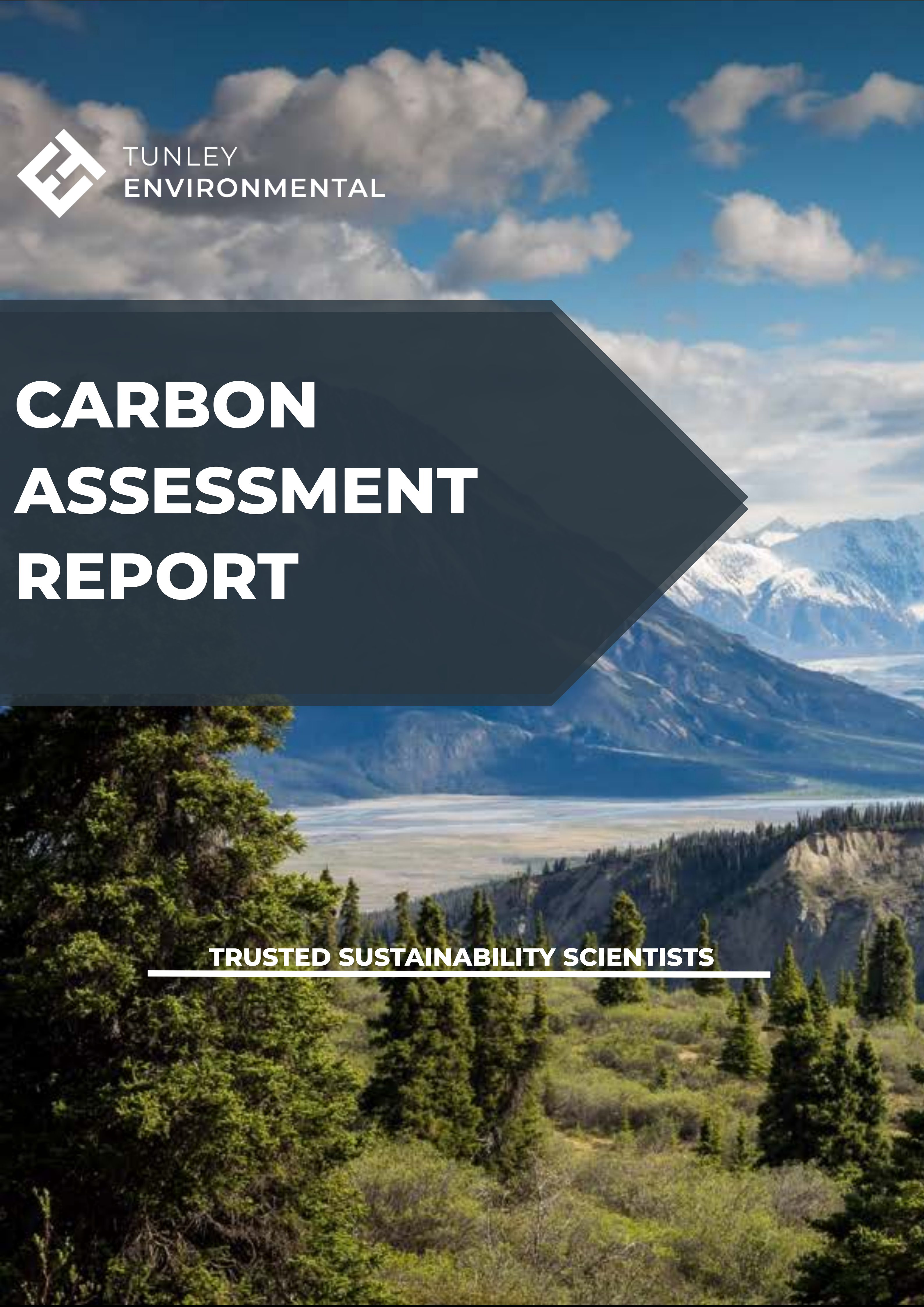

TUNLEY ENVIRONMENTAL

CARBON ASSESSMENT REPORT

TRUSTED SUSTAINABILITY SCIENTISTS

TUNLEY ENVIRONMENTAL

CARBON ASSESSMENT REPORT

FOR

Waterfront Terminal Company

Waterfront
Petroleum Terminal Company

TUNLEY ENVIRONMENTAL

Contents

Nomenclature

Nomenclature	Description
GHG	Greenhouse Gases, gases that trap heat in our atmosphere. GHG include Carbon dioxide, methane, nitrous oxides, and fluorinated gases.
Embodied Carbon / Partial Product Carbon Footprint	The total GHG emissions generated to produce a product; It includes those from extraction, manufacture, processing, transportation, and assembly of every component.
Carbon Equivalent	The effect on global warming of a greenhouse gas (GHG) relative to that of CO_2.
Zero Carbon	The absence of GHG emissions
Greenhouse Gas Protocol	The GHG Protocol Corporate Accounting and Reporting Standard which provides requirements and guidance to prepare a corporate-level GHG emissions inventory.
Net Zero Carbon (NZC)	The sum effect of combining actions to reduce GHG emissions with actions to off-set them.
Carbon Offsetting	A reduction in emissions of GHG to compensate for unavoidable emissions.
Global Warming Potential (GWP)	The heat adsorbed by any GHG as a multiple of the equivalent in carbon dioxide.
IPCC	The Intergovernmental Panel on Climate Change. It provides regular scientific assessment on climate change to policy makers.
AR6	The sixth assessment report of the IPCC. The most recent assessment report is 2021.
t CO_2e	Notation for tonnes of carbon dioxide equivalent emissions.
kg CO_2e	Notation for kilograms of carbon dioxide equivalent emissions.
ICE	The Inventory of Carbon and Energy.
Embodied Carbon Assessment (ECA)	Embodied carbon is the carbon footprint of a material. It considers how much greenhouse gas (GHGs) is released throughout the supply chain and is often measured from cradle to (factory) gate, or cradle to handover/site (of use).
Lifecycle Assessment (LCA)	A Lifecycle Assessment (LCA) is defined as the systematic analysis of the carbon emissions of products or services during their lifecycle.
Cradle-to-gate	A partial lifecycle of a product from raw materials through to the factory's gate.
Cradle-to-handover/site	A partial lifecycle of a product from raw materials through to delivery to the customer and does not include the end-of-life processes.
Cradle-to-grave	A full single lifecycle of a product from raw materials through to its end-of-life.
Cradle-to-cradle	A lifecycle assessment including consideration of reuse of the product or material in lieu of disposal at the end of a single life-time use. Pertains to the circular economy.

Executive Summary

Tunley Environmental has undertaken a comprehensive carbon assessment within the framework of lifecycle assessments (LCAs) to quantify the carbon footprint of B100 biodiesel for Waterfront Terminal Company, herein referred to as Waterfront. The assessment focuses on the impact category of climate change, quantified in terms of greenhouse gas (GHG) emissions. It compares the cradle-to-gate (A1 – A4) and use (B1) of the B100 biodiesel sold by Waterfront, evaluating emissions per Gallon of biodiesel.

The assessment adheres to the BS EN ISO 14067:2018 standard, consistent with the International Standards on Life Cycle Analysis (ISO 14040 and ISO 14044). Tunley Environmental utilised data provided by Waterfront and its suppliers, supplemented by reasonable assumptions from expertise and secondary sources where necessary. The objective of this assessment is to identify significant contributors to emissions and to support Waterfront's internal and external stakeholders in making informed decisions to mitigate their carbon footprint.

The analysis reveals that the carbon footprint of 1 Gallon of B100 biodiesel is 0.0915 kg CO_2e, inclusive of biogenic CO_2 uptake.

The detailed breakdown indicates that the primary contributors to the carbon footprint of the biodiesel are the burning of biodiesel during the use (B1) stage. This is followed by the soybean crushing (A3), the transportation of biodiesel to waterfront (A4) and transportation of feedstock (A2).

The biodiesel benefits from biogenic CO_2 uptake due to the cultivation of its primary material, soybeans. This biogenic carbon refers to the carbon dioxide absorbed from the atmosphere during the growth of soybeans, effectively acting as a carbon store and slightly reducing the overall carbon footprint of the product.

This report serves as a preliminary step towards achieving the International Sustainability and Carbon Certification (ISCC), ensuring that biofuels are produced sustainably. This assessment underscores the benefits of biodiesel (B100) over standard biodiesel blends, positioning B100 as a more carbon friendly choice within fuel industry.

Introduction

Climate change, driven by an increase in greenhouse gases (GHGs), commonly referred to as carbon emissions, poses a significant challenge to the environment. Climate change impacts businesses, natural systems, and communities. This necessitates mitigation measures at international, national, and local levels.

Tunley Environmental has conducted a comprehensive carbon assessment based on the framework of lifecycle assessments, quantifying the single impact category of climate change (carbon footprint) for B100 biodiesel for Waterfront. This assessment calculates the life cycle of the biodiesel over a cradle-to-gate and use phase. This is assessed by the $kgCO_2e$ per gallon of biodiesel.

This assessment adheres to the standard BS EN ISO 14067:2018 in a manner consistent with the International Standards on Life Cycle Analysis (LCA) (ISO 14040 and ISO 14044). Tunley Environmental has used data provided by Waterfront and its suppliers for quantification. Where data was limited, reasonable assumptions were made based on expertise and information from secondary sources. Appreciating the importance of determining major contributors to the emissions, Tunley Environmental also provides detailed analysis and discussion on the findings of the assessment. Therefore, supporting Waterfront's internal and external stakeholders with their decision-making processes to reduce their carbon emissions.

Figure 1. Life-cycle Carbon Assessment stages for consideration advised by BS EN ISO 14040 & 14044.

Waterfront is a leading wholesale provider of petroleum and petroleum products, renowned for its high-quality products and services. Based in Detroit, US, Waterfront offers an extensive range of biodiesel blends, with over 25 years of experience in serving commercial marine fleet, industrial, and governmental agencies.

Methodology, Goals, and Scope

A detailed description of all methodology, goal, and scope aspects considered for this assessment is provided in Appendix A. Covering all required methodology in line with the international standard BS EN ISO 14067:2018 in a manner consistent with the International Standards on Life Cycle Analysis (LCA) (ISO 14040 and ISO 14044). This section provides a broad summary of the most critical methodology information.

To ensure that emissions data was reliable, carbon equivalent data conversions were calculated in accordance with the emission factors for Greenhouse gas reporting: conversion factors published by DEFRA, the UK government Department for Business, Energy, and Industrial Strategy for 2023 and 2024. Additionally, peer-reviewed academic papers and databases such as ICE and Ecoinvent 3 have been utilised.

For ease of reference and transparency, the functional unit and scope of this lifecycle assessment is tabulated below (Table 1).

Table 1. Functional unit and Scope of this life cycle assessment.

Item	Functional Unit	Scope	Specifications
B100 Biodiesel	One functional unit is reported: One gallon of fuel	Cradle-to-Grave	Please see Biodiesel Full Specification (B100) in the Appendix C – Product Specification.

The lifecycle modules quantified as part of this life cycle assessment and data utilised are noted within Table 2.

Table 2. Lifecycle modules quantified and corresponding data used.

Module	
A1 (Materials Extraction)	All components with allocated weights and composition were used to quantify all material weights for conversion to emissions.
A2 (Upstream Transportation)	The transportation distance and weight for each component was provided and utilised to provide upstream freight.
A3 (Manufacturing)	The energy requirements of the refinery were used in the manufacturing emissions.
A4 (Downstream Transportation)	A transportation distance from the refinery to Waterfront along with the weight of the product was used to calculate the downstream transportation
B1 (Use)	The use of the product was the burning of the biofuel which creates no remaining components to continue to end of life.

Biodiesel Production Process

Life Cycle Assessment (LCA) is a holistic approach to evaluate the environmental impact of a product throughout its entire life span. For biodiesel, this means analysing the emissions and energy use from the initial production of the soybean feedstock to the final use of the biodiesel fuel. By carefully examining each stage of the production process, from cultivation, harvesting, and transportation of soybeans to refining them into biodiesel and finally burning the biofuel, we can gain a comprehensive understanding of its carbon footprint. The detailed process flow diagram shown in Figure 2 illustrates the various stages involved in biodiesel production and the associated emissions at each step.

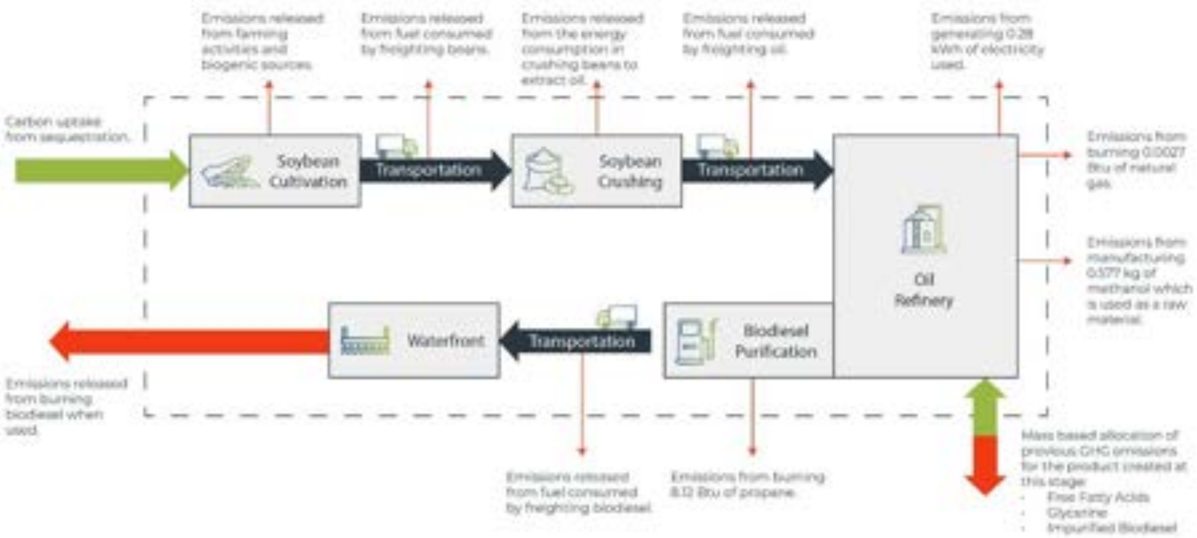

Figure 2. The process flow diagram for the biodiesel production process.

The process begins with the production of feedstock through the cultivation of soybeans. Emissions are released and sequestered during various stages of soybean cultivation, including soil preparation, planting, irrigation, and harvesting. These stages contribute to emissions through the use of fertilizers, pesticides, and fuel for agricultural machinery. Simultaneously, soybeans sequester CO2 from the atmosphere during their growth, which partially offsets the emissions produced. Emissions for this stage are accounted for in Module A1 - Material Extraction. The mass of soybeans required to produce one gallon of biodiesel is multiplied by a reliable emission factor sourced from the Ecoinvent database. This emission factor is utilized due to the lack of primary data from Waterfront's distant suppliers. Since it was not feasible to collect primary data directly from the farms, previously calculated and trusted data from secondary sources were used to estimate the emissions from soybean cultivation.

The crushing process for soybean oil extraction involves several key steps. Initially, soybeans are cleaned and dried to remove impurities and excess moisture. The beans are then cracked and dehulled to separate the oil-rich cotyledons from the hulls. These cotyledons are subsequently flaked to increase surface area and facilitate oil extraction. The flakes undergo solvent extraction, typically using hexane, which dissolves the oil. The resulting mixture is then separated, with the solvent being recovered for reuse. Finally, the crude soybean oil undergoes further refining processes to improve quality and remove any remaining impurities. The emissions from this crushing process were calculated as A1 Material Extraction due to the absence of primary data from Waterfront's suppliers. This methodological approach was necessitated by data limitations. To ensure a robust and scientifically sound assessment, a reliable and accurate emission factor from the Ecoinvent database for the production of Soybean Oil was utilized to estimate the emissions from the crushing process. This approach aligns with standard life cycle assessment (LCA) practices when primary data is unavailable, allowing for a comprehensive evaluation of the environmental impacts associated with soybean oil production while maintaining the integrity of the assessment through the use of peer-reviewed and widely accepted secondary data sources.

In the absence of primary data from suppliers, the emissions associated with the transportation of soybeans from farms to the crushing facility and the subsequent movement of oil to the refinery were calculated using estimated distances. The weight of goods being freighted was meticulously calculated and is presented in Appendix A for reference. However, due to data limitations, an assumption of 1,000 km was applied for the transportation distance. To account for variability in transportation methods, a modal split of 50% rail and 50% truck transport was assumed. These transportation-related emissions were categorised and measured within module A2 - Upstream Transportation, in accordance with standard Life Cycle Assessment methodologies. This approach, whilst based on estimations, provides a reasonable approximation of the transportation-related emissions within the biodiesel production process, allowing for a comprehensive assessment of the environmental impact whilst acknowledging the inherent uncertainties associated with the use of secondary data and assumptions.

The emissions associated with the refinery process for converting Soybean Oil to biodiesel were calculated using primary data obtained from Waterfront's direct supplier, ensuring a high degree of accuracy in the assessment. The refinery process encompasses several key stages, including degumming, neutralisation, bleaching, and transesterification. During degumming, phospholipids are removed from the crude oil. Neutralisation then eliminates free fatty acids, followed by bleaching to remove colour-imparting compounds. The critical transesterification reaction involves the conversion of triglycerides in the oil to methyl esters (biodiesel) through reaction with methanol in the presence of a catalyst, typically sodium hydroxide. This process yields impure biodiesel alongside two significant by-products: free fatty acids and glycerine. Emissions during the refinery process primarily originate from energy consumption in heating and cooling operations, methanol usage, and the potential release of volatile organic compounds during various stages of processing. The comprehensive primary data utilised for these emissions calculations, including specific energy consumption figures and raw chemical inputs are documented in Appendix A of this report. This data set was provided directly to Tunley Environmental by Waterfront, facilitating precise emissions calculations in alignment with established Life Cycle Assessment methodologies and ensuring a robust evaluation of the environmental impact associated with this critical phase of biodiesel production.

The allocation of emissions from the biodiesel production process, encompassing cultivation, crushing, refining, and transportation, was conducted using the mass allocation procedure for the three resultant products: biodiesel, free fatty acids (FFA), and glycerin. This method distributes emissions based on the relative mass of each product output, providing a quantitative basis for environmental impact assessment. In the production process, for every gallon of biodiesel produced, the suppliers have reported an output of 0.0119 lbs of FFA and 1.2081 lbs of glycerin. To facilitate accurate mass calculations, the density of biodiesel was assumed to be 7.3 lbs/gallon, resulting in a mass of 7.3 lbs for one gallon of biodiesel. Utilising these figures, the mass allocation percentages were determined. Biodiesel, as the primary product, was allocated 85.75% of the total emissions. The by-products, FFA and glycerin, were allocated 0.14% and 14.11% of the total emissions, respectively. These percentages were derived by dividing the mass of each product by the total mass of all products and converting to percentages. It is important to note that this mass allocation method operates under the assumption that the environmental burden is directly proportional to the mass of each product. While this approach provides a straightforward and transparent method for distributing environmental impacts, it may not always reflect the economic value or functionality of the products. Furthermore, this method does not account for potential further processing or use of by-products, which could influence their overall environmental impact. The results of this allocation procedure indicate that the majority of the emissions are attributed to biodiesel, aligning with its status as the primary output of the process. Glycerin, despite being a by-product, receives a significant allocation due to its relatively high mass output, while FFA receives a minimal allocation due to its low mass output. In the context of a comprehensive Life Cycle Assessment, it is worth considering that alternative allocation methods, such as economic allocation or system expansion, might yield different results. These alternative approaches could be considered for sensitivity analysis to provide a more robust understanding of the environmental impacts associated with biodiesel production and its by-products. This mass allocation approach provides valuable insights into the distribution of environmental impacts among the products of the biodiesel production process. It serves as a crucial component in the overall assessment of the life cycle environmental performance of biodiesel, offering biodiesel users a clear understanding of the emissions associated with its production relative to its by-products.

The purification of biodiesel using propane is a critical step in ensuring the final product meets stringent quality standards. This process, known as propane stripping, involves passing propane gas through the impure biodiesel under controlled temperature and pressure conditions. The propane acts as a solvent, effectively removing residual methanol, water, and other impurities from the biodiesel. As the propane evaporates at a lower temperature than biodiesel, it can be easily separated and recovered for reuse, leaving behind a purified biodiesel product. The emissions associated with this purification stage were calculated using primary data obtained directly from the supplier, ensuring a high degree of accuracy in the assessment. This data encompassed energy consumption, propane usage, and other relevant process parameters.

It is noteworthy that the emissions from the entire refinery process, including the initial conversion of soybean oil to biodiesel and the subsequent purification stage, are categorised under Module A3 in the Life Cycle Assessment framework. This classification reflects the manufacturing stage of the process, which utilises primary activity data such as energy requirements and raw material inputs. By incorporating this detailed, supplier-specific information, the assessment provides a comprehensive and precise evaluation of the environmental impact associated with the biodiesel purification process.

The emissions associated with the transportation of 1 gallon of biodiesel were calculated using a weight-based approach, incorporating primary data provided by Waterfront to Tunley Environmental. The calculation methodology considered the specific weight of the biodiesel and the precise distance travelled, as detailed in Appendix A of this report. The transport mode distribution was predominantly road-based, with 90% of the transportation conducted via truck. This modal split was factored into the emissions calculations to ensure accuracy. The use of primary data for distance and weight, combined with established emission factors for truck transportation, allowed for a robust estimation of the transportation-related emissions. This approach aligns with standard Life Cycle Assessment practices, providing a reliable quantification of the environmental impact associated with the distribution phase of the biodiesel life cycle.

The final stage in the life cycle of biodiesel products is its use phase, which primarily involves the combustion of the fuel in engines. For the purposes of emissions calculations, the

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chemical identity of biodiesel is assumed to be equivalent to that of ordinary diesel. This assumption allows for the application of established emission factors and stoichiometric calculations to determine the direct emissions from biodiesel combustion. The calculation typically involves quantifying the carbon content of the fuel and assuming complete oxidation to CO_2 during combustion, with adjustments made for other pollutants such as NO_x and particulate matter based on empirical data. This use phase represents the culmination of the biodiesel life cycle, as post-combustion, there are no further energy requirements or materials to be maintained or disposed of in an end-of-life scenario. The emissions from this stage are crucial in the overall Life Cycle Assessment, as they often constitute a significant portion of the total environmental impact associated with biodiesel utilisation.

The carbon footprint calculation for soybean-derived biodiesel employs a comprehensive cradle-to-grave lifecycle analysis. This methodology encompasses soybean cultivation, oil extraction, biodiesel production through transesterification, purification, transportation, and final use. Each stage's emissions are accounted for, including energy consumption, chemical inputs, and transportation. Assumptions were made for agricultural practices where direct data was unavailable. The combustion emissions are calculated assuming chemical equivalence to ordinary diesel. This approach provides a thorough assessment of environmental impacts throughout the biodiesel lifecycle, with all raw data and calculations detailed in Appendix A, primarily sourced from Waterfront and their supply chain.

Results

Overview

This section offers an overview of the cradle-to-grave carbon footprint for the B100 biodiesel Waterfront product. The LCA focuses specifically on the impact category of climate change. The analysis highlights the environmental impact associated with the fuel from production to end of life from use. The input data used to calculate the carbon footprint of the product was provided by Waterfront and their suppliers. Assumptions were made regarding the distant suppliers for farming and crushing of soybeans, transport distances and method of transport based on research conducted by Tunley Environmental.

The analysis presented in Table 3 & Figure 3 reveals the carbon footprint associated with the biodiesel and bi-products with biogenic CO_2 uptake. The carbon footprint for the lifecycle of the biodiesel is found to be **0.0915 kg CO_2e / Gallon**.

Table 3. Cradle-to-Grave (A1 – C4) emissions of B100 biodiesel product with biogenic CO_2 uptake, in kilograms of carbon dioxide equivalents per gallon of biodiesel produced.

Life Cycle Module(s)	Description	Biodiesel (kg CO_2e/ Gallon)	Glycerine (kg CO_2e/ Gallon)	Free Fatty Acids (kg CO_2e/ Gallon)
A1 – C4	Cradle-to-Grave Emissions (Inc. Biogenic CO_2 Uptake)	0.0915	-2.09	-0.0206

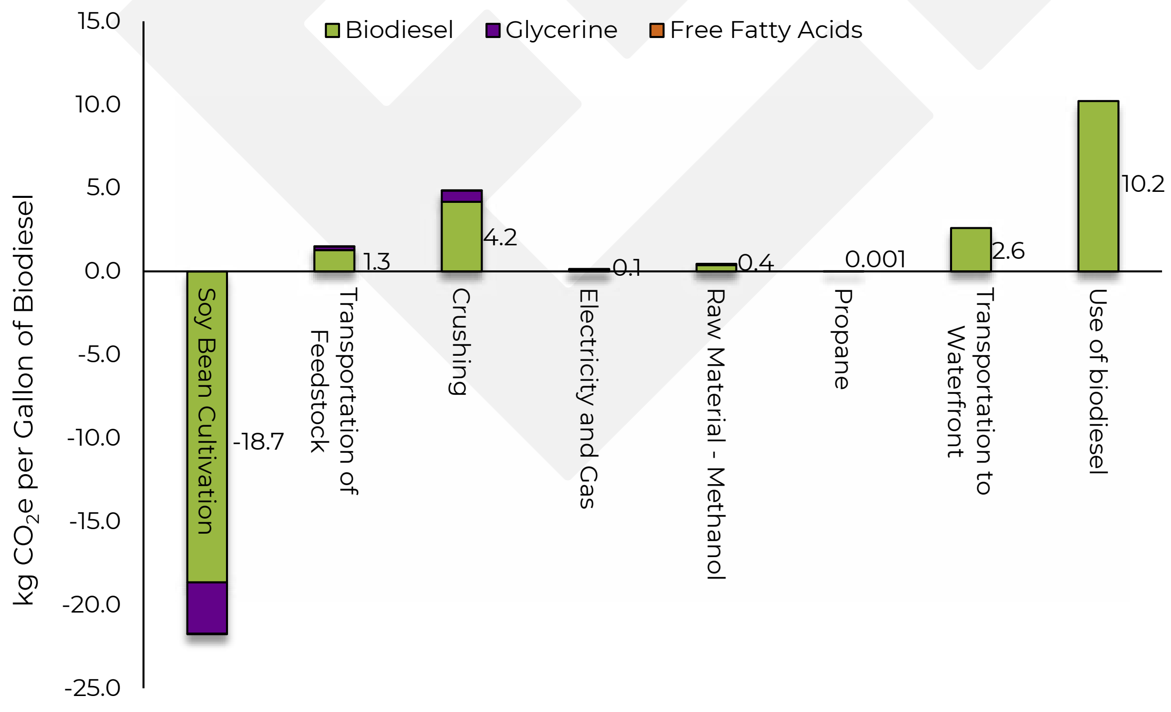

Figure 3. Bar charts showing the total A1-C4 emissions per gallon of B100 biodiesel produced and used.

Granularity of Carbon Footprint

This section provides a deeper dive into the sources of emissions for the B100 biodiesel and the allocation of emissions to the by products Glycerine and Free Fatty Acids. Table 4 presents an overview of the cradle-to-grave carbon emissions broken down into their respective LCA modules and process stage description.

Table 4. LCA module (A1 – C4) emissions of the B100 biodiesel product and the allocated emissions to the by products per gallon of biodiesel produced.

Life Cycle Stage(s)	Process Stage Description	Biodiesel (kg CO_2e/ Gallon)	Glycerine (kg CO_2e/ Gallon)	Free Fatty Acids (kg CO_2e/ Gallon)
A1	Soy Bean Cultivation	-18.7	-3.07	-0.302
A1	Soy Bean Oil Production from Crushing	4.17	0.686	0.00675
A2	Transportation of Feedstock	1.27	0.209	0.00206
A3	Energy Consumption from Refinery	0.110	0.0180	0.000178
A1	Production of Methanol Raw Material used at Refinery	0.378	0.0622	0.000613
A3	Use of Propane	0.000513		
A4	Transportation of Product	2.61		
B1	Use of Product	10.2		

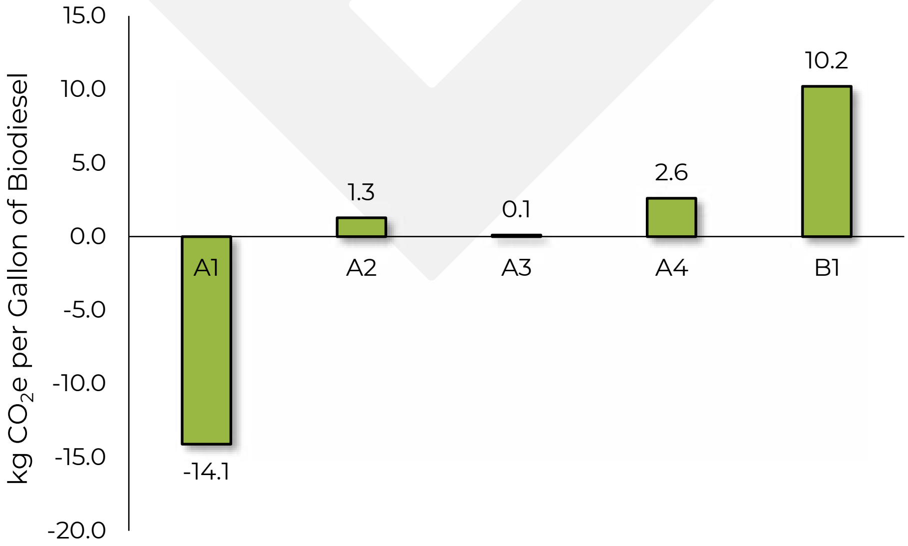

Figure 4. The GHG emissions per life cycle module for the B100 biodiesel product per gallon produced.

The life cycle assessment of B100 biodiesel yields a remarkably low overall carbon footprint of 0.0915 kg CO2e per gallon, significantly lower than traditional diesel fuel. This reduced emission factor is primarily attributed to the biogenic carbon sequestration during soybean cultivation, which effectively offsets the emissions from both biodiesel production and use. The cultivation process results in a substantial net carbon uptake of 18.7 kg CO2e per gallon of biodiesel, derived from the harvesting of 19 kg of soybeans for each gallon produced. This carbon sequestration is a crucial factor in the favourable environmental profile of biodiesel.

The biodiesel production process contributes to emissions at various stages:

- Soybean crushing for oil extraction (4.17 kg CO2e per gallon): This stage involves mechanical and chemical processes to extract oil from soybeans, requiring significant energy input and potentially using solvents like hexane.
- Oil refining into biodiesel (0.488 kg CO2e per gallon): The transesterification process converts triglycerides in the oil to methyl esters (biodiesel) using methanol and a catalyst, typically sodium or potassium hydroxide. Emissions here stem from energy use and chemical production.
- Transportation of raw materials and finished product (3.88 kg CO2e per gallon): This encompasses emissions from vehicles used in transporting soybeans to crushing facilities, oil to refineries, and final biodiesel to distribution points.
- Biodiesel use in engines (10.2 kg CO2e per gallon): These emissions result from the combustion of biodiesel in vehicle engines, primarily producing CO2 and water vapour, with trace amounts of other pollutants.

Despite these emissions, the net carbon footprint remains significantly lower than conventional diesel due to the substantial carbon sequestration during soybean growth. This balance demonstrates the circular nature of biodiesel's carbon cycle, where atmospheric CO2 absorbed during plant growth is later released during fuel combustion, resulting in a near-neutral carbon impact. This life cycle assessment underscores the potential of biodiesel as a sustainable alternative fuel, particularly in sectors where immediate electrification poses challenges.

Comparison to Other Fuels

The emission factor of 0.0915 kg CO2e per gallon for B100 biodiesel produced from soybeans by Waterfront represents a significant reduction in greenhouse gas emissions compared to conventional fuels. This figure stands in stark contrast to the UK Government GHG Conversion Factors 2024, which report average emission factors of 10.1 kg CO2e per gallon for diesel, 0.634 kg CO2e per gallon for biodiesel from waste cooking oil, and 0.135 kg CO2e per gallon for hydrotreated vegetable oil (HVO). These results can be seen in Figure 5.

The B100 biodiesel's emission factor demonstrates a remarkable 99.09% decrease in emissions compared to conventional diesel. This reduction far surpasses the performance of other alternative fuels. For instance, biodiesel from waste cooking oil shows a 93.72% reduction, while HVO achieves a 98.66% decrease relative to diesel. These figures underscore the exceptional environmental benefits of the B100 product.

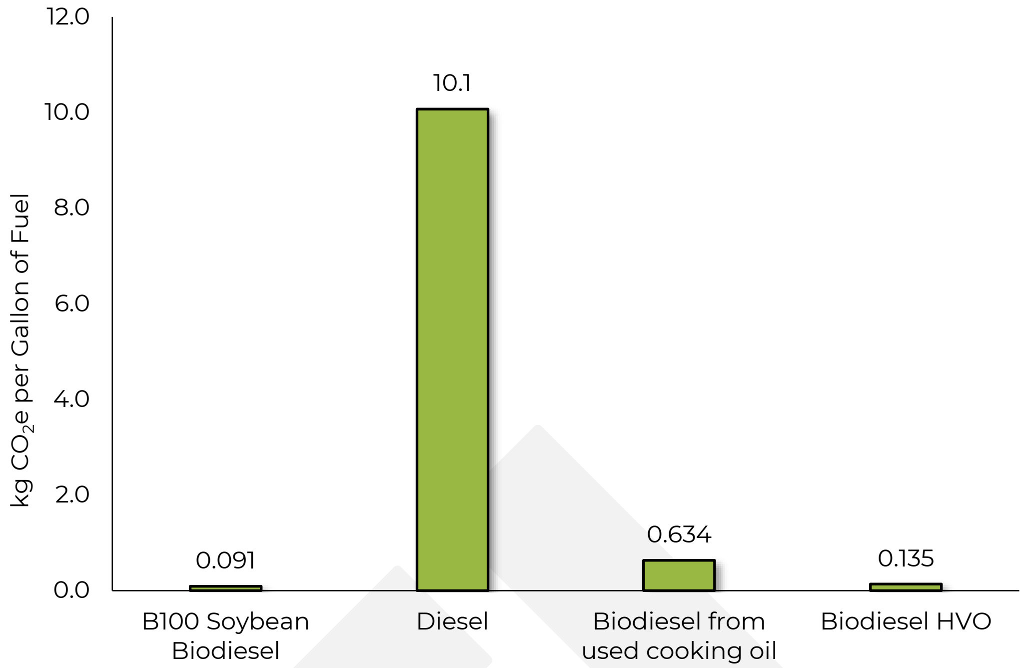

Figure 5. The emission factor per gallon of fuel for each type of fuel.

Comparisons with other alternative fuels further highlight the B100's superior performance. Many biodiesel suppliers report emission reductions ranging from 50% to 80% compared to diesel, depending on feedstock and production methods. For example, some rapeseed-based biodiesels claim up to a 65% reduction, while palm oil-derived biodiesel typically reports around a 50% decrease. The 99.09% reduction achieved by the B100 product significantly outperforms these industry standards.

It's important to note that the exceptionally low emission factor of the B100 biodiesel is likely due to highly efficient production processes and the carbon sequestration potential of soybean cultivation. This underscores the importance of considering the entire life cycle in assessing the environmental impact of biofuels.

ISCC Certifications

The International Sustainability and Carbon Certification (ISCC) is a globally recognized certification system that ensures sustainable and traceable production of biomass and biofuels. This Life Cycle Assessment (LCA) report serves as a crucial initial step towards understanding the B100 product and progressing towards obtaining ISCC certifications.

ISCC certification overview:

- Purpose: ISCC aims to verify and promote sustainable practices throughout the entire supply chain of biomass and biofuel production.
- Significance: It provides credible assurance to stakeholders that certified products meet stringent sustainability and traceability criteria.
- Scope: ISCC covers various aspects, including greenhouse gas emissions reduction, sustainable land use, protection of natural habitats, and social sustainability.

Specific requirements for ISCC certification:

- Compliance with sustainability criteria:- Protection of land with high biodiversity value or high carbon stock
    - Environmentally responsible production to protect soil, water, and air
    - Adherence to good agricultural practices
- Greenhouse Gas (GHG) emissions reduction:
    - Meeting specified GHG savings targets based on the start date of operations
    - Accurate calculation and reporting of life cycle GHG emissions
- Traceability and Chain of Custody:
    - Implementation of mass balance or physical segregation systems
    - Proper documentation and record-keeping throughout the supply chain
- Social sustainability:
    - Ensuring safe working conditions
    - Respecting human rights, labour rights, and land use rights
    - Maintaining responsible community relations
- Continuous improvement:
    - Regular internal audits and management reviews
    - Implementation of corrective actions when non-conformities are identified

Supply chain certification in the biodiesel industry plays a crucial role in ensuring quality, sustainability, and traceability throughout the production process. It provides assurance to consumers and regulators that the biodiesel meets stringent environmental and social standards. Certification schemes, such as the ISCC, verify that biodiesel producers adhere to good agricultural practices, protect biodiversity, and reduce greenhouse gas emissions. This process enhances transparency, allowing stakeholders to trace the origin of feedstocks and monitor the entire production chain. Moreover, certification promotes sustainable practices by encouraging the use of waste and residual materials as feedstocks, thereby reducing the industry's environmental impact. For biodiesel users, certification offers confidence in the product's quality and sustainability credentials, which is increasingly important in meeting regulatory requirements and consumer expectations in the UK and globally.

By pursuing ISCC certification, the B100 product demonstrates a commitment to sustainability and responsible production practices. This LCA report lays the groundwork for meeting ISCC requirements and positions the product favourably in the growing market for sustainable biofuels.

Conclusion

Tunley Environmental has conducted a comprehensive cradle-to-grave life cycle assessment (LCA) of the B100 biodiesel produced for Waterfront, in accordance with the BS EN ISO 14067:2018 standard. The analysis calculated the carbon footprint of the biofuel to be 0.0915 kg CO_2e per gallon of fuel.

The detailed breakdown indicates that the primary contributors to the carbon footprint of the biodiesel are the burning of biodiesel during the use (B1) stage. This is followed by the soybean crushing (A3), the transportation of biodiesel to waterfront (A4) and transportation of feedstock (A2).

The biodiesel benefits from biogenic CO2 uptake due to the cultivation of its primary material, soybeans. This biogenic carbon refers to the carbon dioxide absorbed from the atmosphere during the growth of soybeans, effectively acting as a carbon store and slightly reducing the overall carbon footprint of the product. Many biodiesel suppliers report emission reductions ranging from 50% to 80% compared to diesel, depending on feedstock and production methods. For example, some rapeseed-based biodiesels claim up to a 65% reduction, while palm oil-derived biodiesel typically reports around a 50% decrease. The 99.09% reduction achieved by the B100 product significantly outperforms these industry standards.

This report serves as a preliminary step towards achieving the International Sustainability and Carbon Certification (ISCC), ensuring that biofuels are produced sustainably. This assessment underscores the benefits of biodiesel (B100) over standard biodiesel blends, positioning B100 as a more carbon friendly choice within fuel industry.

Tunley Environmental Report Emission Statement

Tunley Environmental GHG emissions from completing this assessment were 0.79 kg CO_2e.

Appendix A - Methodology

The life cycle assessment was completed using methodology consistent with the international standard BS EN ISO 14067:2018 in a manner consistent with the International Standards on Life Cycle Analysis (LCA) (ISO 14040 and ISO 14044). This Appendix A provides a complete and comprehensive description for all data, scope, goals, function, functional units, data quality rating, cut-offs, exemptions, *etc.* as described in the aforementioned standards.

Activity and Emissions Data

To assess the carbon footprint of the product, two types of data are utilised: activity data and emission data. Specific activity data (primary data) was gathered by Waterfront and its suppliers where feasible. Where specific data was not available, reasonable assumptions were made using relevant databases and expertise. Description of primary data supplied by Waterfront to Tunley is provided in full in Table A1.

Table A1. Waterfront data provided for lifecycle analysis.

Data	Description	Units
Amount of B100	The amount of biodiesel produced over two years that is used to calculate the remaining activity in units per gallon of biodiesel	gallons
Soybean oil purchased	The amount of soybean oil purchased in two years and used to produce the biodiesel directly from the refinery	lb
Methanol used	The amount of methanol used in two years to produce the biodiesel directly from the refinery	lb
Electricity consumption	The amount of electricity consumed by the refinery in the two-year period	kWh
Natural gas consumption	The amount of natural gas consumed by the refinery in the two-year period.	Btu
Free fatty acids output	The amount of Free Fatty Acids produced over 13 months as a by product to the biodiesel from the refinery	lb
Glycerine output	The amount of glycerine produced over 2 years as a by product to the biodiesel from the refinery	
Propane used	The amount of propane used per day to purify the biodiesel	Lb
Product distance travelled	The distance the finished product is transported from the refinery to Waterfront	km

To ensure that emissions data was reliable carbon equivalent data conversions were calculated in accordance with the emission factors for Greenhouse gas reporting: conversion factors published by DEFRA, the UK government Department for Business, Energy, and Industrial Strategy for 2023 and 2024. Additionally, peer-reviewed academic papers and databases such as ICE and Ecoinvent 3 have been utilised.

Impact Assessment

The results of the carbon footprint calculations reveal the potential impact of each emitted greenhouse gas on climate change. This impact is expressed using the IPCC Global Warming Potential indicator, which utilises a 100-year time frame and presents the impact as kg CO_2e per functional unit.

Scope, Function, and Functional Unit

This was a lifecycle assessment aiming to cover all material sources of emissions. Materiality in this context is defined as anything contributing more than an estimated 1% of total lifecycle emissions. A full outline of all lifecycle modules, their description, and the materiality of them in this assessment is provided in Table A2.

Table A2. Materiality assessment and notation for quantified LCA categories as part of the lifecycle assessment.

LCA Category	Data Category Description	Materiality
A1 Raw Materials	Embodied carbon of the raw materials	Material – quantified.
A2 Transport	Emissions from transportation of the raw materials and product to the UK	Material – quantified.
A3 Manufacturing	Emissions from the manufacturing processes	Material – quantified.
A4 Transport to site	Emissions from transportation of the final product to the consumer.	Material – quantified
A5 Installation	Installation processes and related emissions caused through installation.	Zero
B1 Use/Application	This is in relation to usage-based emissions not categorised as water or energy.	Material – quantified
B2 Maintenance	Regular expected maintenance of the equipment over the lifetime including all components, travel, electricity, etc.	Zero
B3 Repair	Emissions related to the repair of any broken-down equipment. Is it the parts, travel, service time, *etc.*	Zero
B4 Replacement	Emissions associated with any wholly replaced items.	Zero
B5 Refurbishment	Emissions associated with the refurbishment of end-of-life items to extend expected lifetime.	Zero
B6 Operational Energy Use	Emissions associated with energy usage of the item/equipment over its lifetime.	Zero
B7 Operational Water Use	Emissions associated with water usage of the item/equipment over its lifetime.	Zero
C1 Deconstruction	Emissions associated with any deconstruction processes.	Zero
C2 Transport	Emissions associated with the transportation of the item/equipment at end-of-life. Included in factors used.	Zero
C3 Waste Processing	Emissions associated with recycling processes for materials at end-of-life.	Zero

LCA Category	Data Category Description	Materiality
C4 Disposal	Emissions associated with non-recycling disposal scenarios for materials at end-of-life.	Zero

System Boundary & Allocation Procedure

The system boundaries encompass all unit processes that contribute measurably to the category indicator results for the greenhouse gas indicators specified in ISO 14067:2018 relevant to the scope. In this study, except where otherwise noted, all required and known materials and processes were included in the life cycle inventory. All cut-offs and assumptions are clearly stated and described in the subsequent Cut-offs, Exclusions & Assumptions section.

Cut-offs, Exclusions & Assumptions

The procedure chosen for this assessment utilises the cut-off method. This method allows for the exclusion of processes that are assumed to contribute less than 1% to the environmental impact regarding GHG emissions. To our understanding, all input and output data for the processes are included. However, the assessment adopts these specific assumptions:

- The transport distances from Waterfront to the final user is assumed negligible in comparison to the final products transportation from the refinery to the Waterfront.

Data and Data Quality Assessment

Assumptions, and life cycle indicators applied to and/or used to inform this LCA are listed in the table below. Each dataset is appropriate to the geographical region the products and raw materials are manufactured in; the data is either region-specific, or the selected generic dataset accurately reflects the intended area. The technical representativeness of the modelled processes is deemed adequate, as the data are representative both temporally and regionally, and only standard methods are employed (Table A1).

Table A3. Assumptions, and life cycle indicators applied to and/or used to inform the calculations.

Data point	Unit	Description	Life Cycle Stage(s)	Why used?	Source/Justification	Data Quality Rating
Soybean	kg CO_2e/kg	Cultivation and farming	A1	To account for the emissions from raw material soybean	Ecoinvent	1.8
Transport to crushing	Kg CO2e/ short ton mile	Distance travelled truck	A2	To account for the emissions from transport of raw material	Standard rule of thumb	1.8
Soybean crushing	kg CO_2e/kg	Drying and crushing beans into oil	A3	To account for the emissions from drying and crushing in refinery	Ecoinvent	1.8
Transport to refinery	kg CO_2e/ short ton mile	Distance travelled - truck	A2	To account for the emissions from travel of soybean meal to refinery	Standard rule of thumb	1.8
Propane	kgCO2e/ mmBtu	Propane to dry goods	A3	To account for emissions from drying	US EPA	1.4
Electricity	kg CO_2e/MWh	Electricity use at refinery	A3	To account for the emissions from refinery of biodiesel	Data from W2 fuel US EPA	1.4
Natural Gas	kg CO_2e/ mmBtu	Natural gas at refinery	A3	To account emissions from refinery of biodiesel	Data from W2 fuel Emission factor - US EPA	1.4
Methanol	kg CO_2e/kg	Methanol	A3	To account for emissions during refinery of biodiesel	Ecoinvent	1.8
Waste Emission Factor - Mixed Organics (landfilled)	kg CO_2e/ short ton	Waste	A3	To account for waste produced during refinery	US EPA	1.5
Transport of biodiesel to waterfront	kg CO2e/ short ton mile	Distance travelled – 50% truck 50% rail	A4	To account for emissions from transport to waterfront	Standard rule of thumb	1.8
Biodiesel emission factor	kg CO_2e/ gallon	Burning of biodiesel	B1	To account for burning of biodiesel during use	US EPA	1.4

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Completeness Check

Overall, the carbon footprints are deemed to be calculated with sufficient representativeness and accuracy concerning both system boundaries and data completeness, in alignment with the goal and scope of the assessment. The data used for calculating the carbon footprint comprises either Waterfront-specific primary data or generic data from databases that meet the set requirements for data quality, thus ensuring representativeness for the studied system.

Limitations

The methodology employed encompasses only one impact category, Climate Change, which assigns a single score to the product's impact. However, this approach overlooks other environmental aspects, leading to a restricted perspective.

Goals and Objectives

This report details the results of a carbon footprint assessment carried out by Tunley Environmental for Waterfront. This assessment evaluated the carbon emissions associated with the raw materials, transport, refinery, and use (A1 – B1) of biodiesel.

The assessment was modelled to assess the impact category of climate change of the products. A critical review of this assessment was carried out internally by impartial experts at Tunley Environmental to ensure conformance to ISO 14067:2018.

The goal of the assessment includes four primary objectives:

1. To assess the cradle-to-gate carbon footprint for Waterfront's B100 biodiesel.
2. Present findings in a clear and actionable manner to inform decision-making.

The intended application of this assessment is the calculation of the carbon footprint for the B100 biodiesel.

The reasons for conducting this assessment are:

- To gain a comprehensive understanding of the GHG footprint of the B100 biofuel product.
- Internal communication by Waterfront.
- Communication with Waterfront's relevant stakeholders and customers.

The intended audience of this assessment is internal communication within the Waterfront and communication with their external stakeholders and customers.

The carbon footprint is calculated using 100-year Global Warming Potentials (GWPs) as stated in the IPCC Sixth Assessment Report, 2021 (AR6) and are reported in kg CO_2e in line with the single impact category, as required by ISO 14067:2018.

Appendix B – Further Data

Table A4. Tabulated data for individual contributions to the total carbon footprint per Gallon of Biodiesel

LCA Module	Item	Total, Emissions (kg CO_2e) Biodiesel	Total, Emissions (kg CO2e) Glycerine	Total, Emissions (kg CO2e) Free fatty acids
A1	Farming	-18.7	-3.07	-0.0302
A1	Crushing	4.17	0.686	0.00675
A2	Transport of feedstock	1.27	0.209	0.00206
A3	Electricity and gas use	0.110	0.0180	0.000178
A3	Propane	0.000513	0.0622	0.000613
A3	Methanol	0.378		
A4	Transport to waterfront	2.61		
B1	Burning biodiesel	10.2		
	Total	0.09	-2.09	-0.0206

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Appendix C – Product Specification

W2FUEL *Certificate of Analysis*

Biodiesel Full Specification (B100)

Report Date: 2022/02/09

Lot ID: ASY22020801 3400

Property	Units of Measure	Method	Analytical Results
Moisture, Karl Fischer	% mass	ASTM D6304	0.012
Flash Point	°C	ASTM D93	>130 [3,4]
Methanol Content	% mass	AOCS CX2-09	0.0121
Water & Sediment	% vol	ASTM D2709	< 0.010
Total Acid #	mgKOH/g	ASTM D664	0.350
Cloud Point	°C	AOCS CX2-09	-1.1
Visual Appearance, pt1: Haze Rating	N/A	ASTM D4176	1
Visual Appearance, pt2: Free of Particulate	N/A	ASTM D4176	Free of Particulate
Cold Soak Filtration	sec	ASTM D7501	104
Oxidation Stability	hr	EN 15751	8.9
Sulfur	ppm	ASTM D5453	< 5
Free Glycerin	% mass	ASTM D6584	0.000
Total Glycerin	% mass	ASTM D6584	0.110
Diglycerides	% mass	ASTM D6584	0.093
Monoglycerides	% mass	ASTM D6584	0.405
Triglycerides	% mass	ASTM D6584	0.000
Phosphorus	% mass	ASTM D4951	< 0.001 [3,4]
Na + K	ppm	EN14538	<1.0 [3,4]
Ca + Mg	ppm	EN14538	<1.0 [3,4]
Distillation Temperature	°C	ASTM D1160	350 [3,4]
Kinematic Viscosity	mm^2/s	ASTM D445	4.096 [3,4]
Sulfated Ash	% mass	ASTM D874	<0.005 [3,4]
Cetane #	N/A	ASTM D613	48.6 [3,4]
Carbon Residue	% mass	ASTM D4530	<0.01 [3,4]
Copper Corrosion	N/A	ASTM D130	1A [3,4]

[1] = Weighted average of blended lots.
[2] = Least favorable value of blended lots.
[3] = Most recent full-specification value (Monthly).
[4] = Result obtained from external, BQ-9000 certified lab.

Notes:

W2Fuel LLC
1571 W. Beecher Rd.
Adrian, MI 49221
517-920-4868

Tank ID: 3400
EPA ID: 5251

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Approval

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Peer-reviewed by:	Dr Anusha Nawoor
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Reviewed Date:	20th September 2024
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Position:	Quality Assurance Manager
Approval date:	20th September 2024
Reference:	Waterfront-LCA_24-1
Revision:	A

Revision History:	Change Description:	Changed by:	Date:	Approved by:	Date:
B					
C					
D					
E					
F					

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