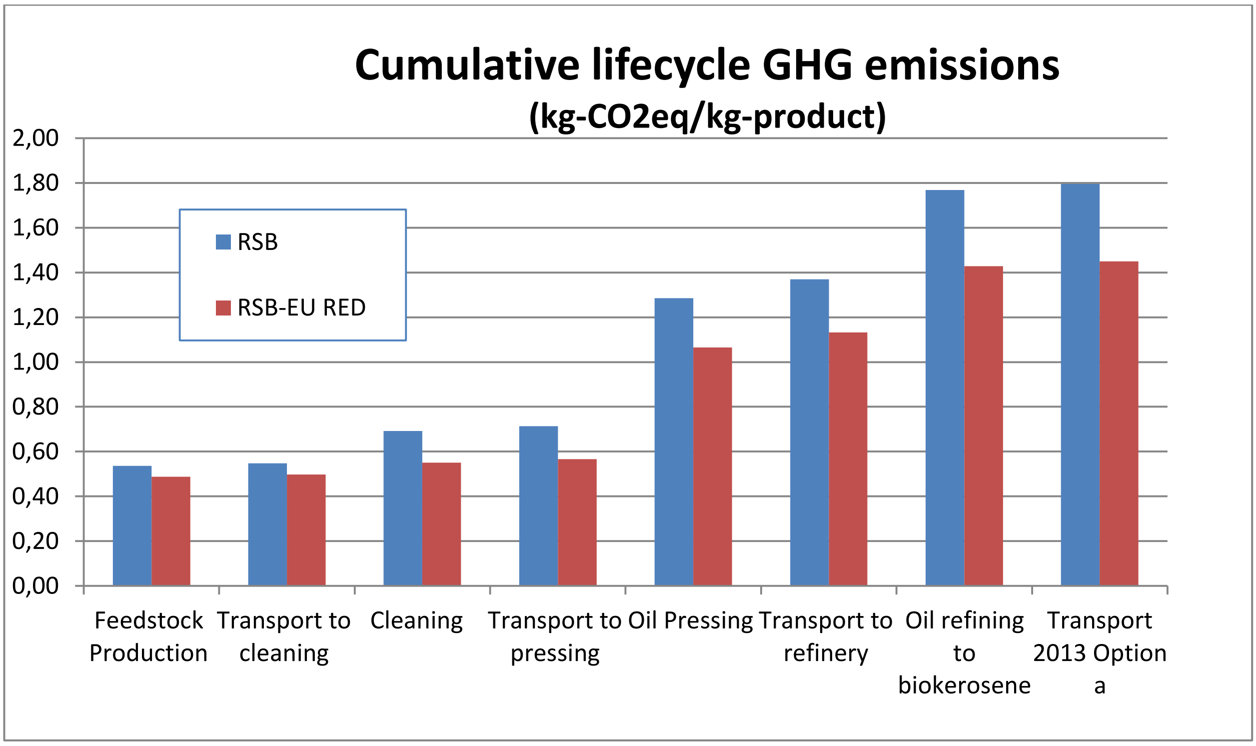

Figure 1: Cumulative lifecycle GHG emissions calculations calculated according to the RSB and RSB-EU RED methodologies

Differences between March 2013 and October 2013 Calculations

The draft GHG calculations conducted in March 2013 (report D5.16) and in this report are compared.

Table 3: Differences between March and October calculations

Lifecycle step	Difference March-Oct (< lower; = same; > higher)	October 2013 Calcs: Calculation change factors
Feedstock Production	<<	The quantity of fertilizers used by farmers was much lower than the one recommended by CCE (about less than half). While yield also diminished, it didn't go down proportionally to such lower fertilizer use, and hence emissions are lower. Also, the yield value now used is a measured value, whereas previously it was a best estimate: - Yield (March calculation): 1470 kg/ha (estimated) - Yield (Oct calculation): 820 kg/ha (measured) In addition, in the previous calculation the only fertilizer used was nitrate. The data from the 2012/2013 harvest reveal that farmers used the following N fertilizers: ammonium sulfate, nitrate and urea, where ammonium sulfate was the fertilizer used in highest proportion. This fertilizer is also the one with the lowest GHG emission factor.
& Transport	=	
& Cleaning	>	The impurity content (in %) of the grain has increased, thus resulting in a higher energy expenditure for grain cleaning. At the same time, the lower heating value of grain and husks have changed, as data for camelina have been measured this time, instead of data for rapeseed (which were used in the last calculation as proxies due to missing camelina data). The LHV affects the allocation of emissions under the EU RED calculation. The LHV used were measured in the laboratory as follows: - Camelina grain: 26,4MJ/kg to 25,41MJ/kg - Camelina husks: 14MJ7kg to 17,13 MJ/kg
& Transport	=	
& Oil Pressing	>>	The oil fraction obtained from pressing has increased from 35% to 36.6%. The LHV used were measured in the laboratory as follows: - Camelina meal: 18,7MJ/kg to 17,075MJ/kg - Camelina oil: 36MJ/kg to 37,033 MJ/kg
& Transport	>	A new distance has been used from Cuenca to Valencia, 275 km, which makes emissions slightly higher.

GHG Improvement Potential

The process steps that most significantly impact GHG emissions are camelina production, oil production, and processing into biofuel via the Neste process. Therefore, GHG emission reductions associated with these process steps can have a large impact on overall lifecycle emissions.

CCE is responsible for camelina production and oil production, and Neste is responsible for transformation into final biofuel. Both companies have provided suggestions on potential ways to reduce GHG emissions and the associated feasibility.

CCE has suggested improvements on the camelina production, transport, oil cleaning and pressing processes.

The main “emission” associated with the Neste process is due to a 10% loss of product as part of the de-oxygenation process. This loss is unavoidable. The listed potential process changes that could lower GHG emissions have only a small reduction potential in comparison.

Table 4: Potential GHG emission reduction options

Process step	**GHG emission reduction measure**	**Lifecycle GHG reduction potential**	**Technical and economic feasibility**
Camelina production	Increased fertilizer use, closer to the higher recommendations made by CCE, could significantly increase yield, which could reduce GHG emissions per unit camelina grain. This is to be determined, as increased fertilizer use also results in higher GHG emissions.	High	Feasible (planned)
Transport	Reduced distances between camelina production and cleaning is expected in the future.	Low	Feasible (planned)
Camelina grain cleaning	Grain impurities are expected to go down, which would lower GHG emissions associated with cleaning.	Low-Mid	Feasible (planned)
Oil pressing	Higher process efficiency is expected in near future, which would result in smaller losses of camelina oil in the meal.	High	Feasible (planned)
Oil pressing	In addition, it is important to point out that the current oil press used is old and inefficient; a more modern and efficient oil press could have much lower energy consumptions and substantially reduce emissions.	High	Feasible (not currently planned)
Biofuel production (Neste)	Use “green hydrogen” (produced from renewable energy) instead of fossil-fuel based hydrogen.	small	Not feasible, not planned

Biofuel production (Neste)	Switch to biofuels in power plant instead of fossil fuels.	small	Feasible, not planned

6 Conclusions

These preliminary results show that the final biofuel meets the RSB and the EU RED GHG reduction requirements. It should be noted, however, that these emission estimates do not take ILUC into account.

The production steps that most impact lifecycle GHG emissions are camelina production (34%), camelina seed crushing (34%), and fuel production.

Transport generally adds a small amount of GHG emissions, though each maritime shipping operation between Spain and Finland/Netherlands adds about 1-2% GHG emissions overall. The 2014 batch is expected to be sent back from Rotterdam to Spain to be used at the Valencia airport and therefore will result in about 1-2% more emissions.

As with all emission estimates based on lifecycle accounting methods, it is important to remember they are based on methodological choices, such as the choice of allocation method, which can have a large impact on final emission estimates. While the RSB methodology attributes a higher portion of emissions to more expensive products (economic allocation), the EU RED does the attribution based on the energy content of products. This also implies that the RSB methodology can yield different results from year to year as market conditions change.

Hence, different methodologies yield different results, which in some instances can be quite divergent. In this case, there is a roughly 20% divergence between the value calculated using the RSB methodology and the value calculated using the RSB-EU RED methodology.

Finally, potential GHG emission reduction measures have been identified, some of which are planned to be implemented in the near future, which are expected to result in lower lifecycle GHG emissions.

7 Future Work

Ideally, the uncertainty associated with each of the input parameters would be estimated, in order to obtain an overall uncertainly value associated with the calculations presented in this report.