Carbon footprint report

BIO ETHYL ACETATE

Sekab

Report name: Carbon footprint of Bio Ethyl acetate Public
Company name: Sekab Biofuels & Chemicals AB
Company ID: Bio Ethyl acetate
Product trade name: Bio Ethyl acetate
CAS: 141-78-6
Commissioner of the study: Sekab Biofuels & Chemicals AB
Product classification: Solvent
Production country: Sweden
Main market: Europe
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Name and affiliation of verifiers: Yevgeniya Arushanyan, Ramboll Sweden AB
Date: 2024-10-18
Updated: 2025-03-19

Disclaimer

This document contains redacted information to protect proprietary data.
Any omitted sections are marked accordingly

Contents

List of used acronyms and abbreviations

Bio EtAc: Bio Ethyl acetate
EtAc: Ethyl acetate
GHG: Greenhouse Gas
Bio HAc: Bio Acetic acid
HAc: Acetic acid
LCA: life cycle assessment
IPCC: Intergovernmental Panel on Climate Change
ISO: International Organization for Standardization
PCF: Product Carbon Footprint guideline for the chemical industry
EtOH: Ethanol
ISCC: International Sustainability and Carbon Certification

Summary

This report presents a detailed analysis of the partial carbon footprintin accordance with ISO14067 and Product carbon footprint guidelines (PCF)[1] associated with the production of the product Bio Ethyl acetate (Bio EtAc). Bio EtAc is a colorless liquid with a characteristic sweet smell (similar to peardrops). It is an organic compound, an ester of EtOH and HAc. EtAc is considered to be one of the least environmentally harmful organic solvents.

This is a carbon footprint study from production of biomass until gate at Sekab following a life cycle approach, covering raw material production, component manufacture, and transport of raw material to the production site. Sekab considers "until gate" as a partial carbon footprint. Since end-of-life and use phase takes place outside Sekabs gate and the scenarios depends on actual use of the product, those events are not included. In the end-of-life the product will evaporate, i.e the uptake becomes an emission to air.

The primary objective of this report is to make a meaningful contribution toward advancing the sustainability objectives within the chemical industry. At gate carbon footprint is shown in Figure 1. The carbon footprint at gate for Bio EtAc is -248 kg CO_2eq, when the biogenic uptake during growth of biomass is taken into account. However, it is important to understand that the uptake might become an emission in the end of life (depending on the application). Without the biogenic uptake the cradle-to-gate carbon footprint of the Bio EtAc is 1878 kg CO_2eq per ton of Bio EtAc.

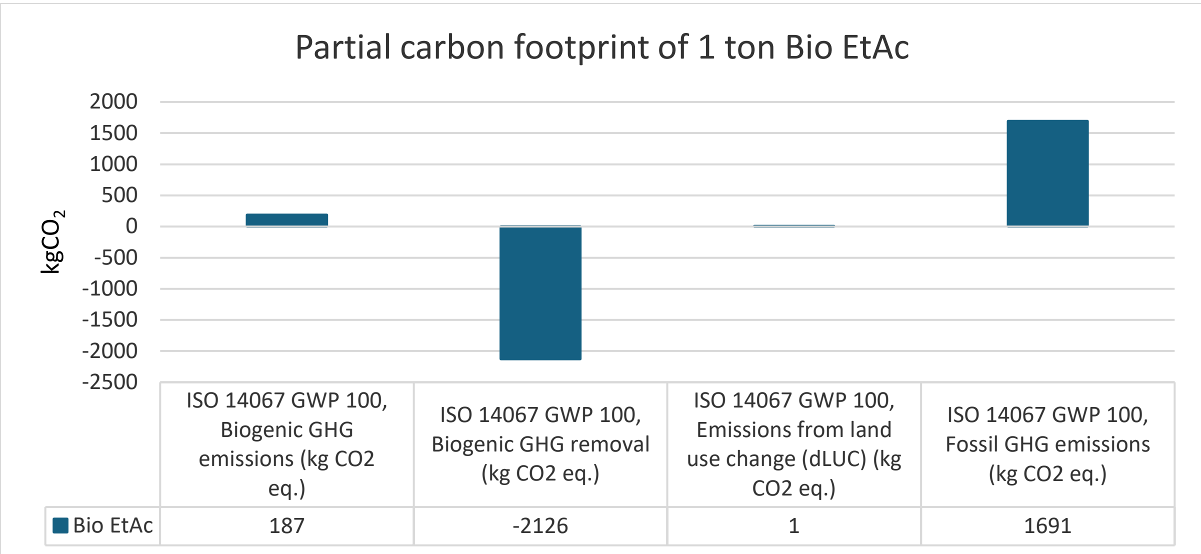
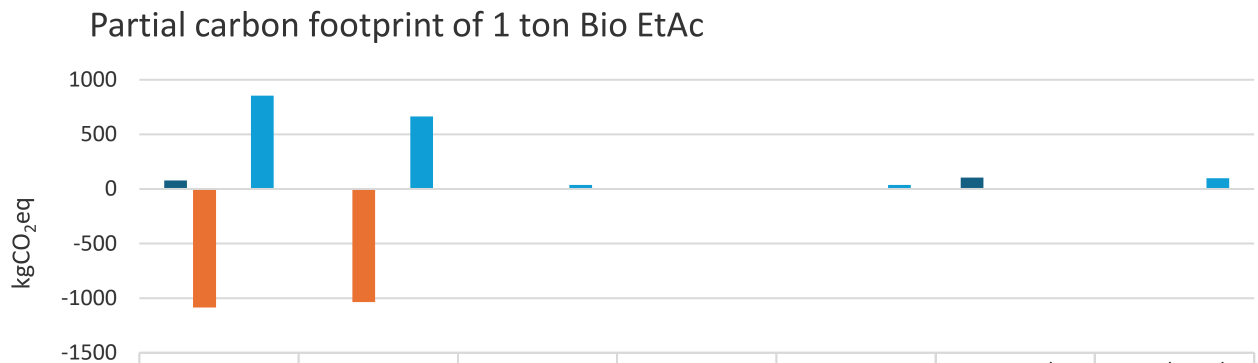


Figure 1. Partial carbon footprint emissions of 1 ton Bio EtAc

A breake down of the results for upstream, which includes tranport input of raw materials, core, which includes all input and outputs related to processing at the production site, are shown in

[1] Together for sustainability. The product carbon footprint guideline for the chemical industry. Specification for product Carbon Footprint and Corporate Scope 3.1 Emission Accounting and Reporting. Version 2.0 - November 2022

Figure 2, and reveals that the upstream process has the largest impact, and it is acetic acid and ethanol that has the largest contributions. Core process is relatively small in comparison to upstream process.



	Acetic acid	Ethanol	Transport	Electricity	Process water	Internal steam	Purchased steam
	Upstream			Core			
ISO 14067 GWP 100, Biogenic GHG emissions (kg CO2 eq.)	77	0	0	4	3	104	0
ISO 14067 GWP 100, Biogenic GHG removal (kg CO2 eq.)	-1085	-1035	0	-3	-2	0	0
ISO 14067 GWP 100, Emissions from land use change (dLUC) (kg CO2 eq.)	0	0	0	0	0	0	0
ISO 14067 GWP 100, Fossil GHG emissions (kg CO2 eq.)	853	664	38	2	36	0	97

Figure 2. Partial carbon footprint emissions of 1 ton Bio EtAc for upstream and core process.

Key findings

- Upstream process has the largest contribution to the carbon footprint at gate , and acetic acid and ethanol are identified as the largest contributor, showing an area for potential improvements.
- Core process has the lowest contribution to the partial carbon footprint.

1. Introduction

In today's world, there is an increasing awareness of the environmental and health impacts of industrial practices. Chemistry is a part of our daily lives, influencing many products we consume.

Sekab is a company located in Örnsköldsvik in northern Sweden and their site has produced bio-based chemicals since the 1940s. Sekab adheres to the Eco Cycle Principle by ensuring production occurs with minimal toxicological effects and reduced impact on the climate. The company specializes in producing ethanol derivatives, taking advantage of the relatively harmless nature of ethanol as a solvent for both health and the environment, illustrating how industrial chemistry can significantly advance the global transition towards more sustainable products by utilizing bio-based raw materials in manufacturing. The company's products include Bio Acetaldehyde, Bio Ethyl acetate, Bio Acetic acid, and various other ethanol-based products, all derived from bio-based sources.

This Life Cycle Assessment (LCA) investigates the partial carbon footprint associated with the production of Bio Ethyl acetate (Bio EtAc), a commonly employed solvent across various industries.

2. Methodology

2.1. Goal of study

Sekab is dedicated to being transparent about the partial carbon footprint of its products. This study aims to enhance transparency by disclosing the carbon footprint of a specific product: Bio Ethyl acetate (Bio EtAc). The investigation is conducted to better understand the carbon footprint associated with Bio EtAc.

The intention is to use this information for informed decision-making, especially in finding areas where efforts can be concentrated to effectively reduce the climate impact. The target audience for this report comprises customers, employees, investors, and other stakeholders with an interest in the environmental performance of the product.

2.2. Scope of the study

This life cycle assessment focuses on the partial carbon footprint of Bio EtAc that follow principles and calculations stated in ISO 14067 and adhering to PCF guidelines[2] from Together for Sustainability, which is the guideline for calculating the carbon footprint and partial carbon footprint of chemical products. The method used in the calculation utilizes the characterization factors for the 100-year global warming potential (based on IPCC AR6) developed by the Intergovernmental Panel on Climate Change[3] .

According to ISO 14067, emissions, and removals in the following categories are included:

- Fossil GHG emissions and removals
- Biogenic GHG emissions and removals
- GHG emissions and removals from direct land use and land use change

Aircraft emissions are excluded since such emissions are not involved in the production or transportation of Bio EtAc.

The data is collected year 2024, and the period from which the data was collected was the full production year 2022.

The time period for which this Carbon footprint study is representative is crucial for ensuring the accuracy and relevance of the data. According to ISO 14067 standards, it is essential to specify and justify the chosen time frame. The time period for which carbon footprint is

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[2] Together for sustainability. The product carbon footprint guideline for the chemical industry. Specification for product Carbon Footprint and Corporate Scope 3.1 Emission Accounting and Reporting. Version 2.0 - November 2022

[3] IPCC (2021). Climate Change 2021: The Physical Science Basis. Contribution of working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

representative is 2022 and is valid until new updates in the data inputs might lead to changes in the results.
Regular recalculation of the footprint is recommended to be done annually. PCFs are typically valid for up to five years, assuming no major production changes, to stay reflective of current practices.

2.3. Description of the product

Bio EtAc is a solvent used in many contexts, including printing inks, varnishes, car care chemicals and as extraction solvent in production of pharmaceuticals. It is also used in manufacturing of plastics and rubber, in the food industry, and in manufacture of flavorings. Bio EtAc is also a common component of cosmetics and nail polish remover. See information about the product in Table 1.

Ethanol used in the production of Bio EtAc is certified by ISCC. The International Sustainability and Carbon Certification (ISCC) is an independent multistakeholder initiative and leading certification system supporting sustainable, fully traceable, deforestation-free supply chains that are conducive to climate sustainability.

Table 1. Product in the study.

Product	CAS number	Description
Bio Ethyl acetate (Bio EtAc)	141-78-6	Bio EtAc is a colourless liquid with a characteristic sweet smell (similar to peardrops). It is an organic compound, an ester of EtOH and HAc. EtAc is considered to be one of the least environmentally harmful organic solvents. It is very effective while it is easily broken down in both air and water.

In Sekab's chemical plant, Bio Acetaldehyde, Bio Acetic acid (Bio HAc) and Bio Ethyl acetate (Bio EtAc) are produced. Ethanol input is bio-based. It is refined and converted into biofuels and ethanol-based chemical products. In catalytic processes the ethanol raw materials react highly effectively, the largest by-product is water.

Bio Acetaldehyde is produced by oxidation of Bio ethanol, it can be sold as a product or used in the production of Bio HAc. Bio HAc is produced by oxidation of Bio Acetaldehyde and can also be sold as a product or used in the production of Bio EtAc.

Bio EtAc is produced by esterification of Bio ethanol with Bio HAc, see figure 3. The production is energy intensive and consumes steam. The reaction, which is an equilibrium reaction, takes place in the presence of a catalyst and water is a biproduct. In several washing steps the Bio EtAc is purified from unreacted Bio HAc and Bio ethanol, but also from odorous compounds. Odour components and other impurities are separated and incinerated in a steam boiler. Bio EtAc is certified by the International Sustainability & Carbon Certification (ISCC), ensuring that it helps Sekab's clients meet their sustainability goals without sacrificing quality.

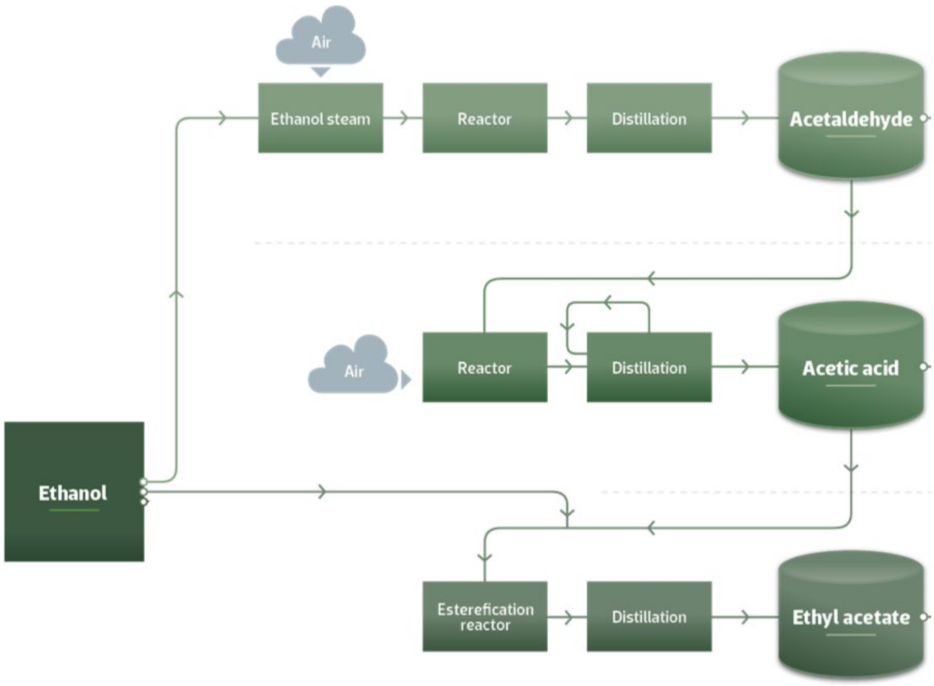

Figure 3. Flowchart of Sekab production of Bio EtAC.

2.4. Declarded unit and reference flow

The declared unit in this study is 1 ton of Bio EtAc at the site gate.

2.5. Description of life cycle and system boundaries

The study assesses the partial carbon footprint from the extraction of raw materials to the point of the final product leaving the plant (no packaging is used), referred to as cradle-to-gate analysis. This includes examining the production and refining of raw materials and considering material, energy, and transportation requirements during manufacturing. Figure 4 illustrates the system boundaries of the upstream processes involving activities prior to manufacturing, like extraction and refining of raw materials as ethanol and Bio HAc. Core processes directly relate to product production processes, involving energy, electricity, chemicals, and consumables in manufacturing, as well as transportation and waste disposal related to manufacturing.

Since biomass is used as raw material for producing the product its life cycle is a part of the natural carbon cycle. This study does not include use phase or end-of-life since those events takes place outside Sekabs gates and the scenarios depends on actual use of the product. In the end-of-life the product will evaporate, i.e the uptake becomes an emission to air.

System Boundaries

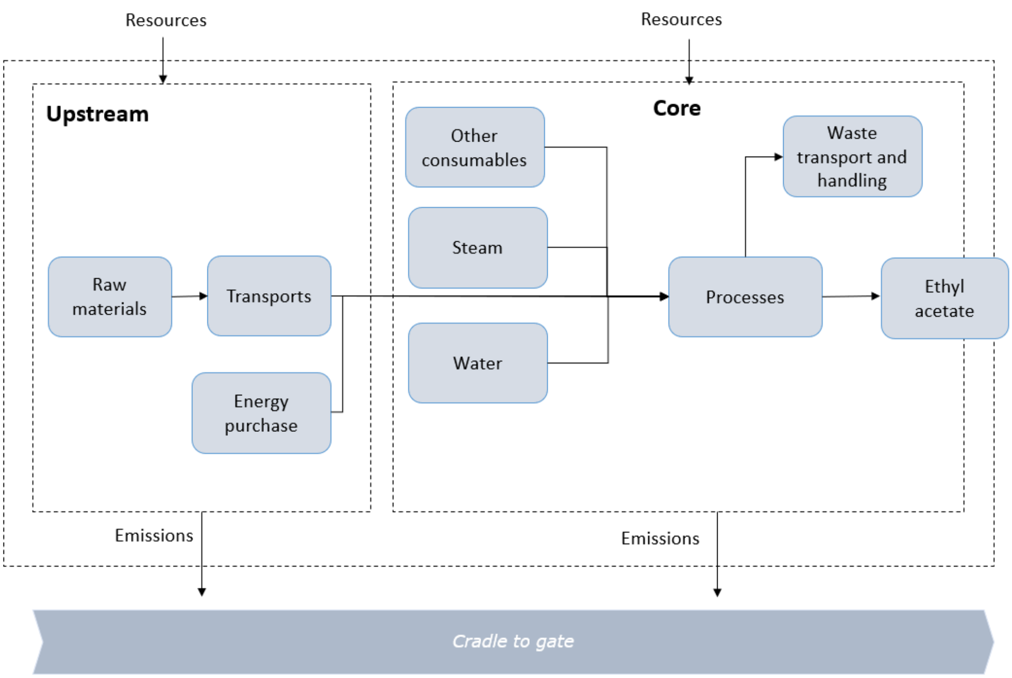

Figure 4. System boundaries for the manufacturing of Bio EtAc.

No system expansion has been applied in this study, i.e. no credits have been given for materials being recycled and potentially avoiding other material production, or for energy generated in waste incineration potentially avoiding other energy production.

The geographical boundary of the study is manufacturing of production of Bio EtAc in Sweden Örnsköldsvik, and the boundary between nature and the product life cycle is crossed when the natural resources are extracted from the ground.

2.6. Data quality requirements

The data quality requirements used in the study are shown in Table 2 below.

Table 2. Data quality requirements used in the study.

Aspect	Description	Requirements in this study
Time-related coverage	Desired age of data and the minimum length of time over which data should be collected.	General data should represent the current situation of the date of study (2024), or as close as possible. All data should be less than 10 years old.
Geographical coverage	Area from which data for unit processes should be collected.	Material production and refining should be representative of region where the material/component is produced, when known.
Technology coverage	Type of technology (specific or average mix).	Data should be representative of the technology used in production processes.
Representativeness	Degree to which the data set reflects the true population of interest.	Primary data that is representative of the process should be used for processes under SEKABs financial control. Secondary data may be used for upstream and downstream processes but fulfilling the requirements above on time-related, geographical and technology coverage.
Precision	Measure of the variability of the data values.	Data that is as representative as possible will be used. Data will be derived from credible sources, and references will be provided.
Completeness	Assessment of whether all relevant input and output data are included for each data set.	Generic data will be derived from credible sources, such as recognised LCI databases. Internal data should cover all relevant inputs and outputs. The data collected from battery module supplier should be verified in close collaboration with the supplier.
Reproducibility	Assessment of the method and data, and whether an independent practitioner will be able to reproduce the results.	Information about the method and data (reference source) should be provided.
Sources of the data	Assessment of the data sources used.	Data will be derived from credible sources, and references will be provided.
Uncertainty of the information	e.g. data, models, assumptions.	Data will be derived from credible sources, and references will be provided.

Considering the data quality requirements, the data used in this study fulfil the requirements except for the data related to production of ethanol.

The data quality assessment matrix for this study can be found in Appendix 1.

2.7. Time boundary for data

The primary data for a Partial carbon footprint calculations should be recent, preferably within five years, to reflect current practices and technology. The calculation usually applies to the most recent full year, ensuring it captures typical emissions. In irregular production, averaging data over three years is advised for stability. Secondary data, like activity data and Life Cycle Inventories (LCIs), should be no older than ten years to maintain accuracy.

2.8. Cut-off criteria and cut-offs

The carbon footprint study encompasses all significant flows associated with a typical product, and detailed information is given in the inventory analysis.

2.9. Allocation procedures

Electricity, steam (own production) and process water are not possible to measure for each product thereby it is calculated from the total production. Allocation of electricity, steam (own production) and process water are distributed between products on a mass basis since there are no major differences between the production of the products. The proportion of Bio EtAc produced out of the total production is multiplied by the total consumed electricity and process water to allocate the correct amounts to produce Bio EtAc. For the steam (own production) the allocation is made based on the total emission from the steam production instead of the amount of steam used. The consumption of acetic acid and ethanol for production is continuously monitored, and annual consumption rates are calculated, which are used in the calculations of GHG emissions. Steam is produced by incinerating by-products. No enivoronmental impacts are allocated to by-products and they are considered burden free. The biogenic carbon content follows the physical flows.

2.10. Impact assessment methodology

This research evaluates the overall global warming potential using the GWP100 method from AR6 IPCC 2021. Fossil carbon, biogenic carbon and land use impacts are reported separately. Aircraft emissions are excluded since such emissions are not involved in the production of Bio EtAc.

2.11. Value choices, assumptions, and limitations

This study is not suitable for making general claims about the environmental friendliness of the products. The results from the Life Cycle Impact Assessment (LCIA) are relative and do not predict specific impacts or risks. The accuracy of these findings depends on the quality of the data provided by Sekab and the datasets used. The amount of catalyst [redacted] to produce Bio EtAc is less than 0,01% for that reason is considered negligible. Regarding transportation of ethanol raw material, greenhouse gas emissions value has been set as a standard value of 2,2 g CO_2 eq/MJ stated in ISCC data.

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Other areas that the study does not include due to negligible connections to the product:

- Non-manufacturing operations such as business travels, R&D activities or other indirect emissions.
- Manufacturing infrastructure e.g., the production and maintenance of buildings, inventories or other equipment used in Sekab's process plant.

2.12. Critical review

Compliance with ISO 14067 see Appendix 5.

3. Life cycle inventory

3.1. Data collection procedures

The modeling was done in LCA for Expert version 10.7 and inventory data is gathered from Sekab and based on inputs and outputs for the whole year 2022. Inputs and outputs to Sekab and data for raw material are specific while data for background processes are generic. Generic data comes from Ecoinvent 3.9.1 and ISCC 205.

The company supplies detailed information regarding the total inputs of raw materials and components, as well as the outputs of products. Volume of Bio HAc, ethanol and [redacted] are delivered by flowmeters that are regulatory calibrated and checked, they are measured for the specific Bio EtAc production. Volume of steam, process water are delivered by flowmeters that are regulatory checked and then allocated based on the total production.

The total input and output of the process is shown in Table 3. The by-product is transported through pipelines to incineration, to be used for producing steam internally at the production site. Produced Bio EtAc is delivered to customer.

Table 3. Input and output for 1 ton of Bio EtAc.

Input		**Output**	
Raw material	**Amount [kg]**	**Raw material**	**Amount [kg]**
Bio Acetic acid, HAc	[redacted] *	Bio EtAc	1000
Ethanol, based on maize	[redacted] *	By-product	[redacted] *

**proprietary information removed*

When it comes to generic data, the company has chosen reliable sources for data from Ecoinvent and ISCC certification. Whenever possible, SEKAB has selected datasets from specific countries that are adherent with the study. In cases where data for materials or processes in those countries is unavailable, the company has selected relevant datasets from comparable nations or more regional datasets, such as "Rest-of-Europe" or "Global".

3.2. Upstream

Ingoing materials for production of 1 ton of Bio EtAc at Sekab during 2022 are given in Table 4 and Figure 5. Amounts of the different materials are confidential and given in the excel inventory sheet.

Table 4. Ingoing raw materials for production for 1 ton of Bio EtAc .

Raw materials	Amount	Unit	Location	Name of data set	Data source
Bio Acetic acid, HAc	* [redacted]	[kg/t EtAc]	SE	N/A	Site specific data
Ethanol, based on maize	* [redacted]	[kg/t EtAc]	US	US ethanol production from maize	ISCC 205

**proprietary information removed*

[redacted]

Figure 5. Raw materials for production of 1 ton of Bio EtAc.

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[redacted] *
[redacted] * serves as a catalyst in Bio EtAc production. It accelerates the esterification reaction between ethanol and acetic acid. To allocate this raw material, the amount of [redacted]* consumed is divided by the amount of Bio EtAc produced. The amount used as catalyst is less than 0,01% of the total output that is why is considered negligible. This raw material is sourced from an external supplier.

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Manganese Acetate

Manganese Acetate is used as catalyst in Bio Acetic acid production. It accelerates the esterification reaction. As catalyst is less than 0,01% of the total output that is why is considered negligible. This raw material is sourced from an external supplier.

Bio Acetic acid, HAc

Acetic acid serves as one of the primary raw materials in the production of Bio EtAc. The amount used during the manufacturing process is provided by the monthly report of Sekab. Table 5 describes the ingoing raw materials for production of 1 ton of Bio Acetic acid.

Table 5. Ingoing raw materials for production for 1 ton of Bio Acetic acid.

Input		**Output**	
Raw material	**Amount [kg]**	**Raw material**	**Amount [kg]**
Acetaldehyde	[redacted] *	Bio Acetic acid	1000

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All input materials and components for producing 1 ton of acetic acid can be found in Table 6. The inventory analysis related to Bio Acetic acid is following the procedure described in ISO 14067.

Bio Acetic acid is produced at Sekab's production plant and Bio acetaldehyde is the main raw material for producing Bio acetic acid. Production of 1 ton of acetaldehyde requires more than 1 ton of ethanol based on maize.

Table 6. Ingoing raw materials and components for producing 1 ton of Bio acetic acid.

Input/Output	Amount	Unit	Location	Name of data set	Data source
Electricity	69	[kWh/t acetic acid]	SE	SE market for electricity, medium voltage agg	Ecoinvent 3.9.1
Acetaldehyde	* [redacted]	[kg/ton acetic acid]	SE	N/A	Site specific data
Steam (purchased)	* [redacted]	[kWh/t acetic acid]	SE	N/A	Örnsköldsvik Energi
Steam (own production)	* [redacted]	[kWh/t acetic acid]	SE	N/A	Site specific data
Process water	118198	[kg/t acetic acid]	SE	RER market group for tap water	Ecoinvent 3.9.1

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Acetaldehyde

Acetaldehyde serves as one of the primary raw materials in the production of Bio Acetic acid. The amount used during the manufacturing process is provided by the monthly report of Sekab.

Table 7. Ingoing raw materials for production for 1 ton of Acetaldehyde.

Input		Output	
Raw material	**Amount [kg]**	**Raw material**	**Amount [kg]**
Ethanol	[redacted] *	Acetaldehyde	1000
		By-product	[redacted] *

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Table 8 describes the ingoing raw materials for production of 1 ton of Bio Acetaldehyde.

Table 8. Ingoing raw materials and components for producing 1 ton of Acetaldehyde

Input/Output	Amount	Unit	Location	Name of data set	Data source
Electricity	69	[kWh/t acetaldehyde]	SE	SE market for electricity, medium voltage agg	Ecoinvent 3.9.1
Steam (purchased)	* [redacted]	[kWh/t acetaldehyde]	SE	N/A	Örnsköldsvik Energi
Steam (own prouction)	[redacted] *	[kWh/t acetaldehyde]	SE	N/A	Site specific data
Process water	118198	[kg/t acetaldehyde]	SE	RER market group for tap water	Ecoinvent 3.9.1
Ethanol, based on maize	* [redacted]	[kg/t acetaldehyde]	US	US ethanol production from maize	ISCC, sustainability declaration

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Ethanol

One of the most crucial raw materials in Bio EtAc production is ethanol, which can be derived from either maize or sugar cane. However, for this report, only maize-based ethanol from US is included. For ethanol data set from ISCC 205 has been used. This dataset represents the production bio-based ethanol from maize with a calorific value of 31.58 MJ/kg.

Transport of raw materials
Raw materials are transported from suppliers to the production site via pipelines originating from United States and then ship, then raw material is via pipline transported to production site. Data regarding this mode of transportation is obtained from the ISCC 205 database with an emission factor of 2,2 gCO_2/MJ. See certificate in Appendix 4.

3.3. Core

Core processes are related to manufacturing of the product Bio EtAc at Sekab's site, enumerates the materials and consumables required for its manufacturing listed in Table 9 and Figure 6.
Included activities are:

- Electricity
- Steam
- Process water
- Electricity

Table 9. Inputs and outputs for core process per ton of Bio EtAc.

Input/Output	Amount	Unit	Location	Name of data set	Data source
Electricity	69	[kWh/t EtAc]	SE	SE market for electricity, medium voltage agg	Ecoinvent 3.9.1
Steam (purchased)	[redacted] *	[kWh/t EtAc]	SE	N/A	Örnsköldsvik Energi
Steam (own production)	[redacted] *	[kWh/t EtAc]	SE	N/A	Site specific data
Process water	118198	[kg/t EtAc]	SE	RER market group for tap water	Ecoinvent 3.9.1

**proprietary information removed*

[redacted]

Figure 6. Energy usage during the manufacturing of 1 ton of Bio EtAc.
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Electricity
Sekab uses electricity in several production processes. For this study, the total electricity use at Sekab has been allocated between the products on a mass basis. For calculations, Swedish market electricity mix has been used with an emission factor of 0,037kg CO_2/kWh.

Steam
There are two sources of steam to produce Bio EtAc: some is generated internally, while the remainder is purchased to fulfil the total steam requirement for production. The amount of purchased steam used in the production is measured specifically for each product. The purchased steam is delivered by Örnsköldsvik Energi with an emission factor of 0,08731 kgCO_2/kWh fossil. See certificate in Appendix 3.
Internally generated steam is not measured and therefore is allocated between products based on the total emissions generated by own steam production and the total production volumes. The internally produced steam is produced on site by combustion of by-products from the process. The biogenic emissions for incinerating by-products are measured by SEKAB. Allocated based on mass (total production) the biogenic carbon emissions result in 103,5 kgCO_2/ton of any product.

Process water
Process water is use as coolant in the process. Process water does not need any wastewater treatment. The proportion of the total process water has been allocated between Sekab's products on a mass basis. The emissions is based on data from ISCC database.

3.4. Biogenic carbon content

The Bio EtAc is using biomass as a raw material, in this case maize. The alternative for this product is fossil based raw material which contributes to increased atmospheric carbon. Biomass has a biogenic carbon content which is defined as carbon sourced from biomass. According ISO 14067, the biogenic carbon content shall be declared, see Appendix 2. To avoid double counting, particularly in products lacking attributed biogenic carbon content, appropriate measures must be in place. The results for biogenic carbon content in ethanol is presented in Appendix 2. This study does not include use phase or end-of-life since those events takes place outside Sekabs gates and the scenarios depends on actual use of the product. In the end-of-life the product will evaporate, i.e the uptake becomes an emission to air.

4. Partial carbon footprint impact assessment

This carbon footprint assessment, covering from cradle to gate, focuses on greenhouse gas (GHG) emissions originating from fossil sources, and biogenic originMost GHG emissions come primarily from the cultivation, growing and processing maize into ethanol. These emissions typically include uptake of CO_2 during plant growth and other agricultural activities like fertilizing and managing of soil. The largest contributor of GHG emissions originates in the production of ethanol and not in the production of Bio EtAc.

4.1.Results

The results of the partial carbon footprint in kg CO_2 eq. per ton of Bio EtAc is presented in Table 10 and Figure 7.

Table 10. Results of partial carbon footprint for production of 1 ton Bio EtAc, including upstream and core processes kg CO_2 eq. Incorrect summation is due to rounding.

	ISO14067 GWP100, Biogenic GHG emissions [kg CO_2 eq.]	ISO14067 GWP100, Biogenic GHG removal [kg CO_2 eq.]	ISO14067 GWP100, Emissions from land use change (dLUC) [kg CO_2 eq.]	ISO14067 GWP100, Fossil GHG emissions [kg CO_2 eq.]	Total kg CO_2 eq. per ton Bio EtAc without calculation of CO_2 uptake from the biomass	Total GWP100, per ton of Bio EtAc
Upstream process						
HAc acetic acid	77,2	-1085,4	0,2	853,2		-154,8
Ethanol (maize)	0	-1035,3	0	664,0		-371,3
Transports type of ingoing materials						
Ship	0	0	0	37,7		37,7
Core processes						
Electricity	3,5	-3,4	0,2	2,2		2,5
Process water	3	-2,2	0,1	36,2		37,1
Steam produced internally	103,5	0	0	0		103,5
Steam (purchased)	0	0	0	97,1		97,1
Total kg CO_2 eq. per ton Bio EtAc	**187,2**	**-2126,3**	**0,5**	**1690,5**	**1878,1**	**-248,2**

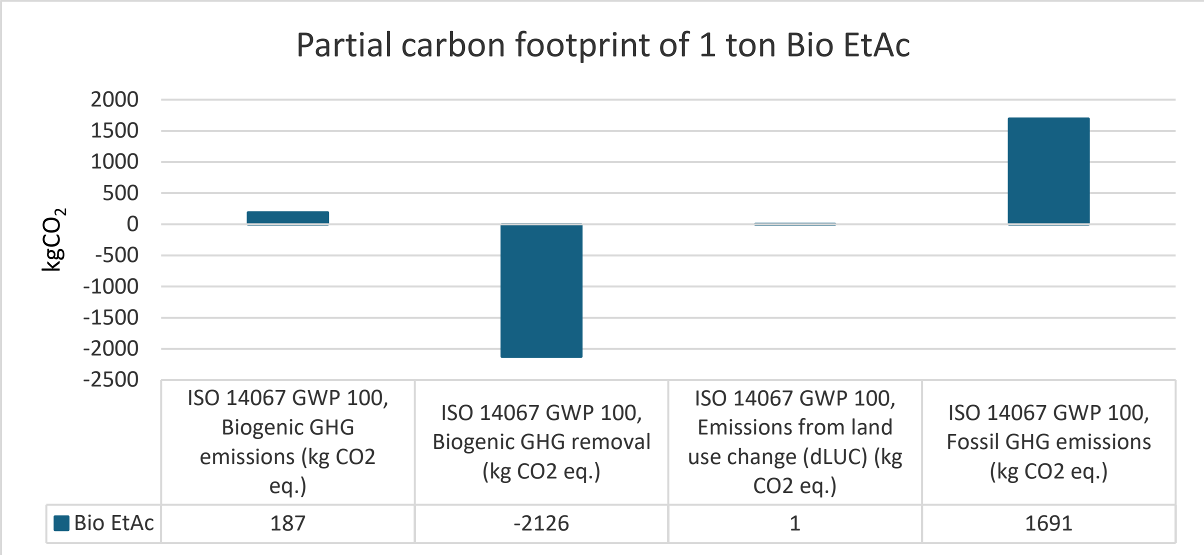
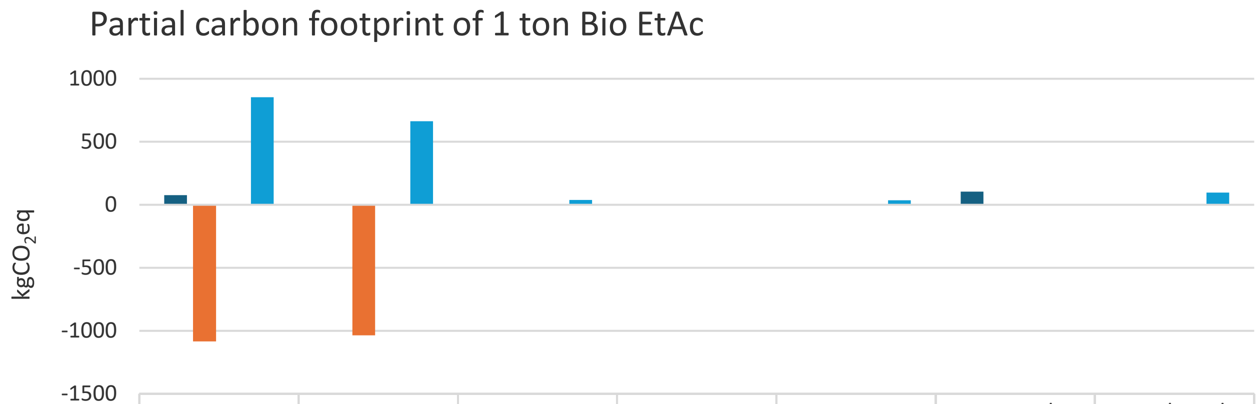


Figure 7. Partial carbon footprint for the production of 1 ton Bio EtAc.

5. Interpretation of partial carbon footprint results

The analysis of climate impact from the production of one ton of Bio EtAc provides a comprehensive overview of the partial carbon footprint associated with various inputs and processes. However, the breakdown of emissions by component, illustrated in Figure 8, are crucial for understanding and improving the climate impact of chemical manufacturing processes.



	Acetic acid	Ethanol	Transport	Electricity	Process water	Internal steam	Purchased steam
	Upstream			Core			
ISO 14067 GWP 100, Biogenic GHG emissions (kg CO2 eq.)	77	0	0	4	3	104	0
ISO 14067 GWP 100, Biogenic GHG removal (kg CO2 eq.)	-1085	-1035	0	-3	-2	0	0
ISO 14067 GWP 100, Emissions from land use change (dLUC) (kg CO2 eq.)	0	0	0	0	0	0	0
ISO 14067 GWP 100, Fossil GHG emissions (kg CO2 eq.)	853	664	38	2	36	0	97

Figure 8. Partial carbon footprint emissions of 1 ton Bio EtAc for upstream and core process.

The breakdown of the results in Figure 8 shows that there is an uptake in production of ethanol which contributes to the negative value for the overall result. Maize, as a bio-based source, absorbs CO_2 from the atmosphere during its growth phase. This absorbed carbon emissions reltated to the ethanol is resulting in a net negative emission. However, in the EoL (which is not included in the analysis) the uptake becomes emission, resulting in a net zero over the product's life cycle. This should be considered in the calculation of the carbon footprints of the products, where Bio EtAc is used.

Purchased steam usage results in moderate fossil emissions of 97 kg CO_2 eq. per ton Bio EtAc. This means that the generation of steam, used for heating processes, has a notable carbon footprint in the core process. The emissions associated with electricity usage is notably low. Transport-related emissions are relatively low, at 38 kg CO_2 equivalents per 1 ton of Bio EtAc due to the fact ethanol is the main raw material and it is transported in an efficient way via ship and pipelines to production site.

Values indicate the partial carbon footprint of the production process and should be evaluated in comparison to industry standards, regulatory requirements, and sustainability objectives of the company. It is essential to consider factors such as operational efficiency, compliance with regulations, and alignment with environmental objectives when interpreting this emissions values in the context of the overall life cycle assessment.

5.1. Sensitivity analysis

A sensitivity analysis can be made to study the effects of certain modelling assumptions, or the effects of certain design and production choices on the product's environmental performance. At Sekab, biobased ethanol is used as the main raw material and fossil emission data for this ethanol is available from ISCC certification. To examine the effects of using the specific data from ISCC compared to regular data from EcoinventSCC, a sensitivity analysis was made. The sensitivity analysis will only consider fossil GHG emissions since ISCC certification only involve fossil GHG emissions. See the results of the sensitivity analysis in Figure 9.

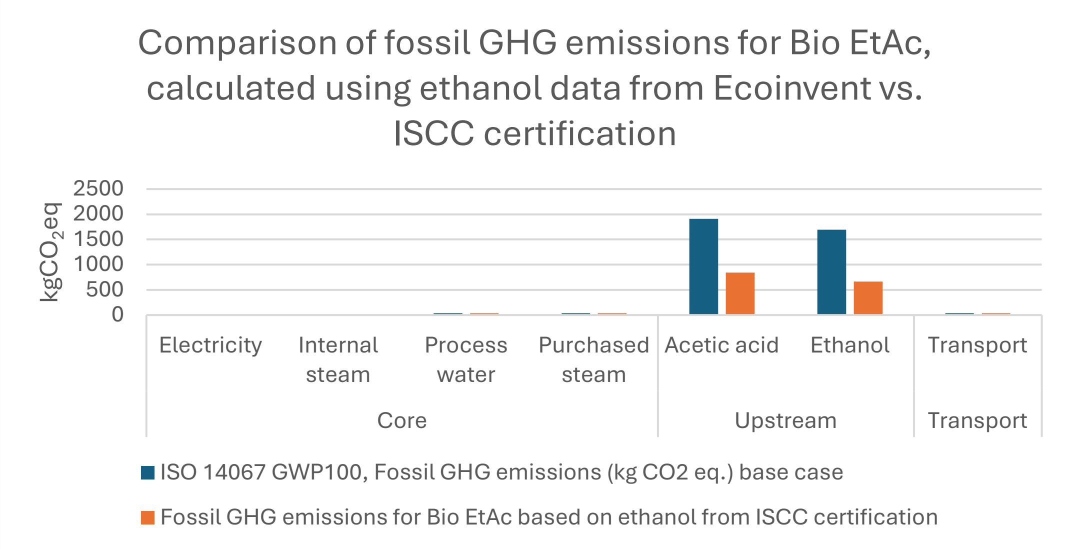


Figure 9. Comparison of fossil GHG emissions for Bio EtAc, calculated using ethanol data from EcoInvent vs. ISCC certification.

The fossil GHG emissions associated with electricity, steam, process water and transport are unchanged when using the ISCC certification, but the fossil GHG emissions from ethanol and acetic acid are 61% and 55% lower for this dataset. The total fossil GHG emissions, that also can be refered to as product carbon footprint according PCF guideline, (1691 kg CO_2 per ton Bio EtAc) are 55% lower.

6. Conclusions, limitations and recommendations

This study is a partial carbon footprint study according to ISO 14067 standard, and that means that not all phases of the life cycle of Bio EtAc are inlcued. So, valuable insights into the partial carbon footprint of the product might be left out. Therefore, conducting a comprehensive full carbon footprint assessment could provide a deeper understanding of the product's overall carbon footprint and inform strategies for mitigating its impact throughout its entire life cycle. This study describes mainly the carbon footprint at gate for Bio EtAc, where the biogenic uptake during growth of biomass is taken into account. However, it is important to understand that the uptake might become an emission in the end of life (depending on the application). The analysis of greenhouse gas (GHG) emissions from the production of 1 ton of Bio EtAc offers important insights into the partial carbon footprint of its manufacturing processes.
Contributions from water, electricity, steam, and transportation also influence the total emissions, but in minor degrees. Due to renewable sources of energy production, the emissions associated with this electricity is comparably small.

Regarding data quality in this study the data quality assessment points all data inlcuded involve high scores. Steam consumption and use of process water and electricity receive overall good score since this data is collected or measured in Sekab's own production.

Two datasets for ethanol were considered – Ecoinvent and ISCC. The results of sensitivity analysis show that the emissions from ethanol from Ecoinvent dataset are higher than those from ethanol from ISCC. ISCC data is concidered more relevant and accurate for this study since it is more up to date and more specific for the ethanol used in this study.

Appendix 1 – Data quality assessment

In Table 12 the data quality assessments are listed. Each datapoint has received a score from 1 (best) to 5 (worst) according to five different correlation aspects. Table 11 lists the data quality indicators used to assess the data used in this study. The quality assessment is based on description in ISO 14067.

Table 11. Data quality requirement.

Aspect	1	2	3	4	5
Temporal correlation (time related coverage)	Less than three years of difference to year of study	Less than six years of difference	Less than 10 years of difference	Less than 15 years of difference	Age of data unknown or more than 15 years of difference
Geographical correlation	Data from area of process origin	Average data from larger area in which area of process origin is included	Data from area with similar production conditions	Data from specified area used for process in unknown area	Data from area with very different production conditions
Technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study but from different enterprise or group of enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technology (e.g. using data for ceramic glass to represent production of MICA)	Data on related processes or materials but different or unknown technology
Representative	Representative data from sufficient sample over an adequate period to even out normal fluctuations (this includes future projection if necessary)	Representative data from a small sample but for adequate periods	Representative data from sufficient sample but from shorter periods	Representative data but from a small sample and shorter periods or incomplete data from sufficient sample and periods	Representativeness unknown or incomplete data from a small sample and/or shorter periods
Precision	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate

Table 12. Quality assessment of data used for materials and processes in the study.

Material/process	Location	Dataset name	Year	Source	Temporal correlation	Geographical correlation	Technological correlation	Representative	Precision
Electricity	SE	SE market for electricity, medium voltage agg	2020	Ecoinvent 3.9.1	2	1	1	1	1
Steam	SE	Site-specific	2023	N/A	1	1	1	1	1
Process Water	SE	Site-specific	2023	ISCC 205	1	1	1	1	1
HAc acetic acid	SE	Site-specific	2023	N/A	1	1	1	1	1
Ethanol	US	Ethanol production from maize	2023	ISCC 205	1	1	1	1	1
Ethanol		Ethanol production from maize	2003	Ecoinvent 3.9.1					
Ethanol	US	Ethanol production from maize	2023	ISCC 205	1	1	1	1	1
Transport-ship	US	N/A	2024	ISCC 205	1	1	1	1	1

Appendix 2 – Biogenic carbon

Biogenic carbon content.
The amount of biogenic carbon in ethanol may differ based on factors like the type of feedstock and how it's produced. However, it's often assumed that ethanol made from renewable biomass sources contains solely biogenic carbon.

Table 13. Biogenic carbon content.

BCC Ethanol (maize)	0,52	(kg BCC/kg ethanol)
BCC Bio EtAc	0,55	(kg BCC/kg Bio EtAc)

Appendix 3 – Certificates process steam

Certificate for steam purchased steam.

[redacted]

**proprietary information removed*

Appendix 4 – Certificate ethanol

Certifacte for ethanol production.

[redacted]

**proprietary information removed*

[redacted]

**proprietary information removed*

Appendix 5 – Critical review statement

I hereby confirm that, following detailed examination as independent 3rd party reviewer, in accordance with the limits of the scope of our appointment, nothing has come to my attention to suggest any unjustified deviations by the Carbon footprint study, issued for Bio Ethyl acetate, based on maize, by Sekab Biofuels & Chemicals AB, and by its project report from the requirements outlined in ISO 14067.

In accordance with the limits of the scope of our appointment, the company specific data and upstream and downstream data have been examined as regards plausibility and consistency; the declaration owner is responsible for its factual integrity.

I confirm that I have been independent in my role as verifier, i.e. I have not been involved in the execution of the study and have no conflicts of interest regarding this verification.

The full verification report is provided to Sekab Biofuels & Chemicals AB in a separate document.

Name and signature of external verifier:

Place and date:

Stockholm, 2025-03-19