Roundtable on
Sustainable Biomaterials

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Report 1.1 - GHG emissions scenarios 1 and 2 to produce SAF at SkyNRG Delfzijl facility

Roundtable on Sustainable Biomaterials

Version 01

WP1 SkyNRG Delfzijl LCA GHG emissions update

Reference 01 – 01 October 2024 – Final report

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1. Introduction

SkyNRG is the global market leader for sustainable aviation fuel (SAF) for jet engines, supplying several airlines on all continents. SkyNRG sources, blends, and distributes SAF, the company guarantees sustainability throughout the supply chain and helps co-fund the premium.

At the same time, SkyNRG focuses on developing regional supply chains that offer a real sustainable and affordable alternative to fossil fuels. To help meeting this ambition, SkyNRG is building Europe's first facility dedicated to producing SAF. The facility will be located at Delfzijl and produce [redacted] of SAF annually.

SkyNRG is approaching a financial investment decision and is going through a debt financing track through the rest of 2024. To support the lenders in their due diligence process, SkyNRG is requesting RSB assistance on a SkyNRG Delfzijl LCA update, which was previously developed by the RSB team in 2020.

For SAF to be truly sustainable, a reputable sustainability certification must independently verify the GHG reductions and demonstrate that it promotes social and environmental sustainability and safeguards food security.

Based on the context above, RSB will assist SkyNRG with the calculation and update of Life Cycle GHG emissions.

In total, the Life Cycle GHG emissions calculation for six scenarios (combining two feedstocks and five production processes) will be assessed in Work Package 1 (WP1) (Table 1). Scenarios 1 and 2 will be the focus of Report 1.1, and Scenarios 3 to 6 will be the focus of Report 1.2.

Table 1: Scenarios definition for LCA GHG emissions calculation.

ID	Production process	Feedstock	Referred as
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

[1] Default production is the standard operating process covered by the FEED design and DSL business case. Emission Factors (EF) are based on standard values for using utilities from Dutch grid.

2. Methodology

2.1 Goal and scope of the LCA GHG emissions calculation

This report covers an attributional LCA focused on LCA GHG emissions of the DSL 01 project, following RSB EU RED (RSB-STD-11-001-01-010) and RSB CORSIA (RSB-STD-12-001) methodologies.

The goal of this attributional Life Cycle GHG work is to calculate the impact of GHG emissions of 2 scenarios developed to produce SAF at SkyNRG Delfzijl under the following scope:

1. SAF production using Typical Operating Feedstock (TOF) as feedstock and a default production process.
2. SAF production using 100% Used Cooking Oil (UCO) as feedstock and a default production process

The functional unit (FU) applied is 1 MJ of SAF, and results will be expressed in g CO_{2eq}/MJ SAF.

The GHG emissions calculation follows an attributional approach, in which allocation methods split the environmental burdens among the product (SAF) and coproducts (renewable butane, renewable propane, renewable naphtha and slop)[1]. The GHG emissions of the process were allocated to the outputs based on the their lower heating value (LHV) under RSB EU RED and RSB CORSIA schemes. No emissions are allocated to the feedstock production (Used Cooking Oil – UCO and Typical Operational Feedstock - TOF) as they are classified as residues[2] and, therefore, are assumed to be produced unintentionally. For additional information on the GHG methodology applied, check Annex I and the RSB standard for Calculation Methodology (RSB-STD-01-003-01). CORSIA methodology for GHG calculation is provided in Annex II.

2.2 System Boundaries

This LCA GHG is calculated from cradle to end-user, included within the system boundaries are the transportation of the feedstock from the points of origin, natural gas and chemicals to the DSL 01 facility, a pre-treatment of the feedstocks, renewable SAF, and final transportation via barge to Amsterdam (Figure 1). The SAF production from SkyNRG facility DSL-01 is based on HEFA technology. The scope adopted captures the main emissions sources within the project boundaries.

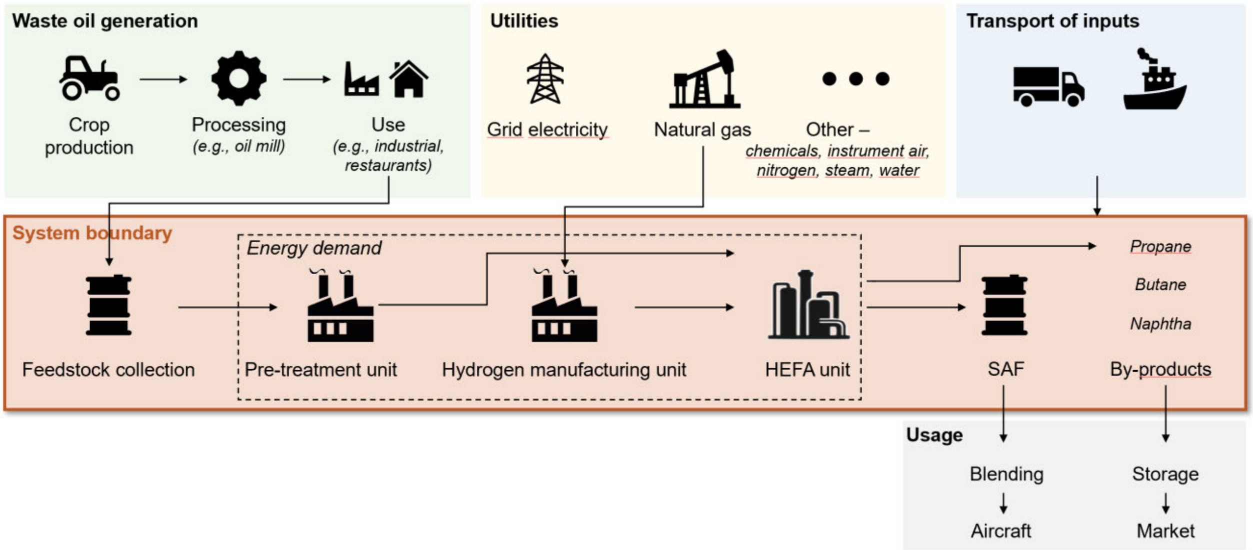

Figure 1: Life Cycle system boundary for scenarios 1 and 2. The scope includes emissions from direct sources (Scope 1), indirect emissions from the generation of purchased electricity and steam (Scope 2) and other indirect emissions that occur across the value chain (Scope 3).

The LCA GHG assessment excludes cultivation, transport and process emissions up to the point of origin of residue feedstock materials, as well as any further transport and distribution emissions of the coproducts LPG, naphtha and light fractions. GHG emissions from the combustion of biogenic carbon of the fuel in use are assumed to be carbon neutral (as CO_2 was taken from the atmosphere to grow the biogenic material). The LCA GHG emissions for the 'hydrogen manufacturing unit' stage are included in the 'HEFA unit' stage.

[1] There is an extra output, a wastewater from pretreatment, that has not been taken into account for the emission allocation, but that taking it into account would have a minor (e.g., <0.1%) impact on the LCA.

[2] This study did not assess the eligibility of feedstocks for classification as residues under the RSB EU RED standard.

2.3 Inventory – Data collection

SkyNRG provided data based on the facility's technical specifications. RSB carried out a high-level sense-check of data but did not review data input values in detail (e.g. comparing them with industry average data for energy use in similar processes) or review the data collection or calibration methods.

Table 2 details the parameters used to calculate scenarios 1 and 2.

Table 2: Parameters assumed in this work for TOF and UCO.

Parameters	Value	Unit
Daily production	[redacted]	t SAF/day
Yearly production	[redacted]	t SAF/year
Daily feedstock processing (treated)	[redacted]	t feedstock/day
Daily feedstock processing (untreated)	[redacted]	t feedstock/day
Feedstock yield	[redacted]	t feedstock treated/untreated feedstock
SAF yield	[redacted]	t SAF/treated feedstock
SAF moisture content	[redacted]	%
Cleaned feedstock moisture (before treatment)	[redacted]	%
Cleaned feedstock moisture (treated)	[redacted]	%
Outputs	**LHV**	**Unit**
Feedstock	[redacted]	MJ/kg
SAF	[redacted]	MJ/kg
Slop	[redacted]	MJ/kg
Renewable Naphta	[redacted]	MJ/kg
Renewable Butane	[redacted]	MJ/kg
Renewable Propane	[redacted]	MJ/kg

Table 3 presents the activity – inventory - data assumed in each scenario.

Table 3: Materials and energy flows assumed in each scenario.

Input products	Unit	SC 1 (TOF - Default)	SC 2 (UCO - Default)
		Activity data	
Electricity use	kWh/kg SAF	[redacted]	[redacted]
Natural gas	MJ/kg SAF	[redacted]	[redacted]
Steam	MJ/kg SAF	[redacted]	[redacted]
Caustic soda	kg/kg SAF	[redacted]	[redacted]
Instrument air	kg/kg SAF	[redacted]	[redacted]
Nitrogen	kg/kg SAF	[redacted]	[redacted]
Citric acid	kg/kg SAF	[redacted]	[redacted]
MDEA	kg/kg SAF	[redacted]	[redacted]
DMDS	kg/kg SAF	[redacted]	[redacted]
Hydrochloric acid (36% solution)	kg/kg SAF	[redacted]	[redacted]
Output products			
Renewable Naphtha	kg/kg SAF	[redacted]	[redacted]
Renewable Butane	kg/kg SAF	[redacted]	[redacted]
Renewable Propane	kg/kg SAF	[redacted]	[redacted]
Slop	kg/kg SAF	[redacted]	[redacted]
Sulphur cake	kg/kg SAF	[redacted]	[redacted]
SAF	kg SAF	[redacted]	[redacted]
Transportation			
Feedstock from consolidator to DSL-01 by truck	km/kg SAF	[redacted]	[redacted]
Natural gas to DSL-01	km/kg SAF	[redacted]	[redacted]
Renewable Jet Fuel to off taker	km/kg SAF	[redacted]	[redacted]
Non-EU feedstock to consolidator (by barge - 20% of feedstock)	km/kg SAF	[redacted]	[redacted]
EU Feedstock to consolidator (by barge - 80% of feedstock)	km/kg SAF	[redacted]	[redacted]
Processing effluents			
Water (pretreatment)	l/kg SAF	[redacted]	[redacted]
Water (HEFA)	l/kg SAF	[redacted]	[redacted]
Wastewater (pretreatment)	m3/kg SAF	[redacted]	[redacted]
Wastewater (HEFA)	m3/kg SAF	[redacted]	[redacted]

2.4 Impact Assessment - Tools and calculations

The background data (e.g. the carbon intensity of heat, chemicals, water, etc.) is sourced from the Ecoinvent database. Ecoinvent 3.7 was used in this project, as this version was implemented in the RSB GHG tool (version 5) and used to calculate the LCA GHG emissions.

This work applies the impact category Climate Change, assessed in terms of g CO_2 eq, using the method IPCC 2013 (GWP 100a). Annex II presents a list of the emission factors (EF) used.

2.5 Uncertainty relating to methodologies

Uncertainties identified in this study are mostly related to the intrinsic uncertainties of the EF used and proxies used for some inputs. For example, for 'instrument air,' an average of datasets for 'compressed air' from Ecoinvent 3.7 was used as a proxy. The EFs for the inputs are presented in Annex III.

3. Results

3.1 General results

Scenario 1 (TOF + Default processing) for the DSL-01 supply chain achieves an LCA GHG emission saving of 82% in the RSB EU RED scheme, relative to a fossil fuel baseline of 94 g CO_{2eq}/MJ (EU RED II comparator). Scenario 2 (UCO + Default processing), for the RSB EU RED scheme, shows an 82% LCA GHG emission savings (also relative to a fossil fuel baseline of 94 g CO_{2eq}/MJ) (Table 4). The minimum emissions savings expected for biofuels under EU RED are 65% and 10% under the CORSIA methodology.

Table 4: Emission savings for RSB EU RED and RSB CORSIA methodologies

Scenario	GHG emissions (g CO_{2eq})	Emissions saving (%) EU RED	GHG emissions (g CO_{2eq})	Emissions saving (%) CORSIA
SC1	16.94	81.97%	17.43	80.42%
SC2	17.24	81.66%	17.24	80.63%
Fossil comparator (g CO_{2eq}/MJ)		94		89

The industrial processing stage 'HEFA' is the one that most contributes to LCA GHG emissions (SC1 % and SC2 – 90%), and, therefore, any effort to reduce carbon dioxide emissions should be focused on this stage (Table 5). Transport contributes 7% (both scenarios) of total impacts and 'Pre-treatment' to 3% (both scenarios). The main differences between SC1 and SC2 are related to a higher natural gas consumption in SC2 and higher electricity consumption in SC1 and the yield of the output 'Renewable naphta'. The results, emissions savings and contribution for scenarios 1 and 2 in the RSB CORSIA scheme are similar to those of the RSB EU RED.

Table 5: Scenarios results and contribution analysis per stage for RSB EU RED scheme (gCO2eq/MJ).

Modelled supply chain	SC1 (g CO_{2eq}/MJ SAF)	SC1 Contribution	SC2 (g CO_{2eq}/MJ SAF)	SC2 Contribution
Cultivation	-	0%	-	0%
Transport	1.16	7%	1.18	7%
Processing: Pre-treatment	0.54	3%	0.47	3%
Processing: HEFA	15.24	90%	15.59	90%
TOTAL	16.94	100%	17.24	100%

Table 6 presents results and contribution analysis for LCA GHG emissions for scenarios 1 and 2 under the RSB EU RED scheme. Regarding the inputs, the most contributors to the 'processing HEFA' stage are natural gas with 53.5% (SC1) and 54.4% (SC2) of total impacts and electricity with 44.3% (SC1) and 43.4% (SC2). For the 'transport' stage, the transport by barge tanker contributes most to the impacts (70% in both scenarios). The contribution for scenarios 1 and 2 in the RSB CORSIA scheme is quite similar to those of the RSB EU RED.

Table 6: Results and contribution analysis per inputs for scenarios 1 and 2

Stage	Input	SC1 - TOF (default process)				SC2- UCO (default process)			
		Emissions (g CO_2 / MJ Fuel)		**Contribution** (% total)		**Emissions** (g CO_2 / MJ Fuel)		**Contribution** (% total)	
Transport	Feedstock from consolidator to DSL-01 by truck	0.27	23.6%		1.6%	0.28	23.6%		1.6%
	Natural gas to DSL-01	-	0.0%		0.0%	-	0.0%		0.0%
	Non-EU feedstock to consolidator (by barge - 20% of feedstock)	0.67	57.5%		3.9%	0.68	57.5%		3.9%
	EU Feedstock to consolidator (by barge - 80% of feedstock)	0.16	14.1%		1.0%	0.17	14.1%		1.0%
	Renewable Jet Fuel to off taker	0.06	4.8%		0.3%	0.06	4.8%		0.3%
Processing: Pre-treatment	Electricity (Grid Mix)	0.51	94.0%		3.0%	0.40	85.4%		2.3%
	Energy (Natural gas)	-	0.0%		0.0%	-	0.0%		0.0%
	Chemical inputs	0.03	5.8%		0.2%	0.07	14.5%		0.4%
	Water use	0.00	0.1%		0.0%	0.00	0.1%		0.0%
	Wastewater	0.00	0.1%		0.0%	0.00	0.1%		0.0%
	Emissions from your facility	-	0.0%		0.0%	-	0.0%		0.0%
Processing: HEFA	Electricity (Grid Mix)	6.76	44.3%		39.9%	6.77	43.4%		39.3%
	Energy (Natural gas)	8.15	53.5%		48.1%	8.48	54.4%		49.2%
	Chemical inputs	0.33	2.2%		1.9%	0.33	2.1%		1.9%
	Water use	0.00	0.0%		0.0%	0.00	0.0%		0.0%
	Wastewater	0.00	0.0%		0.0%	0.00	0.0%		0.0%
	Emissions from your facility	-	0.0%		0.0%	-	0.0%		0.0%
Total		**16.94**				**17.24**			

The main hotspots identified, verifying the contribution to the total emissions of the system in the analysis, are natural gas (SC1 – 48.1% and SC2 – 49.2%), followed by electricity (SC1 – 39.9% and SC2 – 39.3%) and transport by barge tanker (SC1 – 4.9% and SC2 – 4.9%). Lower consumption of natural gas as an energy input or using a secondary energy source such as biogas, wood pellets, or wood chips could also contribute to reducing LCA GHG emissions. Regarding electricity, RSB recommends switching from grid mix to renewable electricity consumption (purchased or self-produced) to help minimise the total impact. To decrease impacts on transportation, reducing the export of feedstock over large distances can also further contribute to reducing GHG emissions within the process. Please note that the purchase of renewable electricity and biomethane need to comply with the requirements in the Directive (EU) 2018/2001.

The carbon intensity of the electricity grid mix within the Netherlands is expected to reduce over time towards the date of the first production at SkyNRG facility DSL-01 in 2028. The SkyNRG team provided RSB with their simulation of the future carbon emissions from the Dutch electricity grid mix in 2028. The expected carbon intensity in the Netherlands is 70 gCO_2/kWh by 2030; therefore, interpolating this number with 2025 values (190 gCO_2/kWh) gives 118 gCO_2/kWh. Applying this EF to the TOF and UCO scenarios, the total LCA GHG emissions under EU RED would be 13.98 and 14.56 gCO_2/MJ, respectively. Table 7 presents a summary of the results. Similar results were obtained when calculating results using the CORSIA methodology.

Table 7: Summary of results considering EF for Dutch electricity grid mix in 2028 (prospective value)

Scenario	GHG emissions (g CO_{2eq})	Emissions saving (%) EU RED
SC1 (2024)	16.94	81.97%
SC2 (2024)	17.24	81.66%
SC1 (2028)	13.98	85.13%
SC2 (2028)	14.56	84.51%
Fossil comparator (g CO_{2eq}/MJ)		94

4. Conclusions

This Report 1.1 presents results for LCA GHG emissions calculations for SAF production at the DSL-01 facility, combining a default production process with two different feedstocks, Typical Operational Feedstock (TOF) and Used Cooking Oil (UCO). Both feedstocks are considered residues. It is important to highlight that this study did not assess the eligibility of feedstocks for classification as residues under the RSB EU RED standard.

Scenario 1 (TOF + default process) has a total LCA GHG emissions of 16.94 (g CO_{2eq}/MJ SAF), representing an emission saving of 82% compared to the fossil comparator established by EU RED (94 g CO_{2eq}/MJ Fuel). Scenario 2 (UCO + default process) has a total LCA GHG emissions impact of 17.24 (g CO_{2eq}/MJ SAF), representing an emission saving of 82% compared to the fossil comparator established by EU RED (94 g CO_{2eq}/MJ Fuel). The results of this are emissions savings and contribution for scenarios 1 and 2 in the RSB CORSIA scheme being similar to those of the RSB EU RED.

The processing HEFA stage is the most impactful process, accumulating 90% of total emissions in both scenarios, with natural gas and electricity as the main impacting inputs, accumulating 98% of total impacts in both scenarios in this stage. Switching the electricity consumption from the grid mix to renewable electricity and adding a secondary source of energy other than natural gas is expected to reduce LCA GHG emissions significantly. In addition, the use of primary EFs for some chemical inputs through the calculation of those EFs can also contribute to lower LCA GHG emissions for SAF production at DSL -01.

Annex

I. RSB EU RED GHG emission calculation methodology

The GHG assessment was conducted in line with the methodologies of the EU Renewable Energy Directive (EU RED I), CORSIA and RSB Global, which are incorporated in the RSB GHG Tool.
The GHG assessment followed the steps:

1. Calculation of emissions from transport, storage and distribution
2. Calculation of emissions from processing
3. Applying feedstock factors and allocation factors
4. Calculating the GHG saving

Emissions from transport, storage and distribution

Emissions from transport, storage and distribution (e_{td}) were calculated for each transport step individually using the following formula and summed up.

$$e_{td} = e_{tr} + e_{st} + e_{fl}$$

Where:

e_{tr}: Emissions from transport

e_{st}: Emissions from storage

e_{fl}: Emissions from distribution

$$e_{tr} = \frac{TD_{vehicle}[km] * TQ[kg] * EF_{transport}\left[\frac{kgCO_2}{tkm}\right]}{TQ[kg]}$$

$$e_{st} = \mathrm{E}_{storage}\left[\frac{\mathrm{MJ}}{\mathrm{MJ}_{\mathrm{fuel}}}\right] * \frac{1}{3.6}\left[\frac{\mathrm{kWh}}{\mathrm{MJ}}\right] * EF_{electricity}\left[\frac{kgCO_2}{kWh}\right] * ED\left[\frac{MJ_{fuel}}{kg}\right]$$

$$e_{fl} = E_{filling}\left[\frac{\mathrm{MJ}}{\mathrm{MJ}_{\mathrm{fuel}}}\right] * \frac{1}{3.6}\left[\frac{\mathrm{kWh}}{\mathrm{MJ}}\right] * EF_{electricity}\left[\frac{kgCO_2}{kWh}\right] * ED\left[\frac{MJ_{fuel}}{kg}\right]$$

With

- TD: transport distance
- TQ: transported quantity of biomass / bioliquid / biofuel
- $EF_{transport}$: emission factor for transport; taken from the *ecoinvent* database (without infrastructure). They are specific for the different vehicle types and consider the average load of the vehicle.
- $EF_{electricity}$: emission factor for electricity at the location of storage or filling
- ED: energy density of fuel
- $E_{storage}$: electricity used at storage facilities, a standard value of 0.00084 MJ/MJ-fuel (JRC, 2008) was used
- $E_{filling}$: electricity used at filling station: standard value of 0.0034 MJ/MJ-fuel (JRC, 2008) was used

Source for $E_{storage}$ and $E_{filling}$: JRC, "*Input data relevant to calculating default GHG emissions according to RE Directive Methodology*," 2008

Emissions from fuel production and fuel refining

Emissions from fuel production and fuel refining were calculated using the following formula.

$$E_{Processing}\left[\frac{kgCO_2}{yr}\right]=\frac{E_{\substack{electricity\\consumption}}\left[\frac{kgCO_2}{yr}\right]+E_{\substack{heat\\production}}\left[\frac{kgCO_2}{yr}\right]+E_{\substack{operating\\material}}\left[\frac{kgCO_2}{yr}\right]+E_{effluent}\left[\frac{kgCO_2}{yr}\right]}{product\ yield_{\substack{main\\product(crop)}}\left[\frac{kg_{produc\ yield}}{yr}\right]}*Allocation\_factor$$

With

$$E_{\substack{electricity\\consumption}}\left[\frac{kgCO_2}{yr}\right]=\sum Electricity\_type_i\left[\frac{kWh}{yr}\right]*EF\_elec_i\left[\frac{kgCO_2}{kWh}\right]$$

EF_elec_i: emission factor of the electricity type (e.g. grid electricity). The emission factors of the electricity type are taken from the *Ecoinvent* database.

$$E_{\substack{heat\\consumption}}\left[\frac{kgCO_2}{yr}\right]=\sum Heat\_type_i\left[\frac{MJ}{yr}\right]*EF\_heat_i\left[\frac{kgCO_2}{MJ}\right]$$

EF_heat_i: emission factor of the heat type (e.g. natural gas). The emission factors of the heat type are taken from the *Ecoinvent* database.

$$E_{\substack{operation\\material}}\left[\frac{kgCO_2}{yr}\right]=\sum material\_type_i[kg]*EF\_mat_i\left[\frac{kgCO_2}{kg}\right]$$

EF_mat_i: emission factor of the material type (e.g. chemicals). The emission factors of the production of operating materials are taken from the *ecoinvent* database.

$$E_{effluent}\left[\frac{kgCO_2}{yr}\right]=\sum effluent\_type_i\left[\frac{kg}{yr}\right]*EF\_eff_i\left[\frac{kgCO_2}{kg}\right]$$

EF_eff_i: emission factor of the effluent (e.g. hexane).

Dealing with co-products and conversion yields

For allocation to co-product streams, greenhouse gas emissions were divided between the jet fuel fraction and the co-products (C1-C2 lights, LPG and Naphtha) in proportion to their energy content determined by the lower heating value:

$$Allocation\ factor\ AF:\ \left[\frac{Energy\ in\ intermediate\ product_a}{Energy\ in\ intermediate\ products\ +\ co-products}\right]$$

A feedstock factor was applied to take losses into account:

Feedstock factor FF:

$$[Ratio\ of\ MJ\ feedstock\ required\ to\ make\ 1\ MJ\ of\ intermediate\ product]$$

For the final HEFA production step, the unit *kg* CO_{2eq} / kg material was transformed into *kg* CO_{2eq}*/MJ* by using the lower calorific value as the conversion factor:

$$E\left[\frac{gCO_{2eq}}{MJ}\right] = \frac{em\_cum_{\substack{final\\product}}\left[\frac{gCO_{2eq}}{kg}\right]}{CF\left[\frac{MJ}{kg}\right]}$$

Where:

$em\_cum_{final\ product}$: Cumulated emissions up to the final product

CF: Conversion factor, here: lower calorific value

Calculating the greenhouse gas saving

The greenhouse gas emission saving was calculated in the last step as

SAVING = (EF – EB)/EF

Where

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

II. RSB CORSIA GHG emission calculation methodology

The methodology used to calculate LCA GHG emissions (called Life Cycle Emissions—LSf) under the CORSIA methodology is available in the ICAO document CORSIA Methodology For Calculating Actual Life Cycle Emissions Values.

The system boundary of the core LCA value calculation will include the entire supply chain of CEF production and use. As such, emissions associated with the following life cycle stages of the CEF supply chain will be accounted for: (1) production at source (e.g. feedstock cultivation); (2) conditioning at source (e.g. feedstock harvesting, collection, and recovery); (3) feedstock processing and extraction; (4) feedstock transportation to processing and fuel production facilities; (5) feedstock-to-fuel conversion processes; (6) fuel transportation and distribution to the blend point; and (7) fuel combustion in an aircraft engine.

The calculated LSf values will include emissions generated during ongoing operational activities (e.g. operation of a fuel production facility, feedstock cultivation and extraction, transportation of feedstock, intermediate products and finished aviation fuels, and other operational activities for life cycle stages 1-6 described in paragraph 2), as well as upstream emissions associated with the material and utility inputs for operational activities, such as processing chemicals, electricity, and natural gas. Emissions generated during one-time construction or manufacturing activities (e.g. fuel production facility construction, equipment manufacturing) will not be included.

III. Emission factors

Input	EF	Unit	Source	Dataset
Electricity	270.00	g CO_{2eq}/kWh	Source Dutch Statistics Bureau. CO2-emissie_Energieverbruik_Rendementen_Elektriciteit_2022	EF from 2022 (most updated value)
Natural gas	66.00	g CO_{2eq}/MJ	Annex IX of Commission Implementing Regulation (EU) 2022/996 of 14 June 2022.	Natural gas (EU mix)
Steam	0	-	-	It is zero because it is a waste flow hydrogen production.
Caustic soda	1294.1	g CO_{2eq}/kg	Ecoinvent 3.7	market for sodium hydroxide, without water, in 50% solution state, GLO.
Instrument air	142.94	g CO_{2eq}/kg	Ecoinvent 3.7	Average of: market for compressed air, 600 kPa gauge; market for compressed air, 700 kPa gauge; market for compressed air, 800 kPa gauge; market for compressed air, 1000 kPa gauge and market for compressed air, 1200 kPa gauge
Nitrogen	434.51	g CO_{2eq}/kg	Ecoinvent 3.7	market for nitrogen, liquid, RoW
Citric acid	6048.7	g CO_{2eq}/kg	Ecoinvent 3.7	market for citric acid, GLO.
MDEA	2369.3	g CO_{2eq}/kg	Ecoinvent 3.7	retention aid production, for paper production
Hydrochloric acid (36% solution)	905.86	g CO_{2eq}/kg	Ecoinvent 3.7	market for hydrochloric acid, without water, in 30% solution state
Water (Tap water)	1.00	g CO_{2eq}/kg	Ecoinvent 3.7	market for tap water, RoW
Water (Completely softned)	0.6769	g CO_{2eq}/kg	Ecoinvent 3.7	market for water, completely softened, RoW
Water (river)	0	-	-	-
Wastewater	549.47	g CO_{2eq}/m^3	Ecoinvent 3.7	treatment of wastewater, average, capacity 1E9l/year, RoW.
Transport (truck)	162.31	g CO_{2eq}/TKM	Ecoinvent 3.7	transport, freight, lorry 16-32 metric ton, EURO6
Transport (barge)	44.06	g CO_{2eq}/TKM	Ecoinvent 3.7	market group for transport, freight, inland waterways, barge tanker