

Carbon footprint report

BIO ACETALDEHYDE

Sekab

Report name: Carbon footprint Report Bio Acetaldehyde Public version
Company name: Sekab Biofuels & Chemicals AB
Company ID: Bio Acetaldehyde
Product trade name: Bio Acetaldehyde
CAS: 75-07-0
Commissioner of the study: Sekab Biofuels & Chemicals AB
Product classification: Platform chemical
Production country: Sweden
Main market: Europe
Name and affiliation of practitioners: Anna C. Olsson, Sekab Biofuels and Chemicals AB
Name and affiliation of verifiers: Yevgeniya Arushanyan, Ramboll Sweden AB
Date: 2025-03-19

Disclaimer

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

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List of used acronyms and abbreviations

Bio HAc: Bio Acetic acid

Bio EtAc: Bio Ethyl Acetate

GHG: Greenhouse Gas

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 footprint in accordance with ISO14067 and Product carbon footprint guidelines (PCF)¹ associated with the production of the product Bio Acetaldehyde based on sugar cane. Bio Acetaldehyde is a colorless liquid. It is an organic compound and has a wide range of applications.

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 Sekab’s 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 Acetaldehyde is -981 kg CO₂eq, 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 Acetaldehyde is 1089 kg CO₂eq per ton of Bio Acetaldehyde.

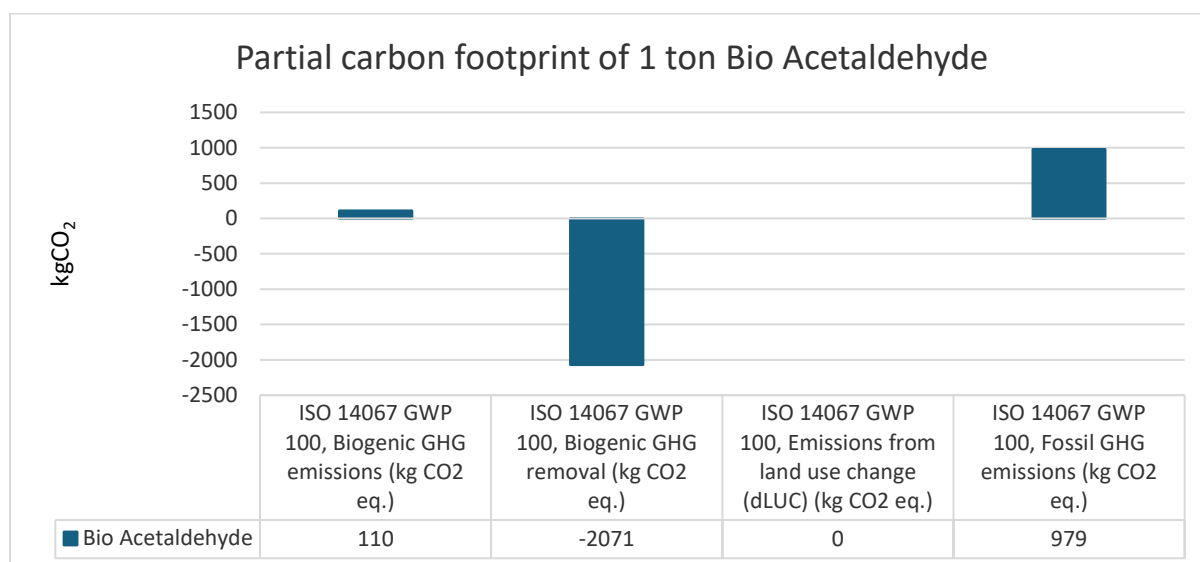


Figure 1. Partial carbon footprint emissions of 1 ton Bio Acetaldehyde.

A break down of the results for upstream, which includes transport input of raw material, core, which includes all input and outputs related to processing at the production site, are shown in Figure 2, and reveals that the upstream process has the largest impact, and it is ethanol that has the largest contribution. Core process is relatively small in comparison to upstream process.

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

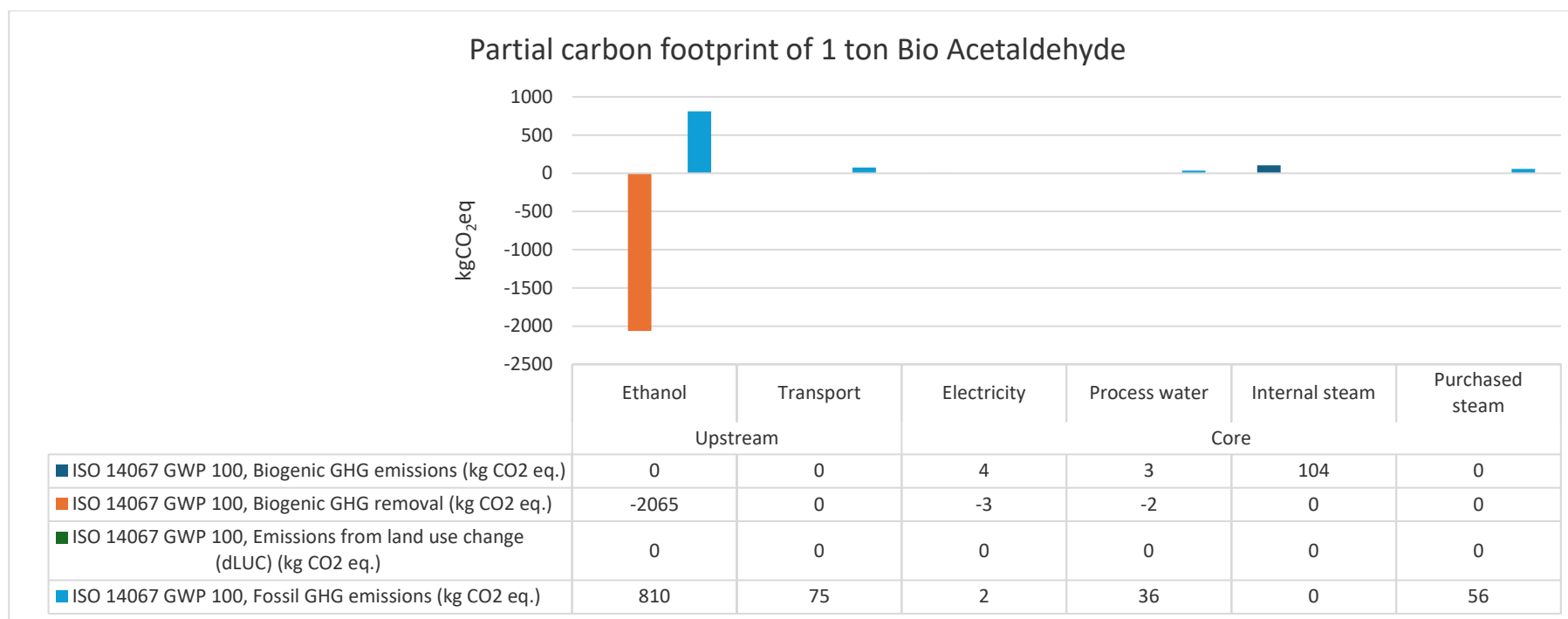


Figure 2. Partial carbon footprint emissions of 1 ton Bio Acetaldehyde for upstream and core process.

Key findings

- Upstream process has the largest contribution to the carbon footprint at gate and ethanol is 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 Acetaldehyde, a commonly employed chemical 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 Acetaldehyde. The investigation is conducted to better understand the carbon footprint associated with Bio Acetaldehyde.

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 Acetaldehyde that follow principles and calculations stated in ISO 14067 and adhering to PCF guidelines² 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 Change³.

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 Acetaldehyde.

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

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 Acetaldehyde is a chemical used in many contexts, including paint binders, plasticisers and superabsorbents in baby diapers. It is also used in synthetic lubricants, explosives and in the manufacturing of various types of building materials. In the pharmaceutical industry acetaldehyde is used, among other things, in manufacture of vitamins, sleeping aids and sedatives. In food industry it is used in the manufacture of preservatives and flavourings. Acetaldehyde is often used in production of acetic acid. See information about the product in Table 1.

Ethanol used in the production of Bio Acetaldehyde 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 Acetaldehyde	75-07-0	Bio Acetaldehyde is a colourless liquid and has a wide range of applications, it is a platform chemical. It is an organic compound, oxidized by EtOH.

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 Acetaldehyde is produced by oxidation of Bio Ethanol in the presence of a catalyst, nitrogen gas and [REDACTED]. Due to the low boiling point nitrogen gas is added to keep acetaldehyde in liquid phase. [REDACTED] acts as an inhibitor. The reaction is exothermic and the reactor must be cooled. In several washing steps the Bio Acetaldehyde is

purified from unreacted Bio Ethanol but also from Bio Acetic acid, water and residual gases such as carbon dioxide, carbon monoxide, nitrogen, hydrogen. Residual gases are incinerated in a steam boiler. An overview of the process is seen in Figure 3. Bio Acetaldehyde is certified by the International Sustainability & Carbon Certification (ISCC), ensuring that it helps Sekab's clients meet their sustainability goals without sacrificing quality.

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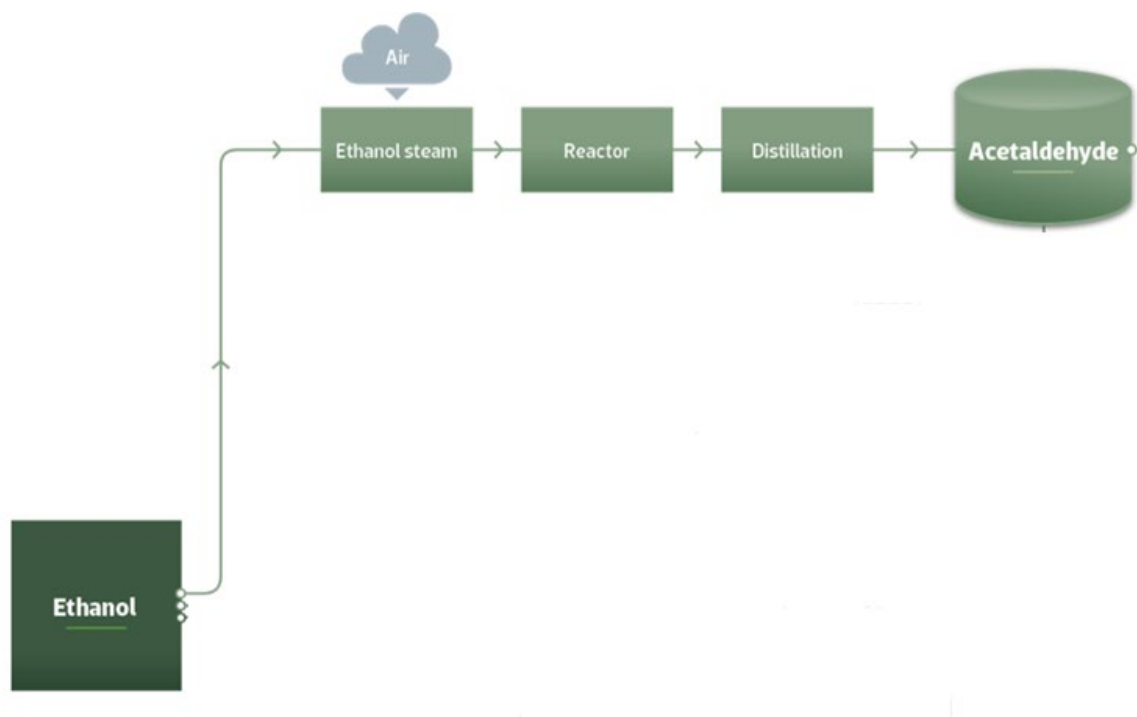


Figure 3. Flowchart of Sekab production of Bio Acetaldehyde.

2.4. Declared unit and reference flow

The declared unit in this study is 1 ton of Bio Acetaldehyde 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

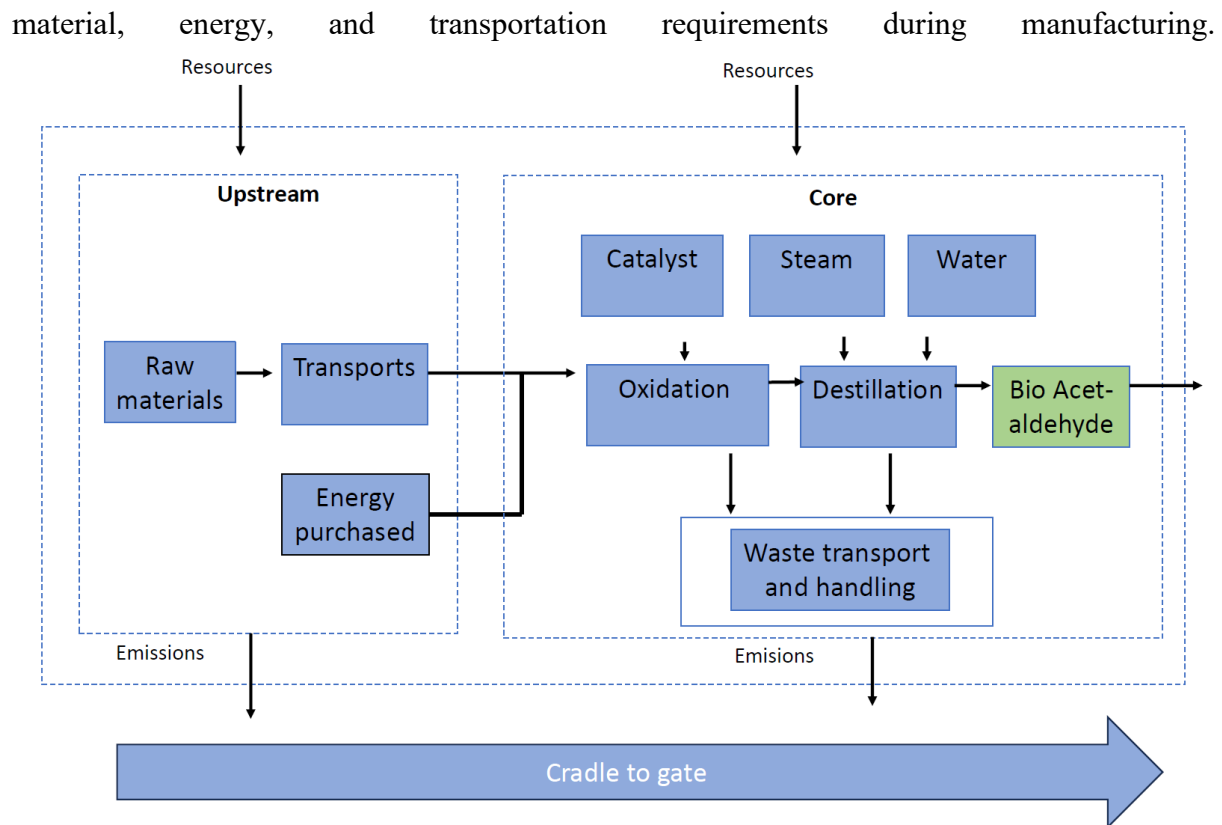


Figure 4 illustrates the system boundaries of the upstream processes involving activities prior to manufacturing, like extraction and refining of raw material. Core processes directly relate to product production processes, involving energy, electricity, chemicals, and consumables in manufacturing, as 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.

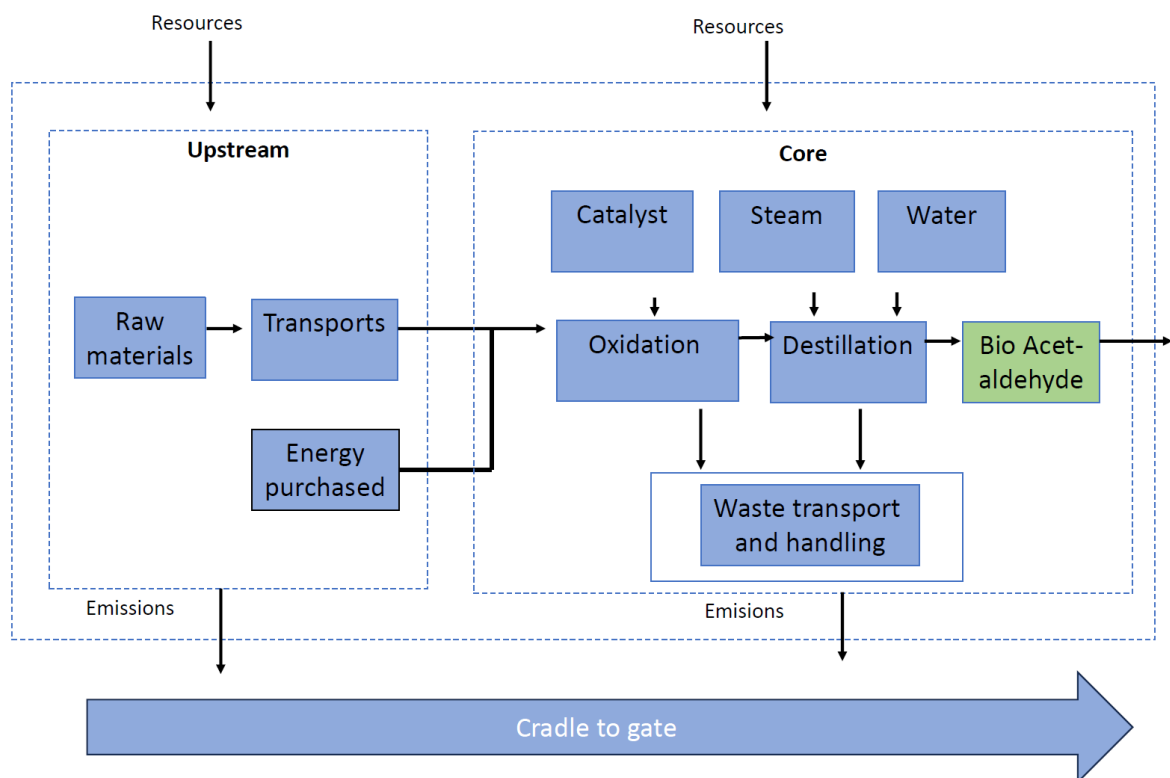


Figure 4. System boundaries for the manufacturing of Bio Acetaldehyde.

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 Acetaldehyde 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 Sekab's 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 Acetaldehyde produced out of the total production is multiplied by the total consumed electricity and process water to allocate the correct amounts to produce Bio Acetaldehyde. For the steam (own production) the allocation is made based on the total emissions from the steam production instead of the amount of steam used. Steam is produced by incinerating by-products. No environmental 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 Acetaldehyde.

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 nitrogen gas and

used in the process of Bio Acetaldehyde are less than 0,01% and therefore considered negligible. Regarding transportation of ethanol raw material, greenhouse gas emissions value has been set as a standard value of 2,2 g CO₂ eq/MJ stated in ISCC database.

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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 2023. 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 Ethanol is delivered by flowmeter which is regulatory calibrated and checked, it is measured for the specific Bio Acetaldehyde 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 Acetaldehyde is delivered to customer.

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

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

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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 material for production of 1 ton of Bio Acetaldehyde at Sekab during 2022 is given in Table 4.

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

Raw materials	Amount	Unit	Location	Name of data set	Data source
Bio Ethanol	██████████*	[kg/t Acetaldehyde]	Brazil	N/A	Site specific data

*proprietary information removed

Bio-Ethanol

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

Nitrogen gas

The boiling point for acetaldehyde is approximately 21⁰C, therefore distillation takes place under nitrogen gas overpressure. To allocate this raw material, the amount of nitrogen gas consumed is divided by the amount of Bio Acetaldehyde produced. The amount used is less than 0,01% of the total output, that is why it is considered negligible and therefore cut-off from the analysis. This raw material is sourced from an external supplier.

██████████

To avoid formation of unwanted compounds ██████████ is added to the process. The amount of total consumed ██████████ is divided by the amount of produced Bio Acetaldehyde and since it is less then 0,01% of total output it is considered negligible and therefore cut-off from the analysis.

*proprietary information removed

Transport of raw materials

Raw materials are transported from suppliers to the production site via pipelines originating from Brazil and then ship, then raw material is via pipeline transported to production site. Data regarding this mode of transportation is obtained from the ISCC 205 database with an emission factor of 2,2 g CO₂eq/MJ. In the certificate, Appendix 4, the value for transport is 0,4 which presents transport to the suppliers gate. For the transport from supplier to Sekab data base value

2,2 g CO₂eq/MJ is used, which also includes all transportations and therefore replaces 0,4 g CO₂ eq/MJ.

3.3. Core

Core processes are related to manufacturing of the product Bio Acetaldehyde at Sekab's site, enumerate the material and consumables required for its manufacturing listed in Table 5 and Figure 5.

Included activities are:

- Electricity
- Steam (purchased)
- Steam (own production)
- Process water

Table 5. Inputs and outputs for core process per ton of Bio 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)	██████*	[kWh/t Acetaldehyde]	SE	N/A	Örnsköldsvik Energi
Steam (own production)	██████*	[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 sugar cane	██████*	(kg/t acetaldehyde)	Brazil	Brazilian ethanol production from sugar cane	ISCC, sustainability declaration

*proprietary information removed

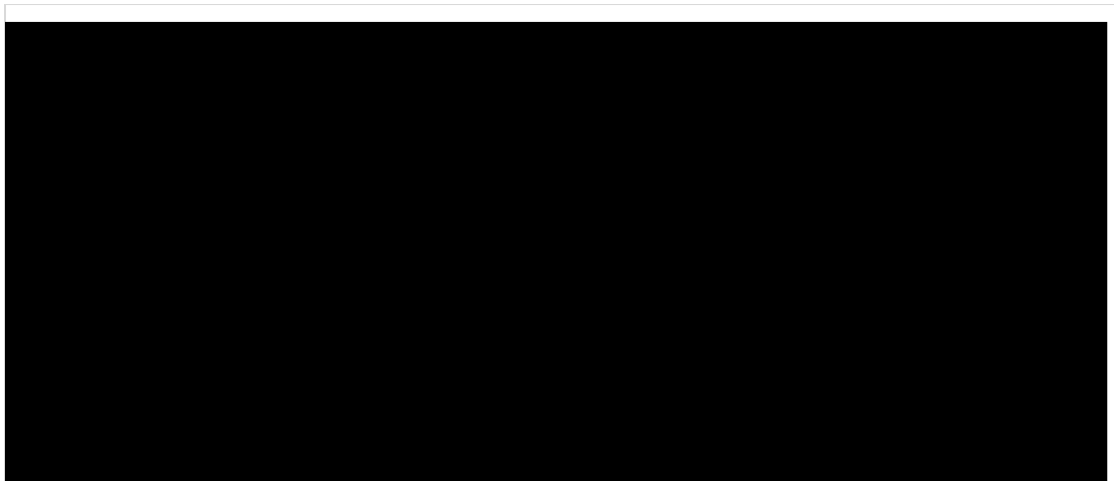


Figure 5. Energy usage during the manufacturing of 1 ton of Bio Acetaldehyde.

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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 CO₂/kWh.

Steam

There are two sources of steam to produce Bio Acetaldehyde: 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 Örnköldsvik Energi with an emission factor of 0,08731 kg CO₂eq/kWh. 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 kgCO₂/ton of any product.

Process water

Process water is used 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 205.

3.4. Biogenic carbon content

The Bio Acetaldehyde is using biomass as a raw material, in this case sugar cane. 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 Sekab's 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 origin. Most GHG emissions come primarily from the cultivation, growing and processing sugar cane into ethanol. These emissions typically include uptake of CO₂ 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 Acetaldehyde.

4.1. Results

The results of the partial carbon footprint in kg CO₂ eq. per ton of Bio Acetaldehyde is presented in Table 6 and Figure 6.

Table 6. Results of partial carbon footprint for production of 1 ton Bio Acetaldehyde, including upstream and core processes kg CO₂ eq. Incorrect summation is due to rounding.

	ISO14067 GWP100 , Biogenic GHG emission s [kg CO ₂ eq.]	ISO14067 GWP100 , Biogenic GHG removal [kg CO ₂ eq.]	ISO14067 GWP100 , Emission s from land use change (dLUC) [kg CO ₂ eq.]	ISO14067 GWP100 , Fossil GHG emission s [kg CO ₂ eq.]	Total kg CO ₂ eq. per ton Bio Acetaldehyd e without calculation of CO ₂ uptake from the biomass	Total GWP100, per ton of Bio Acetaldehyd e
Upstream process						
Ethanol (sugar cane)	0	-2064,9	0	809,9		-1255
Transports type of ingoing materials						
Ship	0	0	0	75,2		75,2
Core processes						
Electricity	3,5	-3,4	0,2	2,2		2,5
Process water	3,0	-2,2	0,1	36,2		37,1
Steam produced internally	103,5	0	0	0		103,5
Steam (purchased)	0	0	0	55,6		55,6
Total kg CO₂ eq. per ton Bio Acetaldehyd e	110	-2070,5	0,3	979,2	1089,5	-981

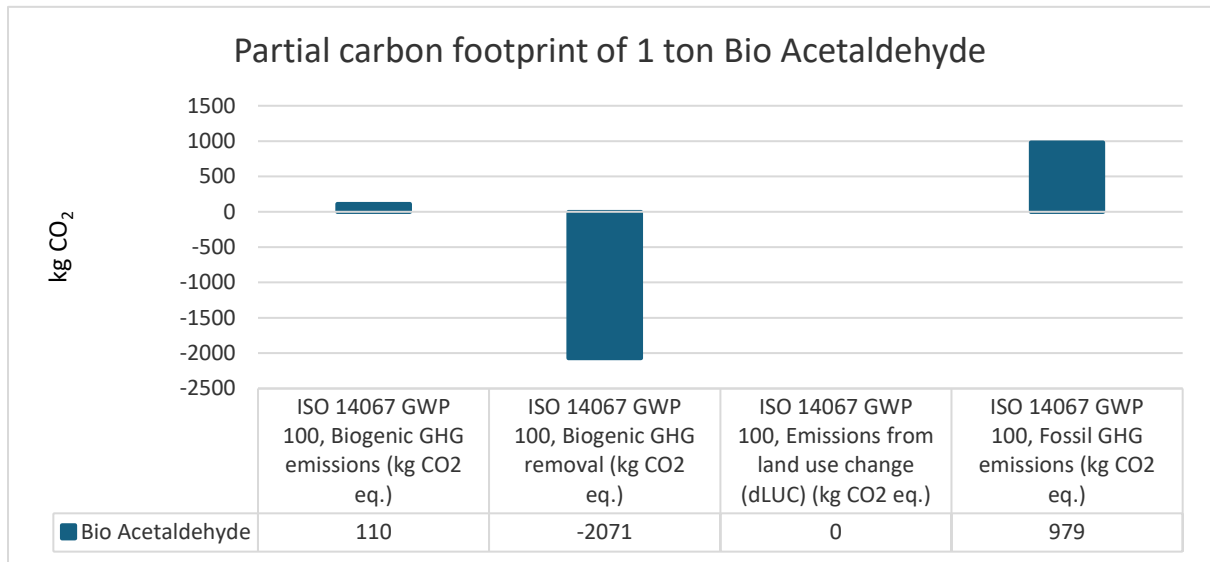


Figure 6. Partial carbon footprint for the production of 1 ton Bio Acetaldehyde.

5. Interpretation of partial carbon footprint results

The analysis of climate impact from the production of one ton of Bio Acetaldehyde 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 7, are crucial for understanding and improving the climate impact of chemical manufacturing processes.

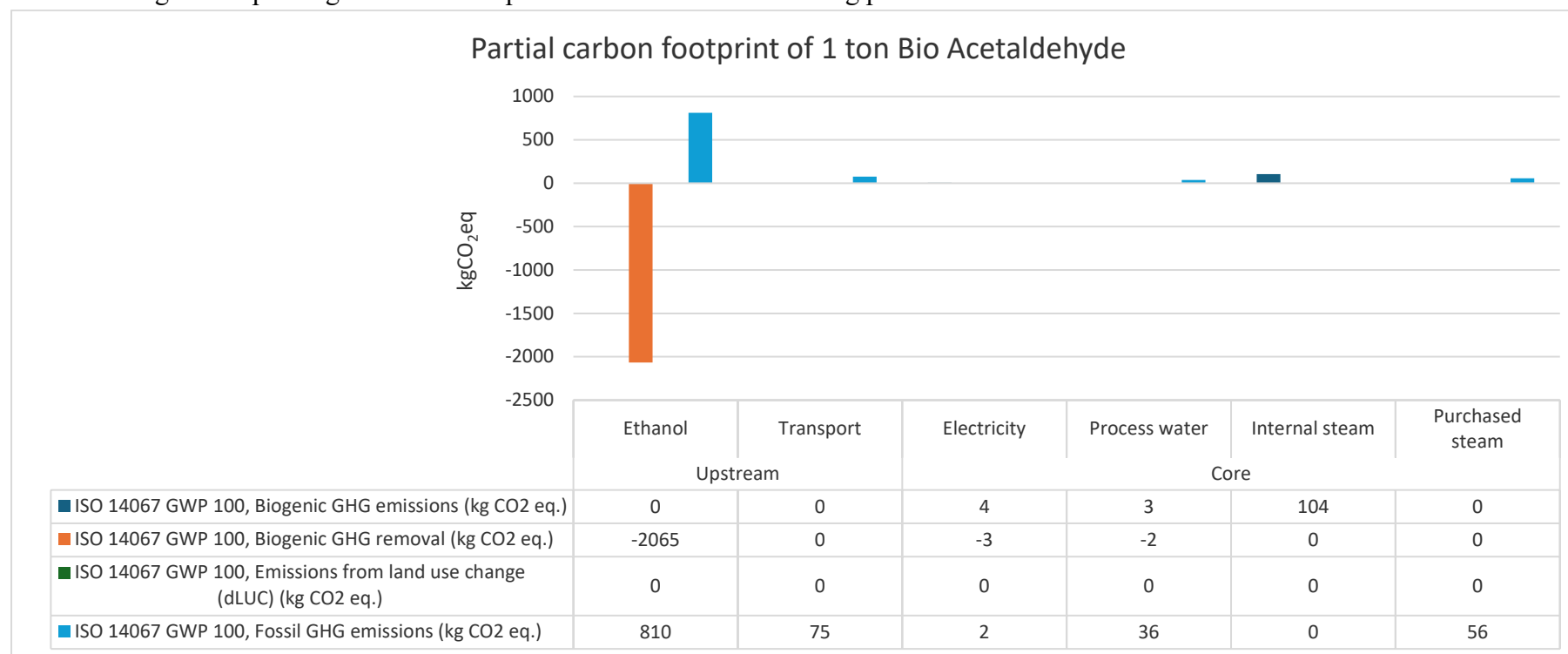


Figure 7. Partial carbon footprint emissions of 1 ton Bio Acetaldehyde for upstream and core process.

The breakdown of the results in Figure 7 shows that there is an uptake in production of ethanol which contributes to the negative value for the overall result. Sugar cane, as a bio-based source, absorbs CO₂ from the atmosphere during its growth phase. This absorbed carbon emissions related 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 Acetaldehyde is used.

Purchased steam usage results in fossil emissions of 56 kg CO₂ eq. per ton Bio Acetaldehyde. This means that the generation of steam, used for heating processes, has the largest contribution to the core process. The emissions associated with electricity usage is notably low. Transport-related emissions are relatively low, at 75 kg CO₂ equivalents per 1 ton of Bio Acetaldehyde 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 ethanol data from Ecoinvent, 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 8.

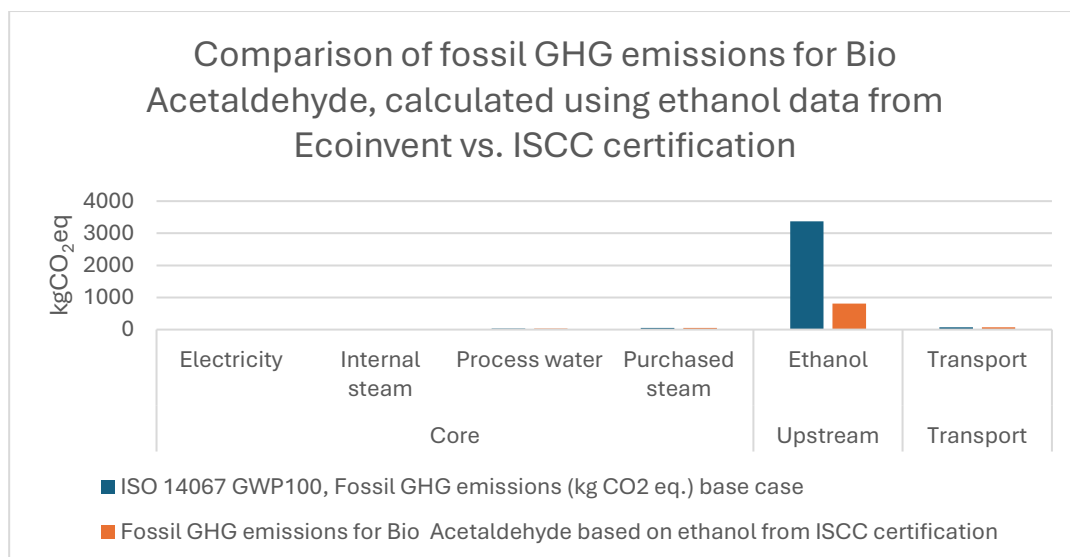


Figure 8. Comparison of fossil GHG emissions for Bio Acetaldehyde, calculated using ethanol data from Ecoinvent vs. ISCC certification.

The fossil GHG emissions associated with electricity, steam, process water and transport are unchanged when using the ISCC certification, but the fossil GHG emission from ethanol is 76 % lower for this dataset. The total fossil GHG emissions, that also can be referred to as product carbon footprint according PCF guideline, (979 kg CO₂ per ton Bio Acetaldehyde) are 72 % 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 Acetaldehyde are included. 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 Acetaldehyde, 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 Acetaldehyde 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. The largest contribution comes from the ethanol, that is clearly shown in this report.

Regarding data quality in this study the data quality assessment points all data included 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 considered 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 8 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 7 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 7. 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 8. 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
Acetaldehyde	SE	Site-specific	2023	N/A	1	1	1	1	1
Ethanol	Brazil	Ethanol production from sugar cane	2023	ISCC sustainability declaration	1	1	1	1	1
Ethanol		Ethanol production from sugar cane	2003	Ecoinvent 3.9.1					
Transport-ship	US	N/A	2024	ISCC 205	1	1	1	1	1

Appendix 2 – Biogenic carbon

Biogenic carbon content.

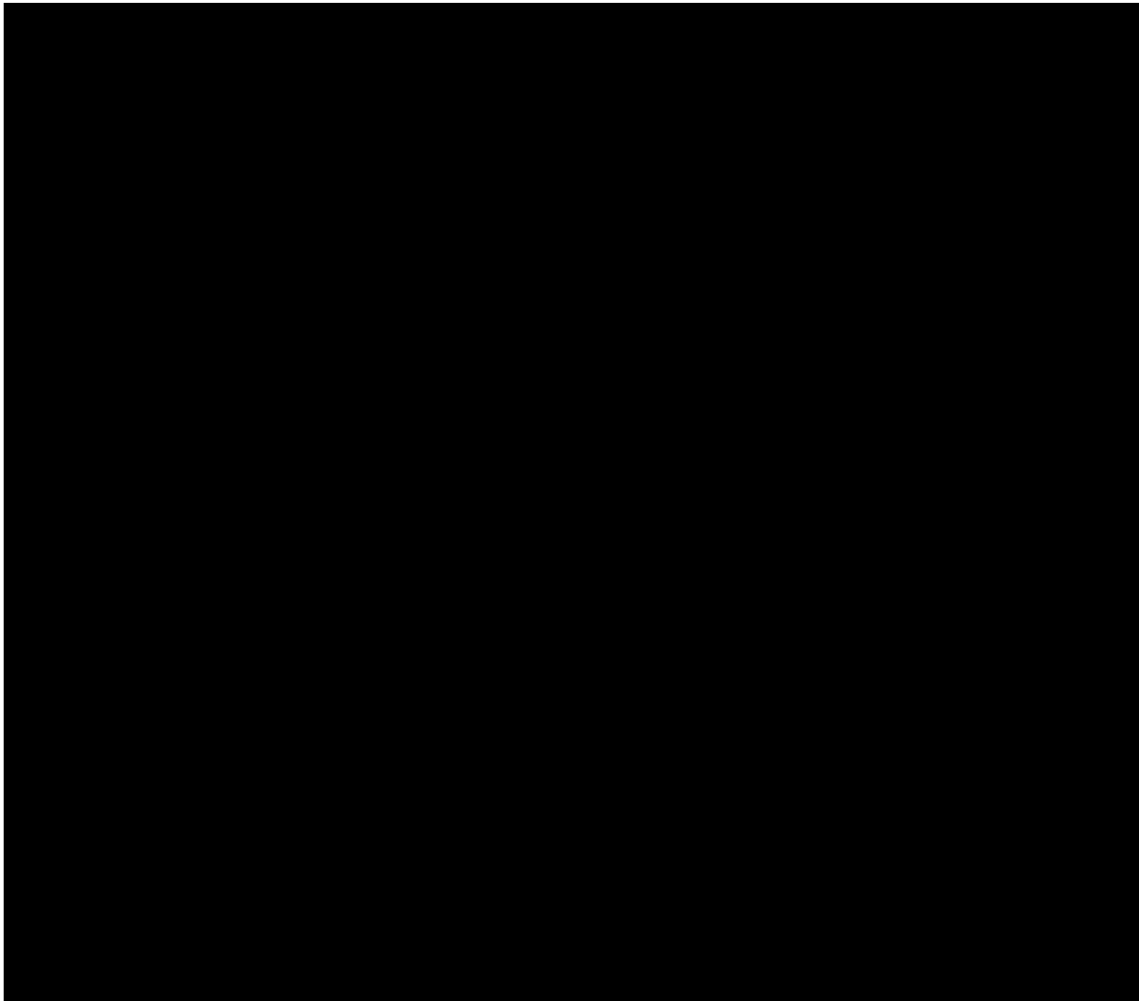
The amount of biogenic carbon in ethanol may differ based on factors like the type of feedstock and how it's produced. However, it's often assumed that ethanol made from renewable biomass sources contains solely biogenic carbon.

Table9. Biogenic carbon content.

BCC Bio Acetaldehyde	0,55	(kg BCC/kg Bio Acetaldehyde)
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Appendix 3 – Certificates process steam

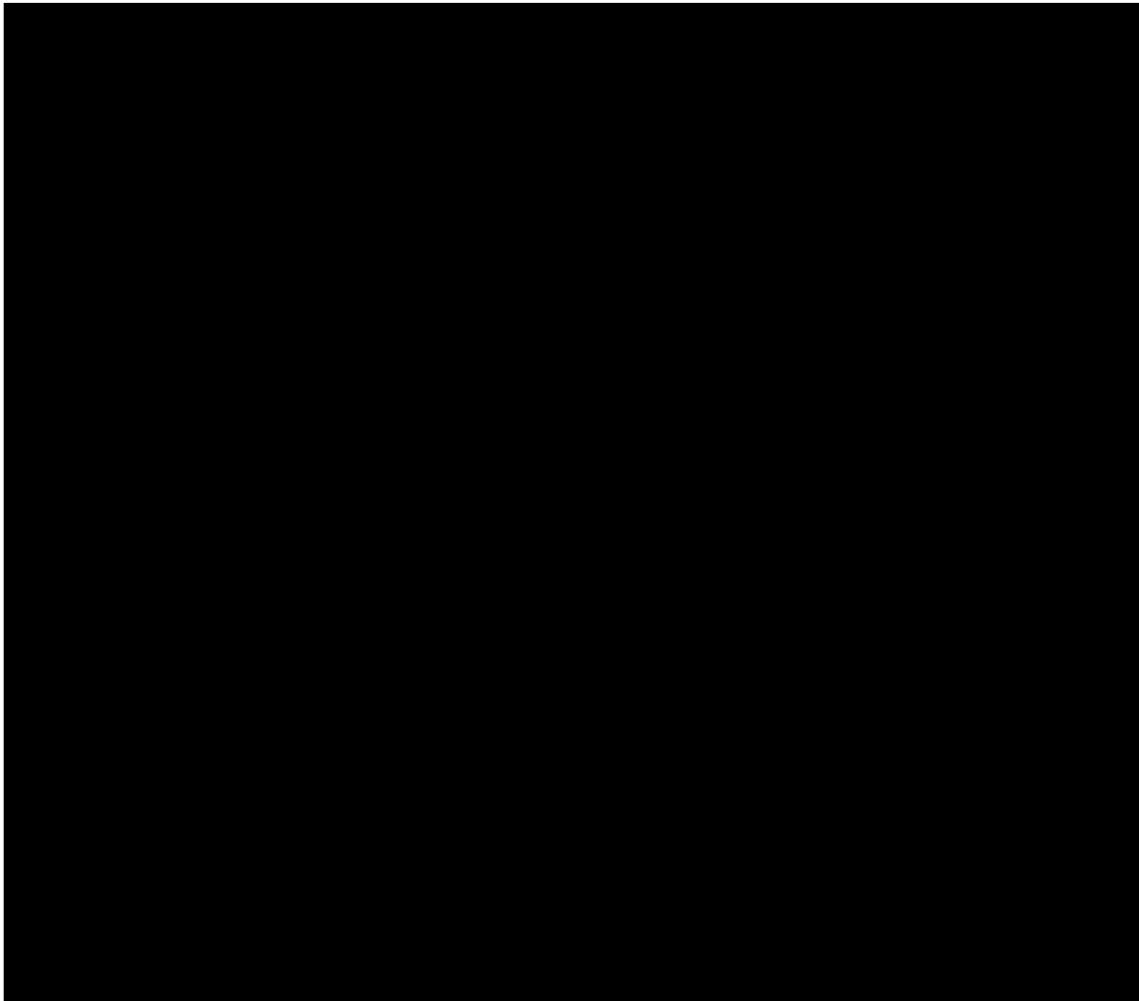
Certificate for steam purchased steam.



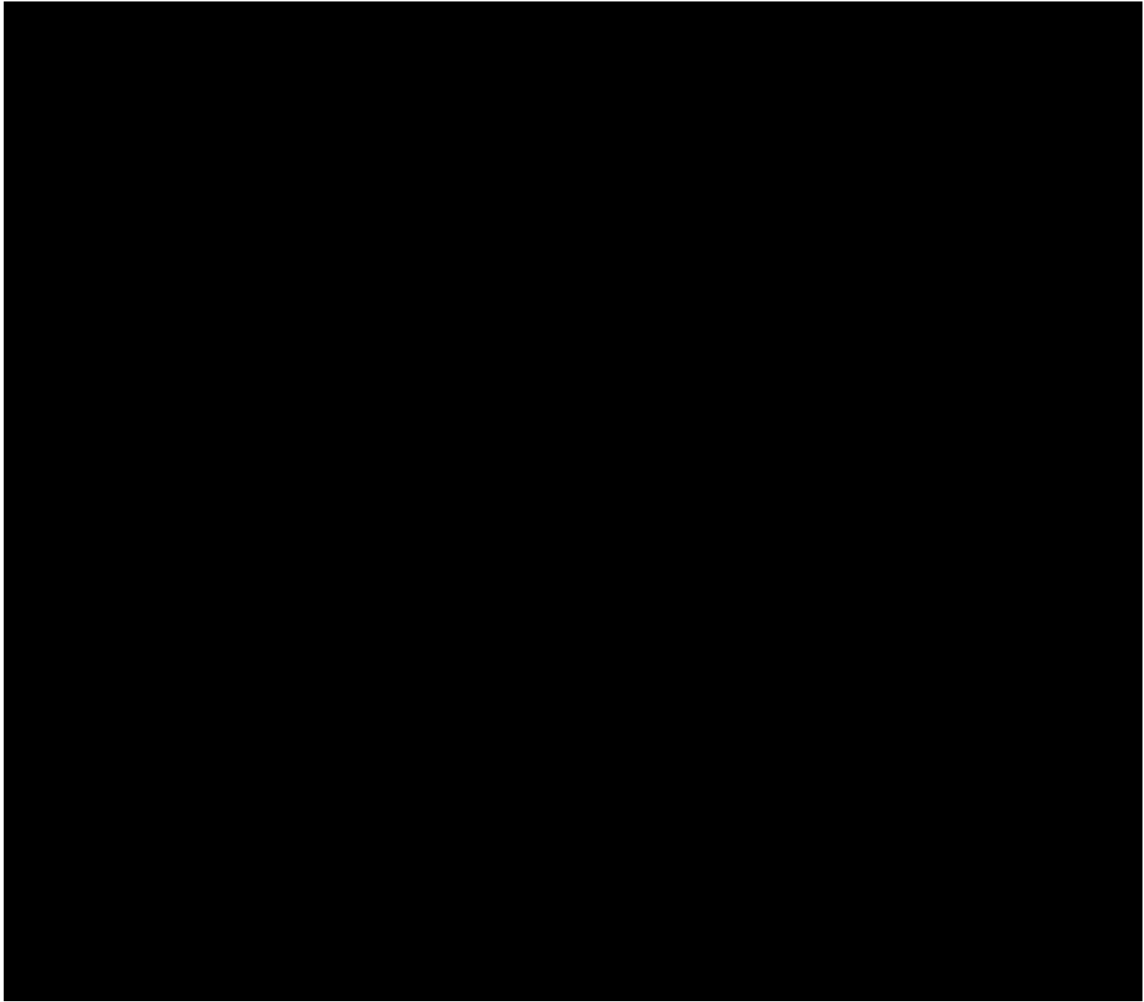
**proprietary information removed*

Appendix 4 – Certificate ethanol

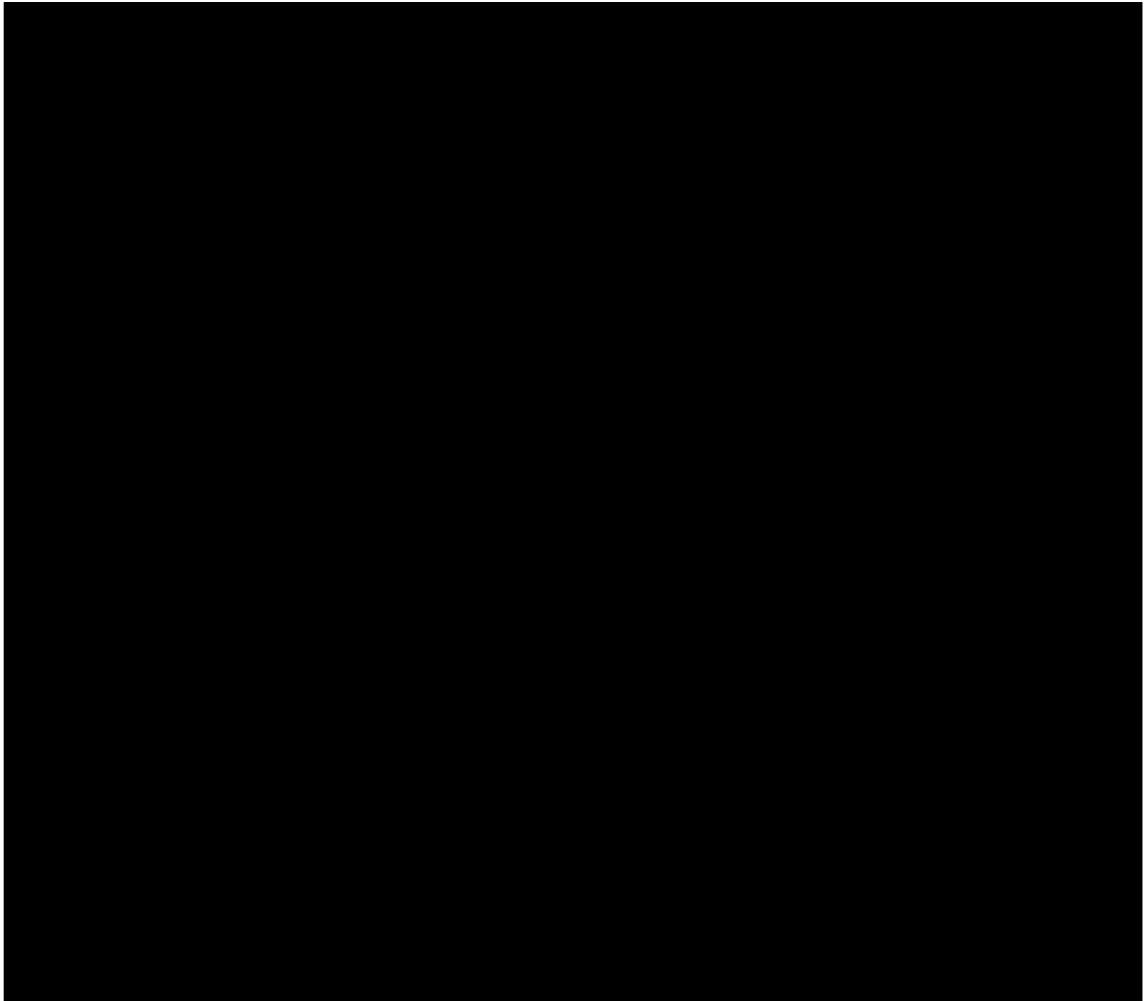
Certifacte for ethanol production.



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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 Acetaldehyde, based on sugarcane, 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