LCA Reporting Category 3 Data
Dutch Environmental Database -
Marine fuels for work and transport vessels

Chapter 18

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EcoReview
Part of the solution.

Change register

Report version	Date	Author	Peer Reviewer	Changed product cards	Explanation
1	07/05/2025	*Stijn Mulder*	Martijn van Hovell	-	Original report

Explanation: If different versions have been used for the (sub)products / product cards in the report (e.g. if (partial) products / product cards have been added at a later stage), it must be clearly indicated here which (partial) products / product cards have been drawn up with the relevant version of the report.

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Summary

Background
The group of commissioning parties has expressed a desire to update and expand the existing LCA category 3 for work and transport vessels. These results are relevant for both policymakers, in relation to procurement, transition strategy, and climate objectives, and for the shipping sector in terms of investment decisions.

Scope
The results from this LCA report provide insight into the environmental impact of work and transport vessels, both seagoing and inland shipping. Work vessels refer to working and sailing for dredging, construction work and foundation work. For equipment on board ships (e.g. a crane), the dry machinery/equipment environmental profiles can be used. Transport refers to the tonne*km transport of (bulk) materials on a seagoing or inlandwaterway vessel. The report contains various energy carriers, fossil, biofuels and RFNBOs, especially the RFNBOs are often not yet available on the market. They have been included to provide a future-oriented perspective on the potential of alternative energy carriers. The modelling is made specific for the Dutch market and readers should take this into consideration when interpreting the results for other European countries.

Methods
This report presents an overview of the (relative) environmental impact resulting from the use of various energy carriers in ships. The focus is on the Environmental Cost Indicator (ECI: A2 and ECI: A1). The ECI score is a monetary value in euros, obtained by weighting and summing various impact categories. In the LCA methodologies (EN15804 and NMD determination methods), raw materials and capital goods are considered, including the production and maintenance of wind turbines or solar panels. Consequently, even sustainable alternatives have a positive environmental impact.

This report primarily compares the delivered work on the drive shaft. This approach was chosen to enable a comparative ECI-assessment across all alternatives. The energy content of different energy carriers varies significantly (for example, 1 tonne of hydrogen contains six times more energy than 1 tonne of methanol).

Structure
The document first provides context in the introduction. Chapter 2 then explains the approach and scope. The LCI (Chapter 3) describes all assumptions, modelling processes, and data points for the base-processes. These processes are the key components (building blocks) that ultimately form different energy carrier-ship combinations. These building blocks are categorised into three groups: energy carrier, emissions profile, and capital goods. Chapter 4 explains how these base-processes are combined into different ship-energy carrier combinations.

For work vessels (both fresh and saltwater), a separate Excel-based calculation tool has been developed. These calculations will not be incorporated into the NMD. This tool enables users to calculate all possible combinations for various work vessels. A selection of 15 transport ships has been made, which will be entered into the NMD, but these are not available in the Excel calculation tool.

Chapter 5 visually presents all results for work and transport vessels. Result tables are provided only for transport vessels, while results for work vessels are available in the Excel tool. Finally, the sensitivity analysis highlights key uncertainties. The primary purpose of these analyses is to provide an

understanding of the critical variables that influence the relative differences between energy carriers. These factors are essential for interpreting the results and should be considered in policy and investment decisions.

Context and uncertainties

The results provide a clear framework for aligning strategies. However, readers should be aware that underlying assumptions may impact the relative differences in results. The data points reflect a snapshot of currently available data and may have a wide range of variation, both now and in the future. The study covers a broad spectrum of energy carriers and technologies, each at different Technology Readiness Levels (TRL). For future energy carriers (RFNBOs), significant uncertainties exist regarding production, storage, usage, and availability. These uncertainties can influence the ECI in both positive and negative directions. The report explains these uncertainties where possible and further explores them in the sensitivity analyses.

Key findings

Fossil

At present, various fossil energy carriers can be used (such as MGO, LNG and Ultra Low Sulfur Diesel) and combustion engines with different emission classes. The fossil variantions of the innovative energy carriers are also included in this category (gray ammonia, hydrogen and methanol). For saltwater vessels, the ECI of these variants range from €45 ECI:A2 per GJ and €30 ECI:A2 per GJ. For freshwater vessels, the ECI ranges from €51 ECI:A2 per GJ to €30 ECI:A2 per GJ in the cleanest combustion engine. Compared to the ECI for the other energy carriers, the spread is limited. In conclusion, the results show that ECI reduction can be achieved in the short term by improving the emission classes of the current ships (20-30% ECI reduction compared to pre TIER/pre CCR).

Biofuels

At present, various biofuels (such as HVO, FAME, bio-LNG, and in the future, bio-methanol) can be used with various combustion engines with different emission classifications. For work vessels, the ECI of these variations ranges from €30 ECI:A2 per GJ to €10 ECI:A2 per GJ with the cleanest combustion engine. Biofuels have a low ECI but are considered a transitional fuel due to availability constraints. Bio-methanol is particularly interesting as it can also be used in fuel cells. It is the only energy carrier that allows a transition from fossil fuels to biofuels and subsequently to RFNBOs within the same energy carrier (and propulsion system).

Towards the Future – RFNBOs

Several innovative energy carriers may be used in the future. The TRL of these variants varies, and not all are currently available on the market. This category includes hydrogen (green and wind energy), synthetic ammonia, e-methanol, and electric propulsion. For saltwater work vessels, the ECI of these variants ranges from €30 ECI:A2 per GJ to €6 ECI:A2 per GJ. For freshwater work vessels, it ranges from €36 ECI:A2 per GJ to €4.8 ECI:A2 per GJ.

Battery-electric propulsion has the lowest ECI, followed by wind-electrolysis hydrogen. The RFNBO variants of methanol (e-methanol, H2 wind mix) and ammonia (synthetic ammonia, H2 wind mix) are derived from hydrogen and have a slightly higher ECI due to additional processing steps. It is crucial that hydrogen is produced from a sustainable electricity source. Hydrogen derived from the current green electricity mix scores similarly to fossil energy carriers in terms of ECI.

Summarised conclusion

The energy carriers with the lowest ECI scores result in an ECI:A2 that is four to seven times lower than that of fossil energy carriers using the oldest engines (Pre-TIER I / Pre-CCR I). This highlights the maximum achievable environmental reduction compared to the current market. The availability of sustainable energy carriers is a significant challenge for the transition in shipping. Supply follows demand; however, investments in alternative propulsion systems only yield benefits once sustainable RFNBOs become available on the market.

In the long term, access to sufficient sustainable electricity (with a low ECI) is crucial. This affects not only electric ships but also hydrogen production and the subsequent RFNBOs (such as e-methanol and synthetic ammonia). Only with sufficient sustainable electricity can the production of RFNBOs scale up.

Figure 1: Overview (from highest to low) for a selection of saltwater vessels, ECI:A2 per GJ work. Red – Fossil, Green – biofuel and blue – RFNBO.

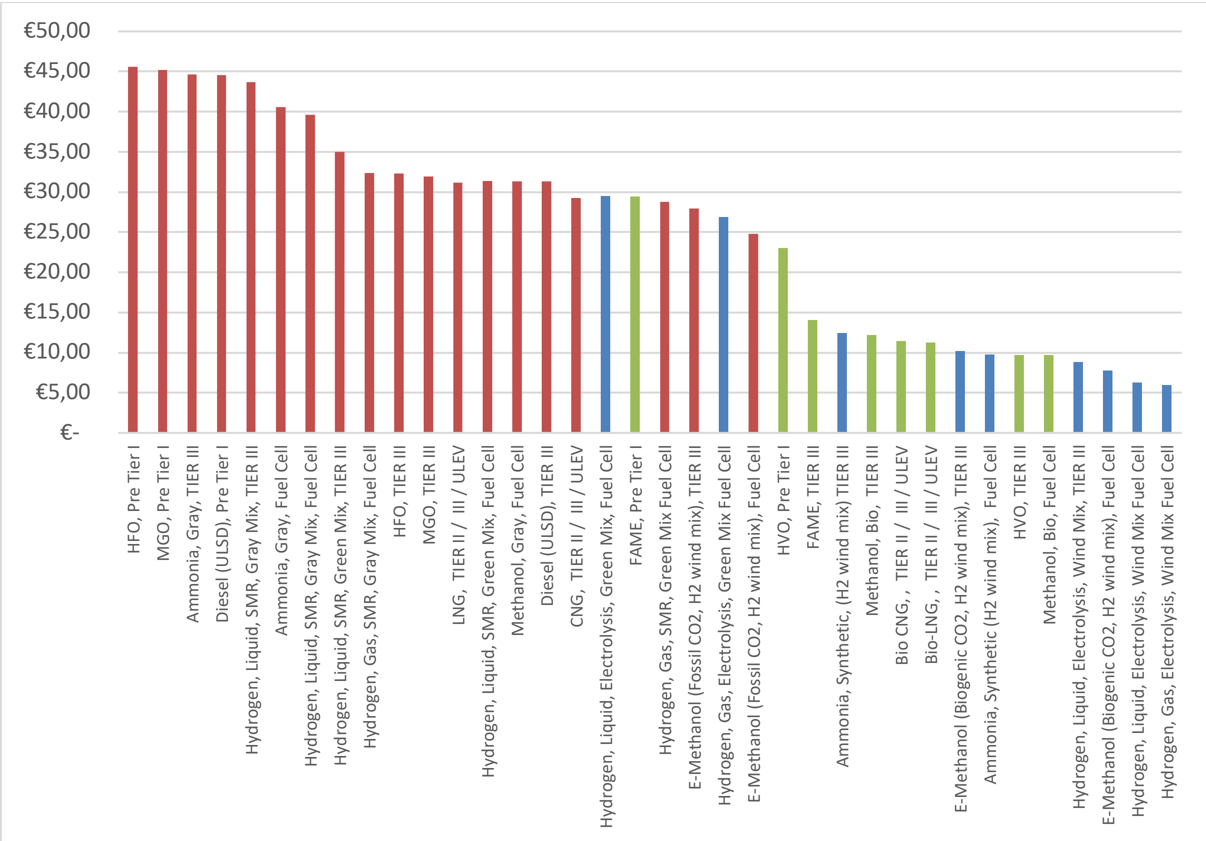
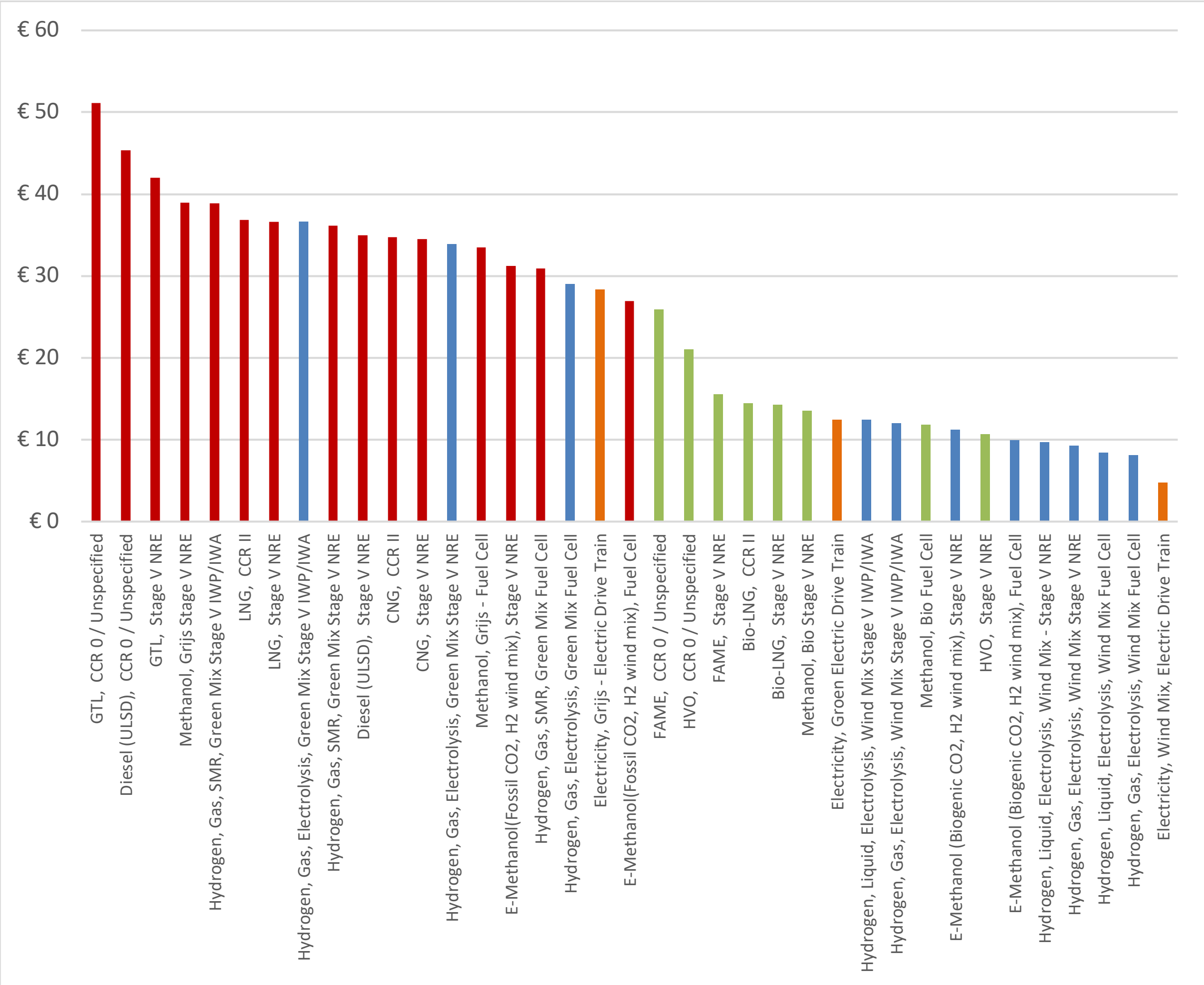


Figure 2: Overview from highest to lowest for selection of freshwater vessels, ECI:A2 per GJ work. Red – Fossil, Green – biofuel, blue – RFNBO and orange – electric.



1. Introduction

This LCA report describes the principles and results for Category 3 data in Chapter 18 *Dredging - Ship Fuels* of the National Environmental Database (*Nationale Milieudatabase*).

The GWW data in the National Environmental Database is used to calculate the *Environmental Cost Indicator* (*ECI-value*) of materials, products, and processes for the realization of a GWW project. This ECI value is calculated using the provisions in the *Determination Method for Environmental Performance of Buildings and GWW Works* (*Bepalingsmethode Milieuprestatie Gebouwen en GWW-werken*). Software tools like DuboCalc utilize the National Environmental Database to compute the ECI value for a product, object, or entire project.

Clients in the GWW sector use these ECI calculations during the design phase of a project to compare different materials, processes, or design options. They evaluate the ECI values of various solutions and can then choose the most sustainable option (the process with the lowest ECI value). Additionally, an award criterion can also be applied in the tendering of a project where the bidder with the lowest ECI value receives the highest fictitious discount.

Stichting NMD aims to regularly update and improve the Category 3 data in the National Environmental Database. Everyone can provide input on these updates. The *Accountability* (*Verantwoording*) section explains how improvement suggestions for Category 3 data can be submitted to Stichting NMD.

Category 3 data is automatically updated when Stichting NMD revises the NMD basic process database. This can occur due to an update of the *EcoInvent* database or modifications in end-of-life processing scenarios. As a result, the values described in this report may become outdated. This report specifies which versions of the *NMD Basic Process Database*(*NMD-Basisprocessendatabase*) and the *Determination Method* (*Bepalingsmethode*) were used for data development and reporting. The most recent Category 3 data is always available in validated calculation tools such as DuboCalc.

Objective and target audience

This study establishes environmental profiles for *Ship Fuels* (*Dredging, Construction Work, Foundation Work, and Transport*) based on Chapter 18 of the *RAW Bepalingen 2020*. The study aims to supplement and improve Category 3 product cards in the National Environmental Database (NMD). The present report documents material choices and environmental data as justification. Alongside the entered product cards, the report will be submitted to the NMD and made available to the sector via calculation tools and the website.

This study is intended for the following audiences:

- Stichting NMD, as the administrator of the NMD.
- Clients in the GWW sector, as a basis for reference designs, exploratory (design) studies, and use in procurement.
- Market players**,** such as engineering and consulting firms and contractors active in the GWW-sector, as a source of information for using NMD data in calculation tools.
- LCA developers, to gain insight into the assumptions underlying Category 3 data.

Accountability

The LCA was conducted in accordance with the requirements and guidelines of the *Protocol for Developing and Peer Reviewing Category 3 Product Cards GWW*, which aligns with the *Determination Method for Environmental Performance of Buildings and GWW Works*. This method is based on the latest versions of ISO 14040 - ISO 14044 and NEN-EN 15804-A2.

The LCA was carried out by Stijn Mulder of EcoReview NL B.V. on behalf of the Port of Rotterdam, Rijkswaterstaat and the Vereniging van Waterbouwers. The data collection took place in the period from June 2024 to February 2025, after which the calculations were carried out and the LCA file was drawn up.

The data collection was carried out by Stijn Mulder (EcoReview) in collaboration with Jorrit Harmsen (TNO). The data obtained was reviewed and discussed with a dedicated technical committee. This committee was formed by relevant market parties including; Boskalis, de Klerk Waterbouw, Van den Herik, Rijkswaterstaat, Van Oord and the Vereniging van Waterbouwers . The provided data represents the state of affairs at the time of writing. Readers should be aware that underlying data points and parameters may change over time.

The LCA dossier drawn up in the context of this study has not been fully assessed in accordance with the assessment protocol by a recognised LCA expert. However, the study has been tested by Martijn Van Hovell (SGS) through a "peer review" in accordance with "Protocol Drafting and Peer Reviewing category 3 product cards GWW". This cross-check assessed aspects such as product composition assumptions and material use based on design and practical knowledge. The calculation method was also verified.

The product cards derived from this study are managed by **Stichting NMD**. The study has been conducted with due care. However, if a third party believes that the entered product cards or this report contain errors, a request for rectification can be submitted to **Stichting NMD**. Such requests will be handled according to their procedures. Requests can be sent via email to **info@milieudatabase.nl**.

Reader's Guide

- **Chapter 2** describes the LCA methodology, including scope, system boundaries, and functional unit definitions.
- **Chapter 3** contains the life cycle inventory, including product descriptions, composition, and life cycle inventory data. Additionally, all combinations based on basic processes are established.
- **Chapter 5** presents the results, hotspot analysis, and specific sensitivity analyses.
- **Chapter 6** summarizes the conclusions.

2. Method

Approach

This report details all (sub)products within RAW Chapter 18, which are listed as product cards in the NMD. For all sub-products, foreground and background data have been collected following the requirements and guidelines from the Protocol for Developing and Peer Reviewing Category 3 Product Cards GWW, with all components and accompanying justifications documented.

Scope

This study focuses on Chapter 18 of the *Standaard RAW Bepalingen 2020* (CROW, 2020), including:

- Ship fuels for dredging and marine works (saltwater)
- Ship fuels for dredging and marine works (freshwater)
- Ship fuels for maritime transport (seagoing vessels)
- Ship fuels for inland waterway transport

The scope of this LCA report covers work vessels (freshwater and saltwater) and transport (inland waterways and seagoing). During work sessions with the technical committee, relevant and commonly used combinations were determined. Based on these discussions, the following table was compiled. Due to the wide variety of combinations within work vessels, it was decided in consultation with stakeholders to cover these environmental profiles using an Excel calculation tool. An Excel tool has been developed for all work vessels, allowing users to create combinations of freshwater/saltwater, drivetrain, energy carrier, and emission class. This tool is a verified calculation instrument that enables users to generate an environmental profile for all possible energy carrier combinations.

The transport cards will not be part of the Excel tool but will be entered into the NMD as Category 3 cards. Unlike the work vessels, no differentiation is made between emission classes for transport cards; instead, the market-average mix is used.

Table 1: Overview of the scope of cat.3. report marine fuels, work and transport.

Propulsion system	Energy carrier	Excel tool		cat. 3. Profiles	
		Work vessels Salt	Work vessels fresh water	Transport salt	Transport fresh
Combustion engine	Diesel	Pre Tier I	CCR0	N/A.	CCR market mix
		TIER I / II	CCRI		
		TIER III	CCR II		
		ULEV	Stage V (2x)		
	HFO	Pre Tier I	N.V.T.	Market mix TIER	N.V.T.
		TIER I / II	N.V.T.		
		TIER III	N.V.T.		
		ULEV	N.V.T.		
	GTL	N.V.T.	CCR0	N.V.T.	N.V.T.
		N.V.T.	CCRI		
		N.V.T.	CCR II		
		N.V.T.	Stage V (2x)		
	MGO	Pre Tier I	N.V.T.	Market mix TIER	N.V.T.
		TIER I / II	N.V.T.		
		TIER III	N.V.T.		
		ULEV	N.V.T.		
	LNG	N.V.T.	N.V.T.	Market mix TIER	N.V.T.
		N.V.T.	N.V.T.		
		TIER II / III	CCR II		
		ULEV	Stage V (2x)		
	Bio-LNG	N.V.T.	N.V.T.	Market mix TIER	N.V.T.
		N.V.T.	N.V.T.		
		TIER II / III	CCR II		
		ULEV	Stage V (2x)		
	CNG	N.V.T.	N.V.T.	Market mix TIER	CCR market mix
		N.V.T.	N.V.T.		
		TIER II / III	CCR II		
		ULEV	Stage V (2x)		
	Bio-CNG	N.V.T.	N.V.T.	N.V.T.	N.V.T.
		N.V.T.	N.V.T.		
		TIER II / III	CCR II		
		ULEV	Stage V (2x)		
	HVO	Pre Tier I	CCR0	N.V.T.	CCR market mix
		TIER I / II	CCRI		
		TIER III	CCR II		
		ULEV	Stage V (2x)		
	FAME	Pre Tier I	CCR0	Market mix TIER	CCR market mix
		TIER I / II	CCRI		
		TIER III	CCR II		
		ULEV	Stage V (2x)		
	Ammonia	N.V.T.	N.V.T.	N.V.T.	N.V.T.
		N.V.T.	N.V.T.		
		TIER III (2 versions)	N.V.T.		
		ULEV (2 versions)	N.V.T.		
	Methanol	N.V.T.	N.V.T.	N.V.T.	N.V.T.
		N.V.T.	N.V.T.		
		TIER III (4 versions)	N.V.T.		
		ULEV (4 versions)	Stage V (2x)		
	Hydrogen	N.V.T.	N.V.T.	TIER III	Stage V
		N.V.T.	N.V.T.		
		TIER III (10 versions)	N.V.T.		
		ULEV (10 versions)	Stage V (2x)		
Fuel cell	Hydrogen	10 versions	Within Scope	N.V.T.	N.V.T.
	Ammonia	2 versions	N.V.T.	N.V.T.	N.V.T.
	Methanol	4 versions	Within Scope	N/A.	N/A.
Battery	Electric	N.V.T.	Within Scope	N/A	Green Mix

System boundaries

The processes that are examined within the LCA are demarcated with so-called system boundaries. The system boundaries determine which phases and processes of the life cycle are included in the LCA. In Table 1, following from the EN 15804 and the Determination Method, it is laid down which information must be considered per life cycle phase. This LCA takes into account the environmental impact over the entire life cycle, whereby in Table 1, the product cards that have different system boundaries are also included.

The LCA considers the use of energy carriers in a specific ship. The energy carriers themselves are consumed and have no benefits and expenses in module D. From a pragmatic point of view, both the income and costs for processing the capital goods have been included in module B.

	Production phase			Construction phase		Usage phase					Demolition and processing phase				Next production system
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
	Extraction of raw materials	Transport	Production	Transport	Construction and ...	Use	Maintenance	Repair	Replacements	Alterations	Demolition	Transport	Waste manageme...	Final waste disposal	Reuse, recovery and recycling options
Marine fuels	x	x	x	x	NA	x	NA	NA	NA	NA	NA	NA	NA	NA	x

Table 1: System boundaries (X: Module included in LCA study, ND: not declared)

In the background processes used, at least the following interventions were included in the analysis:

- emissions to the air when using thermal energy of CO_2, CO, NOx (N_2), SO_2, CxHx and particulate matter (PM10 particles < 10µm);
- emissions to water from CVZ, BOD, P-total, N-total and solids (PM10: particles < 10µm);
- emissions of PAH and heavy metals to soil.

3. Life Cycle Inventory (LCI)

This chapter discusses the product description, product composition and the decomposition of the parts, as described in the scope of chapter 2.

Data collection

To determine the product composition, the use of materials and the associated processes, generic / average products and processes were used, which are representative of the (sub)product including substantiation. For each (sub)product, the starting points and sources are described for each module and based on:

- Fixed background processes, transport distances and scenarios in accordance with the NMD Determination Method
- Desk research, at least 2 different documented and recorded sources if available
- Expert judgement: practical information (civil engineering knowledge) from an engineering firm, contractor, client and/or producer, including a brief substantiation of the expert's background. At least 2 different sources if available.
- Similar category 3 product cards in similar applications

To calculate the life cycle assessment, data were collected from the various production processes that fall within the system boundaries of this LCA study. In the elaboration, attention was paid to the *precision*, *completeness*, *representativeness*, *consistency* and *reproducibility* of the data in accordance with requirements and guidelines from the "Protocol Drafting and Peer Review category 3 product cards GWW".

From the NMD process database, the Determination Method also provides fixed values for the most important background processes that must be used.

3.1 LCI Base Processes

This chapter describes the LCI of all base processes that are required to make up all combinations from Table 1. The basic processes are divided into three categories: Energy carriers, Emission profile and Capital goods. These basic processes will form the basis for the various ship-energy carrier combinations. Both for work vessels (fresh and salt water) and for transport (inland shipping and seagoing).

3.1.1 Energy carriers

The table below shows all the basic processes for the energy carriers. These will be described and explained one by one in this chapter.

Table 2: List of energy carriers

No	Name
1	Diesel (ULSD)
2	HFO
3	GTL
4	MGO
5	LNG
6	Bio-LNG
7	CNG
8	Bio-CNG
9	HVO
10	FAME
11	Ammonia, Synthetic (H2 Wind mix)
12	Ammonia (Grey)
13	Hydrogen Electrolysis Green (Liquid)
14	Hydrogen Electrolysis Green (Gas)
15	Hydrogen Electrolysis Grey (Liquid)
16	Hydrogen Electrolysis Grey (Gas)
17	Hydrogen Electrolysis Wind (Liquid)
18	Hydrogen Electrolysis Wind (Gas)
19	Hydrogen Steam Methane Reforming (Liquid)
20	Hydrogen Steam Methane Reforming (Gas)
21	Methanol (Grey)
22	Methanol (Bio)
23	E-Methanol (fossil CO2, H2 Wind mix)
24	E-Methanol (biogenic CO2, H2 Wind mix)
25	Electricity Green
26	Electricity Grey
27	Electricity: Wind, Sea
28	Electricity, Wind Land
29	Electricity Wind Mix
30	Urea

The table below shows the various properties of all energy carriers. For each energy carrier, the functional unit used for the LCI is shown, in most cases this is "tons". This unit refers to the production and use of 1 ton of energy carrier in a ship. In the supplied Excel calculation tool, it will also be possible for the user to select litres, if this unit better suits the user's wishes.

In addition to the functional unit, the properties of the energy carriers are also provided. These are used to determine the depreciation of the capital goods. From a pragmatic point of view, the capital good (for example, the ship's hull) is depreciated per tonne of diesel (based on service life in years and annual fuel consumption). However, this approach is not realistic for energy carriers with differing energy content—hydrogen, for instance, has nearly three times the energy density (MJ per tonne) of diesel. For this reason, the efficiency of the propulsion system is included, so that the amount of work delivered per functional unit can be calculated for each combination. Based on the work performed, the depreciation of capital goods is thus scaled accordingly. The impact of this on the overall Environmental Cost Indicator (ECI) is minor

For the work vessels (fresh and salt) the return only affects the depreciation of the capital goods and the comparison between the energy carriers based on GJ work. This is because consumption is not included in the functional unit, the total amount of energy carrier consumed is determined project-specific by the user. However, the efficiency does apply to the transport cards, because the functional unit here is ton*km (moving 1 ton of goods over a distance of 1 kilometre). Here, the efficiency determines the total amount of energy carrier needed per tonne*km. However, this has no effect on the differences between them.

The Diesel yields are based on general estimates provided by TNO for fresh (work and inland) vessels and saline (seagoing and work) vessels. It concerns fleet average data over various ships. These are based on two-stroke engines (lower efficiency) for freshwater ships and more efficient four-stroke engines for salty ships. The engine type and the engine load play an important role in the efficiency of the drive. Since the data for a wide range of ships should be representative, the values in Table 3 are used. For example, work boats have various engines, all of which can have a different efficiency (this can also be higher for work engines). There is no detailed insight into the spread of the return.

After consultation with technical specialists at TNO, it has become plausible that the efficiencies of the alternative fuels H2 and Methanol remain comparable to diesel. This is also supported by practical data from dry equipment and (small) maritime engines.

Table 3: Properties of energy carriers and drivetrains.

Propulsion system	Energy-carrier	FU	MJ (input per kg)	ton/m3	Efficiency of propulsion freshwater vessels	MJ unit labour	Efficiency of propulsion saltwater vessels	MJ per labour unit	Remarks
Combustion engine	Diesel	tone	43,1	0,832	0,4	17.240	0,45	19.395	
	HFO	tone	40,5	0,95	0,4	16.200	0,45	18.225	Depending on the quality and composition. MJ/kg can vary between 40 and 42 and density can range from 900 to 1,000.
	GTL	tone	44	0,78	0,4	17.600	0,45	19.800	
	MGO	tone	42,6	0,85	0,4	17.040	0,45	19.170	
	LNG	tone	49	0,428	0,4	19.600	0,45	22.050	
	Bio-LNG	tone	49	0,428	0,4	19.600	0,45	22.050	
	CNG	tone	46,3	0,215	0,4	18.520	0,45	20.835	At 250 bar
	Bio-CNG	tone	46,3	0,215	0,4	18.520	0,45	20.835	At 250 bar
	HVO	tone	44	0,78	0,4	17.600	0,45	19.800	
	FAME	tone	37,2	0,89	0,4	14.880	0,45	16.740	
	Ammonia	tone	18,6	0.6819	0,4	7.440	0,45	8.370	Liquid at -33 degrees
	Hydrogen Liquid	tone	120	0,07085	0,4	48.000	0,45	54.000	
	Hydrogen Gas	tone	120	0,039	0,4	48.000	0,45	54.000	At 700 bar
	Methanol	tone	19,9	0,79	0,4	7.960	0,45	8.955	
Fuel cell	Ammonia	tone	18,6	0.6819	0,47	8.742	0,47	8.742	Liquid at -33 degrees
	Hydrogen Liquid	tone	120	0,07085	0,47	56.400	0,47	56.400	Efficiency of the fuel cells including electric propulsion estimated by TNO at 47%. Highly dependent on load, currently 45-50% realistic and increased efficiency in the future (50-55%).
	Hydrogen Gas	tone	120	0,039	0,47	56.400	0,47	56.400	At 700 bar
	Methanol	tone	19,9	0,79	0,47	9.353	0,47	9.353	
Battery electric	Electric	kWh (input)	3,6	-	0,765	2.754	0,765	2,75	with Li-ion batteries η = 0.9 x η = 0.85 (efficiency charging/discharging Li-ion) gives efficiency of 77%

Fossil energy carriers

Diesel

For Diesel, an NMD process is already available from dry equipment "Well-to-tank Diesel (A1-A4)". The modelling of production (A1-A3) has been adjusted to the market mix of 2023. This is shown in Tabel 5 and Tabel 6 which reflects the adjusted Petroleum market mix. The petroleum market process has been adjusted based on (Eurostat 2024). The transportation of the petroleum contributes significantly to the ECI:A2 (+/- 16%). However, there is no data on all production locations and the specific transport routes via tanker and pipeline. For this reason, the transport has been taken from the existing EcoInvent dataset. The modelling of module A4 has been maintained as it is currently defined in the basic processes database.

Table 4: A1-A4 Diesel (ULSD)

Process	Phase	Environmental profile	Database / source	Quantity	Unit	Principles
Production	A1-A3	Energy carrier Diesel A1-A3 (Market mix 2023) Diesel, low-sulphur {Europe without Switzerland}| diesel production, low-sulphur, petroleum refinery operation | Cut-off, U	E.I. 3.9	1	tone	Custom EcoInvent market mix Diesel dataset, based on Tabel 5 in Tabel 6
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tonkm	150km transport
Storage	A4	Diesel, low-sulphur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	NMD	1	tone	

Tabel 5: Market mix 2023 Petroleum import, based on import data Eurostat.

Origin	Quantity	Unit	Percentage	Transport distance (ship)
Brazil	5229	tone	5%	10000
Great Britain	14.648	tone	14%	-
Iraq	6475	tone	6%	12330
Nigeria	7964	tone	8%	7780
Norway	10.806	tone	11%	1211
Russia	6822	tone	7%	-
U.S.A.	21.392	tone	21%	5317
Remaining - Egypt - Guyana - Angola - Remaining	28.613 - 5605 - 4564 - 4024 - 14.420	tone	28%	6400 (Egypt)
Total	101.949	tone	100%	3654

The table below shows all references for the adjusted petroleum market dataset in EcoInvent 3.9. However, not all of these references are available in EcoInvent 3.6. The modelling for the dataset in EcoInvent 3.6 can be found in Appendix 2 (Tabel 103).

Tabel 6: Adjusted market mix Petroleum {Europe without Switzerland}| market for petroleum | Cut-off, U

Process	Phase	Environmental profile	Database / source	Quantity	Unit	Principles
Production Brazil	A1-A3	Petroleum {BR}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	4.96E-02	kg	97% offshore in EcoInvent dataset
Production Brazil	A1-A3	Petroleum {BR}| petroleum and gas production, onshore | Cut-off, U	E.I 3.9	1.69E-03	kg	3% onshore in EcoInvent dataset
Production Great Britain	A1-A3	Petroleum {GB}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	1.41E-01	Kg	98% offshore in EcoInvent dataset
Production Great Britain	A1-A3	Petroleum {GB}| petroleum and gas production, onshore | Cut-off, U)	E.I 3.9	2.87E-03	kg	2% onshore in EcoInvent dataset

Production Iraq	A1-A3	Petroleum {IQ}| petroleum and gas production, onshore | Cut-off, U	E.I 3.9	6,35E-02	kg	-
Production Nigeria	A1-A3	Petroleum {NG}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	7.03E-02	kg	-
Production Norway	A1-A3	Petroleum {NG}| petroleum and gas production, onshore | Cut-off, U	E.I 3.9	7.81E-03	kg	90% offshore in EcoInvent dataset
Production Norway	A1-A3	Petroleum {NO}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	1.06E-01	kg	10% onshore in EcoInvent dataset
Production Russia	A1-A3	Petroleum {RU}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	1.19E-02	kg	18% offshore in EcoInvent dataset
Production Russia	A1-A3	Petroleum {RU}| petroleum and gas production, onshore | Cut-off, U	E.I 3.9	5,50E-02	kg	82% onshore in EcoInvent dataset
Production: U.S.A.	A1-A3	Petroleum {US}| petroleum and gas production, offshore | Cut-off, U	E.I 3.9	3.06E-02	kg	15% offshore in EcoInvent dataset
Production: U.S.A.	A1-A3	Petroleum {US}| petroleum and gas production, onshore | Cut-off, U	E.I 3.9	1.79E-01	kg	85% onshore in EcoInvent dataset
Production Other	A1-A3	Petroleum {RoW}| petroleum and gas production, on-shore | Cut-off, U	E.I 3.9	2.81E-01	kg	-
Transport	A1-A3	Transport, freight, sea, tanker for petroleum {GLO}| market for transport, freight, sea, tanker for petroleum | Cut-off, U	E.I 3.9	3,654	tonkm	Adjusted to weighted average off Tabel 5
Transport	A1-A3	Transport, pipeline, offshore, petroleum {GLO}| market for transport, pipeline, offshore, petroleum | Cut-off, U	E.I 3.9	0,044997	tonkm	Unadjusted transport distances taken from the EcoInvent market mix. Values are considered representative (2100 km of transport via pipelines)
Transport	A1-A3	Transport, pipeline, onshore, petroleum {RER}| market for transport, pipeline, onshore, petroleum | Cut-off, U	E.I 3.9	2,0545	tonkm	
Emissions to air	A1-A3	Emissions to air	E.I 3.9	-	kg	Maladjusted

HFO

For HFO, the production dataset from EcoInvent has been used for A1-A3 and for module A4 the "market for" dataset has been adjusted. The "market for" dataset contains the production and the associated transports to the user. The production of HFO (A1-A3) has been removed from the "market for" dataset, so that only the transports to the user and the infrastructure are included in the A4 dataset.

Tabel 7: A1-A4 HFO

Process	Phase	Environmental profile	Database / source	Quantity	Unit	Principles
HFO production	A1-A3	Heavy fuel oil {Europe without Switzerland}| heavy fuel oil production, petroleum refinery operation | Cut-off, U	E.I. 3.9	1	tone	Taken from EcoInvent
Transport and storage	A4	Heavy fuel oil {Europe without Switzerland}| market for heavy fuel oil | Cut-off, U	E.I. 3.9	1	tone	"Market for" card without production. Includes transportation, capital goods for regional distribution, waste disposal, and power consumption.

GTL

For GTL, an A1-A4 dataset is already available in the NMD. The modules A1-A3 modelling has been based on the existing NMD profile and converted to the functional unit "tonnes". After going through the existing dataset for GTL, it was found that the existing dataset is still representative. In order to remain consistent with the other datasets in this report, the data on consumption for storage has been adjusted based on JEC 2020 data. For the module A4, transport to the Netherlands and energy for storage and distribution are included based on JEC 2020 data. Subsequent, there may be additional transport by inland vessel, depending on where it is used. However, the contribution of such transport is minimal (+/-4% to module A4), for this reason it is not included in this LCI.

Table 8: A1-A4 GTL, per ton

Process	Phase	Environmental profile	Database / source	Quantity	Unit	Principles
Feedstock1	A1-A3	Natural gas, high pressure {QA}| petroleum and gas production, offshore | Cut-off, U	E.I. 3.9	44.000 / 37,5 = 1173,3	m3	LHV 44 MJ/kg for GTL and an average of 37.5 MJ/m3 for natural gas from Qatar. No specific import statistics. Keeping Qatar as its origin.
Methane losses	A1-A3	Methane, to air (low-pop)	E.I. 3.9	8,0E-5 * 44000 = 3,52	kg	0,08 gr/MJ natural gas (JEC 2020)
Electricity for GTL depot	A1-A3	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, U	E.I. 3.9	35,2	MJ	0,0008 MJ per MJ GTL (JEC 2020)
Process heat	A1-A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U (aangepast voor GTL tbv. categorie 3 data brandstofprocessen)	E.I. 3.9	44000 / 0,65 * 0,35 = 23.692	MJ	65% efficiency of large-scale GTL plant. This means that 65% of the energy input from natural gas ends up in the GTL energy carrier and the remaining 35% is needed as process heat. (JEC 2020)
Capital goods	A1-A3	Chemical factory, organics {RER}| chemical factory construction, organics | Cut-off, U	E.I. 3.9	4.0E-10	p	Based on Ammonia steam reforming process profiles.
Transport to the Netherlands	A4	Transport, freight, sea, tanker for liquid goods other than petroleum and liquefied natural gas {GLO}| transport, freight, sea, tanker for liquid goods other than petroleum and liquefied natural gas | Cut-off, U	E.I. 3.9	11.800	tonkm	Origin Qatar (JEC 2020)
Storage Ship	A4	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	NMD	44000 * 0,0008 = 35,2	MJ	0,0008 MJ per MJ GTL (JEC 2020)
Storage Land	A4	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	NMD /	44000 * 0,0008 = 35,2	MJ	0,0008 MJ per MJ GTL (JEC 2020)

1Geography Qatar not available in EcoInvent 3.6, for the EcoInvent 3.6 profiles see Tabel 104: A1-A4 GTL, per ton

MGO

For MGO, the existing profiles have been taken from the NMD (Table 9) only the origin of Diesel has been adjusted (see LCI Diesel).

Table 9: A1-A4 MGO

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Feedstock	A1-A3	Energy carrier Diesel A1-A3 (Market mix 2023) Diesel, low-sulphur {Europe without Switzerland}| diesel production, low-sulphur, petroleum refinery operation | Cut-off, U	E.I. 3.9	1	tone	Custom market mix Diesel dataset, based on Tabel 5 and Tabel 6
Storage	A4	Diesel, low-sulphur {Europe without Switzerland}| market for | Cut-off, U - COPY with removed inputs belonging to A1-A3	NMD	1	barrel	This is a processed EcoInvent process profiles available in the basic process database, where transport and the fuel itself are set to 0 to avoid double counting.
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tkm	A flat-rate transport distance of 150 km was maintained, because bunkering does not always take place in Rotterdam.

LNG

For LNG, the modelling has been checked and used as a basis. The origin of the gas and the consumption for liquefaction and charging have been adjusted. The feedstock composition is based on import figures from HBR in Q1-3 2023. The percentages are shown in the table below. For module A4 the NMD profile has also been adopted, here the average transport distance has been adjusted based on the new natural gas mix. The transport distances are shown in (TNO 2021) (Eurostat 2024) (Table 11).

Tabel 10: A1-A4 LNG

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Natural Gas USA	A1-A3	Natural gas, high pressure {US}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	1361* 0,64 = 871	m3	Total 49,000 MJ/ton and average energy content of natural gas 36 MJ/m3 means 1361 m3 of natural gas, of which 64% from U.S.A.
Natural gas Norway	A1-A3	Natural gas, high pressure {NO}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	1361* 0,09 = 123	m3	9% Norway at 1306 m3 per ton
Natural gas Angola	A1-A3	Natural gas, high pressure {RoW}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	1361* 0,06 = 81,7	m3	6% Angola, (ROW chosen) at 1306 m3 per tonne
Natural gas Qatar	A1-A3	Natural gas, high pressure {QA}| petroleum and gas production, onshore | Cut-off, U	E.I. 3.9	1361* 0,05 * 0,307 = 20,9	m3	5% Qatar of which 31% onshore
Natural gas Qatar	A1-A3	Natural gas, high pressure {QA}| petroleum and gas production, offshore | Cut-off, U	E.I. 3.9	1361* 0,05 * 0,693 = 47,2	m3	5% Qatar of which 69% offshore
Natural gas Other	A1-A3	Natural gas, high pressure {RoW}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	1361* 0,11 = 150	m3	11% other
Natural gas Russia	A1-A3	Natural gas, high pressure {RU}| petroleum and gas production, offshore | Cut-off, U	E.I. 3.9	1361* 0,05 * 0,177 = 12,1	m3	5% Russia of which 17.7% offshore
Natural gas Russia	A1-A3	Natural gas, high pressure {RU}| petroleum and gas production, onshore | Cut-off, U	E.I. 3.9	1361* 0,05 * 0,823 = 56	m3	5% Russia of which 82.3% onshore
Electricity for Liquefaction	A1-A3	Electricity, high voltage {RoW}| electricity production, natural gas,	E.I. 3.9	0,0246*49000 = 1205	MJ	0,0246 MJ/MJ LNG (JEC 2020)

		combined cycle power plant | Cut-off, U				
Infrastructure	A1-A3	Natural gas processing plant {GLO}| market for natural gas processing plant | Cut-off, U	E.I. 3.9	8,36E-13/0,428 = 1,95E-12	p	Unadjusted (EcoInvent dataset process "Natural gas, liquefied {RoW}| production | Cut-off, U") value in E.I. per m3 corrected by LNG density (0.428 kg/m3)
Electricity for loading terminal	A1-A3	Electricity, high voltage {RoW}| electricity production, natural gas, combined cycle power plant | Cut-off, U	E.I. 3.9	0,0009*49000 = 44,1	MJ	0,0009 MJ/MJ LNG (JEC 2020)
Energy for loading terminal	A1-A3	Heat, district or industrial, natural gas {RoW}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	0,01*49000= 490	MJ	0,01 MJ/MJ LNG (JEC 2020)
Process Emissions	A1-A3	Methane, fossil to air	E.I. 3.9	1,666	kg	0,034 g/MJ LNG (JEC 2020)
Natural gas flare	A1-A3	Waste refinery gas {GLO}| treatment of waste refinery gas, burned in flare | Cut-off, U	E.I. 3.9	0,0113 * 49000 = 553,7	MJ	0,0113 MJ/MJ LNG (JEC 2020)
Transport	A4	Transport, freight, sea, tanker for liquefied natural gas {GLO}| transport, freight, sea, tanker for liquefied natural gas | Cut-off, U	E.I. 3.9	5366	tkm	Weighted average by countries of origin Table 11.
Power consumption terminal offtake location	A4	Electricity, medium voltage {NL}| market for electricity, medium voltage | Cut-off, U	E.I. 3.9	44,1	MJ	0,0009 MJ/MJ LNG (JEC 2020)
Energy consumption terminal offtake location	A4	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	490	MJ	0,01 MJ/MJ LNG (JEC 2020)

Table 11: Transport distances A4 LNG

Origin	Transport distance (km)	Quantity	Remark
Angola	8934	6%	Angola to Rotterdam
USA	6265	64%	USA (N.Y.) to Rotterdam
Norway	1256	9%	Aalesund to Rotterdam
Remaining	-	*11%*	*Weighted average distance from all origins*
Qatar	11747	5%	Doha to Rotterdam
Russia	2405	5%	St. P Burg to Rotterdam
Weighted average	5366	100%	*Weighted average distance from all origins*

CNG

The import of gas to the Dutch market consists partly of imported LNG and partly of imported natural gas. It is possible to make natural gas again from LNG and distribute it. However, this CNG profile is based on the supply of natural gas and the LNG route is not included in the modelling. For the origin of natural gas, import data from Statistics Netherlands from the year 2023 has been used ((CBS 2024)

Table 13). Not all geographies are available for the Dutch import market. For this reason, the Belgian EcoInvent datasets were used for natural gas imported from Belgium and Germany. Compression and methane loss at the offtake location have been modelled for in module A4. (CBS 2024)

Table 12: A1-A4 CNG per ton.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Natural gas mix	A1-A3	Sub dataset energy carrier natural gas mix 2023 (natural gas origin 2023 adjusted, based	Own menu	1000/0,735 = 1360	m3	EcoInvent NL market mix adjusted with data from 2023 (CBS 2023). Natural gas

		on Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U)				feedstock density based on natural gas feedstock EcoInvent dataset, 0.735 kg/m3 (1bar)
User compression	A4	Electricity, medium voltage {NL}| market for electricity, medium voltage | Cut-off, U	E.I. 3.9	0,022 * 46300 = 1019	MJ	0.022 MJ/MJ CNG. Energy content CNG is 46.3 MJ/kg. (JEC 2020)
Methane emissions	A4	Methane, to air, low-pop	E.I. 3.9	1,0E-7 * 46300 = 4,63E-3	kg	1.0E-07 kg per MJ CNG. Energy content CNG is 46.3 MJ/kg. (JEC 2020)

Table 13: Sub dataset natural gas mix 2023, based on Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U, per m3.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Natural gas	A1-A3	Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	0,001	m3	Losses, acquisition from EcoInvent dataset.
Natural gas NL	A1-A3	Natural gas, high pressure {NL}| natural gas, high pressure, domestic supply with seasonal storage | Cut-off, U	E.I. 3.9	0,2666	m3	26.7% Extraction in the Netherlands
Natural gas Norway	A1-A3	Natural gas, high pressure {NL}| natural gas, high pressure, import from NO | Cut-off, U	E.I. 3.9	0,261+0,024 = 0,285	m3	26.1% Norway and 2.4% Denmark. No import card for Denmark so also modelled Norway.
Natural gas Great Britain	A1-A3	Natural gas, high pressure {NL}| natural gas, high pressure, import from GB | Cut-off, U	E.I. 3.9	0,05707	m3	5.7% imports from Great Britain
Natural gas Belgium	A1-A3	Natural gas, high pressure {BE}| market for natural gas, high pressure | Cut-off, U	E.I. 3.9	0,249	m3	24.9% imports from Belgium. No import profiles to NL available, Belgian market-for profiles modelled.
Natural gas Germany	A1-A3	Natural gas, high pressure {BE}| import from DE | Cut-off, U	E.I. 3.9	0,142	m3	14.2% imports from Germany. No profiles for import to NL, profiles German gas import modelled to Belgium.
Transport	A1-A3	Pipeline, natural gas, high pressure distribution network {Europe without Switzerland}| pipeline construction, natural gas, high pressure distribution network | Cut-off, U	E.I. 3.9	3.84E-8	km	Acquisition of EcoInvent, distance inappropriate due to lack of distance data from natural gas pipeline network. Contribution to ECI:A2 is only 1.2%.
Process	A1-A3	Natural gas, burned in gas turbine {NL}| natural gas, burned in gas turbine | Cut-off, U	E.I. 3.9	0,176	MJ	EcoInvent dataset
Emissions to air	A1-A3	Butane, to air	E.I. 3.9	6,64E-06	kg	EcoInvent dataset
Emissions to air	A1-A3	Carbon dioxide, fossil, to air	E.I. 3.9	2.40E-05	kg	EcoInvent dataset
Emissions to air	A1-A3	Ethane, to air	E.I. 3.9	5,74E-05	kg	EcoInvent dataset
Emissions to air	A1-A3	Methane, fossil, to air	E.I. 3.9	6.93E-04	kg	EcoInvent dataset
Emissions to air	A1-A3	NMVOC, non-methane volatile organic compounds	E.I. 3.9	4.78E-07	kg	EcoInvent dataset
Emissions to air	A1-A3	Propane	E.I. 3.9	1.29E-05	kg	EcoInvent dataset

Table 14: Ratio of imports and extraction of gaseous natural gas 2023 (CBS).

Origin	Quantity (m3)	Ratio (%)
Winning NL	11.208	26,7%
Norway	10.974	26,1%
Germany	5.972	14,2%

Belgium	10.468	24,9%
Great Britain	2.399	5,7%
Denmark	1.010	2,4%
Total	42.031	100,0%

Biofuels

The following tables will show the LCI of the various biofuels. For these fuels, additional corrections must be made for the biogenic carbon present in the fuel/energy carrier. The carbon in the energy carrier is absorbed from the air (negative (<0) contribution to biogenic climate change in production) and during use (combustion) this carbon is released again. During the use or production of the energy carrier, greenhouse gases with a higher GWP can be released from the biogenic carbon, this mainly concerns methane emissions. Methane contains 1 carbon atom, which therefore has a negative biogenic climate change impact of 1 kg CO2-eq (in A1-A3). However, methane has a GWP of 28 kg CO2-eq when emitted to air (in module-B).

For all biofuels, a correction is made to align the carbon content of the fuel with the CO2 emissions from combustion, resulting in a net-zero carbon balance. The contribution of methane emissions in production and during the use phase is counted as a positive (>0) contribution to biogenic climate change.

Bio-LNG

For Bio-LNG, the production values from TNO, 2016 have been taken and the biogas profiles has been created using the composition of (NEA 2023). The EcoInvent dataset "Biomethane, high pressure {CH}| biogas purification to biomethane by pressure swing adsorption | Cut-off, U" has been taken over and only the source of the biogas and the applied power mix has been adjusted (Table 16). This composition and modelling is shown in Table 16.

For biofuels, it is relevant that the biogenic carbon uptake in A1-A3 (negative values (<0) because the fuel itself contains carbon that has previously been extracted from the air by plants) is in balance with the emissions in the use phase (B). Since the biogas in EcoInvent is free-of-charge, EcoInvent does not include this biogenic carbon absorption.
The Bio-LNG (A1-A3) profile has a positive (>0) contribution of 1646 kg CO2-eq to the biogenic climate change impact category. Of this, 1298 kg CO2-eq is caused by biogenic CO2 and +348 kg CO2-eq by biogenic methane emissions. In the Bio-LNG (A1-A3) profile, corrections have been made so that the value for biogenic CO2 emissions to air is inversely proportional to the emissions of biogenic CO2 in module-B (2750 kg biogenic CO2).

The emissions of methane in A1-A3 and in module-B continue to be inventoried as a positive contribution (impact due to emissions to air) to the biogenic climate change impact category (12.43 kg in A1-A3 and 38.9 kg in B1), so net over the entire life cycle, only the methane emissions in modules A1-A3 and module-B will count towards biogenic climate change. However, corrections have been made for the biogenic carbon present in this methane (-141 kg). This was done by means of the molar masses of methane and CO2 (1 mol CH4 : 1 mol CO2).

Table 15: A1-A4 Bio-LNG, per ton

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Liquefaction	A1-A3	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	NMD	0.0246 * 49000 = 1205	MJ	Equivalent to LNG, 0.0246 MJ/MJ LNG (JEC 2020)
Feedstock	A1-A3	Bio-gas voor Bio-LNG (o.b.v Biomethane, high pressure {CH}| biogas purification to biomethane by pressure swing adsorption | Cut-off, U)	Own menu	1000 / 0,752 = 1330	m3	Density based on 0.752 kg/Nm3 gives 1330 m3/ton. Profile created as described in Table 16
Correction of Biogenic CO2	A1-A3	CO2 biogenic, to air, (low. pop.)	E.I. 3.9	- 1298 – 2750 - 141 = – 4189	kg	Correction so that biogenic CO2 uptake corresponds to CO2 emissions in module B (2750 kg CO2-eq) (Table 39). And correction for carbon present in biogenic methane (A1-A3 and B1), 141 kg.
Storage and transport	A4	Electricity, medium voltage {NL}| market for electricity, medium voltage | Cut-off, U	E.I. 3.9	44,1	MJ	Storage similar to LNG but without ship transport, mainly raw materials from the Netherlands.
Storage and transport	A4	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	490	MJ	
Storage and transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	NMD	150	tonkm	

Table 16: Modelling of biogas for bio-LNG, based on Biomethane, high pressure {CH}| biogas purification to biomethane by pressure swing adsorption | Cut-off, U

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Gas from sewage sludge	A1-A3	Biogas {CH}| treatment of sewage sludge by anaerobic digestion | Cut-off, U	E.I. 3.9	1,536*0,34 = 0,522	m3	1,536 m3 in original EcoInvent process * 34% sewage sludge (NEA 2023)
Gas from Food Waste	A1-A3	Biogas {CH}| treatment of biowaste by anaerobic digestion | Cut-off, U	E.I. 3.9	1,536*0,20 = 0,307	m3	1,536 m3 in original profile (TNO, 2016)* 20% food waste (NEA 2023)
Gas from UCO	A1-A3	Biogas {RoW}| treatment of used vegetable cooking oil by anaerobic digestion | Cut-off, U	E.I. 3.9	1,536*0,05 = 0,077	m3	1,536 m3 in original profile (TNO, 2016) * 5% UCO (NEA 2023)
Gas from municipal waste	A1-A3	Biogas {CH}| treatment of biowaste by anaerobic digestion | Cut-off, U	E.I. 3.9	1,536*0,28 = 0,43	m3	1,536 m3 in original profile (TNO, 2016) * 28% municipal waste (NEA 2023)
Remaining	A1-A3	Biogas {CH}| treatment of biowaste by anaerobic digestion | Cut-off, U	E.I. 3.9	1,536*0,13 = 0,20	m3	1,536 m3 in original profile (TNO, 2016) * 13% other (NEA 2023)
Process Excipients	A1-A3	Charcoal {GLO}| market for charcoal | Cut-off, U	E.I. 3.9	0,000208		EcoInvent dataset
Capital goods	A1-A3	Chemical factory, organics {GLO}| market for chemical factory, organics | Cut-off, U	E.I. 3.9	5.4E-11		EcoInvent dataset
Process Excipients	A1-A3	Lubricating oil {RER}| market for lubricating oil | Cut-off, U	E.I. 3.9	0,00015		EcoInvent dataset
Process Excipients	A1-A3	Potassium hydroxide {GLO}| market for potassium hydroxide | Cut-off, U	E.I. 3.9	3.98E-6		EcoInvent dataset
Stream	A1-A3	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and	E.I. 3.9	0,1856		Acquisition of EcoInvent values,

		renewable (27%), per kWh (based on explanation in process), (01-2028)				reference adjusted to NL-mix instead of CH
Emissions to air	A1-A3	Carbon dioxide, biogenic	E.I. 3.9	0,97457	kg	EcoInvent dataset
Emissions to air	A1-A3	Heat, waste	E.I. 3.9	1,28	MJ	EcoInvent dataset
Emissions to air	A1-A3	Hydrogen sulphide	E.I. 3.9	6.7E-6	kg	EcoInvent dataset
Emissions to air	A1-A3	Methane, biogenic	E.I. 3.9	0,0086	kg	EcoInvent dataset
Emissions to air	A1-A3	Nitrogen, atmospheric	E.I. 3.9	0,04878	kg	EcoInvent dataset
Emissions to air	A1-A3	Sulphur dioxide	E.I. 3.9	6,599E-6	kg	EcoInvent dataset

Bio-CNG

The same feed stock has been maintained for Bio-CNG as for Bio-LNG, but as for CNG compression, instead of liquefaction (as with LNG). The correction of biogenic CO2 emissions was carried out in the same way as for Bio-LNG, only for the 1297 kg of biogenic CO2 and not for the 348.6 kg CO2-eq of methane in A1-A3. Over the entire life cycle, only methane emissions will count towards the biogenic climate change impact category, and the CO2 uptake in A1-A3 will offset the emissions in module-B.

Table 17: Bio-CNG A1-A4

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Biogas mix	A1-A3	Biogas for Bio-LNG (based on Biomethane, high pressure {CH}| biogas purification to biomethane by pressure swing adsorption | Cut-off, U)	Custom profiles	1000/0,752 = 1330	m3	Same biogas profile as for Bio-LNG, assumption density equal to CNG 0.752 kg/m3.
Compression	A1-A3	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	E.I. 3.9	0,022 * 46300 / 3,6 = 282,94	kWh	0,022 MJ electricity per MJ CNG. LHV 46,3 MJ per kg means 282,9 kWh per ton CNG. (JEC 2020)
Compression	A1-A3	Methane, biogenic, to air (low.pop.)	E.I. 3.9	0,0046	kg	1E-4 gr per MJ CNG adjusted to biogenic. (JEC 2020)
Correction of Biogenic CO2	A1-A3	CO2 Biogenic, to air (low.pop.)	E.I. 3.9	- 1298 – 2750 - 141= – 4189	kg	Correction for biogenic CO2 emissions
User compression	A4	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	E.I. 3.9	0,022 * 46300 = 1019	MJ	0.022 MJ/MJ CNG. Energy content CNG is 46.3 MJ/kg. (JEC 2020)
Methane emissions	A4	Methane, Biogenic, 1,852to Air	E.I. 3.9	1,0E-7 * 46300 = 4,63E-3	kg	1.0E-04 gr per MJ CNG. Energy content CNG is 46.3 MJ/kg. (JEC 2020)

HVO

The fuel HVO consists entirely of oils extracted from waste streams from other industries, mostly imported from the Far East. International policy on climate change has put pressure on efficient use of organic waste streams. This pressure leads to higher prices of organic waste streams, partly due to the high demand for biofuels, which makes the reprocessing of such waste streams profitable. In such cases, the residual flows have a positive financial contribution to the product system. For this reason, from a LCA perspective, there is room for interpretation within the EN15804 about potential allocation of impact to these oils obtained from residual flows. However, such allocation is not in line with the definition of waste streams formulated in the RED. (Imam et al. 2024)

The existing profile for HVO consists of 100% UCO. However, this is not representative for the market mix in the year 2023. This consists of 60% POME (palm oil mill effluent), 28% UCO, 7% used bleaching earth and 5% food waste. Since the composition of HVO fluctuates from year to year, the profiles is structured in such a way that the composition can easily be adjusted. A separate HVO profile has been drawn up for each feed stock, which is purchased in the market mix basic process.

For the HVO market mix profile, a correction has also been made so that the net biogenic CO2 in A1-A3 corresponds to the Biogenic CO2 emissions during combustion. The emission of biogenic CO2 during combustion in the ship amounts to 3109 kg (biogenic) CO2 per ton of HVO and the A1-A3 biogenic CO2 of the market mix HVO profiles is -937 kg, so it is corrected with 2097 kg biogenic CO2 (to air). As with Bio-LNG, biogenic methane emissions (only 0.5 kg CO2-eq biogenic methane) have not been corrected, but these do count as a contribution to the biogenic climate change impact category.

Table 18: A1-A4 HVO market mix based on NEA 2023 data.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Food waste	A1-A3	Subprofiles Energy Carrier A1-A3 - HVO (Food Waste)	-	0,05	tone	5% of HVO in 2023 (NEA 2024)
POME Oil (from Palm Oil Wastewater)	A1-A3	Subprofiles Energy Carrier A1-A3 - HVO (POME)	-	0,6	tone	60% of HVO in 2023 (NEA 2024)
UCO	A1-A3	Subprofiles Energy Carrier A1-A3 - HVO (UCO)	-	0,28	tone	28% of HVO in 2023 (NEA 2024)
Used Bleaching Earth	A1-A3	Subprofiles Energy Carrier A1-A3 - HVO (Oil from Bleaching Earth)	-	0,07	tone	7% of HVO in 2023 (NEA 2024)
Biogenic CO2 correction	A1-A3	Biogenic CO2, to air	E.I. 3.9	-3109 + 937 = -1901	kg	Correction for balance modules A1-A3 and B
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tonkm	Flat rate 150km
Storage	A4	Diesel, low-sulfur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	NMD	1	tone	Equal to Diesel

HVO - Used-Cooking Oil (UCO)

For UCO, the modelling as it is currently available in the NMD has been adapted based on the JEC, 2020 process data. The changes are mainly in the process efficiency and consumption, and in the saving of heat and power. Since UCO has already gone through a life cycle, the raw material enters the product system free-of-charge and only the transport and reprocessing steps have been declared.

Table 19: HVO profile based on 100% UCO, per kg.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
UCO	A1-A3	A1 UCO, purified	NMD	44 / 1,039 / 37 = 1,14	kg	HVO yield (process efficiency) is 1,039 MJ/MJ oil. With LHV for UCO of 37 MJ/kg and 44 MJ/kg for HVO, 1.14 kg means UCO per kg HVO. (JEC 2020) (TNO 2021)
Truck (origin)	A2	0001-tra&Transport, vrachtwagen (Based on Transport, freight,lorry, unspecified {GLO}| market group for transport, freight,lorry, unspecified | Cut-off, U)	E.I. 3.9	500 /1000 * 1,14 = 0,57	tonkm	Transport in country of origin, estimated at 500 km
Ship	A2	0290-tra&Transport, vrachtschip, zee (Based on Transport,freight, sea, transoceanic ship {GLO}| market for | Cut-off, U)	E.I. 3.9	11.613 / 1000*1,14 = 13,3	tonkm	Weighted average origin (TNO 2021)
Truck (destination)	A2	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	0	tonkm	Processing in port
Natural gas (for H2 generation)	A3	Natural gas, high pressure {Europe without Switzerland}| market group for natural gas, high pressure | Cut-off, U	E.I. 3.9	0,1337*44 / 37,5 = 0,157	m3	0,1337 MJ/MJ-HVO bij LHV-gas 37,5 MJ/m3. (JEC 2020)
H3PO4	A3	Phosphoric acid,industrial grade, withoutwater, in 85% solutionstate {GLO}| market for	E.I. 3.9	2,9E-5 * 44 = 1,28E-3	kg	2.9E-5kg for MJ HVO. (JEC 2020)
NaOH	A3	Sodium hydroxide,without water, in 50%solution state {GLO}|market fo	E.I. 3.9	2,58E-5 * 44 = 1,14E03	kg	2.58E-5kg for MJ HVO. (JEC 2020)
N2	A3	Nitrogen, liquid {RER}| market for nitrogen, liquid | Cut-off, U	E.I. 3.9	6,0E-6 * 44 = 2,64E-4	kg	6.0E-6 kg/MJ HVO (JEC 2020)

HVO - POME oil

The material flow Palm Oil Mill Effluent (POME) concerns wastewater from palm oil production. This flow consists of 90-95% water, 4-5% solids and 0.6-0.7% oil. The discharge of this raw POME has a major environmental impact, partly due to the high organic matter content. According to the WHO, the material flow must be processed before it can be discharged into the environment. The POME itself has not yet reached the end-of-waste point and its processing is still part of palm oil production. (Chin Hing Chung et al. 2017) (Akhbari et al. 2020) (Imam et al. 2024) (Akhbari et al. 2020)

The waste stream has no positive financial value, and it costs the palm oil plantation money to process the POME. Due to the properties of the waste stream (95% water), it is unlikely that a market will emerge for raw POME. The assumption is that waste processing/reprocessing will always take place on location.

Biological processing of the wastewater often takes longer than physio- and thermochemical processing. These processing methods cost more money but are faster and produce high-quality residual flows. The recovery of POME oil from the wastewater is done by skimming and pumping out the oil that floats on the wastewater. Furthermore, heating and filtering steps are required to acquire clean oil. The diesel and power consumption for these process steps are shown in the HVO production route documentation in JEC. (Sheng Lee et al. 2019) (JEC 2020)

From a global perspective, it is essential to make the most of valuable organic waste streams, POME is a good example of this. Due to this increasing demand for organic raw materials, as a replacement for fossil raw materials, it has become profitable to process POME oil at a higher quality. Due to the many possibilities of processing it into a raw material, POME oil is considered a valuable raw material with great potential for sustainable raw material use. For example, palm oil suppliers also mix POME oil with crude palm oil. (Imam et al. 2024) (Imam et al. 2024) (Vesper 2024)

In Thailand, POME oil is used for electricity production, and it is estimated that POME oil could become the main source of renewable energy for Malaysia. Examples of other products that can be extracted from POME oil are biofuels, chemicals, nutrients, pesticides and solvents. In addition to producing biogas, the recovery of oils for HVO is also possible. The processing of POME oil into biodiesel is done via biocatalytic and chemical transesterification. The processing of the POME oil therefore increases value for the palm oil producer. (Seekao et al. 2021) (Chin et al. 2013) (Imam et al. 2024) (Imam et al. 2024)

Per ton of palm oil, 2.5 to 3.75 tons of POME wastewater is generated. By means of the aforementioned composition, about 15 – 26 kg of oil can theoretically remain after recovering oils from these 2.5-3.75 tons of POME. The value of this oil is estimated at $300-$795 per ton (in Indonesia and on the Western market this value is around $1000 per ton). The value of 1 ton of palm oil is $865 - $1000 dollars. This means that the financial output of the POME oil is between 0.5% and 2.5% of the primary palm oil. (Ho et al 1984) (Chin et al. 2013) (Vesper 2024)

The EN15804:A2 states that with a very small financial contribution (<1%) there is no need for financial allocation. For POME, this value is around this indicative value limit. In order to stay in line with the RED regulations regarding waste status of residual flows, it has been decided not to allocate any impact to the POME oil. The impact of this choice will be explained in more detail in the sensitivity analysis.

The table below shows the LCI of the POME HVO. The process consumptions are obtained from the JEC dataset. The JEC data shows savings of electricity and heat for HVO production from POME (as opposed to UCO), which is allocated based on energy content. The process steps for separating the POME oil from the POME wastewater have been added to the LCI. Furthermore, there has been no financial allocation as described in the above paragraphs.

Table 20: HVO profile, 1kg HVO based on 100% POME.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Feedstock POME-olie	A1-A3	Sub-process energy carrier POME oil (free-of-charge raw material)	E.I. 3.9	(44 / 0,9767 / 38) = 1,185	kg	HVO yield is 0.9767 MJ/MJ oil. With LHV for POME oil of 38 MJ/kg, this means 1.185 kg of POME oil per kg HVO. (JEC 2020)
Truck (origin)	A2	0001-tra&Transport, vrachtwagen (Based on Transport, freight,lorry, unspecified {GLO}| market group for transport, freight,lorry, unspecified | Cut-off, U)	E.I. 3.9	500 /1000 * 1,185 = 0,593	tonkm	Estimate 500km country of origin
Ship	A2	0290-tra&Transport, vrachtschip, zee (Based on Transport,freight, sea, transoceanic ship {GLO}| market for | Cut-off, U)	E.I. 3.9	14.800 / 1000*1,185 = 17,5	tonkm	POME oil from Malaysia, calculated with 14800 km of sea transport.
Truck (destination)	A2	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	0	tonkm	Processing in port
H2	A3	Hydrogen, liquid {RER}|market for	E.I. 3.9	6,63E-2/120*44 = 0,0243	kg	6.63E-2 MJ/MJ-HVO Converted to kg H2 per kg HVO through LHV out (JEC 2020) Table 3.
H3PO4	A3	Phosphoric acid,industrial grade, withoutwater, in 85% solutionstate {GLO}| market for	E.I. 3.9	1,69E-5 * 44 = 7,436E-4	kg	1.69E-5kg for MJ HVO. (JEC 2020)
NaOH	A3	Sodium hydroxide,without water, in 50%solution state {GLO}|market fo	E.I. 3.9	2,7E-5 * 44 = 1,19E03	kg	2.7E-5kg for MJ HVO. (JEC 2020)
Output						
Surplus Electricity (output)	A3	Co-product	E.I. 3.9	-1,6E-3 * 44 = -7,04E-2	MJ	-1,6E-3 MJ/MJ HVO allocation to by product based on MJ output (0,16%) (JEC 2020)
Surplus heat (output)	A3	Co-product	E.I. 3.9	-7,9E-3 * 44 = -0,35	MJ	- 7,9E-3 MJ/MJ HVO allocation to by product based on MJ output (0,78%) (JEC 2020)
HVO (*output)	A1-A3	Product	E.I. 3.9	1	Kg	44 MJ, 99.05% impact allocation

Table 21: Sub-profile of energy carrier POME-oil (reprocessing from wastewater raw material free-of-load), per kg

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Diesel for processing POME wastewater	A1-A3	Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U	E.I. 3.9	6,76E-6*38*0,0205 = 5,27E-6	MJ	6.76E-3 MJ Diesel per MJ POME oil, total 20.5 kg POME oil with LHV of 38 MJ/kg (JEC 2020)
Stream for processing POME wastewater	A1-A3	Electricity, high voltage {MY}| market for electricity, high voltage | Cut-off, U	E.I. 3.9	3,46E-3/3,6*38*0,0205 = 7,49E-4	kWh	3.46E-3 MJ of power per MJ of POME oil, total 20.5 kg of POME oil with LHV of 38 MJ/kg (JEC 2020)

HVO - Oil from used bleaching earth

Bleaching earth is used during the refining process for cleaning and filtering oils and fats. The flow of used bleaching earth has various applications, including extraction of oils for biofuels or in the cement industry. It has a positive energetic value and provides energy when burned.

These recovered oils have positive financial values. The value of this recovered oil is estimated at €433 per ton (Gemeente Rotterdam 2018). The value of primary vegetable oils varies depending on the type of oil, but typically ranges between €800 and €1,200 per tonne. In practice, a variety of primary oils may form the basis of the resulting waste stream. As with food waste, no allocation has been made to the oil recovered from the bleaching earth. However, the upgrading steps must still be included. Since there is no detailed insight into the energy consumption or process steps, a soybean oil refining process has been used as a proxy for the upgrading steps required to convert the waste stream into oil suitable for HVO production. (Table 23).

Table 22: Modelling of HVO from used Bleaching Earth.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Oil from Bleaching Earth	A1	Processing of Oil from bleaching earth by means of Hexane (based on Hexane {RER}| molecular sieve separation of naphtha | Cut-off, U, without Naphtha input)	Own menu	44 / 0,9767 * 37 = 1,22	kg	Yield 0,9767 MJ HVO per MJ-oil (37 MJ/kg). (JEC 2020)
Ship	A2	0290-tra&Transport, vrachtschip, zee (Based on Transport,freight, sea, transoceanic ship {GLO}| market for | Cut-off, U)	E.I. 3.9	16.000*1,22 / 1000 = 19,5	tonkm	Imported from China, Malaysia and Indonesia. Calculated with 16,000 km of transport (on average China and Malaysia).
Truck (origin)	A2	0001-tra&Transport, vrachtwagen (Based on Transport, freight,lorry, unspecified {GLO}| market group for transport, freight,lorry, unspecified | Cut-off, U)	E.I. 3.9	500 /1000 * 1,22 = 0,609	tonkm	-
Truck (destination)	A2	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	0	tonkm	Processing in port
H2	A3	Hydrogen, liquid {RER}|market for	E.I. 3.9	9,09E-2/120*44 = 0,033	kg	0.0909 MJ/MJ-HVO Converted to kg H2 per kg HVO through LHV out (JEC 2020) Table 3.
H3PO4	A3	Phosphoric acid,industrial grade, withoutwater, in 85% solutionstate {GLO}| market for	E.I. 3.9	1,69E-5 * 44 = 7,436E-4	kg	1.69E-5kg for MJ HVO. (JEC 2020)
NaOH	A3	Sodium hydroxide,without water, in 50%solution state {GLO}|market fo	E.I. 3.9	2,7E-5 * 44 = 1,19E03	kg	2.7E-5kg for MJ HVO. (JEC 2020)
Output						
Surplus Electricity (output)	A3	Co-product	E.I. 3.9	-1,6E-3 * 44 = -7,04E-2	MJ	-1,6E-3 MJ/MJ HVO allocation to by-product based on MJ output (0,16%) (JEC 2020)
Surplus heat (output)	A3	Co-product	E.I. 3.9	-7,9E-3 * 44 = -0,35	MJ	- 7,9E-3 MJ/MJ HVO allocation to by-product based on MJ output (0,78%) (JEC 2020)
HVO (*output)	A1-A3	Product	E.I. 3.9	1	Kg	44 MJ, 99.05% impact allocation

Table 23: Processing of oil from bleaching earth per kg, sieving by means of Hexane (based on Hexane {RER}| molecular sieve separation of naphtha | Cut-off, U, without Naphtha input)

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Water process	A1	Water, cooling, unspecified natural origin, RER	E.I. 3.9	0,018	m3	EcoInvent dataset
Capital good	A1	Chemical factory, organics {RER}| chemical factory construction, organics | Cut-off, U	E.I. 3.9	2,85E-10	p	Raw material set to zero. Process steps only
Raw material	A1	Naphtha {RER}| market for naphtha | Cut-off, U	E.I. 3.9	0	kg	Raw material set to zero. Process steps only
Stream	A3	Electricity, medium voltage {RER}| market group for electricity, medium voltage | Cut-off, U	E.I. 3.9	0,018	kWh	EcoInvent dataset
Warmth	A3	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	1,68	MJ	EcoInvent dataset
Warmth	A3	Heat, district or industrial, other than natural gas {RER}| market group for heat, district or industrial, other than natural gas | Cut-off, U	E.I. 3.9	094	MJ	Replace GLO reference for RER. Values unchanged.
Emissions to air	A3	Several	E.I. 3.9	-	m3	EcoInvent dataset
Emission to Water	A3	Different	E.I. 3.9	-	m3	EcoInvent dataset

HVO - Food waste

The 2023 HVO mix consists of 5% oils extracted from food waste. This is a varied flow that can consist of various types of food, which can be both pre- and post-consumer waste. For this reason, it is not possible to estimate the end-of-waste point. Therefore, this flow enters the system as free-of-charge. For transport, an average distance of 9,500 km has been calculated as 50% of the food waste is imported from China. The assumption is that only the oily substances that have already been separated from the waste will be imported. The production data of the HVO is based on the production route of soybean oil, this includes the process efficiency and other processes as shown in (JEC 2020)Table 24 (excluding the reprocessing of soybean oil).

Table 24: Modelling of HVO from Food waste per kg, based on soybean oil production route JEC.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Remark
Food waste	A1	Free-of-burden	E.I. 3.9	44 / 0,9767 / 37 = 1,218	kg	Process yield (burned) 0.9767 MJ HVO per MJ oil (37 MJ/kg)
Ship	A2	0290-tra&Transport, vrachtschip, zee (Based on Transport,freight, sea, transoceanic ship {GLO}| market for | Cut-off, U)	E.I. 3.9	9.500*1,218 /1000 = 11,571	tonkm	50%+ from China (16,000km) and the rest largely from Europe. (3000 km). Calculated with 9,500 km
Truck (origin)	A2	0001-tra&Transport, vrachtwagen (Based on Transport, freight,lorry, unspecified {GLO}| market group for transport, freight,lorry, unspecified | Cut-off, U)	E.I. 3.9	150 /1000 * 1,218 = 0,183	tonkm	Acquisition of NMD card
Truck (destination)	A2	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	0	tonkm	Processing in port
H2	A3	Hydrogen, liquid {RER}|market for	E.I. 3.9	9,09E-2/120*44 = 0,033	kg	0.0909 MJ/MJ-HVO Converted to kg H2 per kg HVO through LHV out (JEC 2020) Table 3.
H3PO4	A3	Phosphoric acid, industrial grade, without water, in 85% solutionstate {GLO}| market for	E.I. 3.9	1,69E-5 * 44 = 7,436E-4	kg	1.69E-5kg for MJ HVO. (JEC 2020)
NaOH	A3	Sodium hydroxide, without water, in 50%solution state {GLO}|market for	E.I. 3.9	2,7E-5 * 44 = 1,19E03	kg	2.7E-5kg for MJ HVO. (JEC 2020)
Output						
Surplus Electricity (output)	A3	Co-product	E.I. 3.9	-1,6E-3 * 44 = -7,04E-2	MJ	-1,6E-3 MJ/MJ HVO allocation to by-product based on MJ output (0,16%) (JEC 2020)
Surplus heat (output)	A3	Co-product	E.I. 3.9	-7,9E-3 * 44 = -0,35	MJ	- 7,9E-3 MJ/MJ HVO allocated to co-product, allocation to by-product based on MJ output (0,78%) (JEC 2020)
HVO (*output)	A1-A3	Product	E.I. 3.9	1	Kg	44 MJ, 99.05% impact allocation

FAME

The table below shows the modelling of FAME, which is based on the modelling data from JEC. The raw material flows have been taken from the data of the NEA. The animal fat is modelled as described in the 2018 fuel machine combination report. The animal fat comes partly from Europe, but the other flows are mainly from Asia. The transport distances have been adjusted accordingly, and an average distance of 16,000 km has been calculated (Jakarta to Rotterdam via SUEZ). (JEC 2020) (NEA 2023) (TNO 2018)

One of the residual flows in the NEA, 2023 market mix, cashew nut shell liquid (CNSL), is a residual flow produced from a waste stream of cashew nut production. About 25% of the weight of the cashew is not in the nut but in the skin around it. Previously, this was dumped into the environment as waste. However, the peels have a calorific value of 18.9 MJ/kg and can be used as biofuel or as an energy source in the cashew production itself. It is also possible to squeeze an oil out of the peels. (Energypedia 2020) (Energy 2013) (Mubofu 2015)

The shells of the cashew nut are already at the end of the waste, but the processing steps for obtaining the oil must be included. For Cashew Nut Shell Liquid (CNSL) it is not clear to what extent the residual flow has already been reprocessed and what the required energy input of these process steps is. The oil can be extracted from the peels in various ways, for example, the CSNL can be hot or cold pressed or obtained through solvents. Additionally, refining may also be required before it can serve as a raw material for HVO.

In the EcoInvent dataset for cashew nuts, no residual flows or waste processing processes are modelled. Corrections have also been made with the Biogenic CO2 emissions from the combustion of FAME, methodically this corresponds to the HVO profiles.

Table 25: A1-A4 FAME per ton

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Food waste (composting)	A1	Free of burden	-	(37,2/0,965 * 37) * 0,27 = 0,25	tone	37.2 MJ/kg LHV FAME, divided by yield of 0.965 , multiplied by LHV secondary oil of 37 MJ/kg means 1.04 kg of oil per kg FAME. 27% from food waste (JEC 2020) (NEA 2023)
Other waste	A1	Free of burden	-	1,04 * 0,05 = 0,052	tone	5%, other (NEA 2023)
Cashew nutshell liquid (CNSL)	A1	CNSL (oil extraction from cashew nut shells)((Based on Rape meal {RoW}| rape oil mill operation | Cut-off, U)	Own menu	1,04 * 0,09 = 0,094	tone	9% CSNL . I (NEA 2023)Pressure of oil pressing (Table 26)
POME-oil (palm oil mill effluent)	A1	Sub profile energy carrier POME oil (free-of-burden raw material)	Own menu	1,04 *0,23 = 0,24	tone	23% POME modelling POME oil equivalent to HVO. (NEA 2023)
UCO	A1	Glycerine {RoW}|treatment of wastecooking oil, purified,esterification.	E.I. 3.9	1,04 * 0,04 = 0,0417	tone	4% (NEA, 2023)
Animal fat	A1	Subprofiles Energy carrier animal fat for FAME (based on TNO 2018)	Own menu	1,04 * 0,3 = 0,313	tone	30% modelling as in (TNO, 2018) ((NEA 2023)Table 27)
Used Bleaching Earth	A1	Sub profile Energy carrier Processing of bleaching earth (based on Soybean oil, refined {RoW}| soybean oil refinery operation | Cut-off, U)	E.I. 3.9	1,04 * 0,02 = 0,021	tone	2% of mass current, modelling as with HVO (NEA 2023)
Truck (country of origin)	A2	0001-tra&Transport, vrachtwagen (Based on Transport, freight,lorry, unspecified {GLO}| market group for transport, freight,lorry, unspecified | Cut-off, U)	NMD 3.9	500	Tonkm	500 km estimate in country of origin
Ship	A2	Transport, freight, sea, tanker for petroleum {GLO}| transport, freight, sea, tanker for petroleum | Cut-off, U	E.I. 3.9	16.000 * 1 = 16.000	tkm	CSNL (Vietnam), Food Waste (50% China), UCO (China, Malaysia and Europe) and POME (Indonesia). Calculated with 16000 km (South-East Asia via Suez)

Truck (destination)	A2	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	0	tonkm	Processing in port
Methanol (fossiel)	A3	Methanol {GLO}| methanol production | Cut-off, U	E.I. 3.9	0,056/19,9*37000 = 105	kg	0,056 MJ/MJ FAME (JEC 2020).. LHV Methanol 19,9 MJ/kg (Table 3)
CO2 emissions from methanol	A3	Carbon Dioxide, fossil to air (low pop)	E.I. 3.9	3,889 * 37 = 145	kg	3,889 gr/MJ FAME (JEC 2020).
Electricity	A3	0569-pro&Electricity, Dutch mix, by consumer, per kWh (73% grey, 27% renewable) (based on see explanation in process), (01-2028)	NMD 3.9	6,8 * 37 = 253	MJ	6.8E-3 MJ/MJ FAME (JEC 2020).
Natural gas	A3	Subprocess Energy carrier Natural gas mix 2023 (Natural gas origin 2023 adjusted, Based on Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U)	Own menu	4,71E-2/ 36 * 37.000 = 48,7	m3	4,71E-2 MJ/MJ FAME (JEC 2020). LHV natural gas van 36 MJ/m3.
H3PO4	A3	Phosphoric acid, industrial grade, without water, in 85% solution state {GLO}| market for phosphoric acid, industrial grade, without water, in 85% solution state | Cut-off, U	E.I. 3.9	0,047 * 37 = 1,75	kg	0,047 gr/MJ FAME (JEC 2020).
KOH	A3	Potassium hydroxide {RER}| potassium hydroxide production | Cut-off, U	E.I. 3.9	0,427 * 37 = 15,9	kg	0,427 gr/MJ FAME (JEC 2020)
H2SO4	A3	Sulfuric acid {RER}| market for sulfuric acid | Cut-off, U	E.I. 3.9	0,295*37 = 11	kg	0,295 gr/MJ FAME (JEC 2020).
Saved K-fertilizer	A3	Inorganic potassium fertiliser, as K2O {RER}| market group for inorganic potassium fertiliser, as K2O | Cut-off, U	E.I. 3.9	-0,381 * 37 = -14,2	kg	-0,381 gr/MJ FAME (JEC 2020)
Correction of biogenic CO2	A3	Biogenic CO2 to air	E.I. 3.9	-2834,64 + 77 = -2790	kg	Correction for balance modules A1-A3 and B. -77 kg of biogenic CO2 in A1-A3 (and +7.16 kg CO2-eq of biogenic methane), 2834.6 kg of CO2 emissions in B.
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tonkm	150km flat rate
Storage	A4	Diesel, low-sulfur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	E.I. 3.9	1 tone	tone	Equal to Diesel

The table below shows the modelling of the CNSL. It is a copy of the EcoInvent dataset "Rape meal {RoW}| rape oil mill operation | Cut-off, U", which has been chosen as a proxy, but without the input of the rapeseed itself. As a result, only the processes for pressing are included.

Table 26: CNSL (oil extraction from cashew nut shells)((Based on Rape meal {RoW}| rape oil mill operation | Cut-off, U)

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Input from nature	A1-A3	Carbon dioxide, in air	E.I. 3.9	0,406	kg	Ecoinvent dataset
Input from nature	A1-A3	Water, cooling, unspecified natural origin, RoW	E.I. 3.9	1.19E-5	M3	Ecoinvent dataset
Input from nature	A1-A3	Water, unspecified natural origin, RoW	E.I. 3.9	2.98E-6	M3	Ecoinvent dataset
Adjuvant	A1-A3	Activated bentonite {GLO}| market for activated bentonite | Cut-off, U	E.I. 3.9	497	Dm3	Ecoinvent dataset
Adjuvant	A1-A3	Hexane {GLO}| market for hexane | Cut-off, U	E.I. 3.9	1000	kg	Ecoinvent dataset
Capital good	A1-A3	Oil mill {GLO}| market for oil mill | Cut-off, U	E.I. 3.9	1314	MJ	Ecoinvent dataset
Process Hollow Fabric	A1-A3	Phosphoric acid, industrial grade, without water, in 85% solution state {GLO}| market for phosphoric acid, industrial grade, without water, in 85% solution state | Cut-off, U	E.I. 3.9	212	MJ	Ecoinvent dataset
Raw material	A1-A3	Rape seed {GLO}| market for rape seed | Cut-off, U	E.I. 3.9	150	tonkm	Rapeseed set to 0
Raw material	A1-A3	Rape seed, organic {GLO}| market for rape seed, organic | Cut-off, U	E.I. 3.9	0,00	kg	Rapeseed set to 0
Raw material	A1-A3	Rape seed, Swiss integrated production {GLO}| market for rape seed, Swiss integrated production | Cut-off, U	E.I. 3.9	13	kg	Rapeseed set to 0
Energy input (various)	A1-A3	Electricity, medium voltage market for electricity, medium voltage | Cut-off, U(AU, NZ, RAF, RAS,RLA en RNA)	E.I. 3.9	0,02622	KWh	Summarized in one line in one line. Different origins
Heat (various)	A1-A3	Heat, district or industrial, natural gas {RoW}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	0,0536	MJ	Acquisition of E.I. (98.4% ROW and 1.6% from CA-QC)
Emissions	A1-A3	Carbon dioxide, biogenic, to air, high pop.	E.I. 3.9	0,41	kg	Ecoinvent dataset
Emissions	A1-A3	Hexane, to air, high pop.	E.I. 3.9	8,324E-5	Kg	Ecoinvent dataset
Emissions	A1-A3	Water/m3, to air, high pop.	E.I. 3.9	5.92E-6	M3	Ecoinvent dataset
Wastewater	A1-A3	Water, RoW, to water	E.I. 3.9	8.98E-6	M3	Ecoinvent dataset
Wastewater	A1-A3	Wastewater, average {CA-QC}| market for wastewater, average | Cut-off, U	E.I. 3.9	7,25E-10		Ecoinvent dataset
Wastewater	A1-A3	Wastewater, average {RoW}| market for wastewater, average | Cut-off, U	E.I. 3.9	2.04E-7		Ecoinvent dataset

Table 27: Animal fat modelling, LCI for 76kg fat.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Output						
Animal fat	A1-A3	Subprofiles Energy carrier animal fat for FAME (based on TNO 2018)	Own card	76	kg	Based on TNO, 2018
Process heat saved	A1-A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U	E.I. 3.9	425	MJ	Based on TNO, 2018
Input						
Water process	A1-A3	Water, cooling, unspecified natural origin, NL	E.I. 3.9	497	Dm3	Based on TNO, 2018
Animal fats	A1-A3	Free-of-burden	E.I. 3.9	1000	kg	Based on TNO, 2018
Process heat, gas	A1-A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U	E.I. 3.9	1314	MJ	Based on TNO, 2018
Process heat, steam	A1-A3	Heat, from steam, in chemical industry {RER}| market for heat, from steam, in chemical industry | Cut-off, U	E.I. 3.9	212	MJ	Based on TNO, 2018
Transport to factory	A1-A3	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tonkm	1000kg of slaughter waste over 150 km, Acquisition of TNO, 2018
Hazardous waste	A1-A3	Hazardous waste, for incineration {Europe without Switzerland}| market for hazardous waste, for incineration | Cut-off, U	E.I. 3.9	0,03	kg	Based on TNO, 2018
Solid waste	A1-A3	Municipal solid waste {NL}| treatment of municipal solid waste, incineration | Cut-off, U	E.I. 3.9	13	kg	Based on TNO, 2018
Wastewater	A1-A3	Wastewater, average {Europe without Switzerland}| treatment of wastewater, average, wastewater treatment | Cut-off, U	E.I. 3.9	880	dm3	Based on TNO, 2018

Innovative energy carriers – (Renewable Fuels of Non-Biological Origin, RFNBO)

This report describes several innovative energy carriers that may potentially play a role in future shipping. This chapter covers renewable fuels of non-biological origin (RFNBOs), as well as the fossil-based and bio-based variants of these innovative energy carriers, which do not fall under the RFNBO classification. These energy carriers vary in terms of current technological readiness. For example, hydrogen is discussed under this category, but the market for hydrogen is significantly more developed than that for methanol or ammonia. Due to these large differences, the availability and quality of data for these energy carriers vary. Nevertheless, it is relevant to provide an overview of these carriers to offer an initial insight into their potential contribution to sustainability.

Ammonia Synthetic (Hydrogen Wind Mix)

Disclaimer: The current state of technology for ammonia-powered ships is still in the development phase. There is very limited data available on the application of this energy carrier in the maritime sector. This primarily affects the use phase, including nitrogen emissions as well as unregulated emissions such as ammonia slip. The results presented in this dataset should therefore be interpreted within this context..

This dataset concerns the production of ammonia via hydrogenation of nitrogen in a Haber-Bosch reactor, with an assumed efficiency of 70%. The data are based on a production volume of approximately 9,000 tonnes per year. The process requires 200 kWh of electricity per tonne of ammonia produced. Due to a lack of detailed data, the value for capital goods has been adopted from the EcoInvent dataset for grey ammonia.

Since this concerns a future energy carrier, the feedstock used is hydrogen produced via electrolysis using a wind power mix, as this represents the most sustainable option. This dataset therefore only applies to ammonia produced from hydrogen generated through electrolysis powered by wind energy. In this way, the potential environmental impact reduction of synthetic ammonia as an energy carrier is illustrated. However, the electricity source is decisive for the environmental impact of the carrier. This will be further explored in the sensitivity analysis.

The nitrogen is sourced from air (via air separation); for this, the EcoInvent dataset has been adjusted by removing the electricity consumption, as this is already embedded in the stated electricity use for the production process.

Table 28: Ammonia based on hydrogen wind-mix, per tonne.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Hydrogen	A1-A3	Energy carrier Hydrogen, Gas, Electrolysis, wind mix (A1-A3) (based on NMD profiles Hydrogen, Electrolysis, green mix)		239	kg	Process efficiency based on TNO data
N2 gas	A1-A3	Nitrogen, liquid {RER}| air separation, cryogenic | Cut-off, U	E.I. 3.9	761	kg	Air separation, adjusted power consumption removed from card.
Stream	A1-A3	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on explanation in process), (01-2028)	E.I. 3.9	200	KWh	Energy per ton Ammonia (TNO)
Capital good	A1-A3	Chemical factory, organics {GLO}| market for chemical factory, organics | Cut-off, U	E.I. 3.9	3.90E-07	p	Similar to EcoInvent Ammonia profiles.
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tkm	150km based on national production.
Power consumption terminal	A4	Electricity, medium voltage {NL}| market for electricity, medium voltage | Cut-off, U	E.I. 3.9	0,0009 * 18.600 = 16,74	MJ	Store at -33 °C. Conservative consumption based on LNG (storage at -300 °C). 0.0009 MJ/MJ LNG . (JEC 2020)
Energy consumption terminal	A4	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	0,01 * 18.600 = 186	MJ	Store at -33 °C. Conservative consumption based on LNG (storage at -300 °C). 0,01 MJ/MJ LNG (JEC 2020)

Ammonia (Grey)

Disclaimer: The current state of technology for ammonia-powered ships is still in the development phase. There is very limited data available on the application of this energy carrier in maritime vessels. This particularly affects the use phase, including nitrogen emissions as well as unregulated emissions such as ammonia slip. The results presented in this dataset should therefore be interpreted in this context.

This variant is not strictly classified as an RFNBO, as it is produced from natural gas. However, since ammonia is not yet a conventional marine fuel and can therefore be considered an innovative marine fuel, both the synthetic and grey variants have been included. The grey variant has been incorporated to provide insight into the potential of the technology and the energy carrier itself, and to illustrate the implications if the technology is developed but the production of the energy carrier lags behind. The grey ammonia dataset is based on ammonia production via SMR (steam methane reforming), with the gas mix adjusted to reflect the market mix as described in the CNG dataset.

Table 29: Grey Ammonia based on Ammonia, anhydrous, liquid {RER w/o RU}| ammonia production, steam reforming, liquid | Cut-off, U, per kg

Process	Phase	Environmental profile	Database	Quantity	Unit	Principles
Natural gas	A1-A3	Subkaart Energy carrier Natural gas mix 2023 (Natural gas oorsprong 2023 aangepast, Based on Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U)	E.I. 3.9	0,605+0,0043 = 0,61	m3	Based on EcoIvent values (sum of CH and RER geographies), adjusted to NL 2023 natural gas mix.
Capital goods	A1-A3	Chemical factory, organics {GLO}| market for chemical factory, organics | Cut-off, U	E.I. 3.9	3,90E-10	p	Based on EcoIvent values
Adjuvant	A1-A3	Nickel, class 1 {GLO}| market for nickel, class 1 | Cut-off, U	E.I. 3.9	0,000342	kg	Based on EcoIvent values
Adjuvant	A1-A3	Solvent, organic {GLO}| market for solvent, organic | Cut-off, U	E.I. 3.9	2.93E-5	kg	Based on EcoIvent values
Water	A1-A3	Tap water {CH}| market for tap water | Cut-off, U	E.I. 3.9	0,704	kg	Based on EcoIvent values
Power consumption	A1-A3	Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, U	E.I. 3.9	0,228	KWh	Based on EcoIvent values
Warmth	A1-A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at boiler modulating >100kW | Cut-off, U	E.I. 3.9	9,96	MJ	Based on EcoIvent values
Emissions	A1-A3	Carbon dioxide, fossil, to air	E.I. 3.9	1,406	kg	Based on EcoIvent values
Emissions	A1-A3	Nitrogen oxides, to air	E.I. 3.9	6.83E-4	kg	Based on EcoIvent values
Emissions	A1-A3	Water/m3, to air	E.I. 3.9	5.31E-2	m3	Based on EcoIvent values
Emissions	A1-A3	Nitrogen, atmospheric, to water	E.I. 3.9	1.17E-4	kg	Based on EcoIvent values
Emissions	A1-A3	Water, RER w/o RU, to water	E.I. 3.9	8.44E0-2	m3	Based on EcoIvent values
Waste	A1-A3	Municipal solid waste {RER}| market group for municipal solid waste | Cut-off, U	E.I. 3.9	1.95E-4	kg	Based on EcoIvent values
Transport	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	tkm	150km based on national production.
Power consumption terminal	A4	Electricity, medium voltage {NL}| market for electricity, medium voltage | Cut-off, U	E.I. 3.9	0,0009 * 18.600 = 16,74	MJ	Store at -33 °C. Conservative consumption based on LNG (storage at -300 °C). 0.0009 MJ/MJ LNG . (JEC 2020)
Energy consumption terminal	A4	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	0,01 * 18.600 186	MJ	Store at -33 °C. Conservative consumption based on LNG (storage at -300 °C). 0,01 MJ/MJ LNG (JEC 2020)

Hydrogen

The tables below show the LCI of hydrogen production (SMR Table 30 an electrolysis Table 31). The modelling is based on the production routes mentioned in the JEC, 2020 documentation. Depending on the liquid or gaseous variant, the consumption of liquefaction or compression is applied. Furthermore, there are three types of electricity; grey, green or wind mix. In these variants, both the electricity for electrolysis and for compression/liquefaction are adjusted. An overview of the multiple electricity references can be found in (JEC 2020)Table 32.

In module A4, power consumption for the cryogenic storage of the liquid hydrogen has been calculated. The assumption is that bunkering is mostly done ashore. However, 150 km of flat-rate transportation has been calculated. The contribution of this transport to the ECI:A2 is very small (<1%). Due to the large volumes, this transport can vary in practice, for example, sometimes only 400 kg can be moved per truck (gaseous).

Table 30: Hydrogen SMR liquid and gaseous per tonne.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Natural gas	A1-A3	Subkaart Energy carrier Natural gas mix 2023 (Natural gas oorsprong 2023 aangepast, Based on Natural gas, high pressure {NL}| market for natural gas, high pressure | Cut-off, U)	E.I. 3.9	120.000 * 1,315 /36 = 4,38E3	M3	1,315 MJ NG per MJ H2, 120 MJ/kg H2)) , LHV 36 MJ/m3 (JEC 2020)
Process heat	A1-A3	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U (adapted for SMR hydrogen production process for category 3 fuel processes)	E.I. 3.9	4208 * 0,02 = 84,16	MJ	0,02 MJ/MJ-NG (JEC 2020)
Infrastructure	A1-A3	Natural gas processing plant {GLO}| natural gas processing plant production | Cut-off, U	E.I. 3.9	4.38E-9	p	Same as NMD profile
Emissions to air	A1-A3	Methane, fossil, to air	E.I. 3.9	120.000 * 1,59E-5 = 1,908	kg	0,0159 gr/MJ H2 (JEC 2020)
Emission to Air	A1-A3	Carbon Dioxide, Fossil, to Air	E.I. 3.9	0,89/0,0899 * 1000 = 9,9E3	kg	0.89 kg CO2 per NM H2 , density of 0.0899 kg/Nm3 (IEAGHG 2017)
Gaseous						
Compression for truck transport (grey)	A1-A3	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	120.000 * 0,0537 = 6.444	MJ	0.0537 MJ/MJ H2 to 50.0 MPa (JEC 2020)
Transport Gas	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	NMD 3.9	150	tonkm	Flat-rate 150km transport
Compression at location collection (grey)	A4	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	120.000 * 0,0528 = 6.336	MJ	0.0528 MJ/MJ H2 to 88.0 MPa (JEC 2020)
H2 losses when taking off location	A4	Energy carrier Hydrogen, Gas, SMR grey mix (A1-A3) (based on NMD profiles Hydrogen, Steam methane reforming (SMR), green mix)	E.I. 3.9	0,02	tone	2% (JEC 2020)
Liquid						
Liquefaction Grey	A1-A3	pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD 3.9	120.000 * 0,3 = 36.000	MJ	0,3 MJ/MJ H2, LHV 120 MJ/kg (JEC 2020)
Transport liquid	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	NMD 3.9	150	tonkm	Flat-rate 150km transport.
Power consumption cryo-compression at offtake location	A4	pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD 3.9	0,01 * 120.000 = 1200	MJ	0,01 MJ/MJ H2 (JEC WTW Pathway 2020)

H2 losses when taking off location	A4	Energy carrier Hydrogen, Liquid, SMR grey mix (A1-A3) (based on NMD profiles Hydrogen, Steam methane reforming (SMR), grey mix)	E.I. 3.9	0,005	tone	0,5% (JEC 2020)

Table 31: LCI of hydrogen by electrolysis, liquid and gaseous, per tonne.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Electrolysis (grey)	A1-A3	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	1,538 * 120000 / 3,6 = 51.266	KWh	1,538 MJ of current per MJ H2 (JEC WTW Pathway 2020). With green and wind variant, different current reference (Table 32)
Water	A1-A3	Water, ultrapure {RER}| market for water, ultrapure | Cut-off, U	E.I. 3.9	9	tone	1 kg of H2 gas requires 500 mol of H2, for which 500 mol of H2O is needed. Means 9kg of water per kg of H2 (without losses). Contribution to ECI <1%
Potassium Hydroxide	A1-A3	Potassium hydroxide {RER}| potassium hydroxide production | Cut-off, U	E.I. 3.9	9000 * 0,3 /1000 = 27	kg	30% compared to water and assumption after 100x replacement. Contribution to ECI <1% (TNO 2021)
Fuel cell for conversion	A1-A3	Fuel cell, stack polymer electrolyte membrane, 2kW electrical, future {RoW}| fuel cell production, stack polymer electrolyte membrane, 2kW electrical, future | Cut-off, U	E.I. 3.9	1/135 = 7,4E-3	p	30 Nm3 per hour, 50,000 hours service life, 135 tons of H2 during service life. Contribution to ECI <1% (TNO 2016)
Gaseous						
Compression for truck transport (grey)	A1-A3	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	120.000 * 0,0537 = 6.444	MJ	0.0537 MJ/MJ H2 to 50.0 MPa (JEC 2020)
Transport Gas	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	NMD 3.9	150	tonkm	Flat-rate 150km transport
Compression at location collection (grey)	A4	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	120.000 * 0,0528 = 6.336	MJ	0.0528 MJ/MJ H2 to 88.0 MPa (JEC 2020)
H2 losses when taking off location	A4	Energy carrier Hydrogen, Gas, SMR grey mix (A1-A3) (based on NMD profiles Hydrogen, Steam methane reforming (SMR), green mix)	E.I. 3.9	0,02	tone	2% (JEC 2020)
Liquid						
Liquefaction Grey	A1-A3	pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD 3.9	120.000 * 0,3 = 36.000	MJ	0,3 MJ/MJ H2, LHV 120 MJ/kg (JEC 2020)
Transport liquid	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	NMD 3.9	150	tonkm	Flat-rate 150km transport
Power consumption cryo-compression at offtake location	A4	pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD 3.9	0,01 * 120.000 = 1200	MJ	0,01 MJ/MJ H2 (JEC WTW Pathway 2020)
H2 losses when taking off location	A4	Energy carrier Hydrogen, Liquid, SMR grey mix (A1-A3) (based on NMD profiles Hydrogen, Steam	E.I. 3.9	0,005	tone	0,5% (JEC 2020)

		methane reforming (SMR), grey mix) (ADD LIQUEFACTION)				

Table 32: Electricity profiles for the various Hydrogen Electrolysis and SMR profiles.

Process	Phase	Environmental profile	Database / Source	Unit	Principles
Grey electricity	A1-A3	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	KWh	Same as NMD profile
Green electricity	A1-A3	0496-pro&Electricity, Renewable, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	KWh	Same as NMD profile
Wind Mix	A1-A3	- 0571-pro&Electricity, renewable, from offshore wind turbines, at consumer, per kWh (based on see explanation in process), (01-2028) 7.7% - 0572-pro&Electricity, renewable, from onshore wind turbines, at consumer, per kWh (based on see explanation in process), (01-2028) 92.3%	NMD	KWh	Ratio offshore:onshore from NL "market for" reference.

Methanol grey

For grey Methanol, the EcoInvent datasets have been used as shown in the table below. Data from 2020 shows that most of the grey methanol is imported (Trinidad & Tobago, Venezuela, Equatorial Guinea and Russia). For this reason, the GLO profile is considered as a representative. (TNO 2020)

The EcoInvent process dataset is more detailed and based on more recent sources (2007 compared to 1998) than those available in the JEC 2020 dataset. The values for gas and energy consumption are of the same order of magnitude.:

- 0,53 m3 Natural gas per kg methanol Based on JEC 2020 dataset en 0,65 m3 in EcoInvent
- 9.2 MJ of energy input per kg of methanol (based on a 68.3% process efficient from JEC, 2020 dataset) and 7.2 MJ per kg of methanol in EcoInvent.

For this reason, it was decided not to adjust the EcoInvent dataset.

Table 33: EcoInvent dataset for methanol grey, Methanol {GLO}| methanol production | Cut-off, U, per kg.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Methanol grey	A1-A3	Water, cooling, unspecified natural origin, GLO	E.I. 3.9	8,16E-3	m3	EcoInvent dataset
Adjuvant	A1-A3	Aluminium oxide, non-metallurgical {IAI Area, EU27 & EFTA}| market for aluminium oxide, non-metallurgical | Cut-off, U	E.I. 3.9	3,47E-5	kg	EcoInvent dataset
Adjuvant	A1-A3	Aluminium oxide, non-metallurgical {RoW}| market for aluminium oxide, non-metallurgical | Cut-off, U	E.I. 3.9	2.05E-4	kg	EcoInvent dataset
Adjuvant	A1-A3	Copper oxide {GLO}| market for copper oxide | Cut-off, U	E.I. 3.9	9.0E-5	kg	EcoInvent dataset
Capital goods	A1-A3	Methanol factory {GLO}| market for methanol factory | Cut-off, U	E.I. 3.9	3,72E-11	P	EcoInvent dataset
Adjuvant	A1-A3	Molybdenum {GLO}| market for molybdenum | Cut-off, U	E.I. 3.9	1.05E-5	kg	EcoInvent dataset
Raw material	A1-A3	Natural gas, high pressure {GLO}| market group for natural gas, high pressure | Cut-off, U	E.I. 3.9	0,65	m3	EcoInvent dataset
Adjuvant	A1-A3	Nickel, class 1 {GLO}| market for nickel, class 1 | Cut-off, U	E.I. 3.9	2.0E-5		EcoInvent dataset
Adjuvant	A1-A3	Water, deionised {CH}| market for water, deionised | Cut-off, U	E.I. 3.9	7.2E-4	kg	EcoInvent dataset

Adjuvant	A1-A3	Water, deionised {Europe without Switzerland}| market for water, deionised | Cut-off, U	E.I. 3.9	0,2	kg	EcoInvent dataset
Adjuvant	A1-A3	Water, deionised {RoW}| market for water, deionised | Cut-off, U	E.I. 3.9	0,65	kg	EcoInvent dataset
Adjuvant	A1-A3	Zinc {GLO}| market for zinc | Cut-off, U	E.I. 3.9	3.0E-5	kg	EcoInvent dataset
Power consumption	A1-A3	Electricity, medium voltage {GLO}| market group for electricity, medium voltage | Cut-off, U	E.I. 3.9	0,074	KWh	EcoInvent dataset
Process heat	A1-A3	Heat, district or industrial, natural gas {GLO}| market group for heat, district or industrial, natural gas | Cut-off, U	E.I. 3.9	6,93	MJ	EcoInvent dataset
Emissions to air	A1-A3	Emission to air, various	E.I. 3.9	-	kg	EcoInvent dataset
Emissions to water	A1-A3	Emission to water, various	E.I. 3.9	-	kg	EcoInvent dataset
Storage	A4	Diesel, low-sulfur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	NMD	1,00	tone	Assumption equal to Diesel, contribution marginal.

Methanol Bio

For bio-methanol, various feedstocks are possible. However, it is currently unclear which feedstocks will be most relevant for marine fuels. The Swiss dataset has been chosen for this study, as the RER datasets based on pulp are overly complex. The selected dataset therefore provides a better starting point for future updates concerning feedstocks and energy use. In this dataset, the feedstock is synthetic gas — a biogenic gas produced via gasification of wood and biomass, with an energy content of 6.21 MJ/m³.

Table 34: Methanol Bio, based on Methanol, from biomass {CH}| methanol production, from synthetic gas | Cut-off, U, per kg.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Methanol Bio	A1-A3	Water, cooling, unspecified natural origin, CH	E.I. 3.9	0,00816	m3	EcoInvent dataset
Adjuvants	A1-A3	Aluminium oxide, non-metallurgical {RoW}| market for aluminium oxide, non-metallurgical | Cut-off, U	E.I. 3.9	0,00024	kg	EcoInvent dataset
Adjuvants	A1-A3	Copper oxide {GLO}| market for copper oxide | Cut-off, U	E.I. 3.9	9.0E-5	kg	EcoInvent dataset
Capital goods	A1-A3	Methanol factory {GLO}| market for methanol factory | Cut-off, U	E.I. 3.9	3.70E-11	p	EcoInvent dataset
Adjuvants	A1-A3	Molybdenum {GLO}| market for molybdenum | Cut-off, U	E.I. 3.9	1.0E-5	kg	EcoInvent dataset
Adjuvants	A1-A3	Nickel, class 1 {GLO}| market for nickel, class 1 | Cut-off, U	E.I. 3.9	2.0E-5	kg	EcoInvent dataset
Raw material	A1-A3	Synthetic gas {CH}| market for synthetic gas | Cut-off, U	E.I. 3.9	7,13	m3	EcoInvent dataset
Adjuvants	A1-A3	Water, deionised {CH}| market for water, deionised | Cut-off, U	E.I. 3.9	0,85	kg	EcoInvent dataset
Adjuvants	A1-A3	Zinc {GLO}| market for zinc | Cut-off, U	E.I. 3.9	3.0E-5	kg	EcoInvent dataset
Power consumption	A1-A3	0081-fab&Electricity, at consumer, materialisation external supply, average grid mix grey (73%) and renewable (27%), per kWh (based on	E.I. 3.9	0,277	KWh	Acquisition of EcoInvent, adapted to NL mix

		explanation in process), (01-2028)				
Emissions to air	A1-A3	Emission to air, various	E.I. 3.9	-	kg	EcoInvent dataset
Emission to water	A1-A3	Emission to water, various	E.I. 3.9	-	kg	EcoInvent dataset
Wastewater treatment	A1-A3	Wastewater, average {CH}| market for wastewater, average | Cut-off, U	E.I. 3.9	5.32E-3	m3	EcoInvent dataset
Biogenic correction	A1-A3	Carbon dioxide, biogenic, to air	E.I. 3.9	-1371,1 + 808 = 563	kg	1371,11 kg CO2 per ton Methanol combuistion Emissions in B en 808 kg biogenic CO2 in A1-A3
Storage	A4	Diesel, low-sulfur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	NMD	1,00	tone	Assumption equal to Diesel, contribution marginal.

e-Methanol (Fossil/Biogenic CO2)

The fuel e-methanol is considered an energy carrier of the future. The assumption is that it will be produced from green hydrogen and captured CO2. Capturing CO2 from flue gases requires both energy and financial input. For this energy carrier, two CO2 sources are possible: captured fossil-based or biogenic CO2. However, a mix of biogenic and fossil CO2 is also conceivable — for example, from a waste incineration plant. In addition to capturing CO2 from flue gases, it may in the future be possible to extract CO2 directly from the atmosphere through Direct Air Capture (DAC). The DAC option is included in the sensitivity analysis.

There are currently no well-defined accounting rules for how to calculate or allocate captured CO2 emissions. It is also important to maintain consistency between LCA methodologies and how the market addresses carbon compensation and offsetting. At present, there is no market for large-scale production of e-methanol using captured CO2. Nevertheless, it is crucial to take a critical approach when accounting for captured CO2 and to avoid double counting of environmental benefits across different product systems.

On the topic of CO2 storage, EN15804 states: "The effect of temporary carbon storage and delayed emissions, i.e. the discounting of emissions and removals, shall not be included in the calculation of the GWP." This means that negative CO2 emissions cannot be accounted for. However, this situation is not applicable here, as the CO2 is physically captured and therefore no emission occurs — it does not enter the atmosphere and instead leaves the system as a residual stream or co-product. This stream becomes an input in a subsequent system or can be permanently stored (in the case of fossil CO2, permanent storage may be accounted for under EN15804, but not for biogenic CO2).
For the fossil CO2 variant in this LCA, the environmental burden of the captured CO2 is allocated to the first production system from which it is captured, and not to the e-methanol product system. The CO2 then leaves the initial system not as an emission, but as a burden-free residual stream. This means that the production site avoids emissions, but this cannot be counted as a negative CO2 emission. For every tonne of e-methanol produced, 1.482 tonnes of CO2 are used. This CO2 enters the e-methanol system as a burden-free raw material. The emissions released into the atmosphere during the fuel's combustion are, however, accounted for in the use phase.

EN15804:A2 specifies that both temporary and permanent storage of biogenic CO2 are not included in the GWP calculation (EN15804:A2, Section 5.4.3). For the biogenic variant, the biogenic carbon balance must be zero over the full life cycle. Therefore, a biogenic CO2 correction has been applied in modules A1–A3. From an EN15804 LCA perspective, there is no quantitative benefit to capturing biogenic CO2.

The added value of capturing biogenic CO2 is realised in the subsequent e-methanol production phase, where the use of biogenic CO2 results in a low Environmental Cost Indicator (ECI). The current modelling for biogenic e-methanol thus represents a best-case scenario, where no impact is allocated to the biogenic CO2, but the benefits are assigned to the fuel user. Taking the above into consideration, one could also argue that the burdens of capturing biogenic CO2 should be allocated to the e-methanol supply chain. In that case, the ECI of e-methanol would increase — further nuances on this are discussed in the sensitivity analysis.

The following LCI has been based on a dataset from JRC. Since it is an energy carrier of the future, hydrogen based on electrolysis wind has been used for the feedstock as this is the most sustainable variant. This provides the most realistic representation of the potential of e-methanol (JEC 2020).

Table 35: Production of e-methanol (A1-A3), per tonne

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Output						
Methanol	A1-A3	-	E.I. 3.9	1	Tone	
Recess of heat from methanol synthesis	A1-A3	Heat, district or industrial, natural gas {NL}| heat and power co-generation, natural gas, conventional power plant, 100MW electrical | Cut-off, U	E.I. 3.9	1717,37	MJ	0.0863 MJ/MJ methanol . Assumption of heat recess based on natural gas EcoInvent dataset. (JEC 2020)
Input						
Hydrogen for methanol synthesis	A1-A3	Energy carrier Hydrogen, Gas, Electrolysis, wind mix (A1-A3) (based on NMD profiles Hydrogen, Electrolysis, green mix)		*203,66*	kg	1.2281 MJ per MJ of methanol, conversion by LHV into energy carrier overview (JEC 2020)
Electricity for methanol synthesis	A1-A3	0496-pro&Electricity, Renewable, at consumer, per kWh (based on see explanation in process), (01-2028)	NMD	297,95	KWh	0,0539 MJ/MJ methanol (JEC 2020)
CO2	A1-A3	Free of burden	E.I. 3.9	0,0745 * 19900 = 1482,55	kg	0,0745 kg/MJ methanol.
Transport CO2	A1-A3	0001-tra&Transport, vrachtwagen (Based on Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U)	E.I. 3.9	150 * 1,482 = 222	tonne-km	Assumption of a flat-rate transport of 150 km of CO2, production location to Methanol plant.
Biogenic CO2 correction	A1-A3	Carbon Dioxide, biogenic, to air	E.I. 3.9	-1371,11	Kg	Correction for combustion emissions. Only relevant for the biogenic variant.
Storage	A4	Diesel, low-sulfur {Europe without Switzerland}| market for | Cut-off, U (adapted to storage fuels for category 3 fuel processes)	NMD	1,00	barrel	Assumption equal to Diesel, contribution marginal.

Electricity

The processes for electricity are already available in the NMD, only a wind-mix process will be added. This process can be used if the energy supplier does not specify whether it concerns wind energy from sea or land. The mix is based on the data from 2023. (CBS 2024)

Table 36: Electricity references

Name	Reference
Electricity Green	0496-pro&Electricity, Renewable, at consumer, per kWh (based on see explanation in process), (01-2028)
Electricity Grey	0494-pro&Electricity, Grey, at consumer, per kWh (based on see explanation in process), (01-2028)
Electricity Wind (Sea)	0571-pro&Electricity, renewable, from offshore wind turbines, at the consumer's premises, per kWh (based on see explanation in process), (01-2028)
Electricity Wind (land)	0572-pro&Electricity, renewable, from onshore wind turbines, at the consumer's premises, per kWh (based on see explanation in process), (01-2028)
Electricity Wind Mix	• 37% - 0571-pro&Electricity, renewable, from offshore wind turbines, at consumer, per kWh (based on see explanation in process), (01-2028) • 63% - 0572-pro&Electricity, renewable, from onshore wind turbines, at consumers, per kWh (based on see explanation in process), (01-2028)

Ad-Blue - Urea

This table shows the production of AdBlue (Urea) and the associated emission of CO2 to air.

Table 37: AdBlue per kg, 32.5% Urea

Name	Module	Reference	Database	Quantity	Unit	Remark
Urea	A1-A3	Urea {RER}| market for urea | Cut-off, U	E.I. 3.9	0,325	Kg	32.5% Urea contains 0.15 kg of nitrogen.
Urea	A1-A3	Water, deionised {Europe without Switzerland}| market for water, deionised | Cut-off, U	E.I. 3.9	0,675	Kg	67,5% demi water
Transport to user	A4	0320-tra&Transport, tractor (>32 ton), Euro 5, diesel, per TKM	E.I. 3.9	150	kgkm	150km transport flat rate
CO2 to air	B	CO2 to air	E.I. 3.9	0.733 * 0.325 = 0.238	Kg	From molecular properties, 0.733 kg CO2 emissions per kg of urea.

3.1.2 Emission profiles

The emission profiles cover all emissions resulting from the use of the energy carriers modelled in stages A1–A3. This includes usage in either combustion engines or fuel cells. In terms of Environmental Cost Indicator (ECI), the emission profiles are particularly relevant for combustion engines.

CO2 and NOx emissions are the primary contributors to the total ECI associated with combustion emissions. Different emission classes have varying limits for these emissions, which result in differing environmental impacts. The structure of this report allows users to distinguish between specific emission classes or use their own measured values (for NO_x and PM), depending on the vessel or engine level. For certain emission classes, there are also limits for CO and HC; however, these are not flexibly included in the modelling.

Table 38 shows all combustion emissions without PM and NOx. These are based on the worst-case emission standard (CCRO and Pre TIER I). The Excel calculation tool then gives the user the option to specify PM and NOx by setting a default value (emission classes)Table 40 t/m Table 43 . It is also possible to manually adjust the emissions in the supplied Excel tool. The rules regarding the application of this are not described in this LCA report.

For the ULEV vessels, TNO has indicated that very little real-world data (emissions measurements) is available. It is expected that such vessels will perform similarly to Stage V IWP/IWA standards, with a particularly strong reduction in PM and, to a lesser extent, in NOx (without an increase in AdBlue usage). Therefore, Stage V IWP/IWA values have been used for all ULEV vessels.

For several energy carrier and emission class combinations, no data is available — often because such combinations are not applicable in practice. For example, a new ammonia combustion engine complying only with the outdated CCR I standard would not exist.

For some fuels, specific emission data is lacking — notably for GTL and FAME (Table 38). For GTL, the emission profile of HVO has been used, with all biogenic emissions replaced by fossil emissions. This assumption is based on the fact that GTL is a synthetic fuel and therefore contains very few contaminants. For FAME, emissions are assumed to be equal to those of diesel, but with fossil emissions replaced by biogenic ones. Experts at TNO consider these assumptions representative, since in practice, FAME does not result in lower emissions than diesel.

Table 38: Emission profiles per tonne of fuel (excl. PM and NOx, in kg/tonne fuel)

	Diesel (ULSD)	**HFO**	**GTL**	**MGO**	**LNG / CNG**	**Bio-LNG / Bio-CNG**	**HVO**	**FAME**
Unit	tone	tone	tone	tone	Tone	tone	tone	tone
Source	EcoInvent 3.91	(TNO 2016)	(TNO 2021)	(TNO 2021)	(TNO 2016)/ (TNO 2021)	(TNO 2016)/ (TNO 2021)	(TNO 2021)	
Carbon dioxide, fossil	3152	3206	3124	3181,6	2741,04			
Carbon dioxide, biogenic						2750	3109,3	2834,64
Carbon monoxide, fossil	2,7	13,5	similar to HVO (fossil instead of biogenic)	2,67	14,8			similar to Diesel (biogenic instead of fossil)
Carbon monoxide, biogenic						14,8	2,67	
NMVOC	1,0	2,1		2,36	1,5	1,5	2,36	
Sulfur Dioxide	6.01E-01	2,0		2,57	0,1	0,1	0,03	
Methane, biogenic		0,1		0,112		38,92	0,112	
Methane, fossil	2.40E-02				38,92			
Dinitrogen monoxide	3.31E-01	0,08		0,08	0,08	0,08	0,08	
Ammonia	5.19E-02	0,01		0,01	0,01	0,01	0,01	
Arsenic, ion		2.34E-04		1.80E-04				
Cadmium	1,00E-05	7.05E-06		2.10E-03				
Chromium III	5.01E-05	8,82E-05		2.74E-03				
Copper	1.70E-03	1.76E-04		7,30E-04				
Lead	2.00E-05	5,29E-05		3.70E-04				
Nickel	7.01E-05	1.41E-02		5,30E-04				
Vanadium		1.06E-05		2.38E-03				
Zinc	1.00E-03	3.53E-02		2,45E-03				
Arcolein		3.36E-02		3.49E-02	0,001555	0,001555	3.49E-02	
Benzene	1.90E-02	4.48E-02		4.66E-02	0,002073	0,002073	4.66E-02	
Ethene		2.69E-01		2.80E-01	0,012437	0,012437	2.80E-01	
Formaldehyde		1.34E-01		1.39E-01	0,006219	0,006219	1.39E-01	
Toluene	8.01E-03	3.27E-02		3.39E-02	0,001511	0,001511	3.39E-02	
Xylene	8.01E-03	4.48E-02		4.66E-02	0,002073	0,002073	4.66E-02	
Phenanthrene		7,93E-04		8,24E-04	3,70E-05	3,70E-05	8,24E-04	
Anthracene		6.07E-05		6.30E-05	3,00E-06	3,00E-06	6.30E-05	
Fluoranthene		9,33E-05		9,70E-05	4,00E-06	4,00E-06	9,70E-05	
Chrysene		4.20E-05		4.37E-05	2.00E-06	2.00E-06	4.37E-05	
Benzo(a)anthracene		1.45E-05		1.50E-05	1.00E-06	1.00E-06	1.50E-05	
Benzo(a)pyrene	7.71E-09	1.28E-05		1.34E-05	1.00E-06	1.00E-06	1.34E-05	
Benzo(b)fluoranthe ne		1.07E-05		1.11E-05	4.97E-07	4.97E-07	1.11E-05	
Benzo(k)fluoranthe ne		5,37E-06		5,58E-06	2.48E-07	2.48E-07	5,58E-06	
Benzo(g,h,i)perylen e		4.20E-06		4.37E-06	1.94E-07	1.94E-07	4.37E-06	
Indeno(1,2,3-cd)pyrene		2.33E-09		2.42E-09	1.08E-10	1.08E-10	2.42E-09	
Naphthalene		5,60E-03		5.82E-03	2,59E-04	2,59E-04	5.82E-03	
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-		2,33E-10		2.42E-10	1.08E-11	1.08E-11	2.42E-10	
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a		0,016		0,016	0,016	0,016	0,016	
Hydrogen Chloride	1.06E-03							
mercury	7.01E-08							
Selenium	1,00E-05							

1based on Transport, freight, inland waterways, barge {RER}| transport, freight, inland waterways, barge | Cut-off, U

2Emissions based on TNO, 2016 as these are pure LNG emissions, and not a mix with MGO. However, methane sludge emissions adopted as described in TNO, 2021.

The table below shows the CO_2 emissions for the alternative energy carriers (combustion engine and fuel cell). At the time of writing, there is no measurement data available on other emissions besides CO_2, NOx and PM. As indicated earlier, there is no data available for the (un)regulated emissions from Ammonia ships. There is still great uncertainty about potential emissions of ammonia, sludge, etc.

Table 39: Emission profiles per tonne of fuel, excluding PM and NOx.

	Combustion engine			Fuel cell			
Emission	**Ammonia**	**Methanol**	**Hydrogen**	**Ammonia**	**Hydrogen**	**Methanol**	**Unit**
Carbon dioxide, fossil/biogenic	0	1371,11	0	0	0	1371,11	kg

In Table 40 and

Table 41 show the values for PM and NOx emissions for existing energy carriers. These emissions depend on the vessel's emission class. The values presented are reference figures used in the national emission registry for inland and maritime shipping. These values represent average real-world emissions, based on either on-board measurements or quayside testing. These real-world emissions tend to be higher than the official engine limit values, especially for the higher-tier emission classes. This is largely due to relatively high emissions under low engine load, where exhaust after-treatment systems often perform less effectively.

Since the values for TIER I and TIER II are virtually identical in the dataset, it was decided to cluster them, and a combined class is therefore presented as TIER I / II. The same applies to TIER II, TIER III and ULEV (Stage V IWP/IWA) for (bio)-LNG and (bio)-CNG, which also have identical PM and NOx values.For Tier III, there is still relatively little real-world emissions data available, partly because only a small portion of the fleet currently meets this requirement. Initial measurement results from the SCIPPER project suggest that NO_x values for part of the Tier III fleet appear to be higher than expected. However, the cause of this discrepancy is still unclear, and it remains to be seen whether this applies to the entire (future) fleet.
The emission values for GTL, HVO, and FAME are derived from those of diesel or marine gas oil (MGO). The values only differ for emission classes that do not use after-treatment systems.

Table 40: PM emissions from fuels in internal combustion engines.

PM	Diesel	HFO	GTL	MGO	LNG	Bio-LNG	HVO	FAME	CNG	Bio CNG	Unit
CCR0	0,6	N/A	0,51	N/A	N/A	N/A	0,54	0,54	N/A	N/A	gr/KWh
CCRI	0,3	N/A	0,255	N/A	N/A	N/A	0,27	0,27	N/A	N/A	gr/KWh
CCR II	0,2	N/A	0,17	N/A	0,02	0,02	0,18	0,18	N/A	N/A	gr/KWh
Stage V IWP/IWA[1]	0,03	N/A	0,03	N/A	0,02	0,02	0,03	0,03	0,02	0,02	gr/KWh
Stage V NRE	0,03	N/A	0,03	N/A	0,02	0,02	0,03	0,03	0,02	0,02	gr/KWh
Pre Tier I	0,29	0,74	N/A	0,29	N/A	N/A	0,261	0,261	N/A	N/A	gr/KWh
TIER I	0,24	0,74	N/A	0,24	N/A	N/A	0,216	0,216	N/A	N/A	gr/KWh
TIER II	0,24	0,74	N/A	0,24	0,02	0,02	0,216	0,216	0,02	0,02	gr/KWh
TIER III	0,24	0,74	N/A	0,24	0,02	0,02	0,216	0,216	0,02	0,02	gr/KWh
ULEV (Stage V IWP/IWA)	0,03	0,03	0,03	0,03	0,02	0,02	0,03	0,03	0,02	0,02	gr/KWh
source			(TNO 2014)	Poseidon model entry v1.41	Poseidon model entry v1.41	Poseidon model entry v1.41	(TNO 2023)	(TNO 2023)			

[1]*Waarden gehanteerd voor ULEV variant bij zout*

Table 41:NOx emissions from fuels in internal combustion engines.

NOx	Diesel	HFO	GTL	MGO	LNG	Bio-LNG	HVO	FAME	CNG	Bio CNG	Unit
Unspecified	10,1	N/A	9,09	N/A	N/A	N/A	10,1	10,1	N/A	N/A	gr/KWh
CCRI	9,2	N/A	8,28	N/A	N/A	N/A	9,2	9,2	N/A	N/A	gr/KWh
CCR II	7	N/A	6,3	N/A	1,9	1,9	7	7	1,9	1,9	gr/KWh
Stage V IWP/IWA[1]	3,61	N/A	3,61	N/A	1,9	1,9	3,61	3,61	1,9	1,9	gr/KWh
Stage V NRE	1,38	N/A	1,38	N/A	1,38	1,38	1,38	1,38	1,38	1,38	gr/KWh
Pre Tier I	14	14	N/A	14	N/A	N/A	14	15,7	N/A	N/A	gr/KWh
TIER I	9,9	9,9	N/A	9,9	N/A	N/A	9,9	11,1	N/A	N/A	gr/KWh
TIER II	10	10	N/A	10	1,9	1,9	10	11,2	1,9	1,9	gr/KWh
TIER III	2,9	2,9	N/A	2,9	1,9	1,9	2,9	2,9	1,9	1,9	gr/KWh
ULEV (Stage V IWP/IWA)	3,61	3,61	3,61	3,61	1,9	1,9	3,61	3,61	1,9	1,9	gr/Kwh

[1]*Waarden gehanteerd voor ULEV variant bij zout*

In Table 42 in Table 43 present values for PM and NOx emissions for energy carriers with a lower TRL (technology readiness level). The values are indicative and based on studies and reports. It is expected that, in the coming years, more results from practical measurements will become available for hydrogen and methanol, including data from projects under the Maritime Master Plan. There are indications that, in addition to the listed emissions, other currently unregulated emissions may also be released during the combustion process of new fuels. This includes ammonia slip with ammonia and formaldehyde with methanol. The extent to which this may occur, and thus the impact on the ECI, cannot currently be determined. It is advisable to supplement the values given in the tables as soon as more data from practical measurements becomes available.

Table 42: PM emissions of various innovative fuels in an internal combustion engine and fuel cell.

	Combustion engine			Fuel cell			
PM	**Ammonia ***	**Methanol**	**Hydrogen**	**Hydrogen**	**Ammonia**	**Methanol**	**Unit**
Stage V	0,03	0,015	0,03	0	0	0	gr/KWh
TIER III	0	0,034	0	0	0	0	gr/KWh
ULEV (Stage V IWP/IWA)	0,03	0,015	0,03	0	0	0	gr/Kwh
Source	(Vries 2019)	(TNO 2020)	(Vries 2019)				

* Hardly PM of ammonia, because no carbon in the fuel.

Table 43: NOx emissions from various innovative fuels in an internal combustion engine and fuel cell.

	Combustion engine			Fuel cell			
NOx	**Ammonia**	**Methanol**	**Hydrogen**	**Hydrogen**	**Ammonia**	**Methanol**	**Unit**
Stage V IWP/IWA	N/A	3,61	3,61	0	N/A	0	gr/KWh
Stage V NRE	N/A	1,38	1,38	0	N/A	0	gr/KWh
TIER III	2,9	2,9	2,9	0	0	0	gr/KWh
ULEV (Stage V IWP/IWA)	3,61	3,61	3,61	-	-	-	gr/Kwh
Source	(Zero Carbon Shipping 2023)	(TNO 2020)	(Zero Carbon Shipping 2023)	(Zero Carbon Shipping 2023)	(Zero Carbon Shipping 2023)	(TNO 2020)	

3.1.3 Capital goods

This section describes the capital goods for all combinations of ship and energy carrier combinations. First, the LCI will be described for all basic processes. Next, the underlying assumptions for depreciation will be described for all combinations.

Table 44: List of basic processes of capital goods.

No	Name
1	Salt work vessels
2	Fresh water work vessels
3	Salt transport vessel
4	Fresh water transport vessel
5	Combustion engine
6	Battery packs
7	Electric propulsion
8	Fuel cell

Saltwater work vessel

This profile shows the capital goods of a conventional salt work vessels with an internal combustion engine. The profile includes the hull ship, machinery, port facilities, coolants and lubricating oil. To determine the depreciation, the Technical Committee provided data on various salt work vessels (Table 45). These data show that the mass of the ships scales directly proportional to the fuel consumption over their lifetime. This is reflected in a similar depreciation of tonnes of capital goods per tonne of fuel. It was decided to use the data of ship 3 as this is an average depreciation value. Calculations were made with a ship of 5208 tons, a lifespan of 30 years and an annual fuel consumption of 8466 tons.

Table 45: Data on depreciation of salt work vessels

No	Weight (LSW)	Fuel use	Operational time	Fuel use	Tech. lifetime	Fuel use lifetime (FUL)	LSW/FUL
	tone	ton/hour	NOH/year	ton /year	years	tone	ton steel/ton fuel
1	1450	0,456	5544	2528	30	75.842	0,0191
2	2725	0,850	5544	4710	30	141.305	0,0193
3	5208	1,527	5544	8466	30	253.971	0,0205
4	12100	3,046	5544	16885	30	506.544	0,0239

The depreciation of the machinery remains unchanged. The environmental impact offset resulting from the end-of-life (EOL) phase of the capital goods is also declared in Module B. This approach aligns with the Category 3 reporting of dry equipment.

Table 46: Capital goods of saltwater work vessel per tonne (MGO).

Process	Phase	Environmental profile	Database	Quantity	Unit	Principles
Ship	B	Capital goods Dredging Salt (B1) (based on Dredging ship production + waste processing)	NMD/ Own process	1/(30*8466 = 3,94E-06	p	Scaling parameter in process profiles adjusted to 5208 tons of ship Depreciation based on 30 years of lifespan and fuel consumption of 8466 tons per year.
Ship reD	B	*RWS Subprofiles Capital Goods Dredger Salt (D)	NMD/ Own process	1/(30*8466 = 3,94E-06	p	reD included for ease of use.
Machines (pumps etc.)	B	Extra machines dredger production + waste processing (based on Liquid manure tank trailer {RoW}| production | Cut-off, U)	NMD	2,36	kg	100 tons of depreciation 5 years at 8466 tons per year
Machines (pumps etc.)	B	Extra machines dredger module D (based on Liquid manure tank trailer {RoW}| production | Cut-off, U)	NMD	2,36	p	reD included for ease of use.
Port facility security	B	port facilities {RER} construction | excl electricity for transshipment	E.I. 3.9	5.08E-09	p	Related to fuel consumption, acquisition from NMD card.
Coolant	B	Refrigerant R134a {GLO}	E.I. 3.9	1.6E-02	Kg	Minimal contribution conservatively included
Lubricant	B	Lubricating oil RER	E.I. 3.9	2,46	Kg	Minimal contribution conservatively included
Processing lubricating oil	C4	Bilge oil {Europe without Switzerland}| treatment of bilge oil, hazardous waste incineration | Cut-off, U	E.I. 3.9	2,46	Kg	-

Freshwater work vessel

The capital goods for fresh work vessels are based on the current modelling of the salt dredgers available in the NMD. The most important adjustment is the mass of the freshwater ships, the lifespan and the annual fuel consumption. The profile uses the unit "tons" and is based on data inventory of a Diesel ship (Table 47) which was provided by the Technical Committee. For the other profiles, they will be scaled according to the work performed per functional unit (Table 3).

Table 47: Freshwater transport vessel data

Name	Mass (tons)	Diesel consumption (tonnes/year)	Service life (years)	Depreciation (p/ton of fuel)	Depreciation (tonnes of steel/tonnes of fuel)	Lifetime Energy Input	Lifetime labour Delivered on the Axis	Depreciation of ship per MJ of labour delivered	Depreciation tonnes of steel per MJ of labour	Installed power (kW)
Piling ship	635	65	40	3.85E-04	2.44E-01	1.12E+08	3,37E+07	2.97E-08	1.89E-05	1350,00
Crane ship	560	80	40	3.13E-04	1.75E-01	1.38E+08	4,14E+07	2.41E-08	1.35E-05	1150,00
Work ship	155	20	40	1.25E-03	1.94E-01	3,45E+07	1.04E+07	9,66E-08	1.50E-05	345,00

Although the mass of the freshwater vessels is five times lower than that of the saltwater vessels, their annual fuel consumption is 43 times lower. For this reason, the relative contribution of capital goods to the ECI (Environmental Cost Indicator) per tonne of fuel is relatively higher. Machinery is not applicable for the freshwater work vessels.

Table 48: Capital goods of freshwater work vessels, per tonne of fuel (Diesel)

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Ship	B	Capital goods Dredging Salt (B1) (based on Dredger production + waste processing) adjusted to 635 tonnes	NMD	1/(75*65) = 2,05E-4	p	The existing NMD profile has been formatted in mass scalability, it has been adapted to a ship of 635 tons (conservative in supplied mass of fresh work vessels). Lifespan adjusted to 75 years. Fuel consumption of 65 tons per year maintained.
Schip module-D	B	*RWS Subprofile Capital Goods Dredger Salt (D)	E.I. 3.9	1/(75*65) = 2,05E-4	p	Profiles adjusted to 635 ton ship (conservative in supplied data on mass of fresh work vessels).
Port facility security	B	port facilities {RER} construction | excl electricity for transshipment	E.I. 3.9	5.08E-09	p	Related to fuel consumption, equivalent to Working Salt.
Coolant	B	*Refrigerant R134a {GLO}*	E.I. 3.9	*1.6E-02*	*kg*	Minimal contribution conservatively included
Lubricant	B	*Lubricating oil RER*	E.I. 3.9	*2,46*	*kg*	Minimal contribution conservatively included
Processing lubricating oil	C4	Bilge oil {Europe without Switzerland}| treatment of bilge oil, hazardous waste incineration | Cut-off, U	E.I. 3.9	2,46	*kg*	-

Transport ship inland waterways

For the capital goods of the freshwater transport vessels, the modelling is based on the EcoInvent dataset "Transport, freight, inland waterways, barge {RER} | transport, freight, inland waterways, barge | Cut-off, U." Fuel production and emissions have been removed from this dataset. Subsequently, as with the work vessels, the EOL and recycling offsets for steel have been added to the chart. In line with EcoInvent methodology, no separate lubricating oil consumption is modelled, but bilge oil generation is included.

Table 49: Capital goods freshwater transport, per tonne-km.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Barge	B	Barge {GLO}| market for barge | Cut-off, U	E.I. 3.9	1.05E-09	p	EcoInvent dataset
Waterways	B	Canal {RER}| canal construction | Cut-off, U	E.I. 3.9	1.2E-04	my	EcoInvent dataset
Maintenance	B	Maintenance, barge {RER}| maintenance, barge | Cut-off, U	E.I. 3.9	1.1E-09	p	EcoInvent dataset
Port facility security	B	Port facilities {RER}| port facilities construction | Cut-off, U	E.I. 3.9	2.5E-14	p	EcoInvent dataset
Waste	B	Bilge oil {CH}| market for bilge oil | Cut-off, U	E.I. 3.9	1.20E-06	kg	EcoInvent dataset. Bilge oil not relevant for electric and hydrogen etc. Contributes a total of 0.6% to ECI:A1. Just take conservative with you.
Waste	B	Bilge oil {Europe without Switzerland}| market for bilge oil | Cut-off, U	E.I. 3.9	4,58E-05	kg	EcoInvent dataset

Recycling	B	0315-reC&Sorteren en persen oud ijzer (Based on Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Cut-off, U)	NMD	441,5 * 0,95 * 1,1E-9 = 4,61E-7		Total 414,5 ton staal 95% recycling
Large	B	0253-sto&Stort staal (Based on Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, U)	NMD	441,5 * 0,05 *1,1E-9 = 2,43-8	tone	5% large
Benefits	B	0282-reD&Module D, staal, per kg NETTO geleverd ongelegeerd schroot (World Steel methode obv Steel, low-alloyed {RER&RoW}| steel production, electric, low-alloyed | Cut-off, U - Steel, unalloyed {RER&RoW}| steel production, converter, unalloyed | Cut-off, U)		(265 *0,95 *0,75 + 17,3 * 0,95* 0,613)*1,1E-9 = 2,19E-7	tone	265 ton reinforcing steel 25% secundair (37% low-alloyed . 31,6 secundair en 63% unalloyed, 21% secundair) 17,3 ton cast iron (38,7% secundair)
Benefits	B	0647-reD&Module D, stainless steel, per kg GROSS delivered stainless steel scrap (construction profiles, sheet material and pipes) (avoided: Ferronickel, 25% Ni and Ferrochromium, high-carbon, 68% Cr based on ratios chromium steel 18/8 {GLO} market for)		3,45 * 0,95 * 1,1E-9 = 3,61E-9	tone	3.45 tonnes of stainless steel per kg of gross scrap supplied.

Saltwater transport vessels

For the capital goods of the saltwater transport vessels, modelling is based on the EcoInvent dataset "Transport, freight, sea, bulk carrier for dry goods {GLO} | transport, freight, sea, bulk carrier for dry goods." Fuel production and emissions have been removed from this dataset. As with the work vessels, the recycling offset for steel has been added. The waste processing of the steel is already included in the EcoInvent dataset for the bulk carrier. This dataset models 1 tonne of ship engine. It includes waste processing, and only the recycling offset for the steel has been added.

Table 50: Capital goods transport salt water, per tonne-km.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Ship	B	Bulk carrier, for dry goods {GLO}| market for bulk carrier, for dry goods | Cut-off, U	E.I. 3.9	7.9E-12	p	
Maintenance	B	Maintenance, bulk carrier, for dry goods {GLO}| market for maintenance, bulk carrier, for dry goods | Cut-off, U	E.I. 3.9	7.9E-12	p	
Haven-Facilities	B	Port facilities {GLO}| market for port facilities | Cut-off, U	E.I. 3.9	2.3E-16	p	
Waste	B	Bilge oil {CH}| market for bilge oil | Cut-off, U	E.I. 3.9	7,27E-08	kg	Bilge oil not relevant for electric and hydrogen etc. Contributes a total of 1.1% to ECI:A1. Just take conservative with you.
Waste	B	Bilge oil {Europe without Switzerland}| market for bilge oil | Cut-off, U	E.I. 3.9	2.78E-06	kg	
Waste	B	Bilge oil {RoW}| market for bilge oil | Cut-off, U	E.I. 3.9	5,78E-06	kg	
Benefits	B	0282-reD&Module D, staal, per kg NETTO geleverd ongelegeerd schroot (World Steel methode obv Steel, low-alloyed {RER&RoW}| steel production, electric, low-alloyed | Cut-off, U - Steel, unalloyed {RER&RoW}| steel production, converter, unalloyed | Cut-off, U	NMD	11065*0,95*0,75*7,9 E-12 -7 = 6,23E-8	tone	Total 11.065 ton reinforcing steel 95% recycling, 75% primary. 7,9E-12 per tonkm

Combustion engine

This profile models 1 ton of marine combustion engine. Previously, the combustion engine was not modelled separately; it was assumed to be part of the steel mass in the hull of the ship. For this LCA, the combustion engine is now included separately and is depreciated independently. This was done to ensure consistency with a fuel cell and battery-electric drivetrain.

Table 51: Internal combustion engine, per tonne

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Engine	B	Marine engine {GLO}| marine engine construction | Cut-off, U	E.I. 3.9	1	p	1 ton each, including module EOL
Benefits	B	0647-reD&Module D, stainless steel, per kg GROSS delivered stainless steel scrap (construction profiles, sheet material and pipes) (avoided: Ferronickel, 25% Ni and Ferrochromium, high-carbon, 68% Cr based on ratios chromium steel 18/8 {GLO} market for)	NMD	340 * 0,95 = 323	kg	95 % recycling
Benefits	B	0282-reD&Module D, staal, per kg NETTO geleverd ongelegeerd schroot (World Steel methode obv Steel, low-alloyed {RER&RoW}| steel production, electric, low-alloyed | Cut-off, U - Steel, unalloyed {RER&RoW}| steel production, converter, unalloyed | Cut-off, U)	NMD	650 * 0.95 * 0.613 = 379	Kg	95 % recycling, cast iron 38,7% secondary

Battery packs

For the battery packs, it was decided to remain aligned with the dataset used for land-based equipment. This battery is of the LiMn2O4 type, which is not representative of maritime applications. In shipping, LFP and NMC battery types are primarily used. These types are available in EcoInvent 3.9, but not in EcoInvent 3.6. Currently, it is necessary to have both the ECI:A1 (based on E.I. 3.6) and ECI:A2 (based on E.I. 3.9) available. For this reason, it was chosen for consistency not to deviate from the LiMn2O4 battery.

The dataset assumes an energy density of 200 Wh. In the battery chart below, a reuse rate of 70% is assumed, with a K-factor of 50% and a recycling rate of 30% (NMD 2024). A lifespan of 2,000 charge cycles is used for depreciation

Approximately 80% of the ECI:A2 of lithium battery packs is caused by the battery cells themselves. The source data for lithium-ion battery cells in EcoInvent is relatively outdated (2010). Since then, there have been significant developments in chemistry, materials, and performance. Adjusting this dataset would require an in-depth literature study of the production processes for the various materials and components in the battery cells. The sensitivity analysis will elaborate further on these nuances.

Table 52: Reference for the battery packs

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Battery	A to D	Accu, Lithium-ion, per kWh accucapaciteit (Based on 5kg per kWh)	NMD	1	KWh	including module D

Electric drivetrain
This dataset models all systems required for the electric drivetrain, excluding the fuel cell and battery packs (which are modelled separately). At the time of writing, the required data for the drive systems on electric ships is still lacking. The available dataset for the drivetrain of a passenger vehicle from EcoInvent has been used. This dataset includes the following components: electric motor, inverter, converter, charger, power distribution unit, and cabling. While this is not fully representative of the situation on board an electric vessel, no alternative data is currently available. The dataset is structured per 100 kW of power and will be scaled at a later stage to match the ship's required capacity.
In line with the battery packs, waste processing has been added for the end of life and recess of all metals. The recess of metals is based on the amount present in the various sub-cards, the secondary percentage of these references and a recycling rate of 90%.

Table 53: LCI for the electric drivetrain, per piece (100kW) total mass 80.2 kg.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Drive	A-C	Powertrain, for electric passenger car {GLO}| powertrain production, for electric passenger car | Cut-off, U	E.I. 3.9	80,22	Kg	Values for 100kW
Waste management	C3	Used industrial electronic device {RoW}| market for used industrial electronic device | Cut-off, U	E.I. 3.9	80,22	Kg	100% processing
Incineration	C4	Waste, electrical and electronic cables {RoW}| treatment of waste, electrical and electronic cables, open burning | Cut-off, U	E.I. 3.9	8,022	kg	10% burn
	D	0269-reD&Module D, aluminium, per kg NETTO geleverd schroot (vermeden: Aluminium, cast alloy {GLO}| aluminium ingot, primary, to market | Cut-off, U; Aluminium, cast alloy {RER}| treatment of aluminium scrap, new, at refiner | Cut-off, U; excl. toevoeging van legeringselementen)	NMD 3.9	24,08*(0,9-0,3)+1,13*(0,9-0,74) = 1,46E+01	kg	24,08 kg wrought alloy 30% secondary and 1,13kg cast alloy 74% secondary, 90% recycling
Copper	D	0277-reD&Module D, copper, per kg NET delivered scrap (avoided: Raw materials equivalent global market mix copper)	NMD 3.9	(11,5+0,62)*(0,9 -0,174) = 8,8E+00	kg	12.12 kg Copper, cathode including part present in brass (17.4% secondary), 90% recycling
Zinc	D	0283-reD&Module D, zink, per kg NETTO geleverd schroot (vermeden: Zinc {RoW}| primary production from concentrate | Cut-off, U)	NMD 3.9	0,27*0,9 = 2,40E-01	kg	Zinc present in brass, 100% primary, 90% recycling
Steel	D	0282-reD&Module D, staal, per kg NETTO geleverd ongelegeerd schroot (World Steel methode obv Steel, low-alloyed {RER&RoW}| steel production, electric, low-alloyed | Cut-off, U - Steel, unalloyed {RER&RoW}| steel production, converter, unalloyed | Cut-off, U)	NMD 3.9	36,75*(0,9-0,316 = 2,15E+01	Kg	36.75kg steel, 31.6% secondary, 90% recycling
Stainless steel	D	0647-reD&Module D, stainless steel, per kg GROSS delivered stainless steel scrap (construction profiles, sheet material and pipes) (avoided: Ferronickel, 25% Ni and Ferrochromium, high-carbon, 68% Cr based on ratios chromium steel 18/8 {GLO} market for)	NMD 3.9	6.55*0.9 = 5.90E+00	Kg	6.55kg stainless steel, 90% recycling, reD process for delivered scrap.

Fuel cell

For the fuel cell, the modelling has been adopted from the Category 3 report for land-based equipment (NMD 2024). At present, this is the most representative dataset available. This dataset is based on the following EcoInvent dataset: "Fuel cell, stack polymer electrolyte membrane, 2 kW electrical, future {RoW} | fuel cell production, stack polymer electrolyte membrane, 2 kW electrical, future | Cut-off, U." The EcoInvent dataset models a Polymer Electrolyte Membrane (PEM) fuel cell stack and is based on literature from 2007, which at the time provided a forward-looking estimate based on manufacturer data.

Table 54: LCI for the fuel cell, per kW.

Process	Phase	Environmental profile	Database / Source	Quantity	Unit	Principles
Fuel cell	A to D	Fuel cell Hydrogen, per kW machine power	NMD	1	p	1 piece is 1 kW

4. LCI Combinations

The basic processes described in Chapter 3.1 “LCI Basic Processes” serve as the building blocks for the final combinations. This chapter outlines how these combinations are constructed and under which assumptions/parameters they are calculated. First, the work vessels (freshwater and saltwater) will be explained, which are not entered as Category 3 (Cat.3) datasets. For the environmental profiles of the work vessels, reference is made to the accompanying Excel calculation tool. Then, the transport datasets (seagoing and inland waterway) will be highlighted, which are entered as Cat.3 datasets in the NMD.

4.1 Work vessel combinations

4.1.1 Saltwater

Table 55 presents all combinations for saltwater operations. The assumptions behind depreciation are then substantiated in two example LCI tables: one for a combustion engine (MGO) and one for a fuel cell (hydrogen). For the combustion engines, the AdBlue and capital goods have been scaled from the MGO dataset. For the fuel cell datasets, scaling has been applied from the hydrogen dataset. This is explained under the column “Assumptions” in
Table 56 and
Table 57.

For diesel-electric vessels, calculations can be based on the Diesel dataset. The contribution of the additional capital goods (battery and drivetrain) is marginal (±2% on ECI:A2). This assumes a TIER III diesel vessel where all MJ of work is delivered via the battery. In practice, this will vary depending on the situation and vessel. The potential benefits of the diesel-electric system will become apparent in the fuel consumption per MJ of performed work.

For the ULEV vessels, very little real-world data (emissions measurements) is available. It is expected that such vessels will perform similarly to Stage V IWP/IWA standards, with a particularly strong reduction in PM and, to a lesser extent, in NOx (without an increase in AdBlue usage). Therefore, Stage V IWP/IWA values have been used for all ULEV vessels.
The ULEV map has been included in this report for completeness; however, data on it is very limited. As a result, actual emission values may turn out to be either lower or higher than estimated here. Users should take this into account and, ideally, substantiate NOx and PM emissions with measurement data.

Table 55: Number of base processes per combination, saltwater working vessels.

Drivetrain	Energy carrier		Energy carriers				Usage profile				Capital goods				
			Energy carrier (A1-A3)	Energy carrier (A4)	AdBlue (A1-A3)*	AdBlue (A4)*	Combustion emissions	Emissions AdBlue*	PM	Nox	Casco Ship	Combustion engine	Electric propulsion	Battery	Fuel cell
		Unit	barrel	barrel	kg	kg	tone	kg	Kg	kg	tone	tone	p	KWh	Kw
Combustion engine	Diesel	tone	1	1	66,6	66,6	1	66,6	variable TIER classes	variable TIER classes	1,01	1.13E-03	N/A		
	HFO	tone	1	1	62,63	62,63	1	62,63			0,95	1.06E-03			
	GTL	tone	1	1	68,04	68,04	1	68,04			1,03	1.15E-03			
	MGO	tone	1	1	65,87	65,87	1	65,87			1,00	1.11E-03			
	LNG	tone	1	1	75,77	75,77	1	75,77			1,15	1.28E-03			
	Bio-LNG	tone	1	1	75,77	75,77	1	75,77			1,15	1.28E-03			
	CNG	tone	1	1	71,59	71,59	1	71,59			1,09	1.21E-03			
	Bio-CNG	tone	1	1	71,59	71,59	1	71,59			1,09	1.21E-03			
	HVO	tone	1	1	68,04	68,04	1	68,04			1,03	1.15E-03			
	FAME	tone	1	1	57,52	57,52	1	57,52			0,87	9.72E-04			
	Ammonia (3x)	tone	1	1	28,76	28,76	1	28,76	0,00	6,7	0,44	4.86E-04			
	Hydrogen (liquid) (5x)	tone	1	1	185,56	185,56	1	185,56	0,00	43,5	2,82	3.14E-03			
	Hydrogen (gas) (5x)	tone	1	1	185,56	185,56	1	185,56	0,00	43,5	2,82	3.14E-03			
	Methanol (3x)	tone	1	1	30,77 / 2 = 15,4	15,39	1	15,39	0,08	7,2	0,47	5.20E-04			
Fuel cell	Ammonia (2x)	tone	1	1	0	0	1	0	0,00	0,0	0,46	N/A	4,57E-04	1,35	0,98
	Hydrogen Liquid (5x)	tone	1	1	0	0	1	0	0,00	0,0	2,94		2.95E-03	8,70	6,33
	Hydrogen Gas (5x)	tone	1	1	0	0	1	0	0,00	0,0	2,94		2.95E-03	8,70	6,33
	Methanol (3x)	tone	1	1	0	0	1	0	0,00	0,0	0,49		4.89E-04	1,44	1,05

**AdBlue is only relevant for TIER III engines. Calculated for Diesel (*
Table 56) and scaled to other energy carriers through energy content. For Methanol calculated by half since less AdBlue is needed (2.5% instead of 5%).

Table 56: Work vessel saltwater, MGO, TIER III, per tonne

Process	Phase	Environmental profile	Quantity	Unit	Principles
Energy carrier	A1-A3	Energy carrier MGO (A1-A3)	1	tone	Energy transfer fluid equal to functional unit
Transport to user	A4	Energy carrier MGO storage and transport (A4)	1	kg	Values equal to A1-A3 heat transfer fluid
Production AdBlue (A1-A3)	A1-A3	Energy carrier AdBlue (A1-A3) 32,5% Urea	66,65 * 42,6 / 43,1 = 65,87	**Kg**	Relevant for TIER III only. AdBlue (A1-A3), profiles is drawn up per kg of AdBlue. The assumption is that 4 - 6% (average 5%) litres of AdBlue per litre of Diesel are needed (https://www.auto-motor-oel.de/ratgeber/adblue-der-grosse-ratgeber/2935/#Adblue-Verbrauch) at a density of 0.832 kg/l. Calculated with an average of 5% at a density of 0.832 kg/l. Converted to kg based on density of energy carrier and density AdBlue of 1.109 tons/m3 (32.5% Urea 1.335 tons/m3 and 67.5% water 1 ton/m3). 1000 / 0.832 * 5% * 1.109 = 66.65 kg AdBlue per ton of Diesel. Scaled to other energy carriers by ratio in energy content per ton (42.6 MJ/kg for MGO and 43.1 MJKG for Diesel).
Transport to user	A4	Energy transfer fluid AdBlue (A4) 32.5% Urea	65,87	**Kg**	Equivalent to A1-A3 AdBlue
Combustion emissions	B	Usage profile MGO (combustion emissions) - pre Tier I (without PM and NOx) (B1)	1	**barrel**	Emissions per ton MGO
Emissions AdBlue	B	Emission profile AdBlue (B), CO2 to air per kg AdBlue, 32.5% Urea	65,87	**Kg**	Values equivalent to A1-A3 AdBlue
PM	B	Usage profile - PM emission to air (Particulates, < 10 um, low.pop.)	1,278	**Kg**	Depending on selection TIER class, current value for TIER III. 0.24 g/kWh, 19170 MJ (5325 kWh) labor per ton
NOx	B	Usage profile - NOx emission to air (Nitrogen oxides, low. pop.)	15,44	**Kg**	Depending on selection TIER class, current value for TIER III. 2.9 gr/kWh, 19170 MJ (5325 kWh) labor
Hull/ Ship	B	Capital goods - Dredging Salt (MGO)	1,00	**barrel**	Depreciation is part of the basic process, depreciation based on lifetime fuel consumption (MGO). Scaled to other energy carriers by means of MJ work per functional unit.
Combustion engine	B	Capital goods Combustion engine (1000 kg based on Marine engine {GLO}| marine engine construction | Cut-off, U) (including reD)	1.13E-03	**barrel**	Between 2100- and 16000-kW power. The ship of 5208 (used for capital goods hull ship) has 12725 kW engine power. Estimate 15-40 kg motor per kW. Calculated with a 4500kW motor of 50 tons (11 kg per kW) https://www.yanmar.com/us/marinecommercial/products/propulsion_engine-medium_speed/8ey33w/?utm_source=chatgpt.com Total 12,725 * 11.11 = 141.4 tonnes Lifespan 15 years and 8466 tons of MGO per year. 141.4 / (15 * 8466) = 1.11E-3 tonnes other fuels scaled through labour per F.E.

Table 57: Work vessel saltwater, Hydrogen, fuel cell, per tonne

Process	Phase	Environmental profile	Quantity	Unit	Principles
Energy carrier	A1-A3	Energy carrier Hydrogen, Gas, Electrolysis, wind mix (A1-A3) (based on NMD profiles Hydrogen, Electrolysis, green mix)	1	barrel	Energy carrier equal to functional unit, are 10 options for hydrogen Gas or Liquid, SMR (green or grey) and Electrolysis (green, grey or wind).
Transport to user	A4	Energy carrier Hydrogen, Gas, (A4) wind mix	1	Kg	Values equal to A1-A3 energy carrier, are 6 A4 cards (Gas and liquid and green, grey or wind).
Combustion emissions	B	N/A	1	barrel	N/A
PM	B	Usage profile - PM emission to air (Particulates, < 10 um, low.pop.)	0,0	Kg	N/A
NOx	B	Usage profile - NOx emission to air (Nitrogen oxides, low. pop.)	0,0	Kg	N/A
Hull/ Ship	B	Capital goods - Dredging Salt (MGO)	1.00 * 56400 / 19170= 2,942	barrel	Depreciation is part of the basic process, depreciation based on lifetime fuel consumption (MGO). Scaled to other energy carriers by MJ of labour per functional unit (56400 MJ per ton of hydrogen and 19170 MJH per ton of MGO).
Fuel cell		Fuel cell Hydrogen, per kW machine power	(12725*0.75) / (20000/80) = 38.18	P (1 KW)	Data available of a Hopper dredger sweet with power of 2100 kW Diesel (propulsion, auxiliary engines, work engines). . Assumption 75% of the peak power of fuel cell, so 2100 * 0.75 = 1575kW The H2 hopper dredger (fresh) does 69627 kg of water per year, for 5600 hours = 12.43 kg of hydrogen per hour. The average annual flow rate per kW fuel cell is 12.43 / 1575 = 7.89E-3 kg-H2 per hour per kW fuel cell. Depreciation of 1 ton (functional unit) 1000 kg-H2 /7.89E-3 = 1.27E5 hours per ton-H2 (number of hours that 1kW fuel cell must run to process 1 ton of H2). Fuel cell life at 20,000 hours then gives 1.27E5 / 20000 = 6.33 KW of fuel cell per ton of hydrogen. (both for sweet and salt) (Means replacing every 3.5 years....) For other energy carriers, the assumption is the same life-time labour as H2 fuel cell, scaled based on energy content.
Electric drivetrain	B	Capital goods propulsion electric ship (100 kW) (including EOL and reD)	2.95E-03	P (100kW)	Equivalent to diesel drive power (2100 to 16000kW) 12725 kW Drive passenger car is 0.8022 kg per kW Card per piece (100kW) Assumption lifespan 15 years 127.25 pieces of propulsion, depreciated over the labour output of an MGO ship (8466 * 19170 * 15 = 2.43E9 MJ) but scaled to tons of hydrogen through labour per F.E. for hydrogen fuel cell. 2.43E9 / 56400 = 43,163 tons of hydrogen in 15 years 127.25 / 43163 = 2.95E-3 p
Battery		Accu, Lithium-ion, per kWh battery capacity (based on 5kg per kWh)	8,7	kWh	Hydrogen fuel cell delivers 56400 MJ per ton. 1 kWh = 3.6 MJ. Battery delivers 2000 cycles, 1/2000 depreciation per kWh charged. Conservative approach, any MJ work delivered goes through a battery and not directly from fuel cell. Assuming 90% charging/discharging efficiency. 56400 / 3.6 / 2000 * (1/0.9) = 8.7 kWh per ton of hydrogen

4.1.2 Freshwater working vessels

Table 58 presents all combinations for freshwater operations. The assumptions behind depreciation are substantiated in two example LCI tables: one for a combustion engine (diesel) and one for a battery-electric vessel. For the combustion engines, AdBlue and capital goods have been scaled from the Diesel dataset. For the fuel cell datasets, scaling has been applied from the hydrogen dataset, as described for Saltwater Operations (
Table 57), but using the parameters of the freshwater vessel as detailed in Table 59 (mass, power, etc.). Since battery-electric was not within scope for Saltwater Operations, it has been prepared and presented separately. The scaling to the other energy carriers is explained under the "Assumptions" column in Table 59 and

Table 60.

For diesel-electric vessels, calculations can be based on the Diesel dataset. The contribution of the additional capital goods (battery and drivetrain) is marginal (±2% of ECI:A2). This assumes a TIER III diesel vessel where all MJ of work is delivered via the battery. In practice, this will vary depending on the situation and vessel. The potential benefits of the diesel-electric system will become apparent in the fuel consumption per MJ of delivered work.

Table 58: Number of basic processes per combination, freshwater working vessels.

Drivetrain	Energy carrier		Energy carriers				Usage profile				Capital goods				
			Energy carrier (A1-A3)	Energy carrier (A4)	AdBlue (A1-A3)*	AdBlue (A4)*	Combustion emissions	Emissions AdBlue*	PM	Nox	Casco Ship	Combustion engine	Electric propulsion	Battery	Fuel cell
		Unit	barrel	barrel	Kg	Kg	tone	kg	kg	kg	tone	tone	p	kWh	Kw
Combustion engine	Diesel	tone	1	1	66,65	66,65	1,00	66,6	variable CCR classes	variable CCR classes	1,00	1.57E-03	N/A		
	HFO	tone	N/A												
	GTL	tone	1	1	68,04	68,04	1,00	68,04			1,02	1.61E-03			
	MGO	tone	N/A												
	LNG	tone	1	1	75,77	75,77	1,00	75,77			1,14	1.79E-03			
	Bio-LNG	tone	1	1	75,77	75,77	1,00	75,77			1,14	1.79E-03			
	CNG	tone	1	1	71,59	71,59	1,00	71,59			1,07	1.69E-03			
	Bio-CNG	tone	1	1	71,59	71,59	1,00	71,59			1,07	1.69E-03			
	HVO	tone	1	1	68,04	68,04	1,00	68,04			1,02	1.61E-03			
	FAME	tone	1	1	57,52	57,52	1,00	57,52			0,86	1.36E-03			
	Ammoniac (3x)	tone	N/A								0				
	Hydrogen (liquid) (5x)	tone	1	1	185,56	185,56	1,00	185,56	0,00	0,00	2,78	4.38E-03			
	Hydrogen (gas) (5x)	tone	1	1	185,56	185,56	1,00	185,56	0,00	0,00	2,78	4.38E-03			
	Methanol (3x)	tone	1	1	30,77 / 2 = 15,4	15,4	1,00	15,4	0,08	0,06	0,46	7,27E-04			
Fuel cell	Ammoniac (2x)	tone	N/A								0,51	N/A	7,19E-04	1,35	0,98
	Hydrogen Liquid (5x)	tone	1	1	0,0	0,0	1,00	0,0	0,00	0,00	3,27		4.64E-03	8,70	6,33
	Hydrogen Gas (5x)	tone	1	1	0,0	0	1	0	0,00	0,00	3,27		4.64E-03	8,70	6,33
	Methanol (3x)	tone	1	1	0,0	0	1	0	0,00	0,00	0,54		7,69E-04	1,44	1,05
Battery Electric	Electric	kWh (input)	1	1	N/A						1.60E-04		2,26E-07	5,00E-04	N/A

**AdBlue is only relevant for Stage V engines.*

Table 59: Work vessel freshwater, Diesel, Stage V IWP/IWA per tonne

Process	Phase	Environmental profile	Quantity	Unit	Principles
Energy carrier	A1-A3	Energy carrier Diesel (ULSD) A1-A3 (Market mix 2023) (Based on Diesel, low-sulphur {Europe without Switzerland}| diesel production, low-sulphur, petroleum refinery operation | Cut-off, U)	1	tone	Energy transfer fluid equal to functional unit
Transport to user and storage	A4	Energy carrier Storage and Transport of Diesel/FAME/HVO (A4) (based on NMD profiles Well-to-tank Diesel (A1-A4) without A1-A3 and adapted to tonnes)	1	kton	Values equal to A1-A3 heat transfer fluid
Production AdBlue (A1-A3)	A1-A3	Energy carrier AdBlue (A1-A3) 32,5% Urea	1000 / 0.832 * 5% * 1.109 = 66.65	**Kg**	Only relevant for Stage V. AdBlue (A1-A3), profiles is drawn up per kg of AdBlue. It is assumed that 4 - 6% (average 5%) litres of AdBlue per litre of Diesel are needed (https://www.auto-motor-oel.de/ratgeber/adblue-der-grosse-ratgeber/2935/#Adblue-Verbrauch) at a density of 0.832 kg/l. Calculated with an average of 5%.https://www.auto-motor-oel.de/ratgeber/adblue-der-grosse-ratgeber/2935/#Adblue-Verbrauch) at a density of 0,832 kg/l. Converted to kg based on density of energy carrier and density AdBlue of 1.109 tons/m3 (32.5% Urea 1.335 tons/m3 and 67.5% water 1 ton/m3). 1000 / 0.832 * 5% * 1.109 = 66.65 kg AdBlue per ton of Diesel. Scaled to other energy carriers by ratio in energy content per ton.
Transport to user	A4	Energy transfer fluid AdBlue (A4) 32.5% Urea	66,65	**Kg**	Equivalent to A1-A3 AdBlue
Combustion emissions	B	Usage profile Diesel (ULSD) Combustion emissions (without PM and NOx) B1 (based on Transport, freight, inland waterways, barge {RER}| transport, freight, inland waterways, barge | Cut-off, U)to-tank Diesel (A1-A4) without A1-A3 and adjusted to tonnes)	1	**tone**	Emissions per ton Diesel
Emissions AdBlue	B	Emission profile AdBlue (B), CO2 to air per kg AdBlue, 32.5% Urea	66,65	**kg**	Values equivalent to A1-A3 AdBlue
PM	B	Usage profile - PM emission to air (Particulates, < 10 um, low.pop.)	0,03 / 1000 * 4789 = 0,14	**Kg**	Depending on selection CCR/Stage class, current value for Stage V IWP/IWA, 0.03 gr/kWh, 17240 MJ (4789 kWh) labour per ton
NOx	B	Usage profile - NOx emission to air (Nitrogen oxides, low. pop.)	3,61 / 1000 * 4789 = 17,3	**kg**	Depending on selection CCR/Stage class, current value for Stage V IWP/IWA. 3.61 gr/kWh, 17240 MJ (4789 kWh) labour
Hull/ Ship	B	Capital goods - Dredging Sweet (Diesel)	1,00	**tone**	Depreciation is part of the basic process, depreciation based on lifetime fuel consumption (Diesel). Scaled to other energy carriers by MJ labour per functional unit.
Combustion engine	B	Capital goods Combustion engine (1000 kg based on Marine engine {GLO}| marine engine construction | Cut-off, U) (including reD)	1.57E-03	**tone**	between 345 and 1350 kW of power. 635 ton ship used for capital goods hull ship sweet has 1350 kW engine power. Estimate 15-40 kg per kW. Calculated with a 4500kW motor of 50 tons (11 kg per kW) https://www.yanmar.com/us/marinecommercial/products/propulsion_engine-medium_speed/8ey33w/?utm Total 1350 * 11.11 = 15 tons Lifespan 15 years and 635 tons of Diesel per year. 15 / (15 * 635) = 1.57E-3 ton other fuels scaled through labour per F.E.

Table 60: Freshwater working vessel, Battery Electric, per kWh

Process	Phase	Environmental profile	Quantity	Unit	Principles
Energy carrier	A1-A3	pro&Electricity, renewable, from wind turbines, mix 2023 (37% sea and 63% land), at consumer, per kWh (based on explanation in process), (01-2028)	1	KWh	Energy carrier equal to functional unit, are 5 options for electricity (grey, green, wind mix, wind sea and wind land).
Transport to user	A4	N/A	-	-	-
Hull/ Ship	B	*RWS Capital Goods - Dredging Sweet (Diesel)	1,00 * 2,75 / 17240= 1.6E-4	tone	Depreciation is part of the basic process, depreciation based on lifetime fuel consumption (Diesel). Scaled to other energy carriers by means of MJ of labour per functional unit (2.75 MJ of labour delivered per kWh of electricity and 17240 MJ per ton of Diesel).
Electric Drive	B	Capital goods propulsion electric ship (100 kW) (including EOL and reD)	13,5/ 5,97E7 = 2,26E-7	P (100kW)	Equivalent to diesel drive power (2100 to 16000kW) 1350 kW Card per piece (100kW), 13.5 pieces drive Assumption lifespan 15 years Depreciated on the labour output of a Diesel ship (635 * 17240 * 15 = 1.64E8 MJ) but scaled to electric by labour per F.E. for electric (2.75 MJ). 1.64E8 / 2.75 = 5.97E7 kWh of electricity charged in 15 years. 13,5/ 5,97E7 = 2,26E-7
Battery		Accu, Lithium-ion, per kWh battery capacity (Based on 5kg per kWh)	1/ 2000 = 5,0E-4	kWh	Battery delivers 2000 cycles, 1/2000 depreciation per kWh charged.

4.2 Transport

In this section the transport profiles are described, it concerns a selection of sea bulk transport and inland shipping. The selection arose from consultations with the market parties involved. These profiles consist of the same basic processes as described in this LCA report, but the functional unit is tonne-kilometres (moving a mass of 1 tonne over 1 kilometre). All input is therefore scaled to this functional unit.

Table 61: Profiles for Category 3 NMD Input

No.	Type	Energy carrier
1	Inland waterway transport	Diesel - CCRI
2	Inland waterway transport	CNG - CCRII
3	Inland waterway transport	HVO - CCRI
4	Inland waterway transport	FAME- CCRI
5	Inland waterway transport	Hydrogen – Liquid SMR grey. -Combustion engine -Stage V
6	Inland waterway transport	Hydrogen Liquid - Electrolysis wind - Combustion engine - Stage V
7	Inland waterway transport	Electricity - Green Mix
8	Seagoing transport	CNG - TIER II
9	Seagoing transport	HFO – TIER II
10	Seagoing transport	MGO - TIER II
11	Seagoing transport	Hydrogen – Liquid SMR grey. -Internal combustion engine -TIER III
12	Seagoing transport	Hydrogen Liquid - Electrolysis wind - Internal combustion engine -TIER III
13	Seagoing transport	LNG - TIER II
14	Seagoing transport	FAME - TIER II
15	Seagoing transport	Bio LNG - TIER II

The table below presents the average fleet emission stages for seagoing and inland waterway vessels. Based on this data, the emission limit that most closely matches the average has been determined for the transport datasets submitted to the NMD. For inland waterway transport, this is CCR I (for all energy carriers except hydrogen and CNG), and for seagoing transport, it is TIER II (for all energy carriers except hydrogen).

Table 62: Fleet average emission stages in the year 2022.

Inland navigation	Contribution	NOx (gr/kWh)	Seagoing	Contribution	Nox (gr/kWh)
Pre CCR I	48,1%	10,1	Pre-Tier I	4,0%	14
CCR1	19,9%	9,2	Tier I	35,0%	9,9
CCR2	31,0%	7	Tier II	61,0%	10
Stage-V	1,0%	3,61	Tier III	1,0%	2,9
Inland shipping Mix	100%	8,9	Maritime Mix	100%	10,15
Source: (TNO, TNO Kennisinbreng Mobiliteit voor: Klimaat- en Energieverkenning (KEV-24) en Emissieramingen Luchtverontreinigende stoffen (ERL-25 2025)					

4.1.1 Transport seagoing bulk carrier

For seagoing transport, the dataset “Transport, freight, sea, bulk carrier for dry goods {GLO}| transport, freight, sea, bulk carrier for dry goods | Cut-off, U” was used as a basis. From this dataset, the HFO consumption per tonne-kilometre was adopted as the baseline fuel consumption. This consumption was converted to MJ of delivered work per tonne-kilometre and then scaled to all other energy carriers using the energy content of the fuels (Table 63). Since the delivered work per tonne-kilometre is equal across all variants, there is no difference in the depreciation of capital goods.

Table 63: Fuel consumption per tonne-km of seagoing transport

Fuel	**FE**	**Quantity / tonne-km**	**Unit of energy carrier**	**Drivetrain efficiency**	**MJ (input per kg)**	**MJ output per tonkm**	**Remark**
HFO	**tkm**	**1,727E-6**	**tone**	**0,45**	**40,5**	3.15E-02	Scaled from HFO to other energy carriers through energy content. *Labour delivered per tonne-km / (energy content * efficiency).* Consumption from EcoInvent dataset “Transport, freight, sea, bulk carrier for dry goods {GLO}| transport, freight, sea, bulk carrier for dry goods | Cut-off, U”. 1 piece
MGO	tkm	1,727E-6 * 40,5/ 42,6 = 1,64E-06	tone	0,45	44		
LNG	tkm	1.43E-06	tone	0,45	49		
Bio-LNG	tkm	1.43E-06	tone	0,45	49		
CNG	tkm	1.51E-06	tone	0,45	46,3		
FAME	tkm	1.88E-06	tone	0,45	37,2		
Hydrogen Liquid Combustion Engine	tkm	5,83E-07	tone	0,45	120		
Hydrogen Gas Combustion Engine	tkm	5,83E-07	tone	0,45	120		

Table 64: Structure of the seagoing transport charts.

Energy carrier	Unit	Energy carrier (A1-A3)	Energy carrier (A4)	AdBlue (A1-A3)[1]	AdBlue (A4)[1]	Combustion emissions	Emissions AdBlue	PM	NOx	Capital goods
		tone	tone	kg	kg	tone	kg	Kg	Kg	Tonkm
HFO – TIER II	tkm	1.73E-06	1.73E-06	N/A	N/A	1.73E-06	N/A	6,47E-06	8,74E-05	1,0
MGO – TIER II	tkm	1.64E-06	1.64E-06	N/A	N/A	1.64E-06	N/A	2.10E-06	8,74E-05	
LNG – TIER II	tkm	1.43E-06	1.43E-06	N/A	N/A	1.43E-06	N/A	1.75E-07	1.66E-05	
Bio-LNG – TIER II	tkm	1.43E-06	1.43E-06	N/A	N/A	1.43E-06	N/A	1.75E-07	1.66E-05	
CNG – TIER II	tkm	1.51E-06	1.51E-06	N/A	N/A	1.51E-06	N/A	1.75E-07	1.66E-05	
FAME – TIER II	tkm	1.88E-06	1.88E-06	N/A	N/A	1.88E-06	N/A	1.89E-06	9,79E-05	
Hydrogen (liquid) SMR – TIER III	tkm	5,83E-07	5,83E-07	5.83E-7 * 430 = 2.51 E-4	2.51E-4	5,83E-07	2.51E-4	0.00E+00	2.54E-05	
Hydrogen (liquid) Electrolysis (wind) – TIER III	tkm	5,83E-07	5,83E-07	2.51E-4	2.51E-4	5,83E-07	2.51E-4	0.00E+00	2.54E-05	

1AdBlue only relevant for TIER III, values per tonne of H2 taken from Table 55.

4.2.2 Transport Inland Shipping

For inland waterway transport, practical data on fuel consumption was used as a basis (Table 65). This Diesel consumption per tonne-km is used as a basic fuel consumption and scaled to the other energy carriers by means of the energy densities. This means that the MJ of labour delivered per tonne-km is identical for all transport profiles (Table 63). Because the labour supplied per tonne-km is the same for all variants, there is also no difference in the depreciation of the capital goods

Table 65: Fuel consumption per tonne-km of inland waterway transport

Fuel	FE	Quantity/tonne-km	Unit of energy carrier	Drive efficiency	MJ (input per kg)	MJ output per tonkm	Remark
Diesel	**tkm**	**6.89E-06**	tone	**0,40**	**43,1**	**0,119**	Recalculated: - 6.89E-3 kg Diesel per tonne-km- Assuming an M7 motor freighter-loading capacity is 1900 tonnes (NEA (2009) Cost key figures for inland shipping 2008).- Assuming a utilisation rate of 52.5% (CE Delft (2021), STREAM Freight Transport 2020). This is based on a load factor of 75% and a share of loaded kilometres of 70%. The energy consumption is based on the calculations of the Emission Registration of Inland Shipping. From the results of the model, the average values for the number of kilometres and the calculated fuel consumption (based on speed and flow) based on AIS for M7 motor freighters were taken as a starting point. Scaled from Diesel to other energy carriers through energy content. *Labour delivered per tonne-km / (energy content * efficiency)*
CNG	tkm	6,89E-6 * (43,1 / 46,3) = 6,42E-6	tone	0,40	46,3		
HVO	tkm	6,75E-06	tone	0,40	44		
FAME	tkm	7.99E-06	tone	0,40	37,2		
Hydrogen Liquid Combustion Engine	tkm	2.48E-06	tone	0,40	120		
Hydrogen Gas Combustion Engine	tkm	2.48E-06	tone	0,40	120		
Battery Electric	tkm	0,119 / (3,6 *0,77) = 4,32E-02	KWh	0,77	3,6		

Table 66: Structure of the inland transport profiles.

Energy carrier	Unit	Energy carrier (A1-A3)	Energy carrier (A4)	AdBlue (A1-A3)[1]	AdBlue (A4)[1]	Combustion emissions	Emissions AdBlue1	PM	NOx	Capital goods	Battery[2]	Drive electric[2]
		tone	tone	kg	kg	tone	kg	kg	kg	Tonkm	KWh	p
Diesel – CCR I	tkm	6.89E-06	6.89E-06	N/A	N/A	6.89E-06	N/A	9,90E-06	3.04E-04	1,0	N/A	N/A
CNG– CCR II	tkm	6.42E-06	6.42E-06	N/A	N/A	6.42E-06	N/A	9,66E-07	6,27E-05			
HVO– JRC I	tkm	6,75E-06	6,75E-06	N/A	N/A	6,75E-06	N/A	8,91E-06	3.04E-04			
FAME– CCR I	tkm	7.99E-06	7.99E-06	N/A	N/A	7.99E-06	N/A	8,91E-06	3.04E-04			
Hydrogen (liquid) (SMR) – Stage V	tkm	2.48E-06	2.48E-06	2.48E-6 * 430 = 1.06E-3	1.06E-3	2.48E-06	1.06E-3	0.00E+00	1.19E-04			
Hydrogen (liquid) Electrolysis (wind) – Stage V	tkm	2.48E-06	2.48E-06	1.06E-3	1.06E-3	2.48E-06	1.06E-3	0.00E+00	1.19E-04			
Electric	tkm	4.32E-02	-	-	-	-	-	-	-		4,32E-2 / 2000 = 2,15E-5	2,26E-7 * 4,32E-2 = 9,76E-9

1AdBlue only relevant for TIER III, values per tonne of H2 taken from Table 55.
2Depreciation of battery and drive taken over from works zoet (

Table 60) and scaled with consumption (4.32E-2 kWh).

5. Results

Calculation of environmental profile

The following calculation procedures have been applied in this LCA:

- The calculations in this LCA have been made in accordance with the requirements and guidelines of NEN-EN 15804+A2 (set 1 and set 2) and the Protocol for Drafting and Peer Review category 3 product cards.
- Environmental impacts were calculated using the methods described in NEN-EN 15804+A2, supplemented with characterisation factors from the CML-VLCA calculation method.
- If applicable, the rules for allocation in multi-input, output, recycling and reuse processes from NEN-EN 15804 have been followed, in accordance with NEN-EN-ISO 14044.
- For the workboat datasets, the LCA calculations were performed using the associated Excel calculation tool.
- For the transport datasets, the LCA calculations were performed using SimaPro:
  - EcoInvent processes were modelled including infrastructure processes and capital goods.
  - EcoInvent processes were modelled excluding long-term emissions (>100 years).
- In accordance with paragraph 3.5 of the Determination Method, these impact categories were converted into a single environmental cost indicator (ECI) in euros.

5.1 Characterized results and weighted result

The total ECI-cores for working vessel are reported in table 67 and 68. Detailed analysis can be performed with the accompanying excel calculation tool. For the transport records the characterised results and the weighted outcome are presented in Table 69 through Table 72, per sub-product and per functional unit, for both Set 1 and Set 2. Detailed results per module are included in the annexed result tables for the transport datasets.

Weighting of results is a process by which the outcomes of different environmental impact categories are converted into a single-point score, allowing for integral assessment. In this study, in line with the Determination Method for Environmental Performance of Buildings and Civil Engineering Works, the Environmental Cost Indicator (ECI) is used to weigh the various impact categories into one final score.

5.1.3 Work vessels- Fresh and Salt Water

This chapter only presents the total ECI:A1 and ECI:A2 values. The complete environmental profiles for all work vessel combinations can be generated using the accompanying Excel calculation tool.

Tabel 67: ECI-results for salt work vessels, per ton and per GJ-delivered work.

Work vessel – energy carrier combination	ECI:A2 per ton	ECI:A2 per GJ-delivered energy	ECI:A1 per ton	ECI:A1 per GJ- delivered energy
Diesel, Pre Tier I	€ 864,90	€ 44,59	€ 528,22	€ 27,23
Diesel, TIER I/ II	€ 769,25	€ 39,66	€ 457,56	€ 23,59
Diesel, TIER III	€ 606,93	€ 31,29	€ 341,28	€ 17,60
Diesel, ULEV	€ 623,45	€ 32,15	€ 353,73	€ 18,24
HFO, Pre Tier I	€ 830,96	€ 45,59	€ 511,60	€ 28,07
HFO, TIER I/ II	€ 741,18	€ 40,67	€ 445,22	€ 24,43

HFO, TIER III	€ 588,65	€ 32,30	€ 335,95	€ 18,43
HFO, ULEV	€ 603,21	€ 33,10	€ 347,47	€ 19,07
MGO, Pre Tier I	€ 866,73	€ 45,21	€ 544,72	€ 28,42
MGO, TIER I / II	€ 772,19	€ 40,28	€ 474,88	€ 24,77
MGO, TIER III	€ 611,75	€ 31,91	€ 359,95	€ 18,78
MGO, ULEV	€ 628,09	€ 32,76	€ 372,27	€ 19,42
LNG, TIER II/ III / ULEV	€ 686,94	€ 31,15	€ 374,20	€ 16,97
CNG, general TIER II/ III / ULEV	€ 609,24	€ 29,24	€ 301,15	€ 14,45
Bio-LNG, TIER II / III / ULEV	€ 248,17	€ 11,25	€ 140,56	€ 6,37
Bio CNG, TIER II / III / ULEV	€ 238,09	€ 11,43	€ 135,18	€ 6,49
HVO, Pre Tier I	€ 455,55	€ 23,01	€ 338,03	€ 17,07
HVO, TIER I/ II	€ 357,92	€ 18,08	€ 265,90	€ 13,43
HVO, TIER III	€ 192,21	€ 9,71	€ 147,19	€ 7,43
HVO, ULEV	€ 209,13	€ 10,56	€ 159,92	€ 8,08
FAME, Pre Tier I	€ 492,36	€ 29,41	€ 357,54	€ 21,36
FAME, TIER I /II	€ 399,50	€ 23,87	€ 288,94	€ 17,26
FAME, TIER III	€ 234,66	€ 14,02	€ 170,28	€ 10,17
FAME, ULEV	€ 248,97	€ 14,87	€ 181,04	€ 10,81
Methanol, Bio, TIER III	€ 109,29	€ 12,20	€ 95,28	€ 10,64
Methanol, Bio, ULEV	€ 117,10	€ 13,08	€ 101,06	€ 11,29
Methanol, Bio, Fuel cell	€ 90,69	€ 9,70	€ 95,62	€ 10,22
Methanol, Grey, TIER III	€ 311,62	€ 34,80	€ 171,80	€ 19,19
Methanol, Grey, ULEV	€ 319,43	€ 35,67	€ 177,59	€ 19,83
Methanol, Grey Fuel cell	€ 293,02	€ 31,33	€ 172,14	€ 18,41
E-Methanol (Fossil CO2, H2 wind mix), TIER III	€ 250,21	€ 27,94	€ 173,06	€ 19,33
E-Methanol (Fossil CO2, H2 wind mix), ULEV	€ 258,02	€ 28,81	€ 178,84	€ 19,97
E-Methanol (Fossil CO2, H2 wind mix), Fuel cell	€ 231,61	€ 24,76	€ 173,40	€ 18,54
E-Methanol (Biogenic CO2, H2 wind mix), TIER III	€ 91,16	€ 10,18	€ 104,50	€ 11,67
E-Methanol (Biogenic CO2, H2 wind mix), ULEV	€ 98,97	€ 11,05	€ 110,29	€ 12,32
E-Methanol (Biogenic CO2, H2 wind mix), Fuel cell	€ 72,56	€ 7,76	€ 104,84	€ 11,21
Ammonia, Grey, TIER III	€ 373,30	€ 44,60	€ 204,11	€ 24,39
Ammonia, Grey, ULEV	€ 380,65	€ 45,48	€ 209,52	€ 25,03
Ammonia, Grey Fuel cell	€ 354,38	€ 40,54	€ 202,47	€ 23,16
Ammonia, synthetic, H2 wind mix, TIER III	€ 104,04	€ 12,43	€ 135,50	€ 16,19
Ammonia, synthetic, H2 wind mix, ULEV	€ 111,38	€ 13,31	€ 140,92	€ 16,84
Ammonia, synthetic, H2 wind mix Fuel cell	€ 85,12	€ 9,74	€ 133,86	€ 15,31
Hydrogen, Gas, electrolysis, Grey Mix, TIER III	€ 4.086,31	€ 75,67	€ 2.131,14	€ 39,47
Hydrogen, Gas, electrolysis, Grey Mix, ULEV	€ 4.133,70	€ 76,55	€ 2.166,08	€ 40,11
Hydrogen, Gas, electrolysis, Grey Mix Fuel cell	€ 3.964,23	€ 70,29	€ 2.120,56	€ 37,60
Hydrogen, Liquid, electrolysis, Grey Mix TIER III	€ 4.497,87	€ 83,29	€ 2.335,11	€ 43,24
Hydrogen, Liquid, electrolysis, Grey Mix, ULEV	€ 4.545,26	€ 84,17	€ 2.370,05	€ 43,89
Hydrogen, Liquid, electrolysis, Grey Mix Fuel cell	€ 4.375,79	€ 77,58	€ 2.324,53	€ 41,22
Hydrogen, Gas, SMR, Grey Mix TIER III	€ 1.946,14	€ 36,04	€ 996,30	€ 18,45
Hydrogen, Gas, SMR, Grey Mix, ULEV	€ 1.993,53	€ 36,92	€ 1.031,24	€ 19,10
Hydrogen, Gas, SMR, Grey Mix - Fuel cell	€ 1.824,06	€ 32,34	€ 985,72	€ 17,48
Hydrogen, Liquid, SMR, Grey Mix TIER III	€ 2.357,69	€ 43,66	€ 1.200,27	€ 22,23
Hydrogen, Liquid, SMR, Grey Mix, ULEV	€ 2.405,08	€ 44,54	€ 1.235,21	€ 22,87
Hydrogen, Liquid, SMR, Grey Mix Fuel cell	€ 2.235,61	€ 39,64	€ 1.189,69	€ 21,09
Hydrogen, Gas, SMR, Green Mix - TIER III	€ 1.744,00	€ 32,30	€ 901,05	€ 16,69
Hydrogen, Gas, SMR, Green Mix, ULEV	€ 1.791,39	€ 33,17	€ 936,00	€ 17,33
Hydrogen, Gas, SMR, Green Mix Fuel cell	€ 1.621,92	€ 28,76	€ 890,47	€ 15,79
Hydrogen, Liquid, SMR, Green Mix TIER III	€ 1.891,28	€ 35,02	€ 985,83	€ 18,26
Hydrogen, Liquid, SMR, Green Mix, ULEV	€ 1.938,67	€ 35,90	€ 1.020,78	€ 18,90

Hydrogen, Liquid, SMR, Green Mix Fuel cell	€ 1.769,20	€ 31,37	€ 975,25	€ 17,29
Hydrogen, Gas, electrolysis, Green Mix TIER III	€ 1.636,80	€ 30,31	€ 998,64	€ 18,49
Hydrogen, Gas, electrolysis, Green Mix, ULEV	€ 1.684,19	€ 31,19	€ 1.033,58	€ 19,14
Hydrogen, Gas, electrolysis, Green Mix Fuel cell	€ 1.514,72	€ 26,86	€ 988,06	€ 17,52
Hydrogen, Liquid, electrolysis, Green Mix TIER III	€ 1.784,08	€ 33,04	€ 1.083,42	€ 20,06
Hydrogen, Liquid, electrolysis, Green Mix, ULEV	€ 1.831,47	€ 33,92	€ 1.118,36	€ 20,71
Hydrogen, Liquid, electrolysis, Green Mix Fuel cell	€ 1.662,00	€ 29,47	€ 1.072,84	€ 19,02
Hydrogen, Gas, electrolysis, Wind Mix TIER III	€ 456,08	€ 8,45	€ 545,05	€ 10,09
Hydrogen, Gas, electrolysis, Wind Mix, ULEV	€ 503,47	€ 9,32	€ 580,00	€ 10,74
Hydrogen, Gas, electrolysis, Wind Mix Fuel cell	€ 334,00	€ 5,92	€ 534,47	€ 9,48
Hydrogen, Liquid, electrolysis, Wind Mix TIER III	€ 475,97	€ 8,81	€ 579,07	€ 10,72
Hydrogen, Liquid, electrolysis, Wind Mix, ULEV	€ 523,36	€ 9,69	€ 614,01	€ 11,37
Hydrogen, Liquid, electrolysis, Wind Mix Fuel cell	€ 353,89	€ 6,27	€ 568,49	€ 10,08

Tabel 68: ECI-results for freshwater work vessels, per ton and per GJ-delivered work.

Functional unit (FU)	Work vessel – energy carrier combination	ECI:A2 per FU	ECI:A2 per GJ-delivered energy	ECI:A1 per FU	ECI:A1 per GJ-delivered energy
ton	Diesel (ULSD), CCR 0 / Unspecified	€ 781,75	€ 45,35	€ 476,18	€ 27,62
ton	Diesel (ULSD), CCR I	€ 762,09	€ 44,20	€ 461,94	€ 26,79
ton	Diesel (ULSD), CCR II	€ 715,20	€ 41,48	€ 427,37	€ 24,79
ton	Diesel (ULSD), Stage V IWP/IWA	€ 650,18	€ 37,71	€ 383,20	€ 22,23
ton	Diesel (ULSD), Stage V NRE	€ 602,83	€ 34,97	€ 348,20	€ 20,20
ton	GTL, CCR 0 / Unspecified	€ 900,38	€ 51,16	€ 599,84	€ 34,08
ton	GTL, CCR I	€ 882,35	€ 50,13	€ 586,76	€ 33,34
ton	GTL, CCR II	€ 839,27	€ 47,69	€ 555,00	€ 31,53
ton	GTL, Stage V IWP/IWA	€ 788,12	€ 44,78	€ 521,14	€ 29,61
ton	GTL, Stage V NRE	€ 739,78	€ 42,03	€ 485,41	€ 27,58
ton	LNG, CCR II	€ 722,49	€ 36,86	€ 411,52	€ 21,00
ton	LNG, Stage V IWP/IWA	€ 730,75	€ 37,28	€ 421,88	€ 21,52
ton	LNG, Stage V NRE	€ 718,20	€ 36,64	€ 412,60	€ 21,05
ton	CNG, CCR II	€ 642,83	€ 34,71	€ 336,41	€ 18,16
ton	CNG, Stage V IWP/IWA	€ 650,63	€ 35,13	€ 346,20	€ 18,69
ton	CNG, Stage V NRE	€ 638,73	€ 34,49	€ 337,42	€ 18,22
ton	Bio-LNG, CCR II	€ 283,71	€ 14,48	€ 177,88	€ 9,08
ton	Bio-LNG, Stage V IWP/IWA	€ 291,97	€ 14,90	€ 188,24	€ 9,60
ton	Bio-LNG, Stage V NRE	€ 279,42	€ 14,26	€ 178,96	€ 9,13
ton	Bio CNG, CCR II	€ 271,67	€ 14,67	€ 170,45	€ 9,20
ton	Bio CNG, Stage V IWP/IWA	€ 279,48	€ 15,09	€ 180,23	€ 9,73
ton	Bio CNG, Stage V NRE	€ 267,58	€ 14,45	€ 171,46	€ 9,26
ton	HVO, CCR 0 / Unspecified	€ 370,62	€ 21,06	€ 284,89	€ 16,19
ton	HVO, CCR I	€ 350,61	€ 19,92	€ 270,37	€ 15,36
ton	HVO, CCR II	€ 302,75	€ 17,20	€ 235,08	€ 13,36
ton	HVO, Stage V IWP/IWA	€ 236,41	€ 13,43	€ 190,00	€ 10,80
ton	HVO, Stage V NRE	€ 188,08	€ 10,69	€ 154,26	€ 8,76
ton	FAME, CCR 0 / Unspecified	€ 385,50	€ 25,91	€ 286,70	€ 19,27
ton	FAME, CCR I	€ 368,58	€ 24,77	€ 274,43	€ 18,44
ton	FAME, CCR II	€ 328,12	€ 22,05	€ 244,59	€ 16,44
ton	FAME, Stage V IWP/IWA	€ 272,03	€ 18,28	€ 206,48	€ 13,88
ton	FAME, Stage V NRE	€ 231,17	€ 15,54	€ 176,26	€ 11,85
ton	Methanol, Grey - Stage V IWP/IWA	€ 331,77	€ 41,68	€ 191,20	€ 26,94
ton	Methanol, Grey Stage V NRE	€ 309,91	€ 38,93	€ 175,03	€ 21,99
ton	Methanol, Grey - Fuel cell	€ 313,26	€ 33,49	€ 192,37	€ 20,57
ton	E-Methanol (Fossil CO2, H2 wind mix), Stage V IWP/IWA	€ 270,36	€ 33,96	€ 192,45	€ 24,18
ton	E-Methanol(Fossil CO2, H2 wind mix), Stage V NRE	€ 248,50	€ 31,22	€ 176,29	€ 22,15
ton	E-Methanol(Fossil CO2, H2 wind mix), Fuel cell	€ 251,84	€ 26,93	€ 193,62	€ 20,70
ton	E-Methanol (Biogenic CO2, H2 wind mix), Stage V IWP/IWA	€ 111,31	€ 13,98	€ 123,89	€ 15,56
ton	E-Methanol (Biogenic CO2, H2 wind mix), Stage V NRE	€ 89,45	€ 11,24	€ 107,73	€ 13,53
ton	E-Methanol (Biogenic CO2, H2 wind mix), Fuel cell	€ 92,80	€ 9,92	€ 125,07	€ 13,37
ton	Methanol, Bio Stage V IWP/IWA	€ 129,45	€ 16,26	€ 114,67	€ 14,41
ton	Methanol, Bio Stage V NRE	€ 107,58	€ 13,52	€ 98,51	€ 12,38
ton	Methanol, Bio Fuel cell	€ 110,93	€ 11,86	€ 115,84	€ 12,39
ton	Hydrogen, Gas, electrolysis, Grey Mix - Stage V IWP/IWA	€ 4.208,11	€ 87,67	€ 2.248,13	€ 46,84
ton	Hydrogen, Gas, electrolysis, Grey Mix Stage V NRE	€ 4.076,29	€ 84,92	€ 2.150,67	€ 44,81
ton	Hydrogen, Gas, electrolysis, Grey Mix - Fuel cell	€ 4.086,28	€ 72,45	€ 2.242,50	€ 39,76
ton	Hydrogen, Liquid, electrolysis, Grey Mix Stage V IWP/IWA	€ 4.619,66	€ 96,24	€ 2.452,10	€ 51,09

ton	Hydrogen, Liquid, electrolysis, Grey Mix Stage V NRE	€ 4.487,84	€ 93,50	€ 2.354,64	€ 49,05
ton	Hydrogen, Liquid, electrolysis, Grey Mix - Fuel cell	€ 4.497,83	€ 79,75	€ 2.446,47	€ 43,38
ton	Hydrogen, Gas, SMR, Grey Mix Stage V IWP/IWA	€ 2.067,94	€ 43,08	€ 1.113,30	€ 23,19
ton	Hydrogen, Gas, SMR, Grey Mix Stage V NRE	€ 1.936,11	€ 40,34	€ 1.015,83	€ 21,16
ton	Hydrogen, Gas, SMR, Grey Mix Fuel cell	€ 1.946,10	€ 34,51	€ 1.107,66	€ 19,64
ton	Hydrogen, Liquid, SMR, Grey Mix Stage V IWP/IWA	€ 2.479,49	€ 51,66	€ 1.317,27	€ 27,44
ton	Hydrogen, Liquid, SMR, Grey Mix - Stage V NRE	€ 2.347,67	€ 48,91	€ 1.219,80	€ 25,41
ton	Hydrogen, Liquid, SMR, Grey Mix Fuel cell	€ 2.357,66	€ 41,80	€ 1.311,63	€ 23,26
ton	Hydrogen, Gas, electrolysis, Green Mix Stage V IWP/IWA	€ 1.758,59	€ 36,64	€ 1.115,63	€ 23,24
ton	Hydrogen, Gas, electrolysis, Green Mix Stage V NRE	€ 1.626,77	€ 33,89	€ 1.018,17	€ 21,21
ton	Hydrogen, Gas, electrolysis, Green Mix Fuel cell	€ 1.636,76	€ 29,02	€ 1.110,00	€ 19,68
ton	Hydrogen, Liquid, electrolysis, Green Mix - Stage V IWP/IWA	€ 1.905,87	€ 39,71	€ 1.200,41	€ 25,01
ton	Hydrogen, Liquid, electrolysis, Green Mix Stage V NRE	€ 1.774,05	€ 36,96	€ 1.102,95	€ 22,98
ton	Hydrogen, Liquid, electrolysis, Green Mix Fuel cell	€ 1.784,04	€ 31,63	€ 1.194,78	€ 21,18
ton	Hydrogen, Gas, SMR, Green Mix Stage V IWP/IWA	€ 1.865,80	€ 38,87	€ 1.018,05	€ 21,21
ton	Hydrogen, Gas, SMR, Green Mix Stage V NRE	€ 1.733,97	€ 36,12	€ 920,58	€ 19,18
ton	Hydrogen, Gas, SMR, Green Mix Fuel cell	€ 1.743,96	€ 30,92	€ 1.012,42	€ 17,95
ton	Hydrogen, Liquid, SMR, Green Mix Stage V IWP/IWA	€ 2.013,08	€ 41,94	€ 1.102,83	€ 22,98
ton	Hydrogen, Liquid, SMR, Green Mix Stage V NRE	€ 1.881,25	€ 39,19	€ 1.005,36	€ 20,95
ton	Hydrogen, Liquid, SMR, Green Mix Fuel cell	€ 1.891,24	€ 33,53	€ 1.097,20	€ 19,45
ton	Hydrogen, Gas, electrolysis, Wind Mix Stage V IWP/IWA	€ 577,87	€ 12,04	€ 662,05	€ 13,79
ton	Hydrogen, Gas, electrolysis, Wind Mix Stage V NRE	€ 446,05	€ 9,29	€ 564,58	€ 11,76
ton	Hydrogen, Gas, electrolysis, Wind Mix Fuel cell	€ 456,04	€ 8,09	€ 656,41	€ 11,64
ton	Hydrogen, Liquid, electrolysis, Wind Mix Stage V IWP/IWA	€ 597,77	€ 12,45	€ 696,06	€ 14,50
ton	Hydrogen, Liquid, electrolysis, Wind Mix - Stage V NRE	€ 465,94	€ 9,71	€ 598,60	€ 12,47
ton	Hydrogen, Liquid, electrolysis, Wind Mix Fuel cell	€ 475,93	€ 8,44	€ 690,43	€ 12,24
kWh	Electricity, Grey - Electric motor	€ 0,07814	€ 28,37	€ 0,0463	€ 16,82
kWh	Electricity, Green Electric motor	€ 0,03430	€ 12,46	€ 0,0261	€ 9,47
kWh	Electricity, Wind Mix (37% Sea, 63% Land) Electric motor	€ 0,01317	€ 4,78	€ 0,0179	€ 6,51

5.1.4 Seagoing transport

Table 69: Results of seagoing transport per tonne-km, EN15804:A1 and ECI:A1.

Impact category	*Unit*	**Bio-LNG, TIER II**	**CNG, TIER II**	**FAME, TIER II**	**HFO, TIER II**	**LNG, TIER II/III**	**MGO, TIER II**	**Hydrogen (liquid Electrolysis wind), combustion engine TIER III**	**Hydrogen liquid SMR Grey), combustion engine TIER III**
abiotic depletion, non fuel (AD)	kg Sb eq	1,01E-08	9,32E-09	1,15E-08	9,36E-09	9,28E-09	9,82E-09	2,26E-08	1,59E-08
abiotic depletion, fuel (AD)	kg Sb eq	5,43E-07	7,71E-06	2,78E-06	6,25E-06	7,29E-06	7,03E-06	1,27E-06	9,79E-06
global warming (GWP)	kg CO2 eq	1,29E-04	3,61E-04	1,12E-04	3,26E-04	3,61E-04	3,32E-04	6,28E-05	3,85E-04
ozone layer depletion (ODP)	kg CFC-11 eq	1,19E-09	1,49E-08	7,53E-09	3,08E-08	1,30E-08	3,09E-08	3,17E-09	2,03E-08
photochemical oxidation (POCP)	kg C2H4	5,24E-06	6,65E-06	5,01E-06	7,31E-06	7,42E-06	7,17E-06	4,01E-06	6,08E-06
acidification (AP)	kg SO2 eq	4,28E-05	5,33E-05	2,39E-04	2,24E-04	6,87E-05	2,35E-04	8,25E-05	9,32E-05
eutrophication (EP)	kg PO4--- eq	2,22E-05	2,44E-05	1,31E-04	1,14E-04	2,60E-05	1,14E-04	4,41E-05	4,34E-05
human toxicity (HT)	kg 1,4-DB eq	9,05E-05	9,00E-05	1,36E-04	1,70E-04	1,34E-04	1,62E-04	2,39E-04	1,38E-04
Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	4,35E-07	4,86E-07	1,23E-06	2,07E-06	2,02E-06	2,00E-06	1,20E-06	7,35E-07
Ecotoxicity, marine water (MAETP)	kg 1,4-DB eq	4,52E-06	5,41E-06	9,92E-06	1,25E-05	2,33E-05	1,44E-05	1,15E-05	8,52E-06
Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	6,52E-07	5,79E-07	8,44E-07	7,01E-07	5,67E-07	7,07E-07	5,66E-06	1,50E-06
ECI	€	2,96E-04	5,50E-04	6,38E-04	8,64E-04	6,30E-04	8,74E-04	4,52E-04	6,87E-04

Table 70: Results of seagoing transport per tonne-km, EN15804:A2 and ECI:A2.

Impact category	*Unit*	**Bio-LNG, TIER II**	**CNG, TIER II**	**FAME, TIER II**	**HFO, TIER II**	**LNG, TIER II/III**	**MGO, TIER II**	**Hydrogen (liquid Electrolysis wind), combustion engine TIER III**	**Hydrogen liquid SMR Grey), combustion engine TIER III**
Climate change	kg CO2 eq	2.54E-03	7,11E-03	2.34E-03	7,18E-03	7,47E-03	6.90E-03	1.19E-03	1.03E-02
Climate change - Fossil	kg CO2 eq	5.94E-04	7.10E-03	2.33E-03	7,17E-03	7,46E-03	6,89E-03	1.18E-03	1.03E-02
Climate change - Biogenic	kg CO2 eq	1.94E-03	9,87E-07	-3,50E-06	4.55E-06	-1,38E-06	5.21E-06	7,60E-07	-1.21E-06
Climate change - Land use and LU ch	kg CO2 eq	6,39E-06	6,58E-06	2.26E-05	6,60E-06	6,66E-06	6,59E-06	6,94E-06	6,79E-06
Ozone depletion	kg CFC11 eq	9.95E-12	2.97E-10	7,23E-11	1.37E-10	9,65E-11	6,13E-10	5.25E-11	6,71E-10
Acidification	mol H+ eq	1.51E-05	1.76E-05	8,47E-05	7,55E-05	2.00E-05	7,87E-05	2.71E-05	2.99E-05
Eutrophication, freshwater	kg P eq	3.16E-08	4.18E-08	5.02E-08	3,60E-08	3.71E-08	3,67E-08	3.11E-07	9,83E-08
Eutrophication, marine	kg N eq	6,96E-06	7,45E-06	4.09E-05	3,54E-05	8.15E-06	3,55E-05	1.12E-05	1.23E-05
Eutrophication, terrestrial	mol N eq	7,62E-05	8,16E-05	4.45E-04	3.85E-04	8.93E-05	3.87E-04	1.21E-04	1.35E-04
Photochemical ozone formation	kg NMVOC eq	2.42E-05	2.83E-05	1.13E-04	1.09E-04	3.49E-05	1.05E-04	3.24E-05	3.83E-05
Resource use, minerals and metals	kg Sb eq	1.15E-08	8.59E-09	9,88E-09	8,21E-09	8,67E-09	8,53E-09	8,82E-08	1.38E-08
Resource use, fossils	MJ	6,43E-03	8,40E-02	3.20E-02	8,55E-02	8,55E-02	9,36E-02	1.36E-02	1.56E-01
Water use	m3 depriv.	1.86E-04	2.46E-04	2.99E-05	2.66E-04	2,59E-04	2.58E-04	9,57E-04	9,50E-04
Particulate matter	disease inc.	5.99E-11	5.86E-11	1.14E-10	9,86E-11	6.85E-11	1.29E-10	9,90E-11	8,29E-11
Ionising radiation	kBq U-235 eq	1.50E-05	2.14E-05	2.32E-05	2.33E-05	1.84E-05	2.62E-05	3,67E-05	9,49E-05
Ecotoxicity, freshwater	CTUe	5,54E-03	5.85E-03	1.43E-02	3.92E-02	6,67E-03	3.12E-02	5.14E-02	2.92E-02
Human toxicity, cancer	CTUh	2.91E-12	3,13E-12	3.24E-12	4.06E-12	3.28E-12	3.76E-12	6,27E-12	3,80E-12
Human toxicity, non-cancer	CTUh	2,13E-11	2.07E-11	2.28E-11	3.02E-11	2.28E-11	5,32E-11	9,65E-11	3,28E-11
Land use	Pt	4.52E-03	3.26E-03	8.88E-03	5.93E-03	3.23E-03	4.61E-03	1.16E-02	5,57E-03
ECI	€	4.25E-04	9.90E-04	8,21E-04	1.35E-03	1.05E-03	1.34E-03	3.63E-04	1.46E-03

5.1.5 Transport Inland Waterways

Table 71: Results of transport Inland shipping per tonne-km, EN15804:A1 and ECI:A1.

Impact category	*Unit*	**CNG, CCR II**	**Diesel, CCR I**	**FAME, CCR I**	**HVO, JRC I**	**Electric, renewable mix**	**Hydrogen (Electrolysis Wind Liquid) Combustion Engine Stage V**	**Hydrogen (SMR Grey Liquid) Combustion Engine Stage V**
abiotic depletion, non fuel (AD)	kg Sb eq	3.73E-07	3.76E-07	4.33E-07	4.13E-07	7,27E-07	7,28E-07	4.12E-07
abiotic depletion, fuel (AD)	kg Sb eq	2.56E-04	6,29E-05	1.25E-04	8,54E-05	7,83E-05	8,53E-05	4.23E-04
global warming (GWP)	kg CO2 eq	4.04E-02	3,37E-02	1.93E-02	1.42E-02	1.46E-02	1.50E-02	5.42E-02
ozone layer depletion (ODP)	kg CFC-11 eq	2.82E-09	8,21E-10	1.77E-09	1.21E-09	1.09E-09	1.15E-09	4.64E-09
photochemical oxidation (POCP)	kg C2H4	2.22E-05	1.55E-05	1.87E-05	1.88E-05	1.81E-05	1.66E-05	2.13E-05
acidification (AP)	kg SO2 eq	9.09E-05	2.03E-04	2.36E-04	2.24E-04	8,39E-05	1.31E-04	1.42E-04
eutrophication (EP)	kg PO4--- eq	1.60E-05	4.68E-05	5,29E-05	5,13E-05	1.33E-05	2.78E-05	2.67E-05
human toxicity (HT)	kg 1,4-DB eq	6.12E-03	6,33E-03	8,17E-03	7,74E-03	9,81E-03	1.32E-02	7,88E-03
Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1.32E-04	1.15E-04	2.38E-04	5.01E-04	1.97E-04	2.34E-04	1.64E-04
Ecotoxicity, marine water (MAETP)	kg 1,4-DB eq	3.38E-01	2.81E-01	5.29E-01	3.57E-01	5.58E-01	5.98E-01	4.87E-01
Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	6.24E-05	5,88E-05	8,12E-05	1.69E-04	1.68E-04	4.23E-04	1.22E-04
ECI	€	3.21E-03	3.57E-03	3.24E-03	2.87E-03	2.19E-03	2.85E-03	4.39E-03

Table 72: Results of transport for inland waterways shipping per tonne-km, EN15804:A1 and ECI:A1.

Impact category	*Eenheid*	**CNG, CCR II**	**Diesel, CCR I**	**FAME, CCR I**	**HVO, JRC I**	**Electric, renewable mix**	**Hydrogen (Electrolysis Wind Liquid) Combustion Engine Stage V**	**Hydrogen (SMR Grey Liquid) Combustion Engine Stage V**
Climate change	kg CO2 eq	4,00E-02	3.39E-02	1.97E-02	1.49E-02	1.69E-02	1.48E-02	5.35E-02
Climate change - Fossil	kg CO2 eq	3.97E-02	3,37E-02	1.94E-02	1.43E-02	1.43E-02	1.46E-02	5,33E-02
Climate change - Biogenic	kg CO2 eq	1.05E-04	9,28E-05	8,63E-05	1.20E-04	2.59E-03	1.04E-04	9,61E-05
Climate change - Land use and LU ch	kg CO2 eq	1.02E-04	1.01E-04	1.70E-04	5,31E-04	1.08E-04	1.03E-04	1.03E-04
Ozone depletion	kg CFC11 eq	1.37E-09	1.41E-10	4,20E-10	2.97E-10	3.99E-10	3,36E-10	2.97E-09
Acidification	mol H+ eq	1.12E-04	2.84E-04	3,20E-04	3.11E-04	1.02E-04	1.67E-04	1.78E-04
Eutrophication, freshwater	kg P eq	5,36E-07	4.80E-07	5.72E-07	5,58E-07	6,70E-07	1.68E-06	7,76E-07
Eutrophication, marine	kg N eq	3.86E-05	1.30E-04	1.40E-04	1.41E-04	1.82E-05	6.18E-05	6,66E-05
Eutrophication, terrestrial	mol N eq	4.25E-04	1.43E-03	1.53E-03	1.52E-03	3.03E-04	6,75E-04	7,34E-04
Photochemical ozone formation	kg NMVOC eq	1.56E-04	3.74E-04	4.10E-04	4.14E-04	8.01E-05	1.92E-04	2.17E-04
Resource use, minerals and metals	kg Sb eq	5.62E-08	5,26E-08	6.17E-08	6,29E-08	3.29E-07	3.95E-07	7,83E-08
Resource use, fossils	MJ	4,64E-01	1.29E-01	2.43E-01	1.78E-01	1.58E-01	1.65E-01	7,68E-01
Water use	m3 depriv.	3,60E-03	3.26E-03	2.68E-03	4.32E-03	4.61E-03	6,62E-03	6,58E-03
Particulate matter	disease inc.	6,57E-10	6,91E-10	8,71E-10	8,15E-10	1.07E-09	8,33E-10	7.64E-10
Ionising radiation	kBq U-235 eq	5,75E-04	5,35E-04	5,82E-04	5,62E-04	6.25E-04	6,39E-04	8,87E-04
Ecotoxicity, freshwater	CTUe	6.18E-02	5.45E-02	9,77E-02	1.75E-01	2.59E-01	2.55E-01	1.61E-01
Human toxicity, cancer	CTUh	2,50E-11	2.35E-11	2.55E-11	2.67E-11	2.95E-11	3.83E-11	2.78E-11
Human toxicity, non-cancer	CTUh	1.72E-10	1.48E-10	1.81E-10	1.98E-10	3.21E-10	4,95E-10	2.24E-10
Land use	Pt	3.92E-01	3.91E-01	4.16E-01	4.32E-01	9,98E-01	4.28E-01	4.02E-01
ECI	€	5,80E-03	6.00E-03	4.62E-03	4.05E-03	3.17E-03	3.22E-03	7,89E-03

5.2 Interpretation of the results (Hotspot analysis)

5.2.1 Work vessels saltwater analysis

The figures below illustrate the ratio between all energy carriers per GJ of delivered work for saltwater work vessels (Figure 3 for ECI:A2 and Figure 6 for ECI:A1). The energy content of the various carriers varies greatly, which is why comparison by mass would give a distorted picture. To provide a clear comparison, a limited selection has been made. For internal combustion engines, only the best and worst emission classes are shown, and for all hydrogen variants, a limited subset is also displayed. Further details follow in subsequent figures.

Regarding currently available fuels, there is little difference between the fossil variants. However, the shift from TIER I/II to TIER III has a significant impact on the ECI:A2. With the current modelling, biofuels perform much better—particularly bio-LNG, bio-CNG, bio-methanol, and HVO (TIER III).

Looking further ahead, among the RFNBOs, hydrogen produced through electrolysis powered by wind energy has the lowest ECI:A2. The difference between gaseous and liquid hydrogen is only a few percentage points, depending on the electricity required for liquefaction/compression. The difference between internal combustion engines and fuel cells is primarily due to NOx emissions from the combustion engines, which is elaborated upon in later sections.

After wind-based hydrogen, the RFNBOs synthetic ammonia and e-methanol (biogenic) show a very low ECI:A2. Their ECI is higher than that of hydrogen itself, as both fuels are produced from hydrogen (in this case, from wind-powered electrolysis). The e-methanol variant is based on captured fossil CO2, which is why this energy carrier performs poorly. The implications of this choice are further discussed in the sensitivity analysis.

It should be noted that significant uncertainty remains around RFNBOs. The technologies for these vessels are still in their early stages, and the available data is relatively uncertain. There is limited insight into emissions during the use phase, production, distribution, and capital goods. These uncertainties may influence the relative performance between energy carriers and propulsion systems.

Figure 3: Overview of salt work vessels, total ECI:A2 per GJ of work. By type, red - fossil, green - biofuel and blue - RFNBOs.

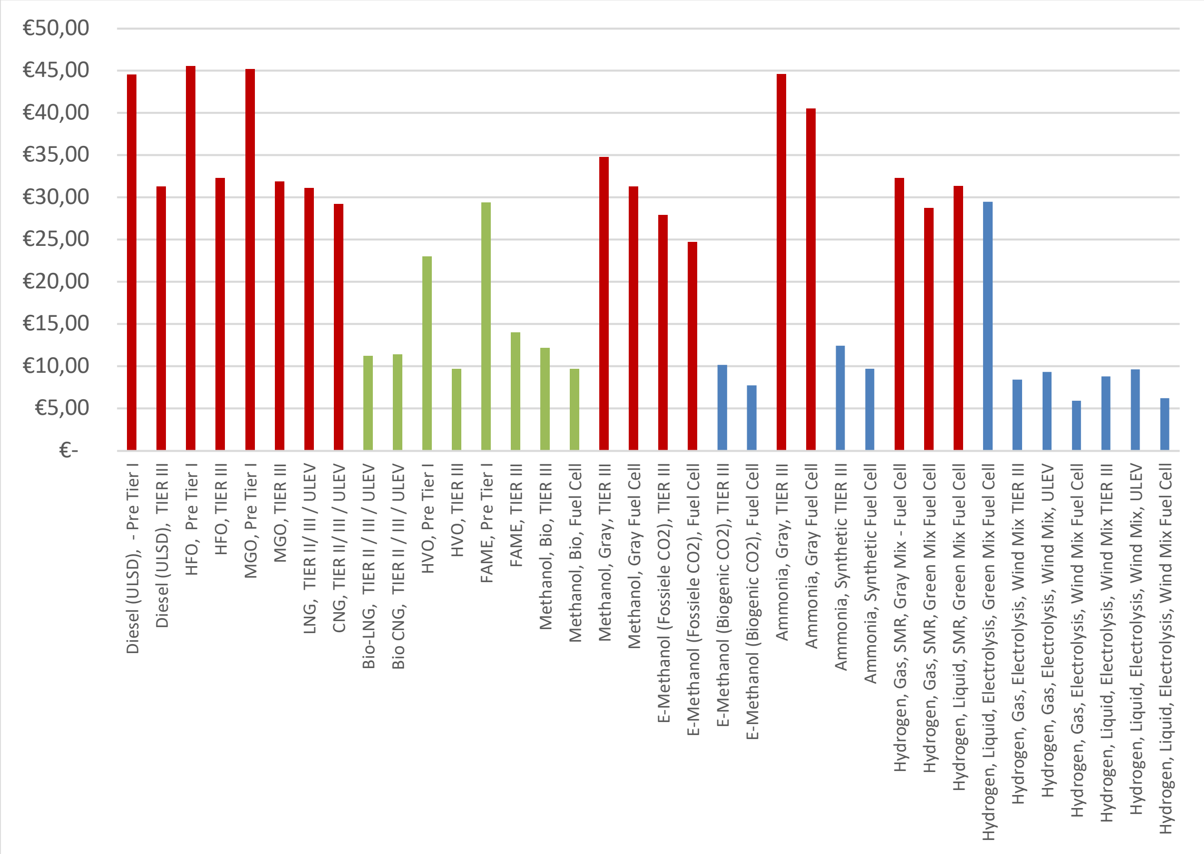
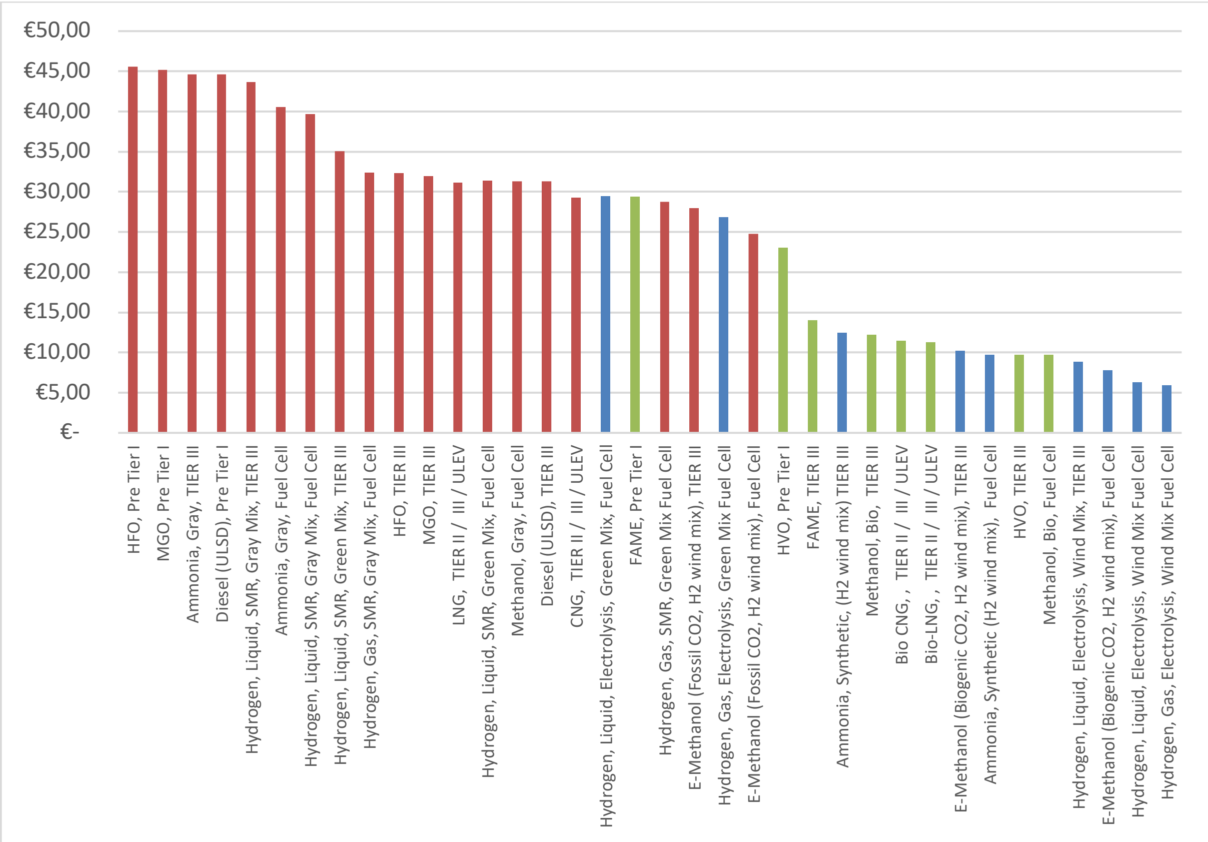


Figure 4 shows the same selection as figure 3 but ranked from highest to lowest ECI:A2 per GJ of delivered work. The left side (highest ECI) is dominated by fossil energy carriers, particularly the lower TIER classes. Note that all intermediate TIER classes are not included in this selection but are shown in Figure 7. In the figure below, all internal combustion engine variants are shown. The contribution of NOx emissions is displayed separately (in light orange). The transition from Pre-TIER I to TIER III results in approximately a 30% reduction for conventional energy carriers (Diesel, MGO, HFO), which is entirely due to the reduction in NOx emissions. Fossil energy carriers perform worse than biofuels—even a fossil TIER III variant scores lower than a biogenic Pre-TIER I variant.

With regard to RFNBOs, only energy carriers based on hydrogen from wind-powered electrolysis are competitive—namely hydrogen (electrolysis wind), e-methanol (biogenic), and synthetic ammonia produced from H_2 via wind-powered electrolysis.

Figure 7). As previously mentioned, only hydrogen produced via wind-powered electrolysis (or other electricity sources—see sensitivity analysis) yields a competitive ECI:A2. The RFNBOs based on this hydrogen also result in relatively low ECI:A2 values. Under the current assumptions, biofuels with TIER III classification provide very low ECI:A2 scores, comparable to the RFNBOs synthetic ammonia and e-methanol. The wind-based hydrogen variants score the lowest (see the sensitivity analysis for more nuance regarding the biofuel approach).

Figure 4: Overview of ECI:A2 from high to low for the selection of salt work vessels, per GJ of delivered work. Red – Fossil, Green – biofuel and blue – RFNBO.



In Figure 5, the above comparison is repeated but with a breakdown into three main components: energy carrier, usage profile, and capital goods. It shows that for conventional fuels, the usage profile is dominant, primarily due to fossil CO2 emissions. The impact of NOx emissions is visible in the decrease in ECI from pre-TIER I to TIER III variants. The contribution from fuel production is relatively minor.

For biofuels, the same pattern holds as for fossil fuels, although the production phase contributes negatively to ECI:A2 due to the uptake of biogenic CO2. Over the full life cycle, biofuels have a biogenic CO2 balance of zero. This results in lower total scores, as shown in

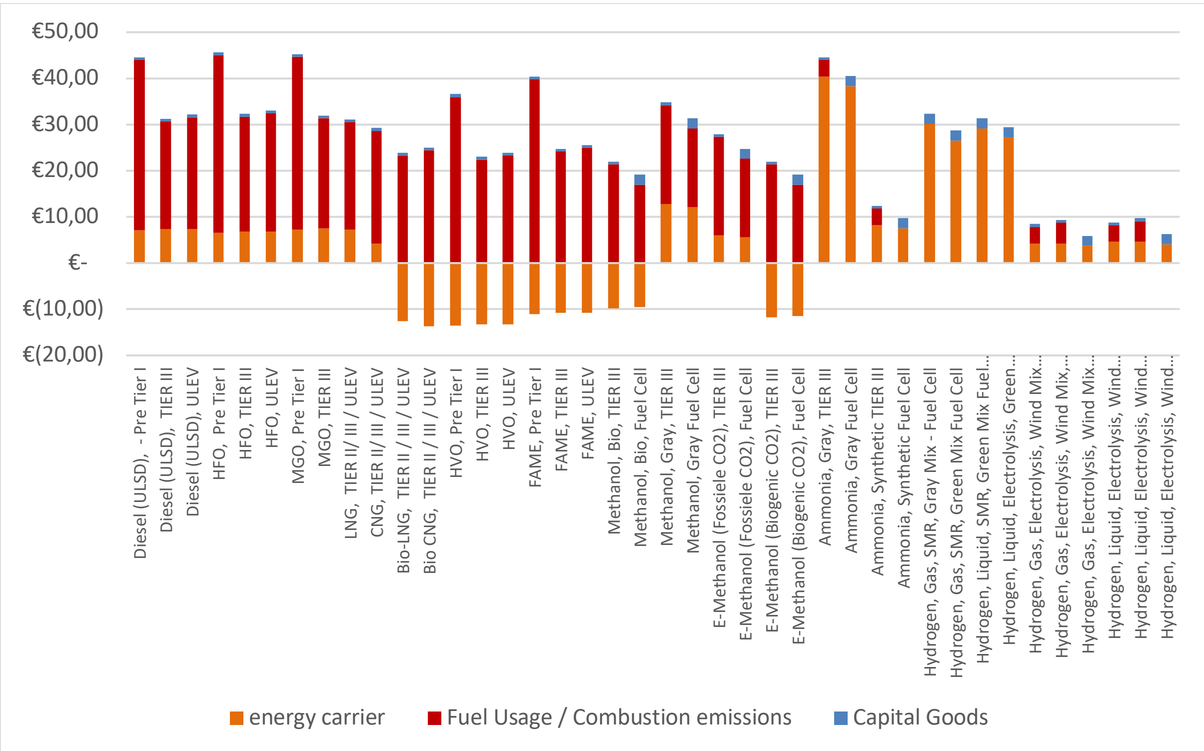
Figure 3

In the case of ammonia, e-methanol (biogenic), and hydrogen, the main impact lies in the production of the energy carrier. In all cases, a substantial ECI:A2 reduction is only achieved when hydrogen is produced using wind energy. This also applies to synthetic ammonia and e-methanol, where hydrogen is the key feedstock.

For energy carriers that can be used in both internal combustion engines and fuel cells, the fuel cell variant shows a lower ECI. This is due to the NOx emissions associated with combustion engines which account for 5% and 40% of the ECI:A2. The efficiencies of combustion engines and fuel cells for saltwater vessels are similar (2% difference for saltwater). As a result, the fuel cell variant uses slightly less energy per GJ of delivered work, marginally widening the difference. The balance differs for freshwater working vessels, where a larger efficiency difference exists (discussed under the freshwater vessel analysis). According to the technical committee and TNO, future efficiencies could reach 50%, with potential for further minor improvements.

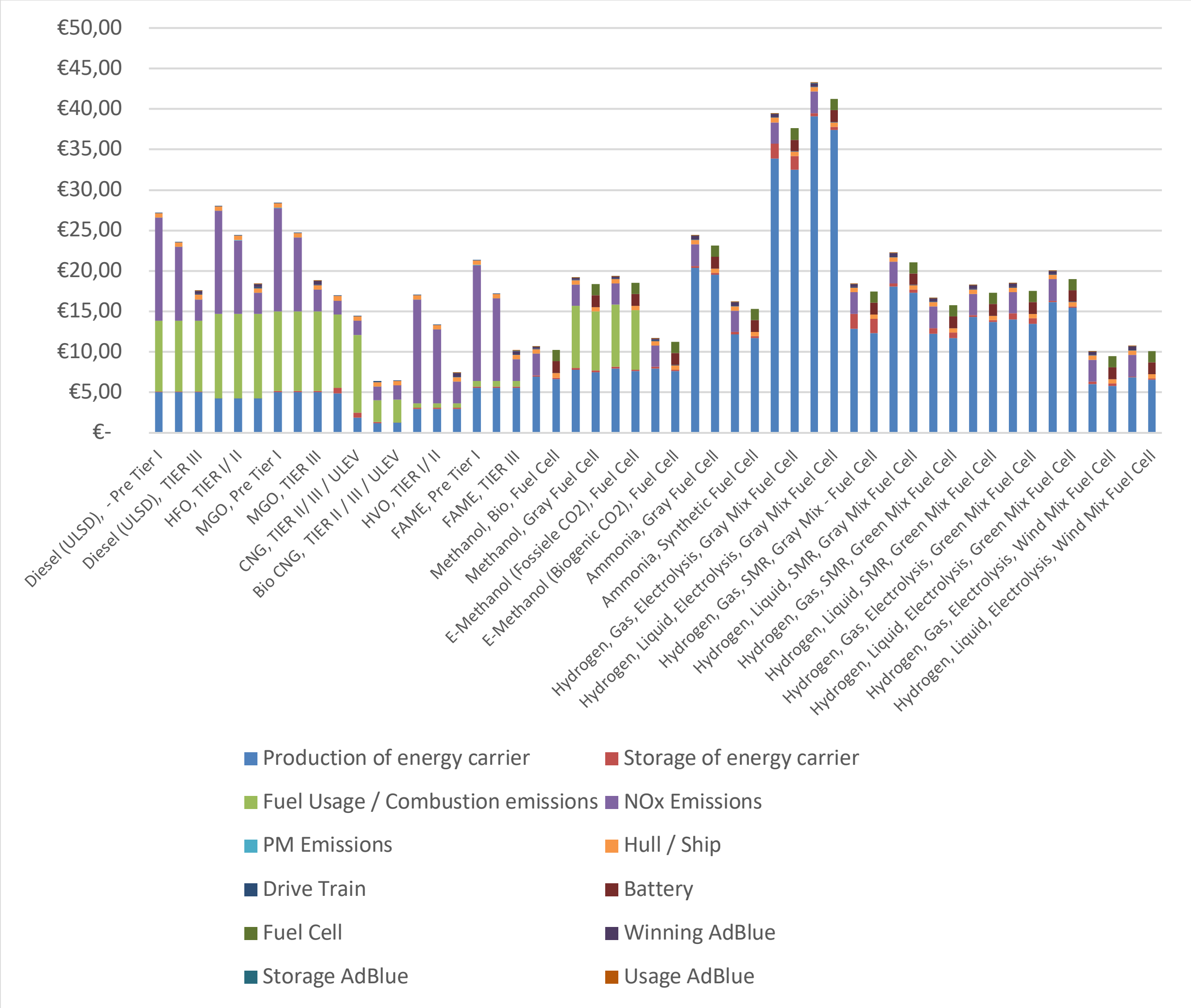
The innovative energy carrier e-methanol (based on fossil CO2) scores similarly to fossil fuels. This is because both the combustion engine and fuel cell produce fossil CO2 emissions during use. This is not the case for biogenic e-methanol, which therefore yields a significantly lower ECI:A2. As previously indicated, this is elaborated upon in the sensitivity analysis.

Figure 5: Overview per part, ECI:A2 per part per GJ delivered work on salt work vessels.



The ECI:A1 is the current ECI score which is based on different impact categories (with a different weighting) compared to the newer ECI:A2. The absolute values differ, but the general ranking is similar, except for the biofuel variants which give a lower ECI:A1 than the RFNBOs.

Figure 6: Overview of salt work vessels, total ECI:A1 per GJ of work.

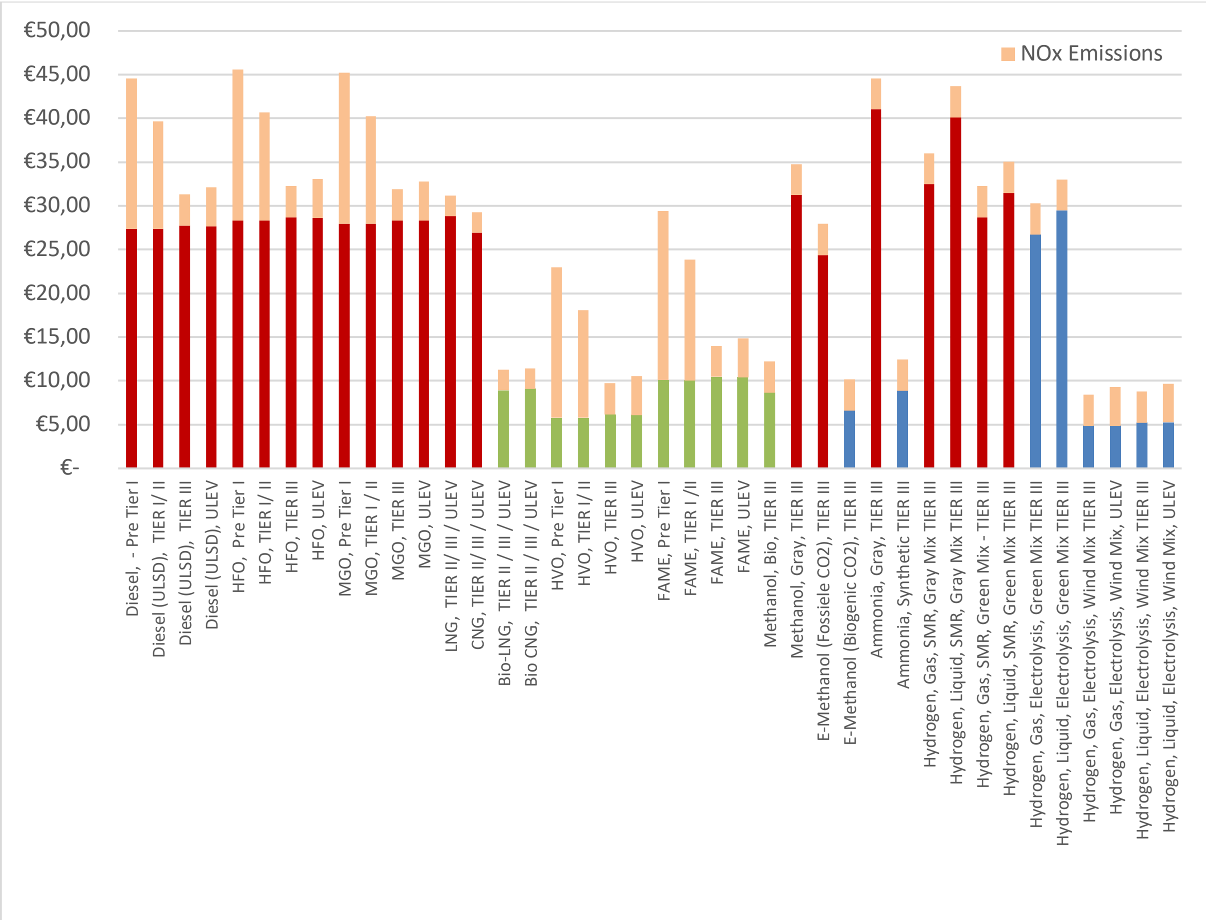


Emission classes

In the figure below, all internal combustion engine variants are shown. The contribution of NOx emissions is displayed separately (in light orange). The transition from Pre-TIER I to TIER III results in approximately a 30% reduction for conventional energy carriers (Diesel, MGO, HFO), which is entirely due to the reduction in NOx emissions. Fossil energy carriers perform worse than biofuels—even a fossil TIER III variant scores lower than a biogenic Pre-TIER I variant.

With regard to RFNBOs, only energy carriers based on hydrogen from wind-powered electrolysis are competitive—namely hydrogen (electrolysis wind), e-methanol (biogenic), and synthetic ammonia produced from H_2 via wind-powered electrolysis.

Figure 7: All internal combustion engines in total ECI:A2 per GJ of work delivered. By type, red - fossil, orange - biofuel, blue - RFNBOs and NOx emissions in light orange.



Outlook

Figure 8 provides an overview of all innovative energy carriers (RFNBOs). For these energy carriers, the energy source is crucial. Hydrogen produced via electrolysis using grey electricity results in a higher environmental impact than hydrogen from SMR. When the current green electricity mix is applied, the ECI:A2 is comparable to that of Diesel. The advantages of hydrogen only become apparent when an energy source with very low environmental impact is used—in this case, the wind mix (combination of onshore and offshore wind). More nuance on the importance of the electricity source is presented in the sensitivity analysis.

This implies that an analysis of the future energy market in relation to hydrogen production is essential for RFNBOs. If, for example, wind power is not used but nuclear energy or solar instead, this will significantly affect the RFNBO outcomes (see sensitivity analysis).

Liquid hydrogen has a higher ECI than gaseous hydrogen; the difference ranges from 4% to 10%, depending on the electricity source used for compression (grey, green, wind). There is also ongoing uncertainty regarding the transport and storage scenarios for hydrogen variants. These aspects will be explored further in the sensitivity analysis.

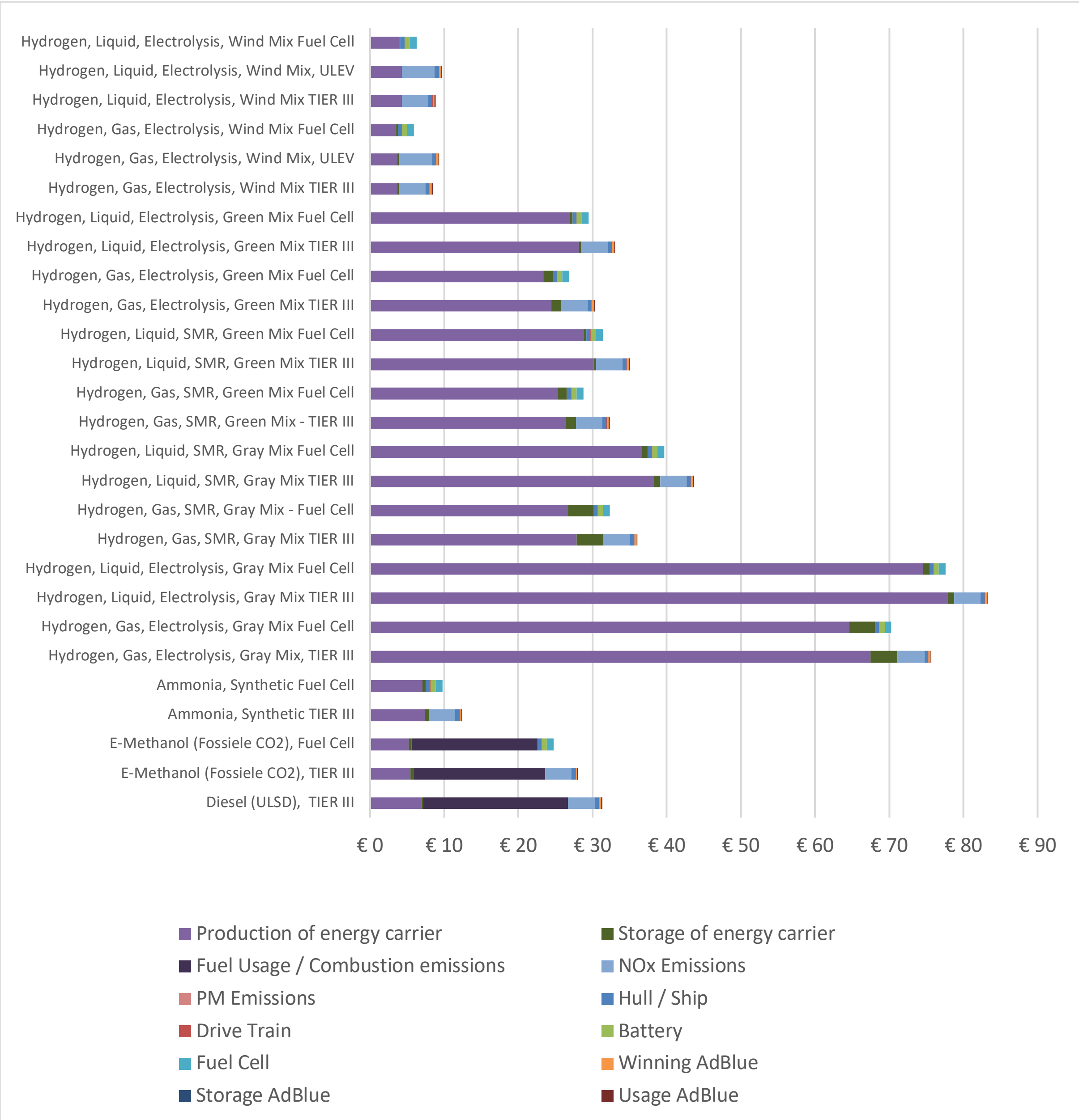
Synthetic ammonia and e-methanol are produced from hydrogen. The current ammonia and e-methanol datasets assume hydrogen from wind-powered electrolysis. If the electricity source changes, this will have a significant impact on the ECI:A2 of these energy carriers. This is further explained in the sensitivity analysis.

As mentioned previously, e-methanol based on fossil-derived CO2 does not yield an ECI:A2 reduction due to fossil CO2 emissions in the use phase—this is not the case for the biogenic variant. The biogenic e-methanol variant therefore scores significantly lower (as shown in

Figure 3).

This variant is not shown separately in Figure 8 due to the negative ECI of the energy carrier, which would make the figure difficult to interpret. A further comparison with e-methanol based on Direct-Air-Capture (DAC) is elaborated in the sensitivity analysis.

Figure 8: All innovative energy carriers, ECI:A2 per GJ delivered work versus Diesel for the salt work vessels.



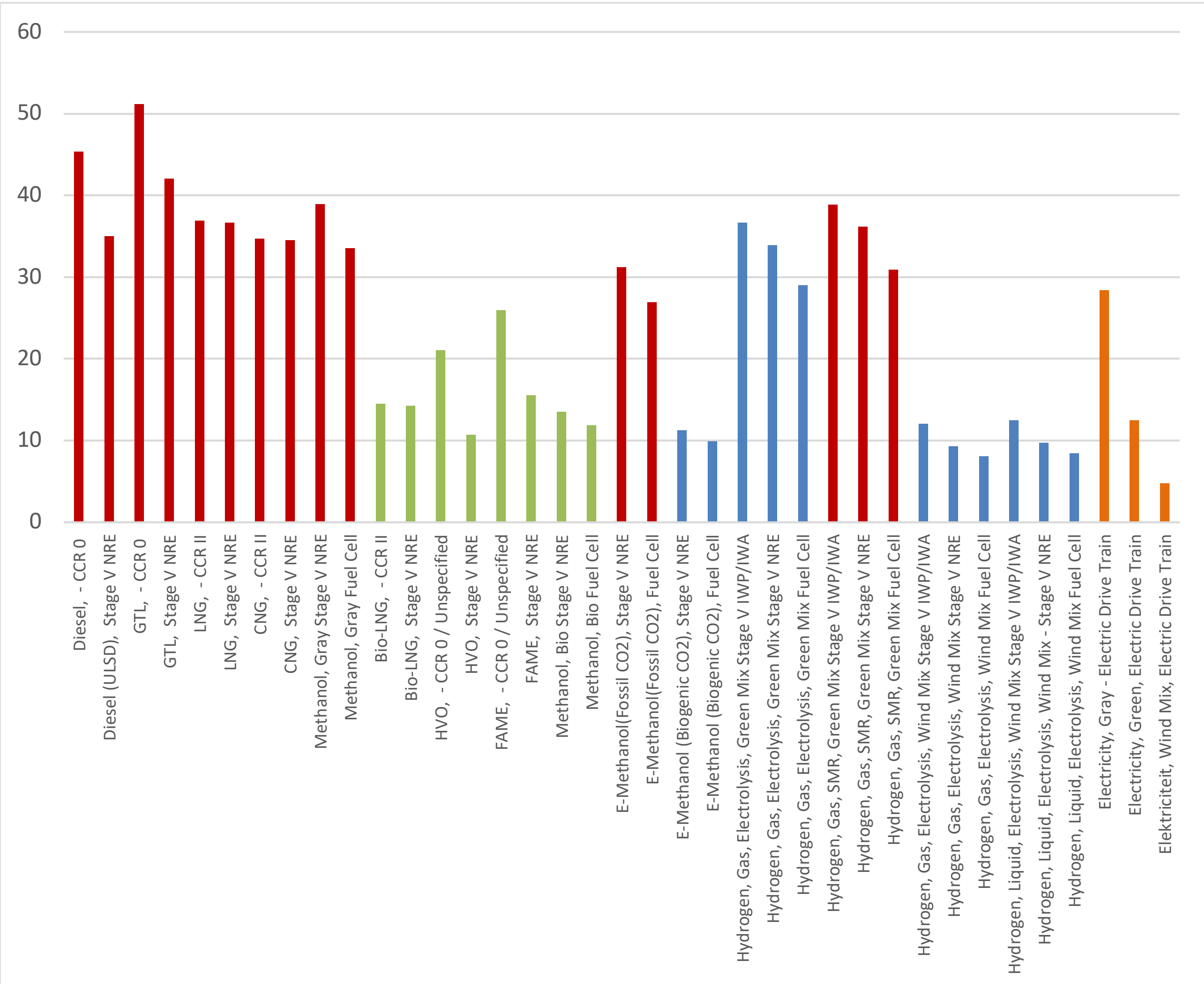
5.2.2 Freshwater work vessel analysis

The figures below illustrate the relationship between all energy carriers per GJ of delivered work for freshwater work vessels (Figure 9 in Figure 12 for ECI:A1). To maintain clarity, a limited selection has been made. For combustion engines, only the best and worst emission classes are shown, and for hydrogen variants, only fuel cells are included.

Among the currently available fuels, there is little variation between the fossil options. However, the transition to Stage V has a significant impact on ECI:A2. Under current modelling, biofuels perform much better—particularly bio-LNG, bio-CNG, HVO, and bio-methanol (Stage V NRE).

Battery-electric ships using green electricity (current green mix) perform similarly to biofuels. If powered by wind energy, electric propulsion achieves the lowest ECI:A2. Looking further ahead, hydrogen produced via wind-powered electrolysis performs best—positioned between electric (green mix) and electric (wind mix). Differences between liquid and gaseous hydrogen and combustion engine versus fuel cell will be addressed later.

Figure 9: Overview of freshwater work vessels, total ECI:A2 per GJ of work. By type, red is fossil, green is biofuel, RFNBO blue and orange is battery electric.



The next figure presents the same selection as Figure 9 but ranked from highest to lowest ECI:A2 per GJ delivered work. On the left (highest ECI:A2) are mainly fossil fuels and hydrogen from green electrolysis via combustion engines. The middle contains most biofuels and some RFNBO combustion engine variants. The best-performing options follow, including a few biofuels, but especially hydrogen from wind electrolysis and biogenic e-methanol in a fuel cell. The lowest ECI is achieved by battery-electric propulsion using wind energy.

Figure 10: Overview from highest to lowest for selection of freshwater work vessels, ECI:A2 per GJ of work. Red – Fossil, Green – Biofuel, Blue – RFNBO and Orange – Electric.

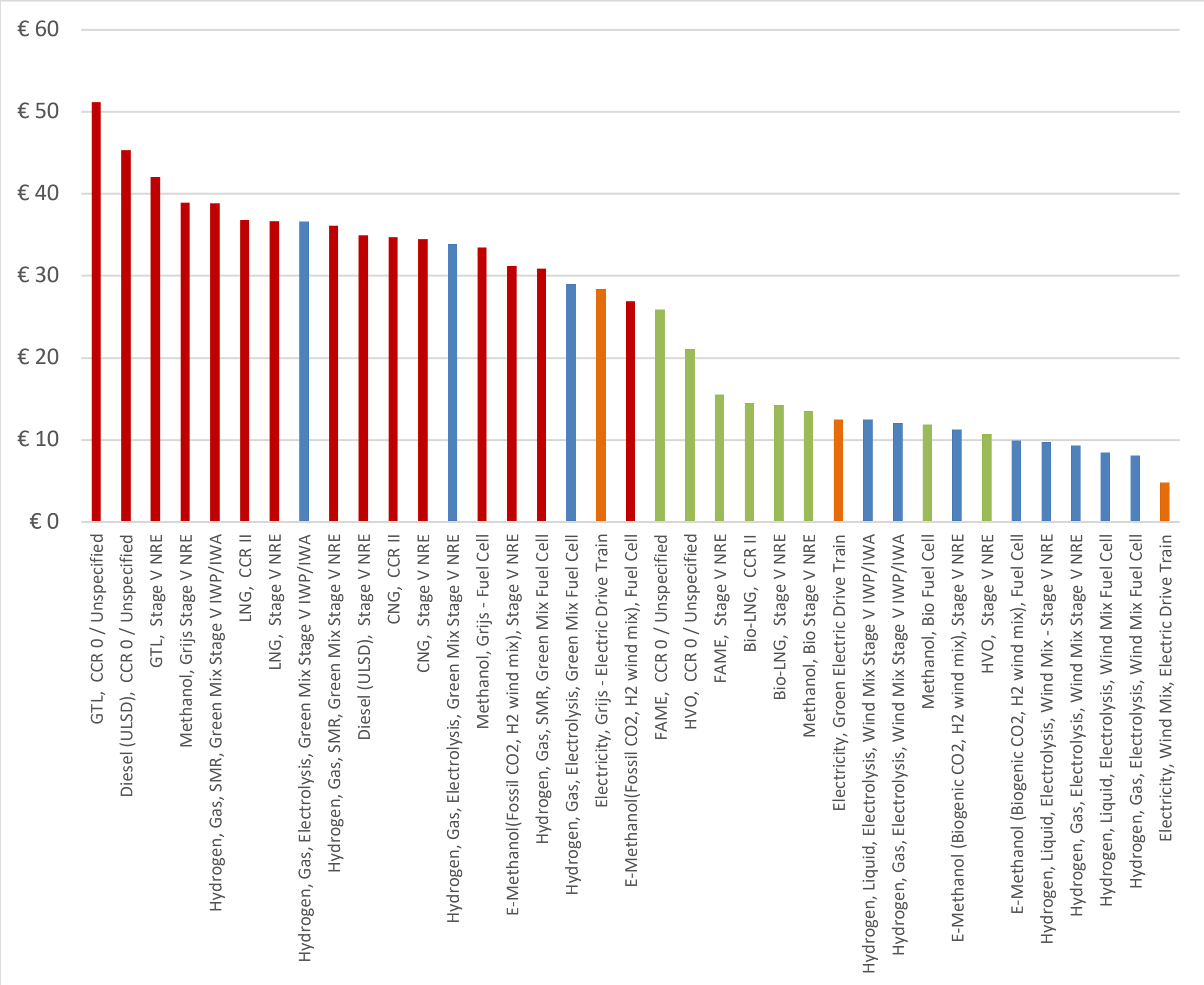


Figure 11 repeats this comparison but with a breakdown into the three main components: energy carrier, usage profile (with NOx separated), and capital goods. For traditional fuels, the usage profile dominates—mainly due to fossil CO2 emissions. The impact of NOx emissions is visible in the reduction from pre-CCR to Stage V (light orange). The production phase of the energy carrier contributes less significantly.

The same pattern applies to biofuels. However, their production phase shows negative ECI:A2 due to biogenic CO2 uptake. Over their life cycle, biofuels have a net-zero CO2 balance, resulting in lower overall ECI scores.

For hydrogen, the main impact lies in the production phase. Hydrogen from wind shows significant ECI reduction compared to biofuels. Fuel cell variants score better due to a 7% higher efficiency over combustion engines, which is particularly relevant for inland vessels.

For electric vessels, the electricity source is decisive. Green electricity is already competitive with biofuels. As the ECI:A2 of the energy carrier drops, the relative contribution of capital goods increases, to the point where for electric (wind), ECI:A2 is mostly from capital goods.

Figure 11: Freshwater work vessels, overview per part, ECI:A2 per part per GJ of work delivered.

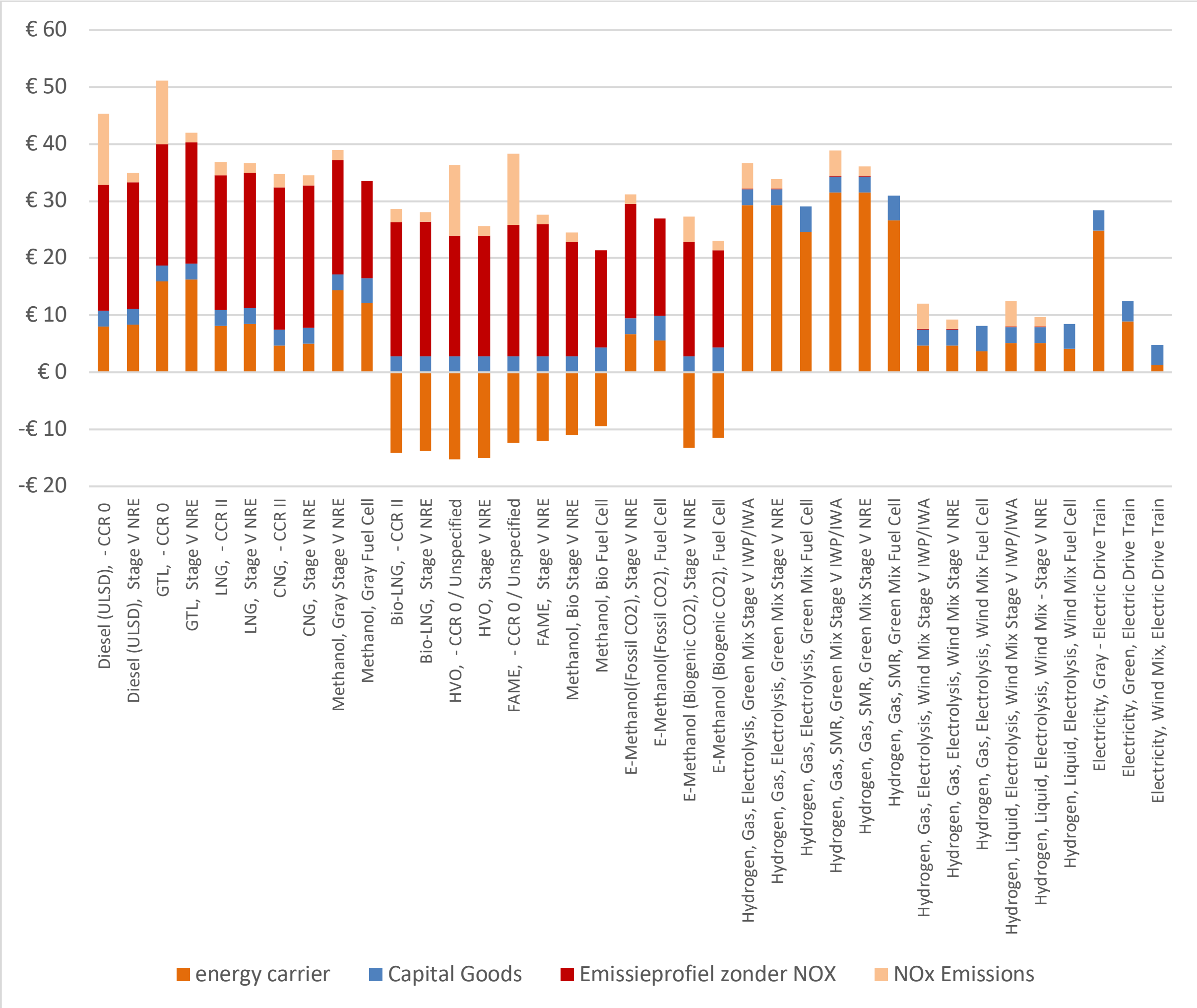
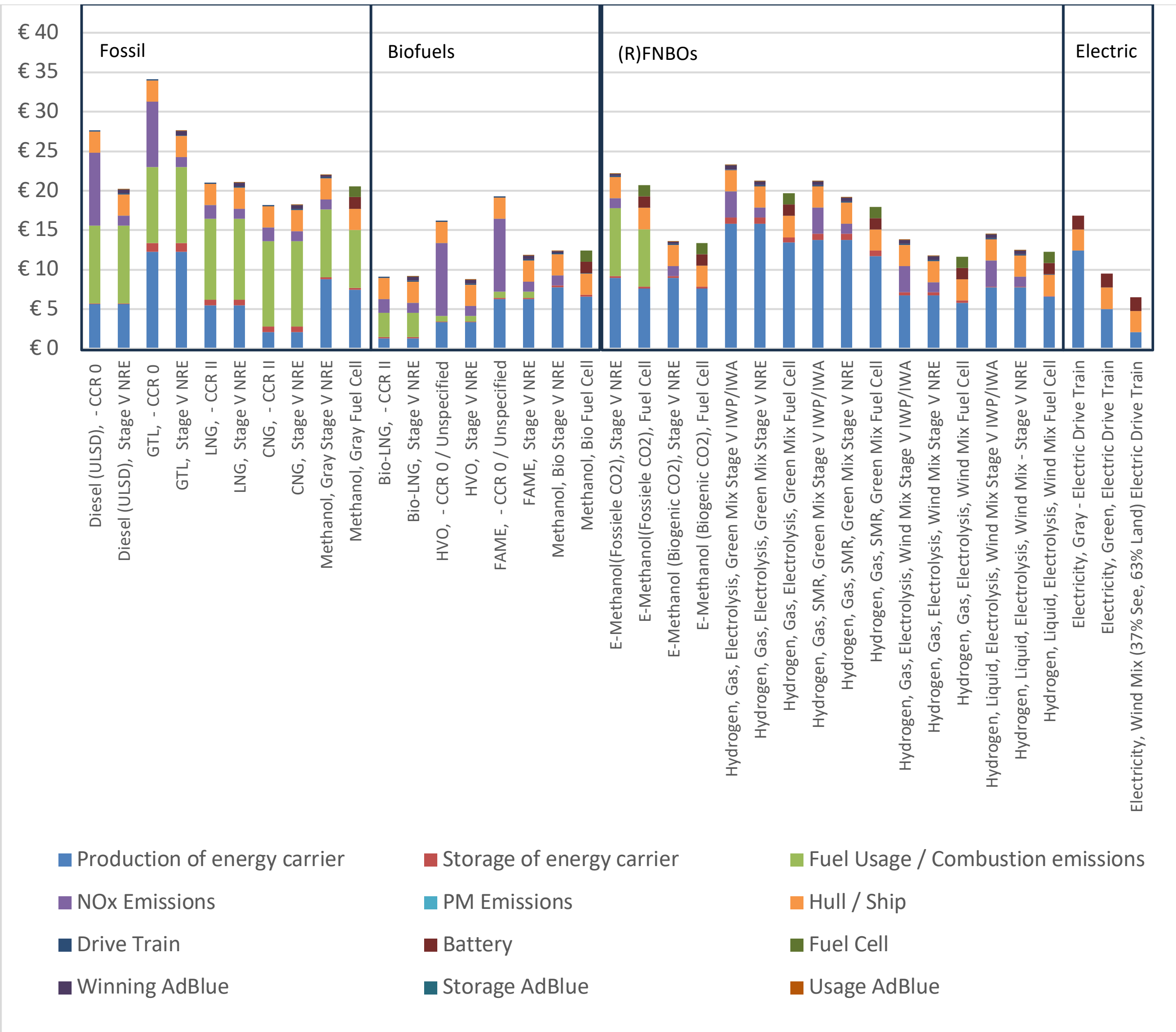


Figure 12 shows the same total overview as Figure 9 but for ECI:A1. ECI:A1 is based on different impact categories and weightings than ECI:A2. Although absolute values differ, the general ranking remains similar. Hydrogen (wind electrolysis) scores higher than some biofuels in ECI:A1. As described in Table 3, the fuel cell's 7% efficiency gain over combustion engines results in less energy needed per GJ delivered work, improving the fuel cell’s ECI compared to a combustion engine using the same energy source.

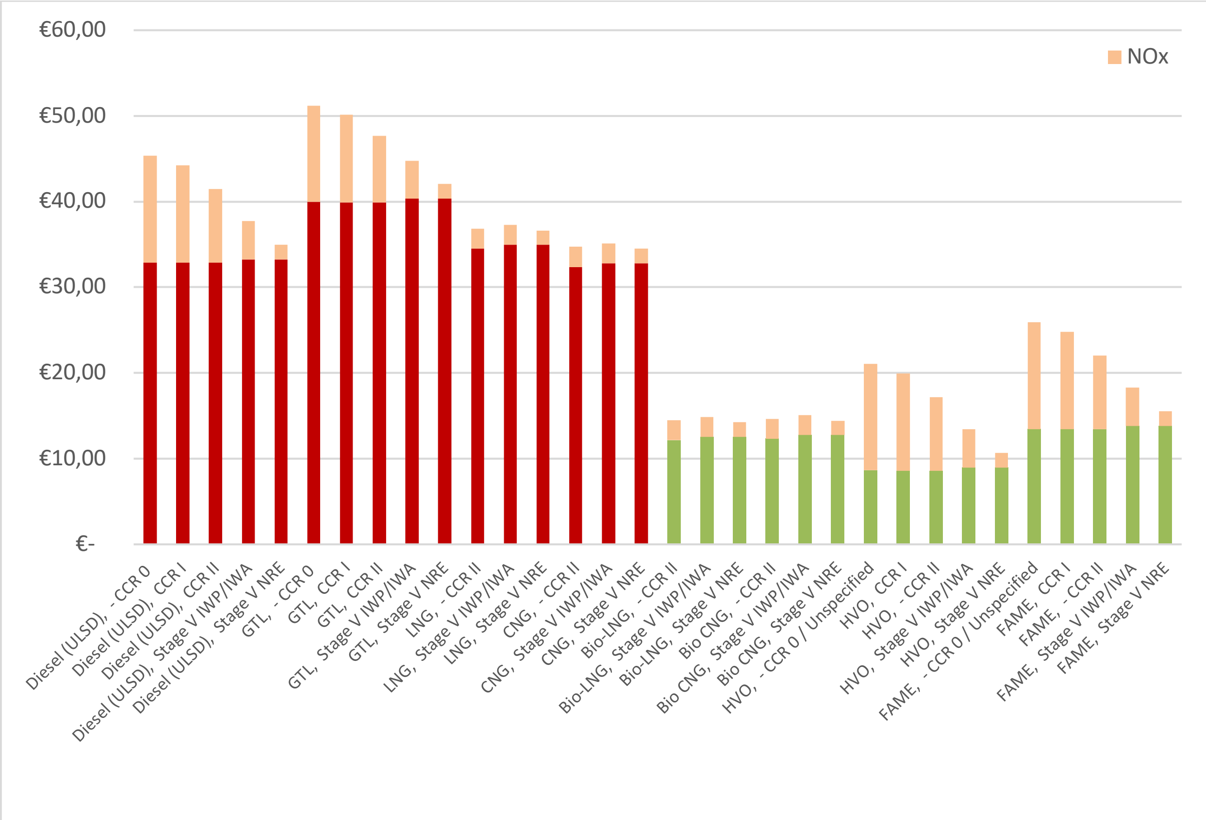
Figure 12: ECI:A1 for freshwater work vessels per GJ of work performed, per product component.



Emission classes

The differences between all CCR and Stage classes are shown in Figure 13. This figure shows ECI:A2 per GJ delivered work for all regular fuels (fossil and biogenic). The contribution of NOx emissions is shown separately (light orange).

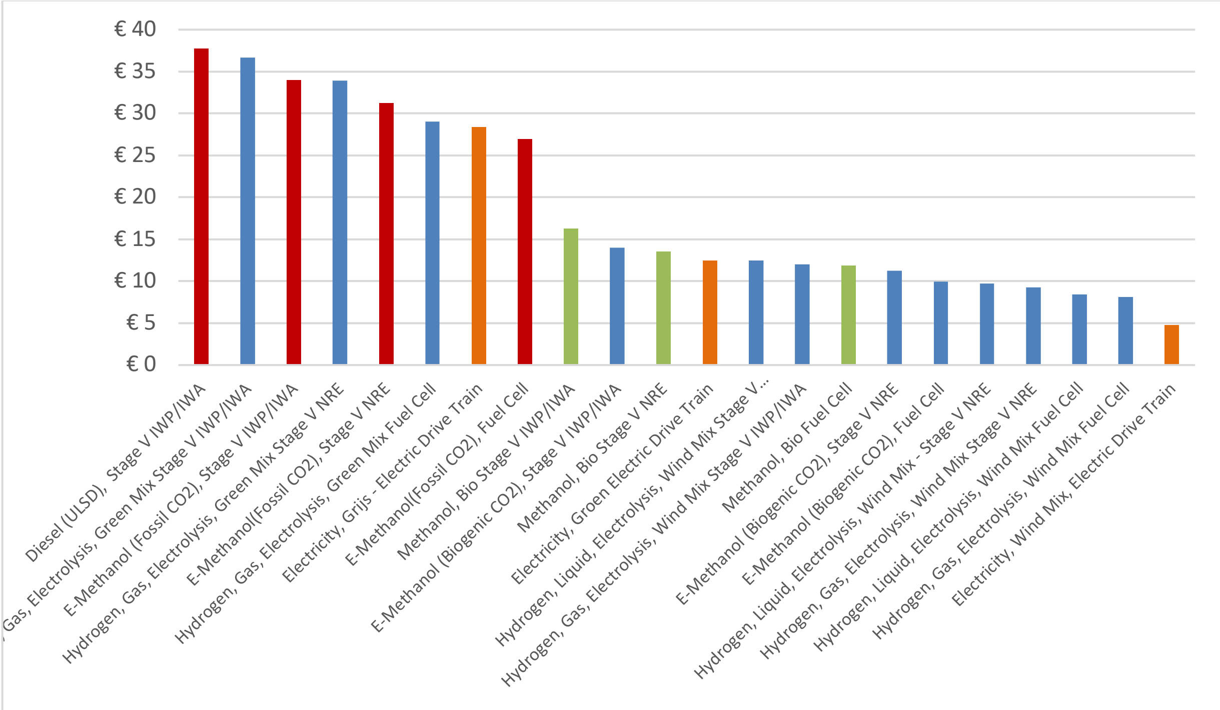
Figure 13: ECI:A2 freshwater work vessels by emission class, per GJ of work performed. Red is fossil, orange is biofuel and light orange is Nox emissions.



Outlook

The following figure compares the best Diesel variant (Stage V) with selected innovative energy carriers (RFNBOs). Hydrogen from green electrolysis is competitive with Diesel (ECI:A2) but less favourable than biofuels. The biggest ECI drop is due to hydrogen from wind electrolysis and e-methanol (biogenic CO2 based on H_2 from wind). Using a fuel cell further reduces the ECI due to higher efficiency. The lowest ECI is achieved by electric propulsion using wind energy.

Figure 14: Ranking ECI:A2 of the innovative energy carriers compared to Diesel, per GJ of work delivered. By type, red is fossil, green is biofuel, blue RFNBO and orange is electric.



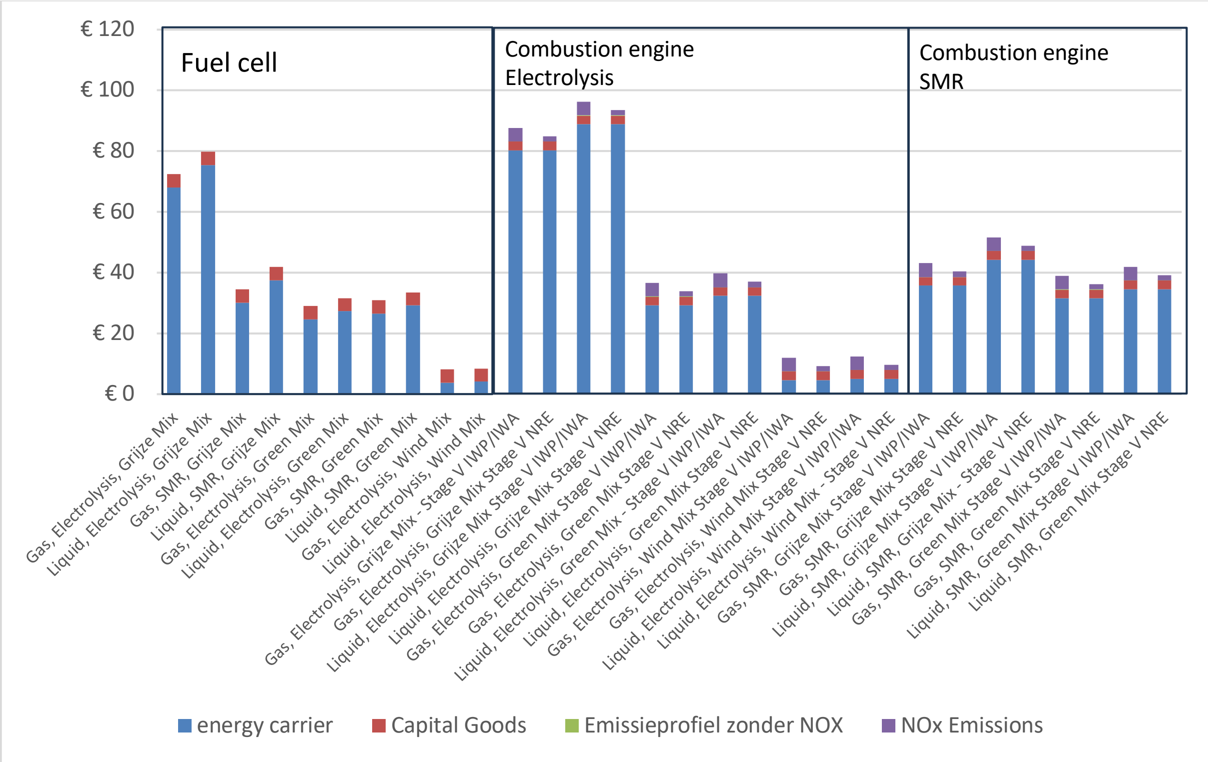
Hydrogen detail

For energy carriers usable in both combustion engines and fuel cells, the combustion engine results in a higher ECI for inland vessels. This is due to lower engine efficiency: 40% for two-stroke engines vs. 47% for fuel cells (for coastal vessels, the difference is smaller: 45% vs. 47%) (see Table 3 for justification). NOx emissions also significantly affect ECI:A2 (€2.71/GJ), contributing between 4% and 30%, depending on the energy carrier/electricity source.

Depreciation of the fuel cell slightly increases the ECI of capital goods (€0.9 ECI/GJ). In total, the fuel cell contributes between 1% and 10% to ECI:A2. This increase is comparable to the reduction gained through higher efficiency. Fuel cell depreciation is based on a lifetime of 20,000 hours, average annual usage, and operating hours for an H_2 hopper dredger, accounting for partial-load operation. Depending on these assumptions, the depreciation impact may vary and is analysed further in the sensitivity analysis.

Liquid hydrogen has a higher ECI than gaseous hydrogen due to the extra energy needed for compression and storage. This effect lessens with more sustainable electricity sources (e.g., wind instead of grey electricity). There's also uncertainty around gaseous hydrogen transport scenarios (Module A4), which could further reduce the difference between gaseous and liquid hydrogen.

Figure 15: Contribution per component to ECI:A2 for all hydrogen variants per GJ of work delivered.



5.2.3 Transport inland waterway

The Transport profiles largely follow the same base processes as work vessels but with a functional unit of ton-km, based on estimated fuel use per ton-km. Only capital goods differ, e.g., port infrastructure and fairways are included. These will be shown in subsequent figures. The next figure presents the total ECI:A1 and ECI:A2 for all Cat. 3 inland shipping transport chains. Both indicators show similar trends, with electric (green mix) performing best, followed by hydrogen from wind electrolysis (Stage V) and HVO CCR I.

Figure 16: ECI:A1 and ECI:A2 for all transport profiles, per tonne-km for inland waterway transport.

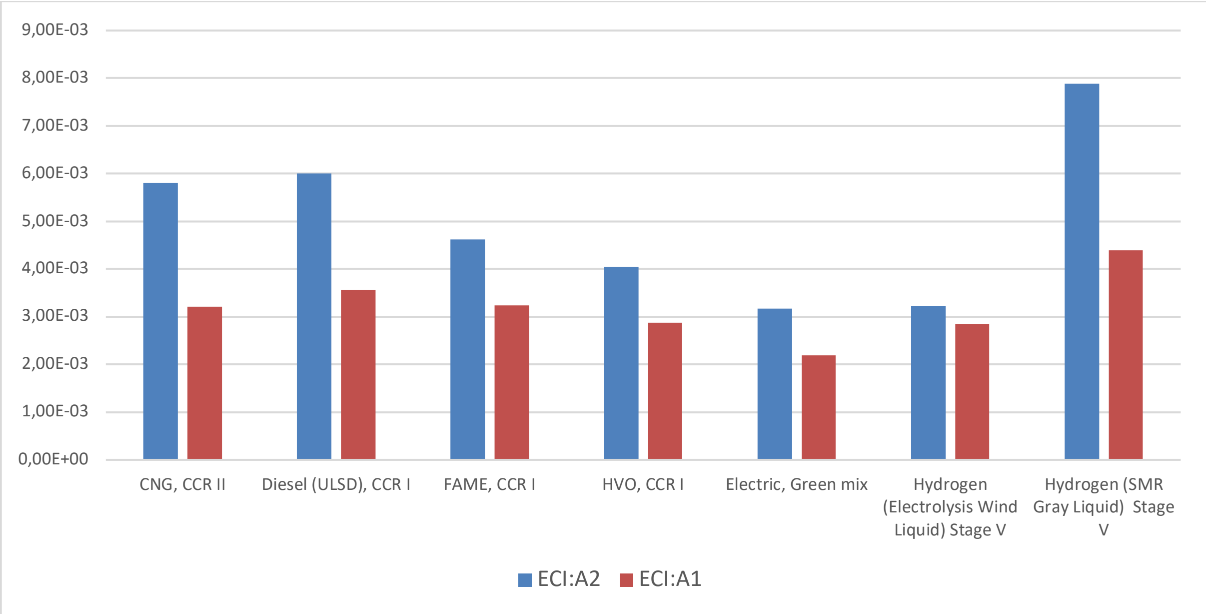


Figure 17: Contribution of all components to ECI:A2, per tonne-km for inland waterway transport.

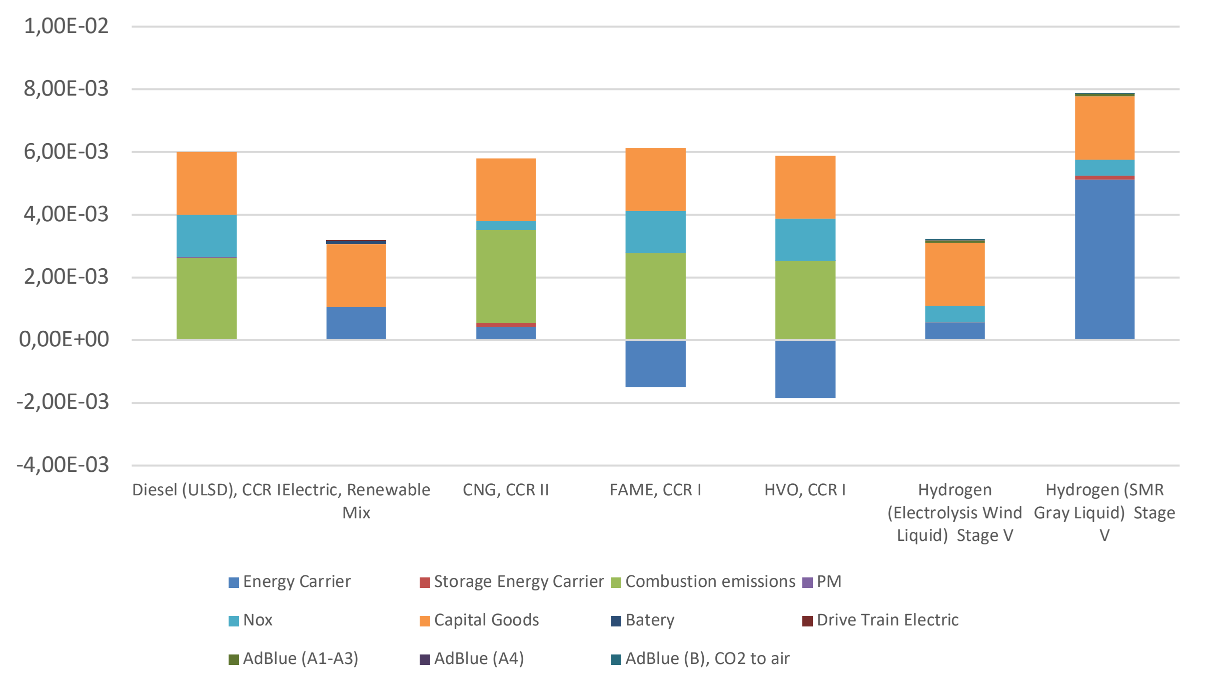


Figure 18: Contribution of EN15804:A2 impact categories to the ECI:A2, per tonne-km for inland waterway transport.

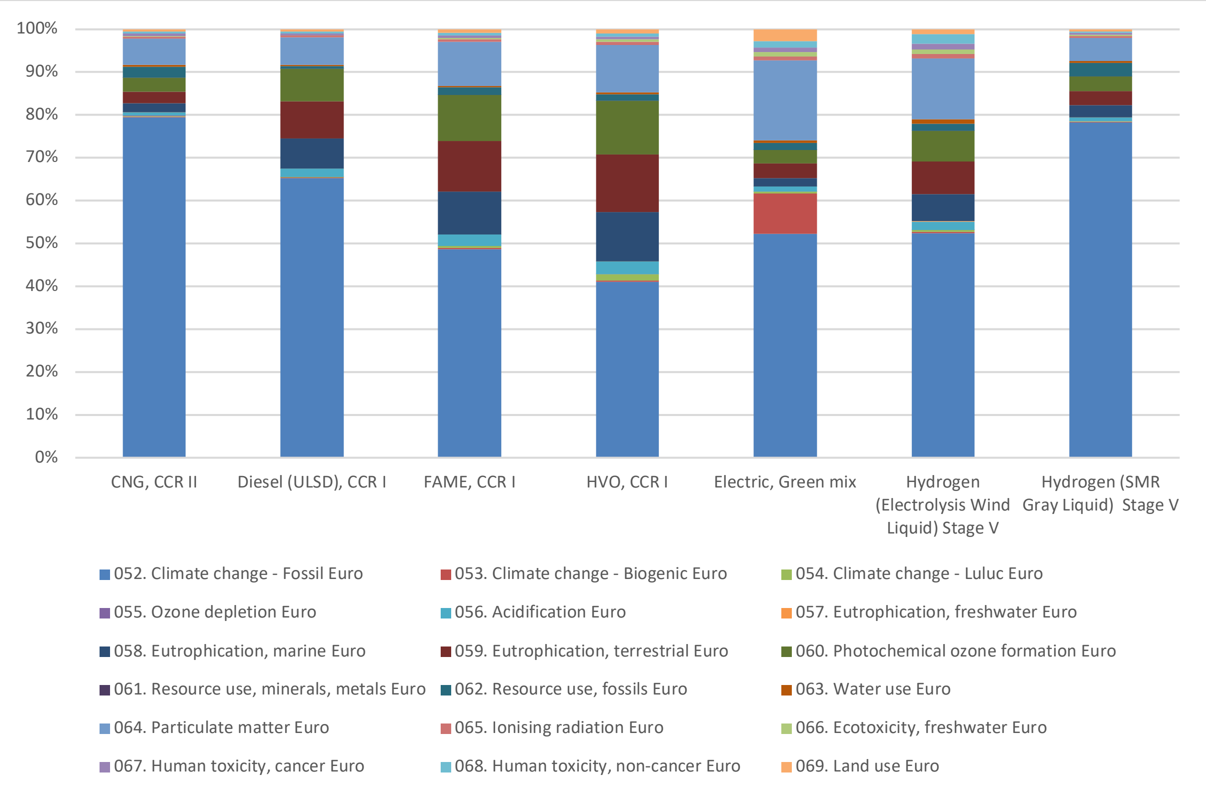
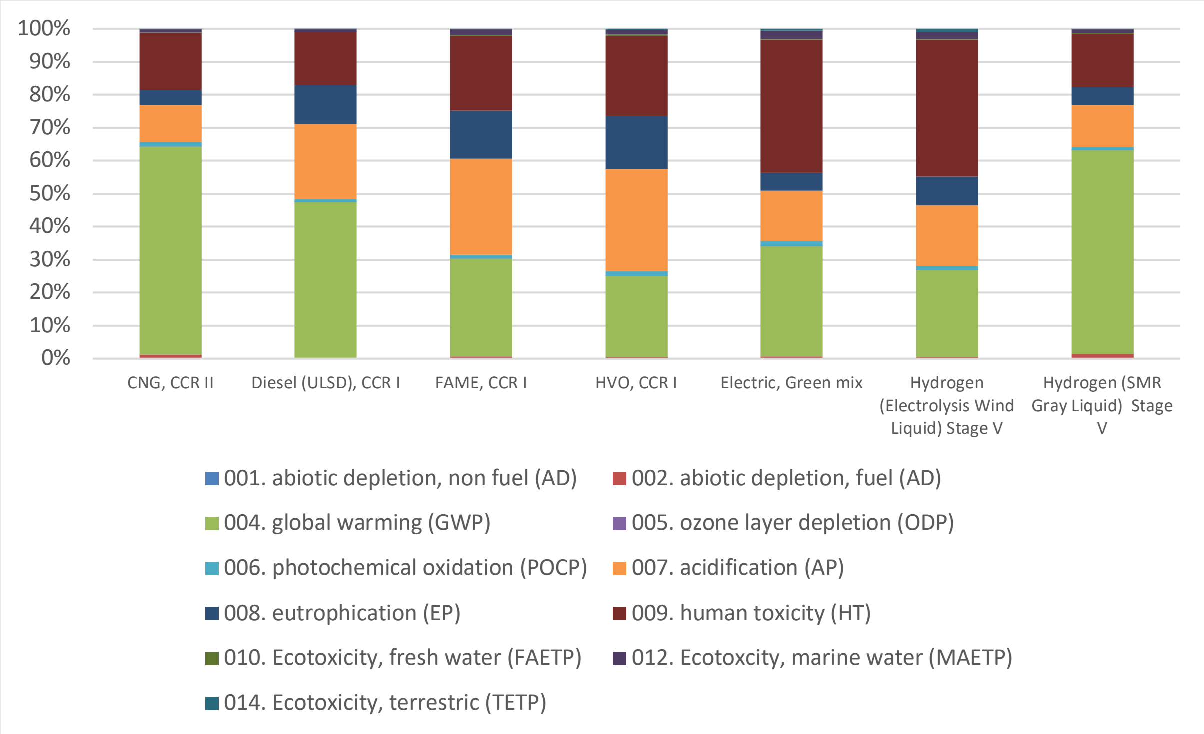
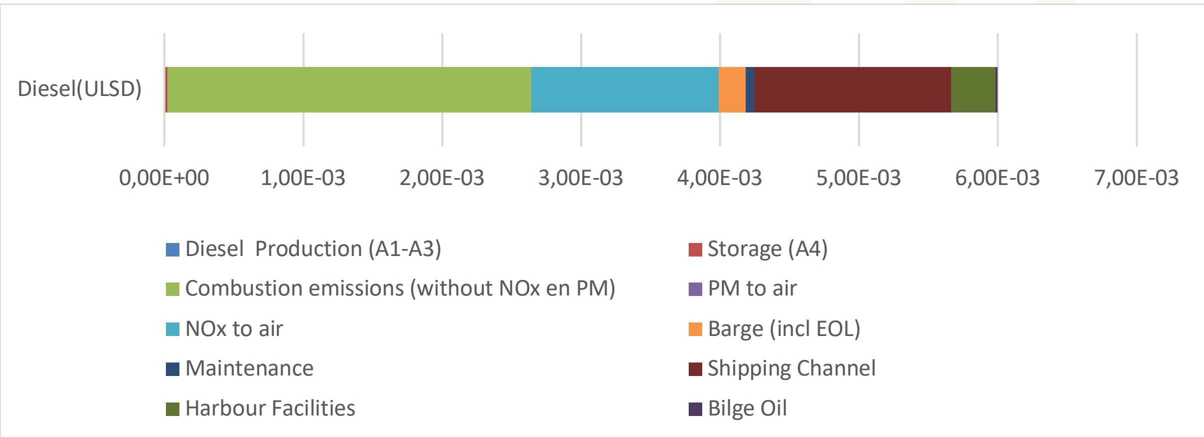


Figure 19: Contribution of all impact categories to ECI:A1, per tonne-km for inland waterway transport.



The figure below provides an overview of the ECI:A2 contribution of the various components to the ECI:A2 per ton-km for Diesel (ULSD) inland waterway transport. This includes the various components of the capital goods. The capital goods contribute to a lesser extent through the vessel itself, but primarily through waterway maintenance. Waterway maintenance has been included to remain consistent with EcoInvent. This maintenance accounts for 24% of the total ECI:A2 for inland waterway Diesel transport and for 70% of the capital goods. For the variant with the lowest ECI:A2, namely electric propulsion using green electricity, waterway maintenance accounts for 44% of the total ECI:A2. The ECI of waterway maintenance is mainly caused by material usage (concrete and steel sheet piling). In a follow-up project, these specific parameters could be identified to obtain a clearer picture of the waterway maintenance activities.

Figure 20: Detailed analysis of ECI:A2 Diesel (ULSD) inland transport per tonne-km.



5.2.4 Transport seagoing transport

Shipping transport profiles follow the same base processes as work vessels, with only capital goods differing. Additionally, Port infrastructure is included. The upcoming figures present total ECI:A1 and ECI:A2 for all Cat. 3 maritime transport profiles, with both indicators again showing similar trends: bio-LNG scores best, followed by hydrogen from wind electrolysis (Stage V) and CNG Tier II.

Figure 21: ECI:A1 and ECI:A2 for all seagoing transport profiles, per tonne-km.

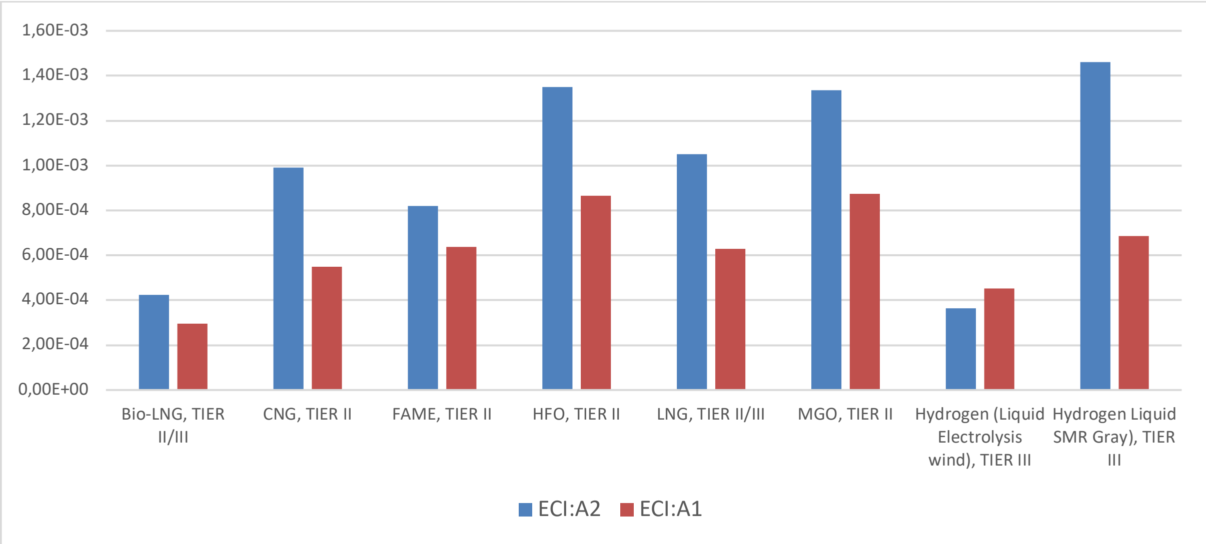
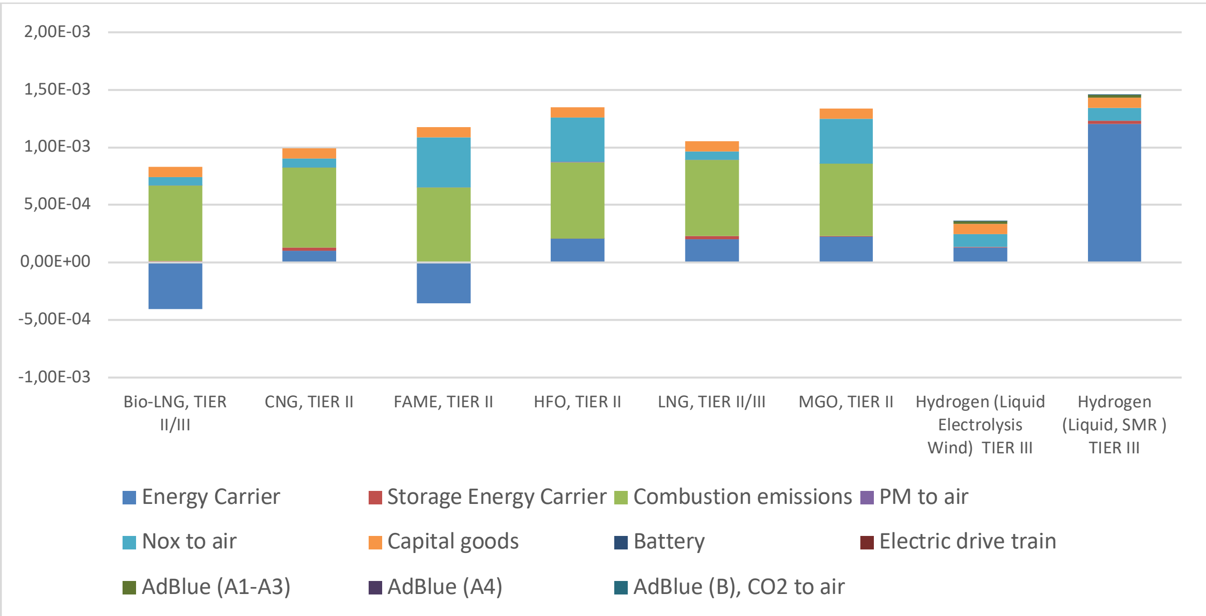


Figure 22: Contribution of all components to ECI:A2, per tonne-km for seagoing transport.



Climate change is the largest contributor to the ECI:A2 for most energy carriers. It is striking that biogenic climate change contributes strongly to bio-LNG, due to methane emissions in the use phase.

Figure 23: Contribution of EN15804:A2 impact categories to the ECI:A2, per tonne-km for seagoing transport.

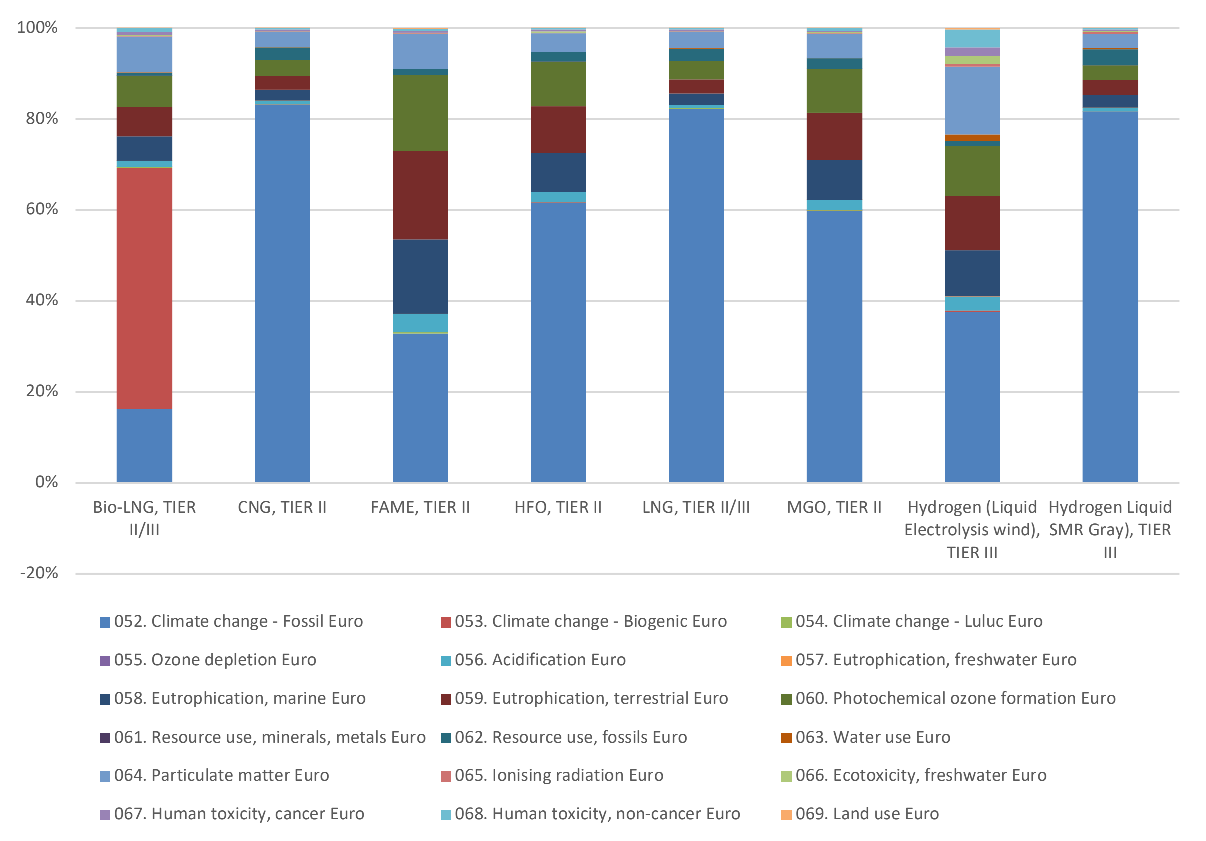
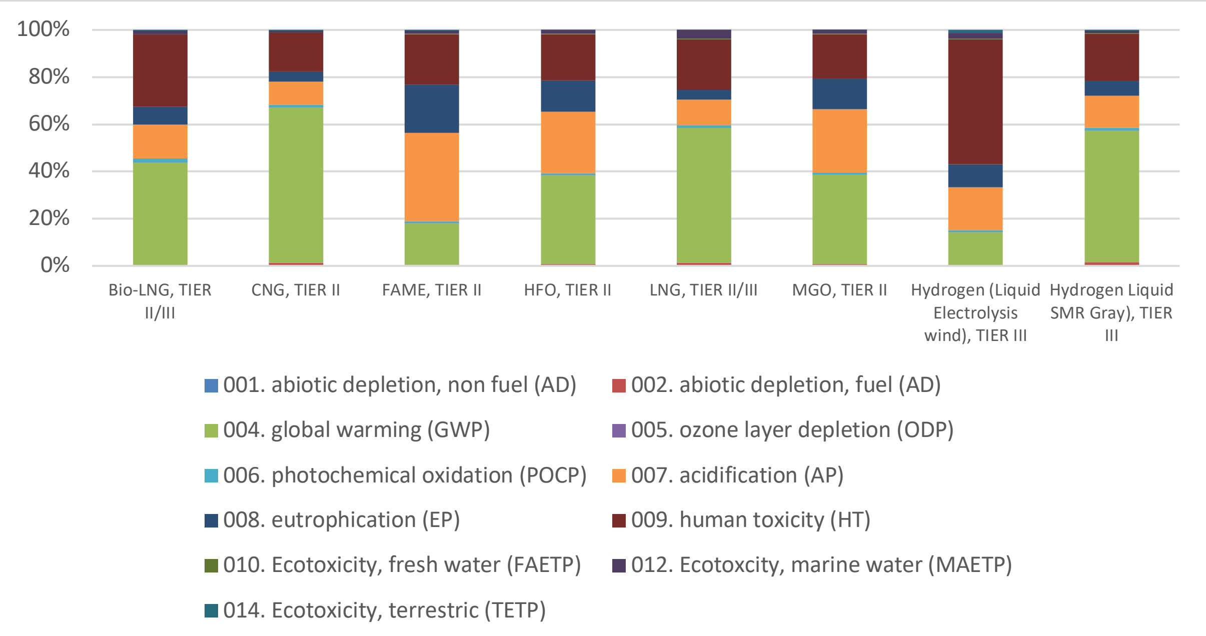
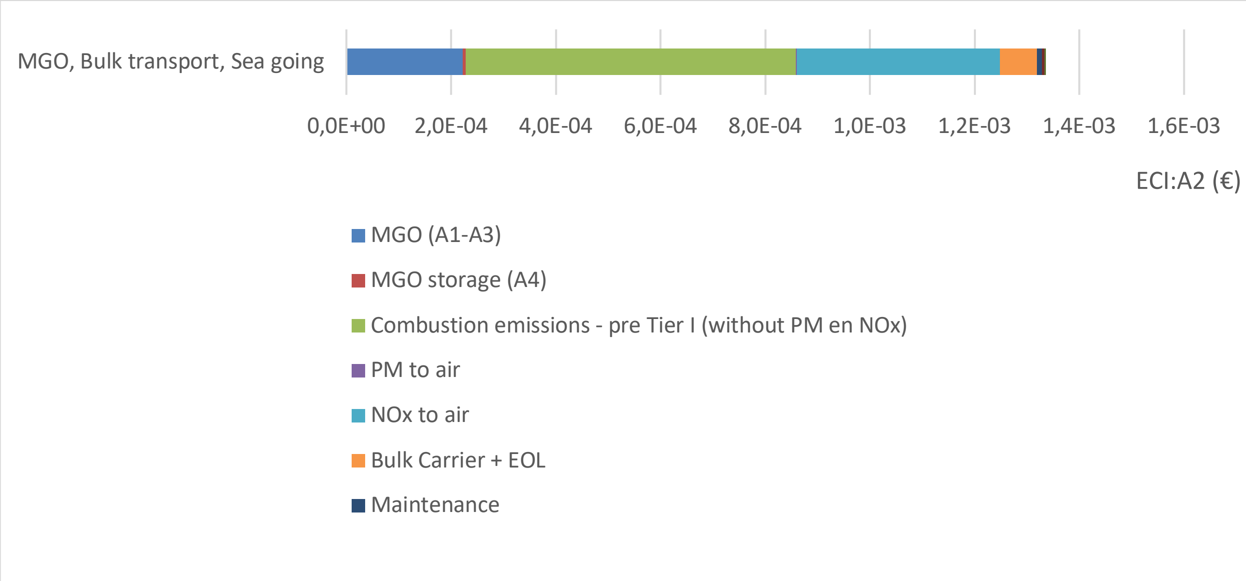


Figure 24: Contribution of all impact categories to ECI:A1, per tonne-km for seagoing transport.



The figure below gives an overview of the ECI:A2 contribution of the various components to the ECI:A2 per tonne-km for MGO seagoing transport. The various components of the capital goods are also highlighted here. The ship itself contributes mainly to the ECI:A2 of the capital goods and the port facilities contribute only marginally.

Figure 25: Detailed analysis of ECI:A2 MGO seagoing transport per tonne-km.



5.3 Sensitivity analysis

In this chapter, the influence of various data points on the total ECI:A2 will be assessed. This will indicate how sensitive the results are to changes in underlying assumptions. These are data points that can have a significant impact on investment decisions regarding future energy carriers. The comparisons made are mainly indicative and serve to illustrate the implications of such uncertainties. In particular, there is still much uncertainty surrounding RFNBOs, due to both the Technology Readiness Level (TRL) and the supply chain that will deliver these energy carriers.

Examples include the efficiency of the drivetrain. The aim is to provide the reader with insight into the underlying mechanisms and their effect on the variability in results. These uncertainties should be taken into account, and the reader is advised to critically interpret the figures before including them in internal decision-making processes.

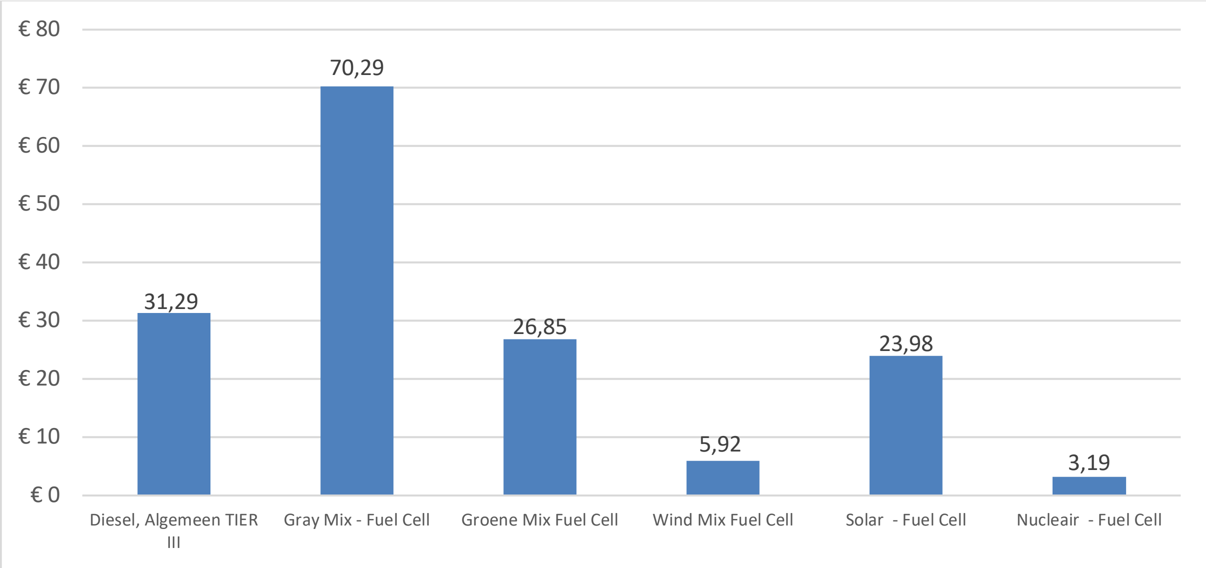
Energy source for hydrogen electrolysis

As described in the hotspot analysis, the electricity source for hydrogen production via electrolysis is essential for all RFNBOs. This applies not only to the direct application of hydrogen but also to the production of synthetic ammonia and e-methanol.

The figure below shows that the environmental impact of solar energy is too high to produce hydrogen with a sufficiently low ECI. However, there is still room for optimization. For instance, if solar energy from Spain is used, the higher yield per panel could reduce the ECI of the solar variant by approximately 35%. It remains uncertain whether wind energy will be a truly pragmatic solution for hydrogen production. Therefore, it is important to obtain a broader view of future developments in hydrogen production.

Other alternatives for electricity include nuclear energy and hydroelectric power. These last two options provide a constant power output and result in an even lower ECI:A2 than wind-based electrolysis. The ECI:A2 for H2 (gaseous), electrolysis, nuclear, TIER III is €3.19 per ton, about 70% lower than that of HVO TIER III. In addition to the electricity source, there may theoretically be further gains to be made in the efficiency of the electrolysis process itself. However, this study did not explore that aspect, and no data was collected within this LCA study.

Figure 26: Comparison between various power sources for hydrogen, gas, electrolysis. ECI: A2 per tonne for salt working vessels.



Fuel cell depreciation

As the ECI of the energy carrier and its use profile decrease, the relative contribution of capital goods increases significantly. For hydrogen (electrolysis, wind), the contribution of the fuel cell is 16% (see Figure 27). This estimate is fairly conservative, as it is based on average annual consumption data. The fuel cell has been depreciated over the total number of operating hours, but it likely did not run at full power for all hours. In practice, the load and lifetime will be linked. If a lifetime of 20,000 hours is achieved at full power, the depreciation could decrease by up to a factor of 10 compared to current values.

While the 20,000-hour lifespan is what is currently projected by the market, this figure is not yet widely substantiated by practical data. It is expected that 20,000 hours represents a future scenario, likely to be reached within the next ten years. However, according to TNO, the currently proven lifespan is closer to 10,000 hours. The following figures show the effect of reducing the fuel cell lifespan to 10,000 hours, which would double the fuel cell's contribution to the ECI. This is a worst-case estimate—as more real-world data becomes available; this contribution could decrease in the future.

Figure 27: Contribution of components to ECI:A2 for seagoing, hydrogen, fuel cell, electrolysis based on wind energy.

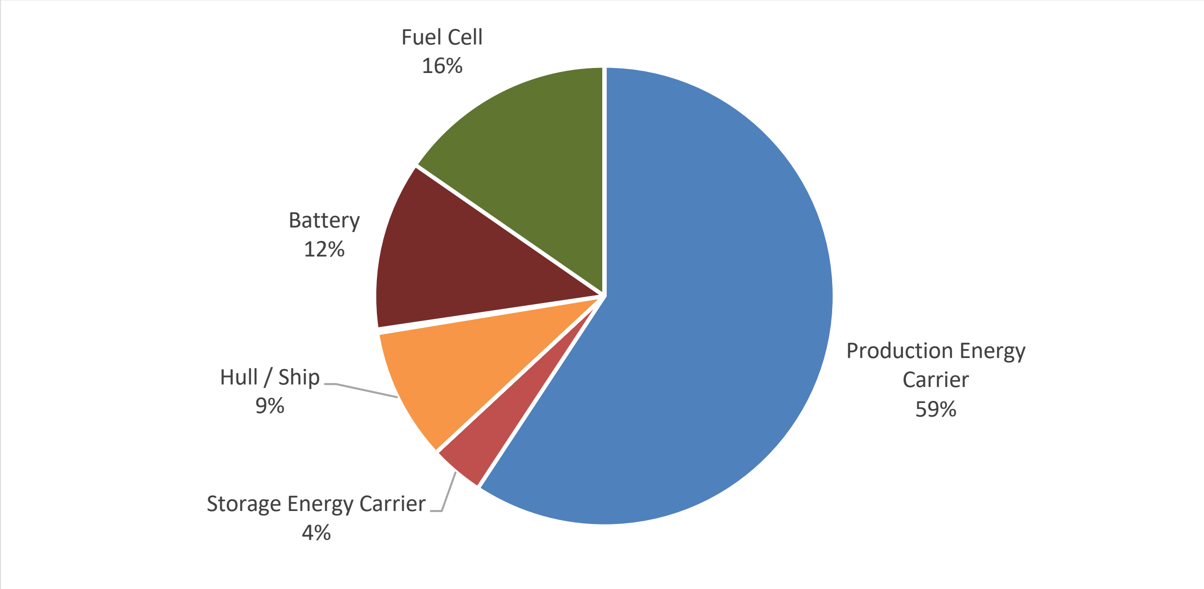
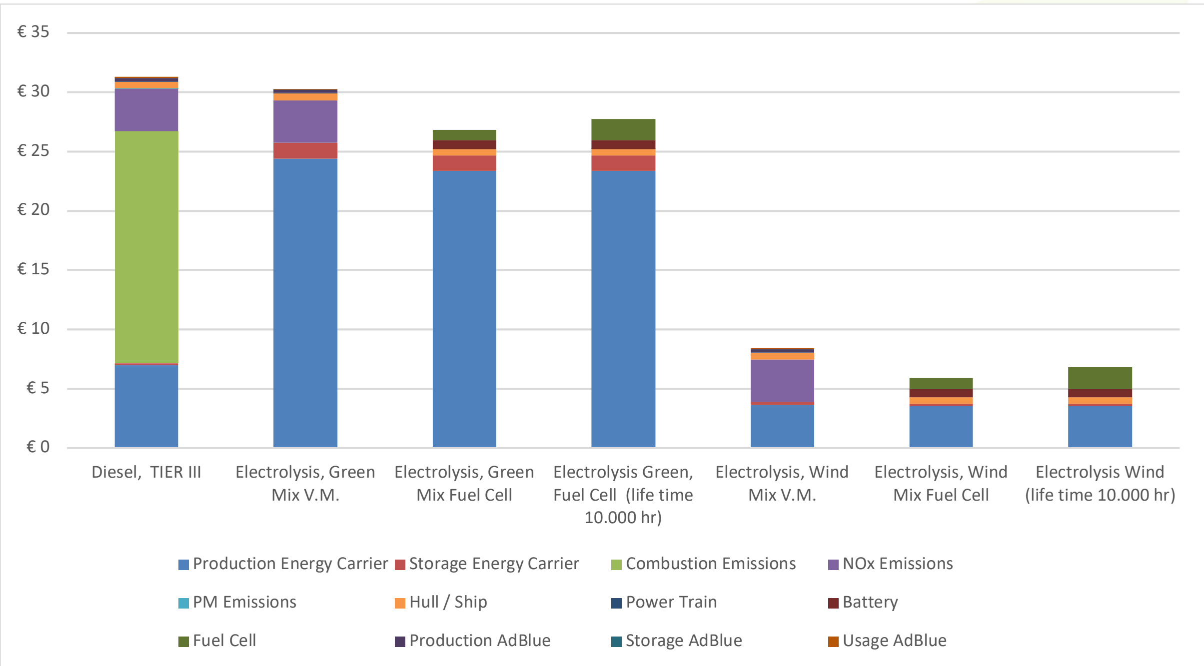


Figure 28 shows the effect of reducing the lifespan from 20,000 hours to 10,000 hours. The ECI:A2 of the fuel cell - electrolysis - green variant increases by 3%, and that of electrolysis - wind by 15%. Based on the current assumptions, this means that even a factor-of-two difference in fuel cell depreciation for saltwater vessels does not affect the ranking compared to an internal combustion engine. However, similar uncertainties in data points also apply to combustion engines, which likewise have a low TRL. One example is the actual NOx emissions during the usage phase, which make a significant contribution to the ECI:A2 for hydrogen combustion engines.

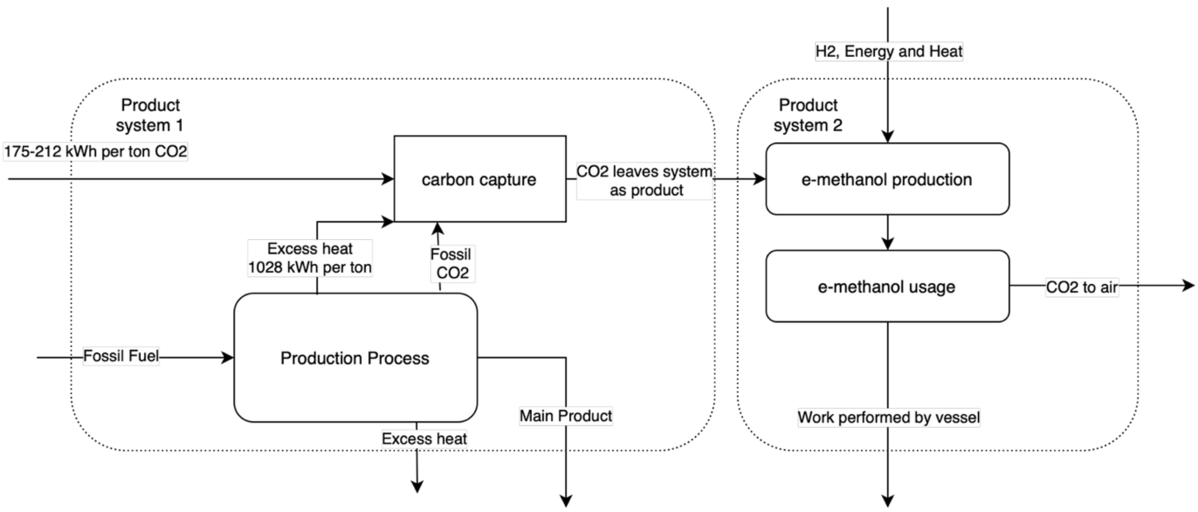
Figure 28: Effect of depreciation of fuel cell for various hydrogen variants of salt work vessels



E-methanol sources of captured CO2

In addition to H2, the e-methanol profile also uses CO2 as a raw material for fuel production. This CO2 is obtained via a post-combustion CO2 capture installation, or in the future perhaps directly from the air (direct air capture, DAC). The current profile is based on captured fossil CO2, a simplified overview of this process is shown in Figure 29.

Figure 29: e-methanol CO2 capture process



The system in question concerns the production system of a product during which CO2 is emitted. This could, for example, be a cement production process or a waste incineration plant. Normally, this CO2 would be released into the atmosphere via the flue gas exhaust. However, the producer may choose to make a capital investment in a CO2 capture system. Such a system consumes electricity and heat to extract the CO2 from the flue gas. The additional environmental impact associated with the electricity consumption (175–212 kWh per ton of CO2) required for capture is attributed to the primary production system (PBL 2024).

The released heat is considered a functional output flow. As can be seen, for instance, in the HVO production diagram, environmental impact is usually allocated to released residual heat. This means that using residual heat for CO2 capture indirectly reduces the functional output flow from the production system (i.e., less residual heat is released). It is estimated that approximately 1028 kWh of residual heat is needed per ton of CO2 captured (PBL 2024).

The assumption is that the total energy consumption (electricity and heat) is net beneficial to the producer, as it leads to a reduction in CO2 emissions from the production process. The captured CO2 can either be permanently stored or used for other purposes. Examples include use in greenhouses, as carbonated gas, or for e-methanol production.

The captured CO2 is considered a residual stream from the primary production process and enters the e-methanol production process as burden-free. Here, it serves as a feedstock for e-methanol production in combination with hydrogen and process energy/heat. During the use phase, this fuel is combusted (or applied in a fuel cell), and the CO2 is ultimately released into the atmosphere.

In practice, the CO2 source can also be a mix of fossil and biogenic CO2, depending on the feedstocks combusted in the primary production process. For biogenic captured CO2, this presents a unique case within the LCA framework. Under EN15804:A2, the biogenic carbon balance must be net zero over the entire life cycle. This means that the benefit of captured biogenic CO2 does not appear in the LCA results of the primary production process. The biogenic CO2 balance for the life cycle of methanol use in the vessel is also net zero, which means there are no CO2 emissions counting toward the ECI:A2.

Therefore, the current modelling of biogenic e-methanol represents the most favourable variant. Since (under EN15804 rules) the production system does not benefit from capturing biogenic CO2, it could also be argued that the additional energy should not be allocated to the production system but rather to the e-methanol production process.

It is essential to establish clear calculation rules regarding the accounting for captured CO2 and its use in fuels. This is necessary to prevent both production systems from claiming avoided emissions and potentially leaving CO2 emissions unallocated.

These aspects must be reflected in future LCAs of specific e-methanol products. This is a key consideration for compliance and evidence requirements concerning LCA calculation rules for available e-methanol, particularly in relation to existing frameworks such as RED II and ISCC.

The third option is to capture CO2 directly from the air (Direct Air Capture, DAC). For this route, the energy required—both electricity and heat—for capturing CO2 from ambient air is allocated to the production of e-methanol. This variant also assumes a net zero carbon balance over the life cycle. The process is still in its infancy, and limited information is available. According to TNO, an indicative figure is 250 kWh of electricity per ton of CO2 captured. For the DAC variant, the version where the impact of heat production is included has been considered (heat from the combustion of wood chips). If heat from natural gas were used instead, it would significantly increase the ECI:A2 of this variant. There is no further insight into additional auxiliary materials or other requirements for such DAC technologies.

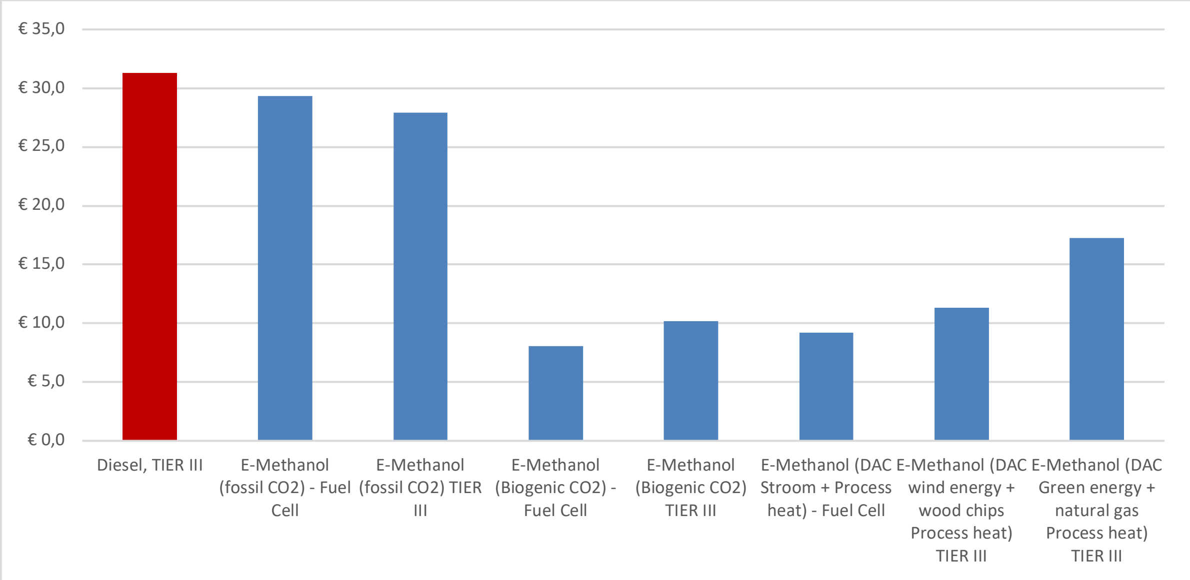
Figure 30 illustrates the impact of the above-described production routes for e-methanol. The fossil-based variant scores comparably to diesel due to fossil CO2 emissions during the use phase. For the biogenic CO2 and DAC routes, biogenic CO2 emissions are considered net zero over the full life cycle.

For the sensitivity analysis of the DAC route, the variant based on heat from wood chip combustion has been included for comparison (Heat, district or industrial, other than natural gas {NL} | heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014 | Cut-off, S). The assumption here is that the heat demand equals that of flue gas CO2 capture (1028 kWh).

The ECI:A2 for the DAC variant is €9.2 (fuel cell) and €11.3 (TIER III) per GJ of delivered work. This is 12% higher than the biogenic e-methanol variant and 36% higher than H_2-gas electrolysis wind (fuel cell). Currently, for this analysis, heat from wood chips has been selected, which represents a reasonably best-case scenario. The additional environmental impact resulting from electricity and heat increases the ECI:A2 of the e-methanol energy carrier production by 10%. Of this increase, 12% stems from the electricity used (wind-based), and 88% from the required heat.

The ECI:A2 of both electricity and heat may vary significantly depending on the source. For example, the A1–A3 ECI:A2 of the DAC e-methanol variant increases by 60% when green electricity and natural gas-based heat are used. This means that both the electricity and heat sources have a significant influence on the total ECI:A2 of the DAC e-methanol variant. The environmental impact of DAC can therefore be considerably higher (see Figure 30).

Figure 30: Total ECI:A2 per GJ of work delivered for various types of e-methanol versus Diesel, saltwater working vessel.



Allocation to organic waste streams for biofuels

For biofuels such as HVO and FAME, various oils derived from waste and residual streams are used. Globally, there is a growing demand for organic residual streams as a sustainable alternative to fossil resources (Imam et al. 2024). This increasing demand significantly drives up the prices of these residual streams. For certain production systems that process such streams internally, this can lead to a situation where these residuals add significant economic value to the system, sparking debate on whether they should be classified as co-products.

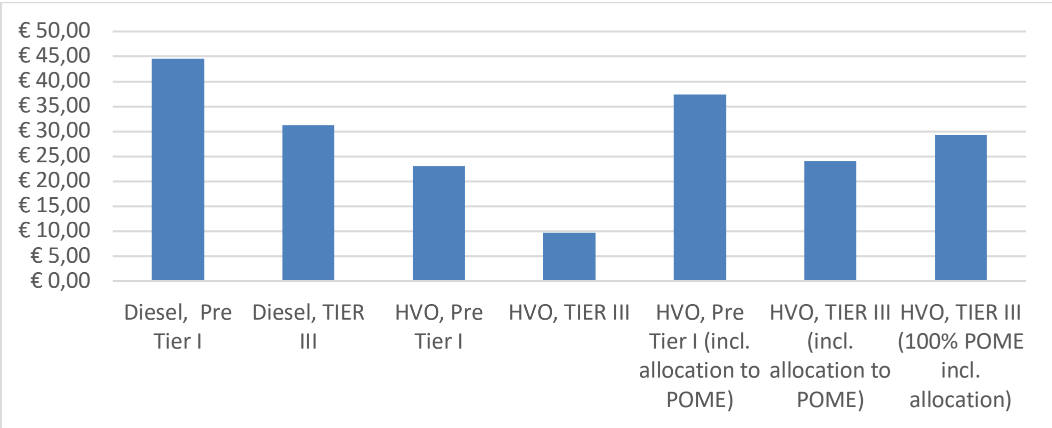
EN15804 specifies that no environmental impact **needs** to be allocated to co-products that contribute minimally to the production system. “Minimal” is further clarified with an example threshold of 1%.

In the case of HVO, the largest residual stream is POME oil, which comprised 60% of the market mix in 2023 (NEA 2023). This oil is extracted from palm oil mill effluent (POME), a waste stream from palm oil production. Due to the aforementioned market demand, it has become economically viable for palm oil producers to recover this oil and refine it into a high-value product. Given its processing potential, POME oil is now considered a valuable resource (Imam et al. 2024). It is estimated that POME oil represents on average 1.1% of the total financial output of palm oil production.

Since this value hovers around the 1% threshold, EN15804 allows LCA practitioners discretion on whether or not to allocate environmental impact to this co-product. To remain consistent with policy—specifically RED II—it was decided not to allocate impact to these residual streams. The implications of this modelling choice are illustrated below with two examples.

The figure below compares Diesel with the HVO market mix used for saline working vessels, per GJ of delivered work. The two central HVO variants represent the current modelling approach: the 2023 NEA market mix, where POME oil (60% of the mix) enters the system burden-free, with only the upgrading step considered. The two rightmost HVO variants depict the same market mix, but with 1.1% of the environmental impact from palm oil production allocated to the POME oil. This allocation increases the ECI:A2 of HVO by a factor of 2.5, meaning that HVO TIER III performs only 25% better than Diesel instead of 70%. This illustrates how strongly the environmental performance of biofuels depends on whether or not environmental impact is allocated to these residual streams. If upstream agricultural and processing impacts are included, these biofuels become less competitive in ECI:A2 compared to RFNBOs.

Figure 31:Comparison of allocation to POME oil for HVO salt work vessel per GJ of labour supplied, ECI:A2.



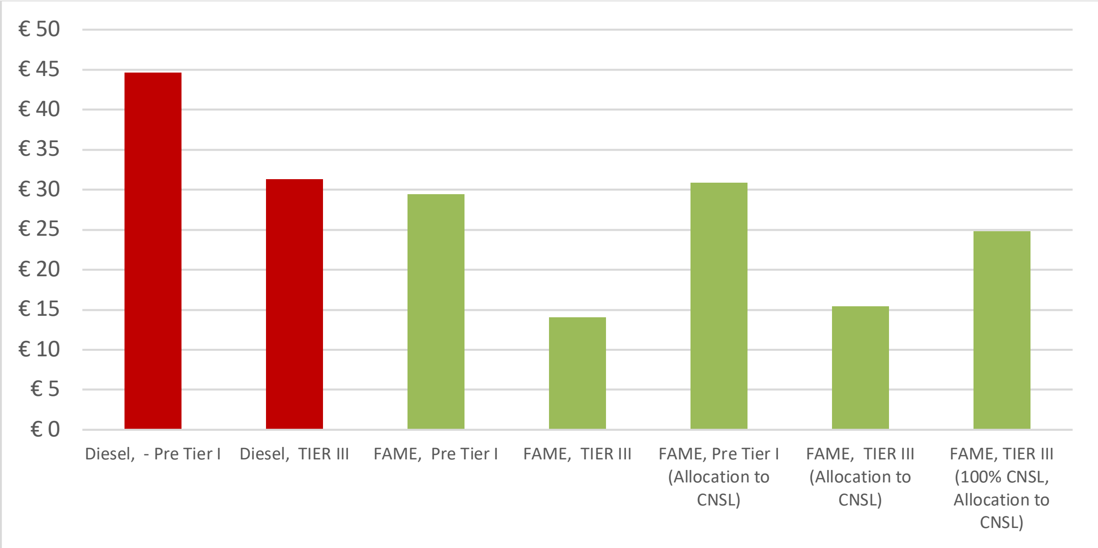
A second example is based on FAME produced using Cashew Nut Shell Liquid (CNSL), an oil extracted from cashew nut shells. These shells already meet end-of-waste criteria. However, the relative value of the shells compared to the nuts themselves is unclear. Several processing steps are required to extract oil from the shells, which can be done via cold or hot pressing, or solvent extraction, and potentially further refining before it can serve as a feedstock for HVO or FAME.

For this sensitivity analysis, a simplified approach is used in which the environmental impact of cashew nut production is allocated to CNSL oil based on relative market values. With cashew nuts valued at $7500/ton and CNSL oil at $500/ton, the allocation is estimated at 6.67%. This allocation increases the ECI:A2 of the TIER III variant by approximately 7%, even though CNSL oil comprises only 9% of the FAME mix. If FAME were produced entirely from CNSL oil (with allocation), the ECI:A2 would be 77% higher (still about 23% lower than Diesel TIER III).

This alternative LCA modelling based on the value of residual streams only affects the distribution (allocation) of environmental burden among the various products derived from the chain (palm oil or cashew nuts). The total environmental burden of the chain remains unchanged—only its allocation differs.

As demand for biofuels increases, it is expected that the value of residual streams will rise further. This was historically illustrated by the price development of used cooking oil, which, due to high demand, at times exceeded the price of virgin palm oil. RED monitors such trends to determine which feedstocks are listed under Annex IA or Annex IXb. The limited availability and scalability of organic residuals must be considered in policymaking for the energy transition in maritime transport.

Figure 32: Comparison of allocation to CNSL oil for FAME salt working vessel per GJ of work delivered, ECI:A2.



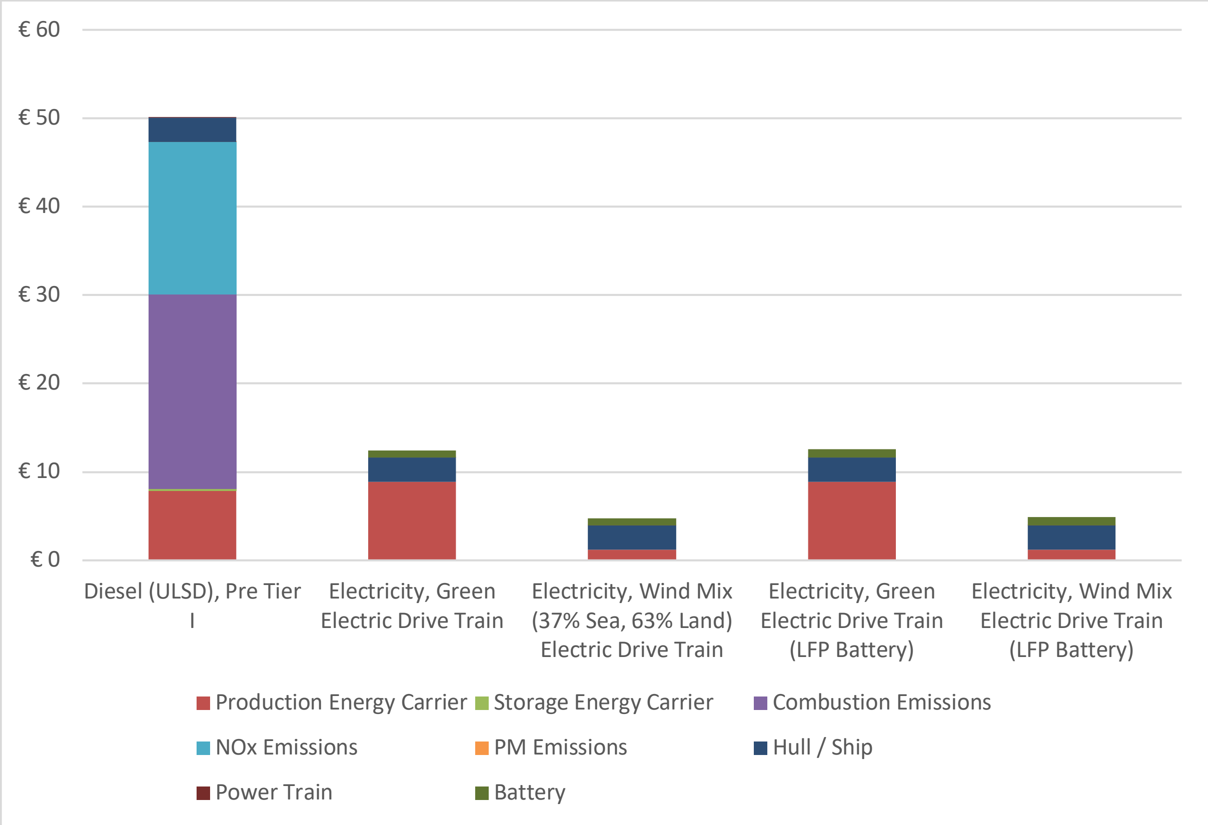
LFP versus $LiMn_2O_4$ battery variants

The ECI:A2 contribution from battery cells is primarily driven by the materials in the anode (graphite), separator, and cathode ($LiMn_2O_4$), which together account for 86% of the total impact of the battery cells. Since their overall contribution to the ECI:A2 of the vessel is relatively small, no adjustments are made to the battery cells in this study. However, performance characteristics relevant to battery depreciation (lifetime, charge cycles, energy density, etc.) are critically evaluated.

In production, the ECI:A2 per kg of battery varies by a factor of 2 to 5. This difference is somewhat mitigated when energy density and maximum charge cycles are also considered. However, there is no insight into the end-of-life scenarios for LFP and NMC battery types, which limits the possibility of a fair complete life cycle comparison. Currently, the NMD models $LiMn_2O_4$, batteries with partial reuse (70%) and partial recycling, where only metals are considered recovered. If the end-of-life treatment of LFP batteries were modelled identically, the ECI:A2 card for saline operations powered by wind would be 6% lower for $LiMn_2O_4$ compared to a LFP battery. This comparison assumes 150 Wh/kg and 5000 cycles for LFP, and 200 Wh/kg and 2000 cycles for $LiMn_2O_4$.

The impact on working vessels is marginal (1–2%). However, assumptions vary widely. The recommendation is to expand the battery data in the NMD database in the future, so that a complete cradle-to-grave environmental profile is available for NMC and LFP battery types in case of large-scale deployment.

Figure 33: ECI:A2 per GJ for battery electric vs diesel. Comparison LFP with LiMn2O4.



6. Conclusion

This report outlines the (relative) environmental impact of using various energy carriers in shipping. The focus is on the Environmental Cost Indicator (ECI: A2 and ECI: A1). The ECI score is a monetary value in euros, obtained by weighting and summing various impact categories. In the LCA methods, raw materials and capital goods are included (e.g., production and maintenance of wind turbines or solar panels). For this reason, even sustainable alternatives have an environmental impact.

This report primarily compares energy carriers based on the delivered shaft work. This approach was chosen to enable a comparable ECI between all alternatives. The energy content of the carriers varies greatly (e.g., one tonne of hydrogen contains six times more energy than one tonne of methanol).

The results show a clear trend on which high-level strategy can be made. While interpreting the results, the reader must consider that the underlying assumptions may influence the relative differences. The data points are a snapshot of currently available data and can show significant variation, both presently and in the future. The study describes a range of energy carriers and technologies, each with a different TRL (Technology Readiness Level). Particularly for future energy carriers (RFNBOs), there are significant uncertainties around production, storage, use, and availability. These uncertainties can affect the ECI in both directions – upward and downward. The implications of these uncertainties are explained and explored in sensitivity analyses where possible.

Figure 34: Overview (from highest to lowest) for a selection of salt work vessels, ECI:A2 per GJ of work. Red – Fossil, Green – biofuel and blue – RFNBO.

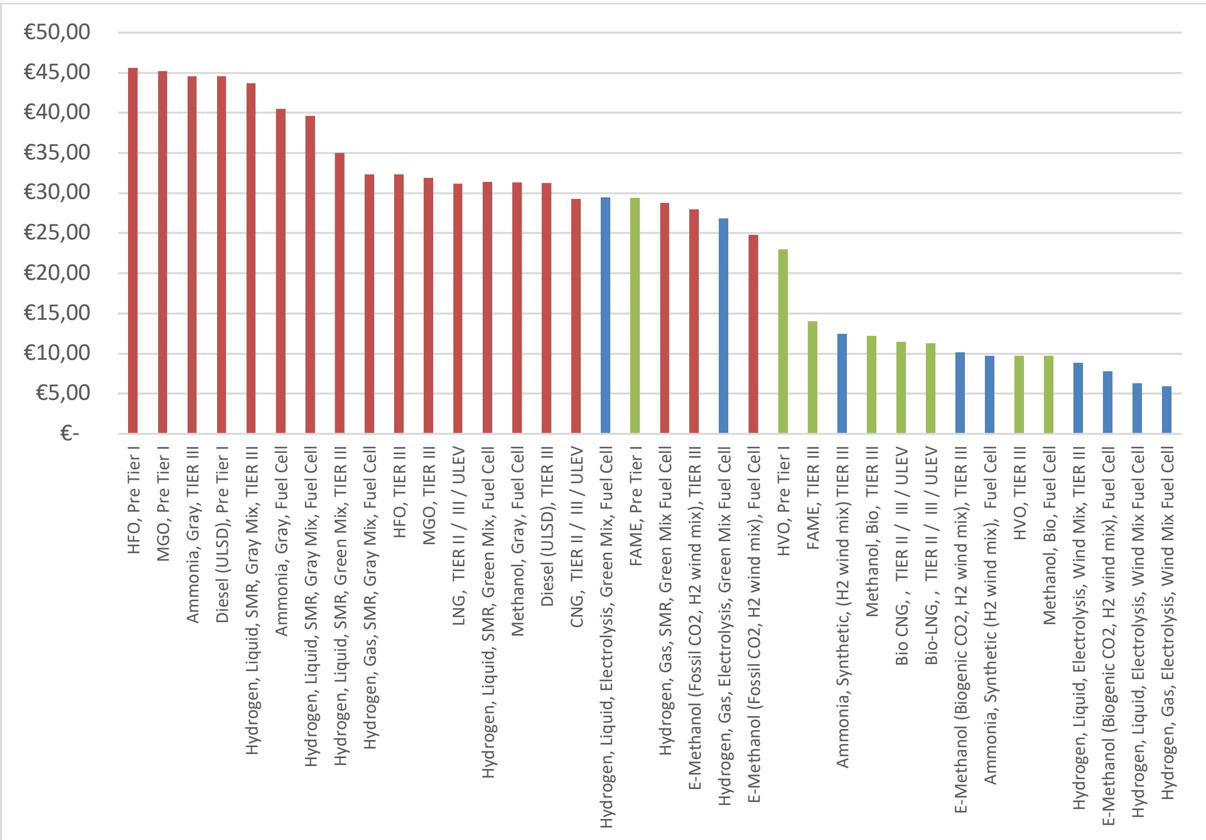
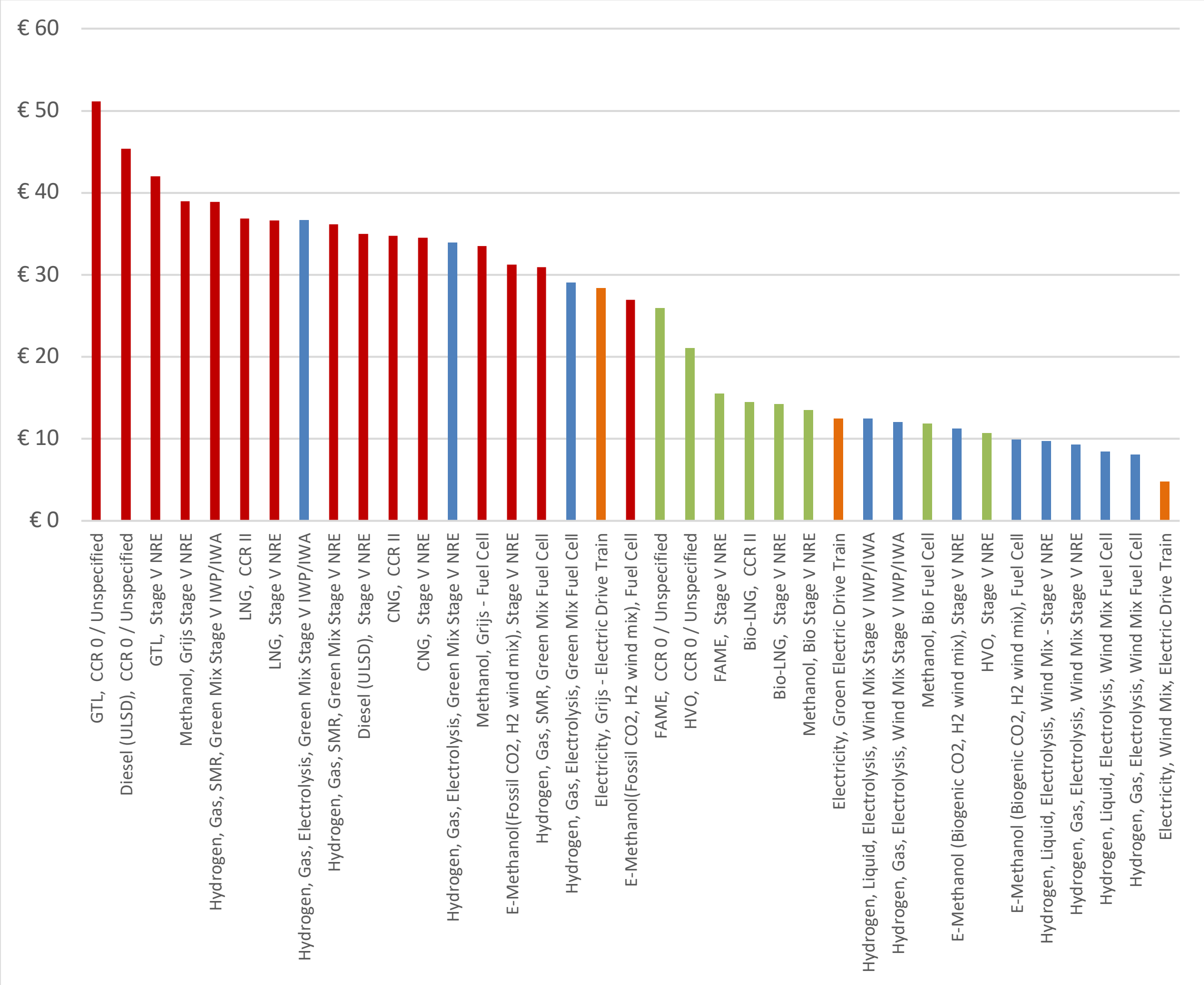


Figure 35: Overview from highest to lowest for selection of freshwater work vessels, ECI:A2 per GJ of work. Red – Fossil, Green – biofuel, blue – RFNBO and orange – electric.



Short term

Fossil

Currently, various fossil energy carriers (such as MGO, LNG and Ultra Low Sulphur Diesel) and combustion engines with differing emission classes can be applied. For saltwater vessels, the ECI ranges from €45 ECI:A2 per GJ to €30 ECI:A2 per GJ. For freshwater working vessels, the ECI ranges from €51 ECI:A2 per GJ to €30 ECI:A2 per GJ with the cleanest combustion engine. Compared to other energy carriers, this variation is relatively limited.

For the lower TIER and CCR classes, NOx emissions account for a significant portion of the ECI:A2 (e.g., 44% for Diesel pre-TIER I). Improving emission classes will reduce NOx emissions and thereby significantly lower the ECI. For working vessels, there is a 20% to 30% reduction from pre-TIER I to TIER III (and from Pre-CCR to Stage V for freshwater). For fossil energy carriers, more than 50% of the ECI:A2 stems from fossil CO2 combustion emissions. The ULEV variant has also been included for the seagoing vessels. Under current assumptions (Stage V IWP/IWA values), this results in marginally higher NOx emissions than TIER III, though real-world data is still limited. In practice, the ULEV variant may perform similarly to or better than TIER III, depending in part on AdBlue usage.

Biofuels

Various biofuels (such as HVO, FAME, bio-LNG and in the future bio-methanol) can currently be used in combustion engines of different emission classes. For working vessels, the ECI of these variants ranges from €30 ECI:A2 per GJ to €10 ECI:A2 per GJ using the cleanest combustion engine.

According to the LCA standard (EN15804), the biogenic CO2 balance must be net zero over the full life cycle. This means the biogenic CO2 is stored in the biomass (a negative value in module A1-A3) and released during the use phase (module B) as combustion emissions. As such, these emissions do not contribute to climate change or to the ECI:A2. (In ECI:A1, biogenic CO2 is not weighted.) This explains much of the difference between fossil energy carriers and biofuels.

The contribution of NOx emissions to ECI:A2 in biofuels is comparable to that of fossil fuels. Biofuels in older engines (pre-TIER I/pre-CCR I) perform similarly (in terms of ECI:A2) to TIER III/Stage V fossil fuel engines. Biofuels combined with modern TIER III/Stage V engines score much lower – a factor of 2 to 3 better than their fossil counterparts, depending on emission class. In the ranking, these biofuels perform comparably to RFNBOs.

The low ECI of biofuels is highly dependent on modelling choices. In alignment with EU biofuel policy, this LCA used modelling approaches consistent with the Renewable Energy Directive (RED II) methodology for CO2 reduction. This assumes organic waste streams are considered "burden-free," and only the upgrading to biofuel is included. The EN15804 standard also allows for financial allocation based on the economic value of main and co-products. The price of organic residues is influenced by the demand-supply ratio. Policies that increase demand for such residues (without a corresponding increase in supply) will likely raise prices. In future, this market dynamic may influence debates on current policy and modelling approaches. Should an economic allocation method assign a portion of agricultural and processing impacts to these residues, then the ECI of, for example, HVO may become comparable to that of Diesel. This underscores that the sustainability of biofuels is intertwined with the availability and demand for organic residues. These nuances are crucial for short-, medium-, and long-term strategies for promoting biofuels.

If, on the basis of such an economic allocation, part of the impact of agriculture and reprocessing processes is attributed to these residual flows, the ECI of HVO, for example, will be comparable to that of Diesel. This shows that the sustainability of biofuels is linked to and the demand for and supply of such organic waste streams. The nuances mentioned above are very important for the short, medium and long-term visions on the promotion of biofuels.

Towards the Future

A range of innovative energy carriers may be adopted in the future. The TRL of these variants varies, and not all are yet market-ready. This category includes Hydrogen (from wind or hydropower), synthetic Ammonia, e-Methanol (biogenic), and battery-electric shipping. For saltwater working vessels, the ECI ranges from €30 ECI:A2 per GJ to €6 ECI:A2 per GJ. For freshwater working vessels, this ranges from €36 ECI:A2 per GJ to €4.8 ECI:A2 per GJ.

Hydrogen - RFNBO

Power source: Hydrogen only achieves a very low ECI score when produced using a sustainable power source such as wind, hydropower, or nuclear. Hydrogen produced from the current green electricity mix scores similarly to a Tier III/Stage V fossil fuel. Hydrogen from average grey electricity scores worse. Electrolysis requires vast amounts of electricity to produce hydrogen. Policymakers must account for this when encouraging hydrogen use in shipping – large-scale adoption would demand far more power generation.

Fuel cell versus combustion engine: The current data shows that fuel cells have higher efficiency than combustion engines. This is particularly noticeable in freshwater vessels (40% engine efficiency vs. 47% for fuel cells). For saltwater vessels, this difference is smaller (engine: 45%). In the future, fuel cell efficiency may increase to 50–55%.

Fuel cell lifespan: The lifespan of fuel cells is uncertain. The current depreciation assumptions are conservative. Even under those assumptions, the absolute contribution is limited (0.9 ECI:A2 per GJ shaft work). As the ECI of the fuel drops, the relative contribution of capital goods rises. For wind-based hydrogen with fuel cell, the fuel cell contributes 15% to the total ECI:A2. More detail is found in the sensitivity analysis (p.101).

Liquid versus gaseous: Liquid hydrogen has a higher ECI due to the extra energy needed for liquefaction. For hydrogen from wind electrolysis using a fuel cell, the ECI:A2 difference is about 3.3%. This difference shrinks when using renewable electricity for liquefaction (e.g., wind instead of grey power). There is also uncertainty about hydrogen delivery. Currently, only 400 kg of gaseous hydrogen can be transported per lorry. With current assumptions, transport contributes <3% to the ECI. This may rise above 5% with long-distance transport.

Other RFNBOs – e-methanol and ammonia

There is still limited data and significant uncertainty regarding e-methanol and synthetic ammonia. TNO indicates very little data is available, with large uncertainties in production methods and emissions during use. No data is available on potential environmental impact from ammonia slip or formaldehyde emissions. Readers must account for this when interpreting results.

Besides combustion uncertainties, both fuels may be viable alternatives with relatively low ECI:A2. Additional upgrading steps mean that their ECI per MJ is higher than hydrogen. However, these carriers offer advantages in transport and usability. It remains essential that sustainable hydrogen (e.g., from wind electrolysis) is used as the base.

E-Methanol presents uncertainties around captured CO_2 and the use of waste heat in capture processes. ECI:A2 is only low when the emissions of captured CO_2 are not assigned to the fuel's use phase – this is only true for biogenic CO_2. Currently, CO_2 is captured from fossil-intensive industries. Using this CO_2 delays but does not avoid emissions, while incurring costs. The burden of capturing biogenic CO_2 is not included in the LCA but is discussed in the DAC variant in the sensitivity analysis (p.103).

Direct Air Capture (DAC) involves very little data. The process requires both heat and electricity, which increases the ECI of DAC-based e-methanol. The source of this energy is key: depending on it, the ECI can be 10% to 200% higher than for the current biogenic variant.

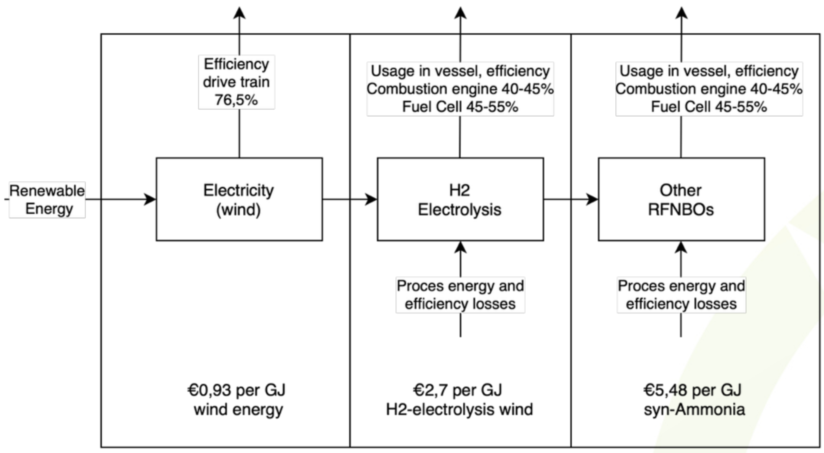
The LCA standard (EN15804) currently lacks a clear framework for capturing, storing, and assigning CO_2 emissions. For e-methanol, consistent CO_2 allocation is essential. Also, attention must be paid to the potential for double counting by companies claiming negative carbon credits for avoided emissions.

Battery-electric
Battery-electric propulsion performs best in terms of ECI. However, it is often not feasible for ocean-going ships and is only suitable for inland vessels that can recharge at shore or port near the work location. This propulsion system has the fewest conversion steps and losses. With low ECI, capital goods contribute significantly. As with fuel cells, there is still uncertainty about drivetrain and battery lifespans.

Production chain losses during RFNBOs production steps
The diagram below outlines key stages of sustainable energy carriers (RFNBOs). Direct use of electricity yields the lowest ECI per MJ, and electric drives are highly efficient – leading to low ECI:A2 per GJ shaft work. Electricity can also produce hydrogen via electrolysis, which adds process emissions and losses. Hence, hydrogen has a higher ECI per MJ than electricity (€0.93 vs. €2.7 per MJ).

If further RFNBOs are made from this hydrogen (e.g., e-methanol or ammonia), additional energy inputs increase the ECI per MJ further (€5.48 per MJ). From an energy perspective (ECI per MJ), fewer conversion steps are preferable. However, many real-world factors not captured by the LCA – such as regulations, energy density, drivetrain type, and availability – influence practical energy carrier decisions.

Figure 36: From electricity to RFNBO, ECI:A2 per GJ of energy carrier



Conclusion
Energy carriers with the lowest ECI scores show a 4 to 7 times lower ECI:A2 than the oldest fossil fuel variants (Pre-TIER I / Pre-CCR I), indicating the maximum environmental gain. However, availability of sustainable carriers is a key challenge. Demand drives supply, but investing in alternative propulsion only makes sense if sustainable RFNBOs are actually available on the market.

In the long run, access to sufficient low-ECI electricity will be critical – not just for electric ships, but also for hydrogen production and subsequent RFNBOs like e-methanol and ammonia. Only with enough sustainable electricity can production scale.

7. Bibliography

Eurostat. 2024. "Gross weight of goods transported to/from main ports - Netherlands - quarterly data [mar_go_qm_nl__custom_11972169]." https://ec.europa.eu/eurostat/databrowser/view/mar_go_qm_nl__custom_11972169/default/table.

JEC. 2020. "WTW study version 5 (JEC_WTTv5_ Appendix 1_Pathways 4_Biodiesel)."

TNO. 2021. *Update milieuprofielen van scheepsbrandstoffen ten behoeve van opname in de Nationale Milieudatabase.*

Eurostat. 2024. https://ec.europa.eu/eurostat/databrowser/view/mar_go_qm_nl__custom_11972169/default/table.

CBS. 2024. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/00372/table?ts=1733829183241.

NEA. 2023. *Rapportage Energie voor Vervoer in Nederland 2023.*

Imam et al. 2024. "Valuable resources recovery from palm oil mill effluent (POME): A short review on sustainable wealth reclamation." *Waste Management Bulletin* 3 (2025) 1–16.

NEA. 2024. *Rapportage Energie voor Vervoer in Nederland 2023.* NEA.

Chin Hing Chung et al. 2017. "RECOVERY OF RESIDUAL OIL FROM PALM OIL MILL EFFLUENT USING POLYPROPYLENE NANOFIBER: A FIELD TRIAL." *MATTER: International Journal of Science and Technology.*

Akhbari et al. 2020. "A study of palm oil mill processing and environmental assessment of palm oil mill effluent treatment." *Environmental Engineering Research* 25(2) 212-221.

Sheng Lee et al. 2019. "Treatment technologies of palm oil mill effluent (POME) and olive mill wastewater (OMW): A brief review." *Environmental Technology & Innovation* Volume 15, August 2019, 100377.

2024. *Vesper.* https://vespertool.com/news/pome-market-update/.

Seekao et al. 2021. "Co-digestion of palm oil mill effluent with chicken manure and crude glycerol: biochemical methane potential by monod kinetics." *Heliyon.*

Chin et al. 2013. "Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective." *Renewable and Sustainable Energy Reviews* Volume 26, October 2013, Pages 717-726.

Ho et al. 1984. "https://www.feedipedia.org/node/15395." *Agricultural Wastes* 61-71.

Gemeente Rotterdam. 2018. https://persberichtenrotterdam.nl/persberichten/verzadigde-bleekaarde-is-miljoenen-waard/.

TNO. 2018. "20 LCA's voor brandstof-machine combinaties."

Energypedia. 2020. https://energypedia.info/wiki/Cashew_Nut_Shells_as_Fuel.

Energy, ISRN Renewable. 2013. *Cashew Nut Shell Waste: Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification.* https://onlinelibrary.wiley.com/doi/10.1155/2013/147365.

Mubofu, Egid B. 2015. "From cashew nut shell wastes to high value chemicals." *Pure and Applied Chemistry.* https://doi.org/10.1515/pac-2015-0603.

Expana. 2024. https://www.expanamarkets.com/insights/article/cashew-prices-update/.

Indiamart. 2025. https://www.indiamart.com/proddetail/cashew-nut-shell-liquid-11927351712.html?srsltid=AfmBOorGqAOqG9sAbPh2msYixjPEv4DXouVX0QaeUvQUiVCgzhNzGmWz.

TNO. 2016. "Milieuprofielen van scheepsbrandstoffen ten behoeve van opname in de NMD."

—. 2020. “Green Maritime Methanol Operation aspects and the fuel supply chain.” https://publications.tno.nl/publication/34637282/W1qAlG/TNO-2020-R11105.pdf.
CBS. 2024. https://www.cbs.nl/nl-nl/longread/rapportages/2024/hernieuwbare-energie-in-nederland-2023/4-windenergie.
TNO. 2014. *Van A to Z: Introductie van emissiereducerende methodes voor binnenvaartschepen en de binnenvaartketen.* TNO.
TNO. 2023. *Green Deal Validation: Sustainability and applicability of biodiesel for sea vessels.* TNO.
Vries, De. 2019. “Safe and effective application of ammonia as a marine fuel.”
TNO. 2020. “Green Maritime Methanol: WP3 factsheet and comparison with diesel and LNG.”
NMD. 2024. *LCA Rapportage categorie 3 data Nationale Milieudatabase Brandstof-machinecombinaties Hoofdstuk 1000 t/m 8000 Processen.* NMD.
TNO. 2025. “TNO Kennisinbreng Mobiliteit voor: Klimaat- en Energieverkenning (KEV-24) en Emissieramingen Luchtverontreinigende stoffen (ERL-25.”
Zero Carbon Shipping. 2023. *Aftertreatment nessecarry MMCZCS, Managing Emissions from Ammonia-Fueled Vessels.* Zero Carbon Shipping.
IEAGHG. 2017. https://ieaghg-publications.s3.eu-north-1.amazonaws.com/Technical+Reports/2017-02+Techno+-+Economic+Evaluation+of+SMR+Based+Standalone+(Merchant)+Hydrogen+Plant+with+CCS.pdf.
PBL. 2024. *EINDADVIES BASISBEDRAGEN SDE++.* PBL.

LCA standards and databases

[1] NEN-EN-ISO 14040 Environmental management -Life cycle assessment -Principles and framework (ISO 14040:2006,IDT), July 2006

[2] NEN-EN-ISO 14044 Environmental management -Life cycle assessment -Requirements and guidelines (ISO 14044:2006,IDT), July 2006

[3] NEN-EN 15804+A1:2013 Duurzaamheid van bouwwerken –Milieuverklaringen van producten – Basisregels voor de productgroep bouwproducten, november 2013

[4] Bepalingsmethode Milieuprestatie Bouwwerken / versie 1.2, Januari 2025

[5] Processendatabase (Nationale Milieu Database): NMD versie 3.9

[6] EcoInvent Database versie 3.9 en 3.6

8. Appendices results tables transport profiles

Results inland waterway transport A1 + A2

Table 73: Results transport, cargo ship, bulk-dry, inland shipping Diesel, CCR I Set A2

Impact category	Unit	Total	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	3.39E-02	4.90E-06	1.33E-04	0.00E+00	3.38E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	3,37E-02	4.89E-06	1.33E-04	0.00E+00	3.36E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	9,28E-05	7,52E-09	1.91E-07	0.00E+00	9,26E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.01E-04	1.15E-09	8,26E-08	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	1.41E-10	2.55E-12	2.79E-12	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	2.84E-04	2.63E-08	5.92E-07	0.00E+00	2.83E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	4.80E-07	3.41E-11	2.72E-09	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	1.30E-04	4.61E-09	1.78E-07	0.00E+00	1.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	1.43E-03	4.11E-08	2.11E-06	0.00E+00	1.43E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	3.74E-04	3.36E-08	7,22E-07	0.00E+00	3.73E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	5,26E-08	3.26E-12	5,32E-10	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	1.29E-01	3.72E-04	2.02E-03	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	3.26E-03	3,88E-07	-8,07E-06	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	6,91E-10	2.42E-13	1.08E-11	0.00E+00	6,80E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	5,35E-04	6,16E-08	4.05E-06	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	5.45E-02	1.10E-04	1.16E-03	0.00E+00	5.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.35E-11	1.85E-15	6,44E-14	0.00E+00	2.35E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	1.48E-10	3.44E-14	1.14E-12	0.00E+00	1.47E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	3.91E-01	7.04E-06	3,55E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 74: Results transport, cargo ship, bulk-dry, inland shipping Diesel, CCR I Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	3.76E-07	1.03E-11	9,11E-09	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	6,29E-05	1.74E-07	9,14E-07	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	3,37E-02	4,00E-06	1.26E-04	0.00E+00	3.36E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	8,21E-10	4.21E-12	2.06E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	1.55E-05	6,16E-09	7,82E-08	0.00E+00	1.54E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	2.03E-04	3.39E-08	5.23E-07	0.00E+00	2.03E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	4.68E-05	4,53E-09	9,21E-08	0.00E+00	4.67E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	6,33E-03	2.27E-06	3.72E-05	0.00E+00	6,29E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1.15E-04	9,57E-08	1.21E-06	0.00E+00	1.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	2.81E-01	4.32E-04	3.24E-03	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	5,88E-05	5.73E-09	3.14E-07	0.00E+00	5,85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 75: Results transport, cargo ship, bulk-dry, inland shipping FAME, CCR I Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	1.97E-02	-1.53E-02	1.55E-04	0.00E+00	3.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	1.94E-02	7,30E-03	1.54E-04	0.00E+00	1.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	8,63E-05	-2.27E-02	2.22E-07	0.00E+00	2,27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.70E-04	6,92E-05	9,58E-08	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	4,20E-10	2.81E-10	3.24E-12	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	3,20E-04	3,55E-05	6,87E-07	0.00E+00	2.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	5.72E-07	9,11E-08	3.16E-09	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	1.40E-04	9,84E-06	2.06E-07	0.00E+00	1.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	1.53E-03	9,50E-05	2.44E-06	0.00E+00	1.43E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	4.10E-04	3.43E-05	8,37E-07	0.00E+00	3.74E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	6.17E-08	8,93E-09	6,17E-10	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	2.43E-01	1.14E-01	2.35E-03	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	2.68E-03	-5,76E-04	-9,35E-06	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	8,71E-10	1.78E-10	1.25E-11	0.00E+00	6,81E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	5,82E-04	4,65E-05	4.70E-06	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	9,77E-02	4.32E-02	1.34E-03	0.00E+00	5.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.55E-11	1.92E-12	7,47E-14	0.00E+00	2.35E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	1.81E-10	3,32E-11	1.32E-12	0.00E+00	1.47E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	4.16E-01	2.48E-02	4.12E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 76: Results transport, cargo ship, bulk-dry, inland shipping FAME, CCR I Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	4.33E-07	5.49E-08	1.06E-08	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	1.25E-04	6,25E-05	1.06E-06	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	1.93E-02	7,17E-03	1.46E-04	0.00E+00	1.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	1.77E-09	9,52E-10	2,39E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	1.87E-05	3.16E-06	9,07E-08	0.00E+00	1.55E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	2.36E-04	3.16E-05	6.06E-07	0.00E+00	2.04E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	5,29E-05	5,97E-06	1.07E-07	0.00E+00	4.68E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	8,17E-03	1.80E-03	4.32E-05	0.00E+00	6,33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	2.38E-04	1.23E-04	1.40E-06	0.00E+00	1.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	5.29E-01	2.48E-01	3.76E-03	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	8,12E-05	2.23E-05	3.65E-07	0.00E+00	5,85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 77: Results transport, cargo ship, bulk-dry, inland shipping HVO, CCR I Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	1.49E-02	-1,80E-02	1.31E-04	0.00E+00	3.28E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	1.43E-02	2.60E-03	1.30E-04	0.00E+00	1.16E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	1.20E-04	-2.10E-02	1.87E-07	0.00E+00	2.11E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	5,31E-04	4.30E-04	8.10E-08	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	2.97E-10	1.59E-10	2.73E-12	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	3.11E-04	3.31E-05	5,80E-07	0.00E+00	2.77E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	5,58E-07	7,75E-08	2.67E-09	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	1.41E-04	1.11E-05	1.74E-07	0.00E+00	1.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	1.52E-03	9,31E-05	2.06E-06	0.00E+00	1.42E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	4.14E-04	2.72E-05	7.07E-07	0.00E+00	3.86E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	6,29E-08	1.03E-08	5,21E-10	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	1.78E-01	4.96E-02	1.98E-03	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	4.32E-03	1.06E-03	-7,90E-06	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	8,15E-10	1.36E-10	1.06E-11	0.00E+00	6,69E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	5,62E-04	2.69E-05	3.97E-06	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	1.75E-01	1.20E-01	1.14E-03	0.00E+00	5.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.67E-11	1.47E-12	6,31E-14	0.00E+00	2.51E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	1.98E-10	3.90E-11	1.11E-12	0.00E+00	1.58E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	4.32E-01	4.11E-02	3.48E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 78: Results transport, cargo ship, bulk-dry, inland shipping HVO, CCR I Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	4.13E-07	3,69E-08	8,93E-09	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	8,54E-05	2.27E-05	8.95E-07	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	1.42E-02	2.49E-03	1.23E-04	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	1.21E-09	3.92E-10	2.02E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	1.88E-05	2.60E-06	7,66E-08	0.00E+00	1.61E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	2.24E-04	2,58E-05	5.12E-07	0.00E+00	1.98E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	5,13E-05	5.07E-06	9.02E-08	0.00E+00	4.61E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	7,74E-03	1.05E-03	3.65E-05	0.00E+00	6,65E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	5.01E-04	2.56E-04	1.18E-06	0.00E+00	2.44E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	3.57E-01	7,55E-02	3.18E-03	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1.69E-04	1.05E-04	3.08E-07	0.00E+00	6,32E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 79: Results transport, cargo ship, bulk-dry, inland shipping CNG, CCR II Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	4,00E-02	2.24E-03	9,27E-04	0.00E+00	3.68E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	3.97E-02	2.24E-03	9,16E-04	0.00E+00	3.66E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	1.05E-04	2.28E-06	1.05E-05	0.00E+00	9,26E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.02E-04	8,72E-07	3.09E-07	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	1.37E-09	1.21E-09	2.81E-11	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.12E-04	1.16E-05	1.57E-06	0.00E+00	9,93E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	5,36E-07	2.26E-08	3,60E-08	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	3.86E-05	2.12E-06	4.14E-07	0.00E+00	3.61E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	4.25E-04	2.33E-05	4.87E-06	0.00E+00	3.97E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	1.56E-04	1.38E-05	1.47E-06	0.00E+00	1.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	5.62E-08	2.88E-09	1.22E-09	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	4,64E-01	3.24E-01	1.33E-02	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	3,60E-03	2.21E-04	1.13E-04	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	6,57E-10	3,77E-11	6,58E-12	0.00E+00	6,13E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	5,75E-04	1.33E-05	3.03E-05	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	6.18E-02	7.08E-03	1.44E-03	0.00E+00	5,33E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2,50E-11	1.25E-12	1.94E-13	0.00E+00	2.35E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	1.72E-10	1.06E-11	4,15E-12	0.00E+00	1.58E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	3.92E-01	2.30E-03	2.67E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 80: Results transport, freighter, bulk-dry, inland shipping CNG, CCR II Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	3.73E-07	4.33E-09	1.98E-09	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	2.56E-04	1.86E-04	8,66E-06	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	4.04E-02	2.69E-03	1.15E-03	0.00E+00	3.66E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	2.82E-09	1.97E-09	5.64E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	2.22E-05	3.35E-06	1.60E-07	0.00E+00	1.87E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	9.09E-05	1.13E-05	1.99E-06	0.00E+00	7,76E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	1.60E-05	8,35E-07	4,34E-07	0.00E+00	1.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	6.12E-03	2.56E-04	9,98E-05	0.00E+00	5.77E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1.32E-04	1.05E-05	2.69E-06	0.00E+00	1.19E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	3.38E-01	4.79E-02	1.22E-02	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	6.24E-05	1.91E-06	1.83E-06	0.00E+00	5,87E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 81: Results transport, cargo ship, bulk-dry, inland shipping, Electric, renewable mix Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	1.69E-02	4.97E-03	0.00E+00	0.00E+00	1.20E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	1.43E-02	2.48E-03	0.00E+00	0.00E+00	1.18E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	2.59E-03	2.50E-03	0.00E+00	0.00E+00	9,29E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.08E-04	6,59E-06	0.00E+00	0.00E+00	1.01E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	3.99E-10	2.46E-10	0.00E+00	0.00E+00	1,53E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.02E-04	4.67E-05	0.00E+00	0.00E+00	5,52E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	6,70E-07	1.58E-07	0.00E+00	0.00E+00	5.12E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	1.82E-05	5,83E-06	0.00E+00	0.00E+00	1.23E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	3.03E-04	1.68E-04	0.00E+00	0.00E+00	1.34E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	8.01E-05	1.71E-05	0.00E+00	0.00E+00	6.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	3.29E-07	2.62E-07	0.00E+00	0.00E+00	6,74E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	1.58E-01	2.36E-02	0.00E+00	0.00E+00	1.34E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	4.61E-03	1.20E-03	0.00E+00	0.00E+00	3.41E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	1.07E-09	4,19E-10	0.00E+00	0.00E+00	6,51E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	6.25E-04	7,69E-05	0.00E+00	0.00E+00	5.48E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	2.59E-01	2.03E-01	0.00E+00	0.00E+00	5.61E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.95E-11	5,62E-12	0.00E+00	0.00E+00	2,39E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	3.21E-10	1.87E-10	0.00E+00	0.00E+00	1.34E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	9,98E-01	6.09E-01	0.00E+00	0.00E+00	3.89E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 82: Results transport, cargo ship, bulk-dry, inland shipping, Electric, renewable mix Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	7,27E-07	2.62E-07	0.00E+00	0.00E+00	4,66E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	1.57E-04	7,46E-05	0.00E+00	0.00E+00	8,20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	2.93E-02	1.41E-02	0.00E+00	0.00E+00	1.51E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	2.17E-09	1.04E-09	0.00E+00	0.00E+00	1.13E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	3.62E-05	1.75E-05	0.00E+00	0.00E+00	1.87E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	1.68E-04	7,58E-05	0.00E+00	0.00E+00	9,21E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	2.66E-05	1.27E-05	0.00E+00	0.00E+00	1.39E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1.96E-02	8,39E-03	0.00E+00	0.00E+00	1.12E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	3.94E-04	1.66E-04	0.00E+00	0.00E+00	2.28E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	1,12E+00	4.33E-01	0.00E+00	0.00E+00	6,83E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	3.36E-04	1.64E-04	0.00E+00	0.00E+00	1.72E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 83: Results transport, cargo ship, bulk-dry, inland shipping, Hydrogen (Electrolysis Wind Liquid) Combustion engine Stage V Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	1.48E-02	2.99E-03	7,79E-05	0.00E+00	1.17E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	1.46E-02	2.97E-03	7,78E-05	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	1.04E-04	1.17E-05	1.25E-07	0.00E+00	9,26E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.03E-04	2.68E-06	3.99E-08	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	3,36E-10	1.97E-10	2.92E-12	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.67E-04	2.63E-05	4.50E-07	0.00E+00	1.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	1.68E-06	1.20E-06	7,25E-09	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	6.18E-05	3.72E-06	1.09E-07	0.00E+00	5,80E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	6,75E-04	3,80E-05	1.16E-06	0.00E+00	6,36E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	1.92E-04	1.15E-05	4.16E-07	0.00E+00	1.80E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	3.95E-07	3.39E-07	3,56E-09	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	1.65E-01	3.72E-02	1.03E-03	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	6,62E-03	3.33E-03	1.85E-05	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	8,33E-10	2.04E-10	6,52E-12	0.00E+00	6,22E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	6,39E-04	1.07E-04	1.22E-06	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	2.55E-01	2.00E-01	2.28E-03	0.00E+00	5.31E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	3.83E-11	1.47E-11	1.67E-13	0.00E+00	2.34E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	4,95E-10	3.46E-10	3.88E-12	0.00E+00	1.45E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	4.28E-01	3.93E-02	1.20E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 84: Results transport, cargo ship, bulk-dry, inland shipping, Hydrogen (Electrolysis Wind Liquid) Combustion engine Stage V Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	7,28E-07	3.56E-07	4.09E-09	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	8,53E-05	2,30E-05	4.78E-07	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

004. global warming (GWP)	kg CO2 eq	1.50E-02	3.48E-03	7.01E-05	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	1.15E-09	3,47E-10	1.06E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	1.66E-05	1.98E-06	4.54E-08	0.00E+00	1.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	1.31E-04	2.61E-05	3.74E-07	0.00E+00	1.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	2.78E-05	5,80E-06	6,75E-08	0.00E+00	2.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1.32E-02	7,32E-03	7.68E-05	0.00E+00	5.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	2.34E-04	1.19E-04	1.51E-06	0.00E+00	1.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	5.98E-01	3.16E-01	3.88E-03	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	4.23E-04	3.61E-04	3.57E-06	0.00E+00	5,85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 85: Results transport, cargo ship, bulk-dry, inland shipping, Hydrogen (SMR Grey Liquid) Combustion engine Stage V Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	5.35E-02	4.09E-02	8,71E-04	0.00E+00	1.17E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	5,33E-02	4.09E-02	8,71E-04	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	9,61E-05	3.43E-06	4,57E-08	0.00E+00	9,26E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	1.03E-04	2.02E-06	5.75E-08	0.00E+00	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	2.97E-09	2.75E-09	7.93E-11	0.00E+00	1.36E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.78E-04	3,70E-05	1.48E-06	0.00E+00	1.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	7,76E-07	2.78E-07	2.04E-08	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	6,66E-05	8,22E-06	4.06E-07	0.00E+00	5,80E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	7,34E-04	9,39E-05	4.52E-06	0.00E+00	6,36E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	2.17E-04	3.58E-05	1.36E-06	0.00E+00	1.80E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	7,83E-08	2.51E-08	1.14E-09	0.00E+00	5.21E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	7,68E-01	6,27E-01	1.43E-02	0.00E+00	1.26E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	6,58E-03	3.19E-03	1.23E-04	0.00E+00	3.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	7.64E-10	1.34E-10	8,27E-12	0.00E+00	6,22E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	8,87E-04	3.36E-04	2.02E-05	0.00E+00	5,31E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	1.61E-01	1.02E-01	6,29E-03	0.00E+00	5.31E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.78E-11	4.28E-12	1.29E-13	0.00E+00	2.34E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	2.24E-10	7,47E-11	3.86E-12	0.00E+00	1.45E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	4.02E-01	1.34E-02	1.39E-03	0.00E+00	3.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 86: Results transport, cargo ship, bulk-dry, inland shipping, Hydrogen (SMR Grey Liquid) Combustion engine Stage V Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	4.12E-07	4.29E-08	1.82E-09	0.00E+00	3,67E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	4.23E-04	3.55E-04	7.09E-06	0.00E+00	6.18E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

004. global warming (GWP)	kg CO2 eq	5.42E-02	4.19E-02	8.03E-04	0.00E+00	1.15E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	4.64E-09	3.77E-09	7,70E-11	0.00E+00	7.97E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	2.13E-05	6,53E-06	1.39E-07	0.00E+00	1.46E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO2 eq	1.42E-04	3,57E-05	1.12E-06	0.00E+00	1.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO4--- eq	2.67E-05	4.55E-06	2.11E-07	0.00E+00	2.19E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	7,88E-03	2.00E-03	7,27E-05	0.00E+00	5.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1.64E-04	4.84E-05	2.00E-06	0.00E+00	1.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	4.87E-01	2.02E-01	7,34E-03	0.00E+00	2.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1.22E-04	6.02E-05	3.37E-06	0.00E+00	5,85E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Results of seagoing transport A1 + A2

Tabel 87: Results transport, cargo ship, bulk-dry, sea Bio-LNG Tier II Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	2.54E-03	-3,58E-03	6,90E-05	0.00E+00	6.05E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO2 eq	5.94E-04	5,76E-05	6,89E-05	0.00E+00	4.67E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO2 eq	1.94E-03	-3,64E-03	1.23E-07	0.00E+00	5,58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO2 eq	6,39E-06	7,70E-08	1.26E-08	0.00E+00	6.30E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	9.95E-12	2,00E-12	2.50E-12	0.00E+00	5.45E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.51E-05	4.32E-07	1.28E-07	0.00E+00	1.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	3.16E-08	3.01E-09	5.68E-10	0.00E+00	2.81E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	6,96E-06	6,21E-08	4.61E-08	0.00E+00	6,85E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	7,62E-05	7,23E-07	5.01E-07	0.00E+00	7,50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	2.42E-05	4,52E-07	2.15E-07	0.00E+00	2.35E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	1.15E-08	3,86E-09	5.86E-11	0.00E+00	7,63E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	6,43E-03	7,83E-04	1.01E-03	0.00E+00	4.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	1.86E-04	1.45E-05	3.96E-06	0.00E+00	1.68E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	5.99E-11	9,55E-12	2.10E-12	0.00E+00	4.82E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	1.50E-05	3.31E-06	4.86E-07	0.00E+00	1.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
066. Ecotoxicity, freshwater	CTUe	5,54E-03	1.52E-03	1.78E-04	0.00E+00	3,84E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	2.91E-12	1.13E-13	1.40E-14	0.00E+00	2.78E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	2,13E-11	4.02E-12	2.25E-13	0.00E+00	1.71E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	4.52E-03	2.07E-03	3.63E-04	0.00E+00	2.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 88: Results transport, cargo ship, bulk-dry, sea Bio-LNG Tier II Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	6.32E-08	6,10E-09	3.61E-10	0.00E+00	5,68E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	3.39E-06	4,34E-07	5.44E-07	0.00E+00	2.42E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO_2 eq	2.58E-03	5,35E-04	6.63E-05	0.00E+00	1.98E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	3.98E-11	9,59E-12	8.92E-12	0.00E+00	2,13E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C_2H_4	2.62E-06	1.50E-07	1.93E-08	0.00E+00	2.45E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
007. acidification (AP)	kg SO_2 eq	1.07E-05	3,98E-07	1.16E-07	0.00E+00	1.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
008. eutrophication (EP)	kg PO_4--- eq	2.47E-06	3.96E-08	2.15E-08	0.00E+00	2.41E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1.01E-03	8,33E-05	7.07E-06	0.00E+00	9,16E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1.45E-05	1.27E-06	2.22E-07	0.00E+00	1.30E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	4,52E-02	4.54E-03	6,75E-04	0.00E+00	3.99E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1.09E-05	2.04E-06	4.75E-08	0.00E+00	8,77E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 89: Results transport, cargo ship, bulk-dry, sea CNG Tier II Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO_2 eq	7,11E-03	5,27E-04	2.18E-04	0.00E+00	6,36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
052. Climate change - Fossil	kg CO_2 eq	7.10E-03	5,26E-04	2.16E-04	0.00E+00	6,36E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
053. Climate change - Biogenic	kg CO_2 eq	9,87E-07	5,37E-07	2.47E-06	0.00E+00	-2.02E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
054. Climate change - Luluc	kg CO_2 eq	6,58E-06	2.05E-07	7,27E-08	0.00E+00	6.30E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
055. Ozone depletion	kg CFC11 eq	2.97E-10	2,85E-10	6,60E-12	0.00E+00	5.45E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
056. Acidification	mol H+ eq	1.76E-05	2.74E-06	3.70E-07	0.00E+00	1.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
057. Eutrophication, freshwater	kg P eq	4.18E-08	5,30E-09	8,46E-09	0.00E+00	2.81E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
058. Eutrophication, marine	kg N eq	7,45E-06	4.98E-07	9,73E-08	0.00E+00	6,85E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
059. Eutrophication, terrestrial	mol N eq	8,16E-05	5.49E-06	1.15E-06	0.00E+00	7,50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
060. Photochemical ozone formation	kg NMVOC eq	2.83E-05	3.24E-06	3.46E-07	0.00E+00	2.47E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
061. Resource use, minerals, metals	kg Sb eq	8.59E-09	6,78E-10	2,86E-10	0.00E+00	7,63E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
062. Resource use, fossils	MJ	8,40E-02	7.62E-02	3.13E-03	0.00E+00	4.64E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
063. Water use	m3 depriv.	2.46E-04	5.21E-05	2.65E-05	0.00E+00	1.68E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
064. Particulate matter	disease inc.	5.86E-11	8,86E-12	1.55E-12	0.00E+00	4.82E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
065. Ionising radiation	kBq U-235 eq	2.14E-05	3.12E-06	7,13E-06	0.00E+00	1.12E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

066. Ecotoxicity, freshwater	CTUe	5.85E-03	1.67E-03	3.40E-04	0.00E+00	3,84E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
067. Human toxicity, cancer	CTUh	3,13E-12	2.95E-13	4,56E-14	0.00E+00	2.79E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
068. Human toxicity, non-cancer	CTUh	2.07E-11	2.50E-12	9,76E-13	0.00E+00	1.72E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
069. Land use	Pt	3.26E-03	5.41E-04	6,27E-04	0.00E+00	2.09E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Tabel 90: Results transport, cargo ship, bulk-dry, sea CNG Tier II Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	5.82E-08	1.02E-09	4,65E-10	0.00E+00	5,68E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	4.82E-05	4.37E-05	2.04E-06	0.00E+00	2.42E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
004. global warming (GWP)	kg CO2 eq	7,23E-03	6.32E-04	2.71E-04	0.00E+00	6,33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	4.98E-10	4,63E-10	1,33E-11	0.00E+00	2,13E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
006. photochemical oxidation (POCP)	kg C2H4	3.33E-06	7,88E-07	3,77E-08	0.00E+00	2.50E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	1,33E-05	2,65E-06	4,67E-07	0,00E+00	1,02E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	2,71E-06	1,96E-07	1,02E-07	0,00E+00	2,41E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,00E-03	6,03E-05	2,35E-05	0,00E+00	9,16E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	1,62E-05	2,47E-06	6,33E-07	0,00E+00	1,31E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	5,41E-02	1,13E-02	2,88E-03	0,00E+00	3,99E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	9,65E-06	4,50E-07	4,31E-07	0,00E+00	8,77E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 91: Resultaten transport, vrachtschip, bulk-droog, zee FAME Tier II Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	2,34E-03	-3,60E-03	3,64E-05	0,00E+00	5,91E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
052. Climate change - Fossil	kg CO2 eq	2,33E-03	1,72E-03	3,63E-05	0,00E+00	5,72E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	-3,50E-06	-5,33E-03	5,21E-08	0,00E+00	5,33E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	2,26E-05	1,63E-05	2,25E-08	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	7,23E-11	6,60E-11	7,61E-13	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	8,47E-05	8,35E-06	1,62E-07	0,00E+00	7,62E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	5,02E-08	2,14E-08	7,43E-10	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	4,09E-05	2,32E-06	4,86E-08	0,00E+00	3,85E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	4,45E-04	2,24E-05	5,75E-07	0,00E+00	4,22E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
060. Photochemical ozone formation	kg NMVOC eq	1,13E-04	8,07E-06	1,97E-07	0,00E+00	1,04E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	9,88E-09	2,10E-09	1,45E-10	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	3,20E-02	2,68E-02	5,52E-04	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

063. Water use	m3 depriv.	2,99E-05	-1,36E-04	-2,20E-06	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	1,14E-10	4,19E-11	2,95E-12	0,00E+00	6,92E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	2,32E-05	1,09E-05	1,11E-06	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	1,43E-02	1,02E-02	3,16E-04	0,00E+00	3,83E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	3,24E-12	4,52E-13	1,76E-14	0,00E+00	2,77E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	2,28E-11	7,82E-12	3,10E-13	0,00E+00	1,47E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
069. Land use	Pt	8,88E-03	5,82E-03	9,70E-04	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 92: Resultaten transport, vrachtschip, bulk-droog, zee FAME Tier II Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	7,22E-08	1,29E-08	2,49E-09	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	1,74E-05	1,47E-05	2,49E-07	0,00E+00	2,42E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	2,25E-03	1,69E-03	3,43E-05	0,00E+00	5,27E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	2,51E-10	2,24E-10	5,62E-12	0,00E+00	2,13E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	2,50E-06	7,44E-07	2,13E-08	0,00E+00	1,74E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	5,97E-05	7,44E-06	1,43E-07	0,00E+00	5,22E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	1,46E-05	1,40E-06	2,51E-08	0,00E+00	1,31E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,51E-03	4,24E-04	1,02E-05	0,00E+00	1,08E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	4,10E-05	2,89E-05	3,29E-07	0,00E+00	1,18E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	9,92E-02	5,83E-02	8,85E-04	0,00E+00	3,99E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1,41E-05	5,26E-06	8,58E-08	0,00E+00	8,72E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 93: Resultaten transport, vrachtschip, bulk-droog, zee HFO Tier II Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	7,18E-03	1,15E-03	5,24E-08	0,00E+00	6,03E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
052. Climate change - Fossil	kg CO2 eq	7,17E-03	1,15E-03	5,19E-08	0,00E+00	6,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	4,55E-06	1,42E-06	4,07E-10	0,00E+00	3,12E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	6,60E-06	2,92E-07	7,17E-11	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	1,37E-10	1,32E-10	9,93E-16	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	7,55E-05	4,22E-06	4,49E-10	0,00E+00	7,13E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	3,60E-08	7,95E-09	1,80E-12	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	3,54E-05	1,01E-06	1,26E-10	0,00E+00	3,44E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	3,85E-04	8,57E-06	1,41E-09	0,00E+00	3,77E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

060. Photochemical ozone formation	kg NMVOC eq	1,09E-04	1,16E-05	4,32E-10	0,00E+00	9,77E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	8,21E-09	5,77E-10	2,13E-13	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	8,55E-02	8,09E-02	7,97E-07	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
063. Water use	m3 depriv.	2,66E-04	9,81E-05	3,87E-09	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	9,86E-11	2,78E-11	3,78E-15	0,00E+00	7,08E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	2,33E-05	1,21E-05	2,75E-09	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	3,92E-02	3,50E-02	3,56E-07	0,00E+00	4,22E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	4,06E-12	3,88E-13	5,30E-17	0,00E+00	3,67E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	3,02E-11	7,94E-12	5,04E-16	0,00E+00	2,23E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
069. Land use	Pt	5,93E-03	3,84E-03	5,18E-07	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 94: **Resultaten transport, vrachtschip, bulk-droog, zee HFO Tier II Set A1**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	5,85E-08	1,72E-09	1,51E-12	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	3,91E-05	3,66E-05	3,51E-10	0,00E+00	2,42E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	6,53E-03	5,54E-04	5,05E-08	0,00E+00	5,98E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	1,03E-09	1,00E-09	7,31E-15	0,00E+00	2,13E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	3,66E-06	1,08E-06	3,65E-11	0,00E+00	2,58E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	5,60E-05	6,45E-06	3,80E-10	0,00E+00	4,96E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	1,27E-05	1,10E-06	6,96E-11	0,00E+00	1,16E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,89E-03	5,98E-04	2,59E-08	0,00E+00	1,29E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	6,90E-05	2,51E-05	4,93E-10	0,00E+00	4,39E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	1,25E-01	8,51E-02	1,66E-06	0,00E+00	4,01E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1,17E-05	1,15E-06	1,59E-10	0,00E+00	1,05E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 95: **Resultaten transport, vrachtschip, bulk-droog, zee LNG Tier II-III Set A2**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	7,47E-03	1,29E-03	1,30E-04	0,00E+00	6,05E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

052. Climate change - Fossil	kg CO2 eq	7,46E-03	1,29E-03	1,30E-04	0,00E+00	6,04E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	-1,38E-06	5,43E-07	1,01E-07	0,00E+00	-2,02E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	6,66E-06	2,95E-07	5,76E-08	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	9,65E-11	8,78E-11	3,28E-12	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	2,00E-05	2,96E-06	2,51E-06	0,00E+00	1,45E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	3,71E-08	8,37E-09	7,17E-10	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	8,15E-06	6,70E-07	6,24E-07	0,00E+00	6,85E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	8,93E-05	7,37E-06	6,91E-06	0,00E+00	7,50E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
060. Photochemical ozone formation	kg NMVOC eq	3,49E-05	8,48E-06	1,90E-06	0,00E+00	2,45E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	8,67E-09	9,48E-10	9,00E-11	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	8,55E-02	7,92E-02	1,71E-03	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
063. Water use	m3 depriv.	2,59E-04	8,66E-05	5,10E-06	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	6,85E-11	1,78E-11	2,55E-12	0,00E+00	4,82E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	1,84E-05	6,69E-06	5,63E-07	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	6,67E-03	2,29E-03	5,36E-04	0,00E+00	3,84E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	3,28E-12	4,57E-13	3,84E-14	0,00E+00	2,78E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	2,28E-11	5,35E-12	3,65E-13	0,00E+00	1,71E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
069. Land use	Pt	3,23E-03	1,04E-03	1,06E-04	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 96: Resultaten transport, vrachtschip, bulk-droog, zee LNG Tier II-III Set A1

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	5,80E-08	7,69E-10	4,86E-10	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	4,55E-05	4,23E-05	8,64E-07	0,00E+00	2,42E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	7,22E-03	1,09E-03	1,23E-04	0,00E+00	6,01E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	4,32E-10	3,94E-10	1,75E-11	0,00E+00	2,13E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	3,71E-06	1,15E-06	1,06E-07	0,00E+00	2,45E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	1,72E-05	4,93E-06	2,04E-06	0,00E+00	1,02E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	2,89E-06	2,56E-07	2,24E-07	0,00E+00	2,41E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,49E-03	5,28E-04	4,40E-05	0,00E+00	9,16E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	6,73E-05	5,36E-05	7,26E-07	0,00E+00	1,30E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	2,33E-01	1,90E-01	3,45E-03	0,00E+00	3,99E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	9,44E-06	5,35E-07	1,41E-07	0,00E+00	8,77E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 97: **Resultaten transport, vrachtschip, bulk-droog, zee MGO Tier II Set A2**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	6,90E-03	1,17E-03	3,31E-05	0,00E+00	5,70E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
052. Climate change - Fossil	kg CO2 eq	6,89E-03	1,16E-03	3,31E-05	0,00E+00	5,69E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	5,21E-06	1,79E-06	-2,95E-08	0,00E+00	3,45E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	6,59E-06	2,74E-07	1,19E-08	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	6,13E-10	6,06E-10	7,58E-13	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	7,87E-05	6,27E-06	1,31E-07	0,00E+00	7,23E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	3,67E-08	8,12E-09	4,82E-10	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	3,55E-05	1,10E-06	4,22E-08	0,00E+00	3,44E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	3,87E-04	9,79E-06	5,00E-07	0,00E+00	3,77E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
060. Photochemical ozone formation	kg NMVOC eq	1,05E-04	7,99E-06	1,71E-07	0,00E+00	9,72E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	8,53E-09	7,76E-10	1,28E-10	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	9,36E-02	8,85E-02	4,70E-04	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
063. Water use	m3 depriv.	2,58E-04	9,23E-05	-2,17E-06	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	1,29E-10	5,76E-11	2,56E-12	0,00E+00	6,85E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	2,62E-05	1,47E-05	3,46E-07	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	3,12E-02	2,61E-02	2,74E-04	0,00E+00	4,78E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	3,76E-12	4,41E-13	1,53E-14	0,00E+00	3,31E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	5,32E-11	8,19E-12	2,62E-13	0,00E+00	4,47E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
069. Land use	Pt	4,61E-03	1,68E-03	8,46E-04	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 98: **Resultaten transport, vrachtschip, bulk-droog, zee MGO Tier II Set A1**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	6,14E-08	2,46E-09	2,17E-09	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	4,40E-05	4,13E-05	2,36E-07	0,00E+00	2,42E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	6,64E-03	9,53E-04	3,23E-05	0,00E+00	5,65E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	1,03E-09	1,00E-09	4,73E-12	0,00E+00	2,13E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	3,58E-06	1,47E-06	1,84E-08	0,00E+00	2,10E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	5,87E-05	8,07E-06	1,15E-07	0,00E+00	5,05E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

008. eutrophication (EP)	kg PO4--- eq	1,27E-05	1,08E-06	2,17E-08	0,00E+00	1,16E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,80E-03	5,41E-04	8,74E-06	0,00E+00	1,25E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	6,65E-05	2,28E-05	2,81E-07	0,00E+00	4,34E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	1,44E-01	1,03E-01	7,39E-04	0,00E+00	4,00E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	1,18E-05	1,36E-06	7,36E-08	0,00E+00	1,03E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 99: **Resultaten transport, vrachtschip, bulk-droog, zee Hydrogen (Liquid Elektrolyse wind), verbrandingsmotor TIER III Set A2**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	1,19E-03	7,03E-04	1,84E-05	0,00E+00	4,65E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
052. Climate change - Fossil	kg CO2 eq	1,18E-03	7,00E-04	1,83E-05	0,00E+00	4,61E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	7,60E-07	2,75E-06	2,95E-08	0,00E+00	-2,02E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	6,94E-06	6,29E-07	9,40E-09	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	5,25E-11	4,64E-11	6,87E-13	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	2,71E-05	6,19E-06	1,06E-07	0,00E+00	2,08E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	3,11E-07	2,81E-07	1,70E-09	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	1,12E-05	8,74E-07	2,56E-08	0,00E+00	1,03E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	1,21E-04	8,94E-06	2,72E-07	0,00E+00	1,12E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
060. Photochemical ozone formation	kg NMVOC eq	3,24E-05	2,70E-06	9,80E-08	0,00E+00	2,96E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	8,82E-08	7,97E-08	8,37E-10	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	1,36E-02	8,77E-03	2,43E-04	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
063. Water use	m3 depriv.	9,57E-04	7,85E-04	4,35E-06	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	9,90E-11	4,80E-11	1,53E-12	0,00E+00	4,95E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	3,67E-05	2,53E-05	2,88E-07	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	5,14E-02	4,70E-02	5,36E-04	0,00E+00	3,80E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	6,27E-12	3,46E-12	3,93E-14	0,00E+00	2,77E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	9,65E-11	8,13E-11	9,12E-13	0,00E+00	1,43E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
069. Land use	Pt	1,16E-02	9,25E-03	2,84E-04	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 100: **Resultaten transport, vrachtschip, bulk-droog, zee Hydrogen (Liquid Elektrolyse wind), verbrandingsmotor TIER III Set A1**

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	1,42E-07	8,38E-08	9,61E-10	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

002. abiotic depletion, fuel (AD)	kg Sb eq	3,24E-06	3,13E-06	8,74E-08	0,00E+00	2,51E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	6,40E-04	5,64E-04	1,31E-05	0,00E+00	6,32E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	4,31E-11	4,06E-11	1,85E-12	0,00E+00	6,40E-13	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	3,96E-07	3,85E-07	8,59E-09	0,00E+00	2,11E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	1,77E-05	4,87E-06	7,54E-08	0,00E+00	1,27E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	4,50E-06	1,19E-06	1,35E-08	0,00E+00	3,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,66E-03	1,61E-03	1,73E-05	0,00E+00	3,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	2,65E-05	2,61E-05	3,25E-07	0,00E+00	3,07E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	6,69E-02	6,60E-02	8,30E-04	0,00E+00	8,23E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	8,53E-05	8,45E-05	8,34E-07	0,00E+00	4,10E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 101: Resultaten transport, vrachtschip, bulk-droog, zee Hydrogen Liquid SMR Grey), verbrandingsmotor TIER III Set A2

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
051. Climate change	kg CO2 eq	7,76E-03	7,28E-03	1,84E-05	0,00E+00	4,65E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
052. Climate change - Fossil	kg CO2 eq	7,42E-03	6,94E-03	1,83E-05	0,00E+00	4,61E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
053. Climate change - Biogenic	kg CO2 eq	3,36E-04	3,38E-04	2,95E-08	0,00E+00	-2,02E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
054. Climate change - Luluc	kg CO2 eq	7,53E-06	1,22E-06	9,40E-09	0,00E+00	6,30E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
055. Ozone depletion	kg CFC11 eq	3,99E-10	3,93E-10	6,87E-13	0,00E+00	5,45E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
056. Acidification	mol H+ eq	3,12E-05	1,03E-05	1,06E-07	0,00E+00	2,08E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
057. Eutrophication, freshwater	kg P eq	6,12E-08	3,14E-08	1,70E-09	0,00E+00	2,81E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
058. Eutrophication, marine	kg N eq	1,18E-05	1,52E-06	2,56E-08	0,00E+00	1,03E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
059. Eutrophication, terrestrial	mol N eq	1,44E-04	3,12E-05	2,72E-07	0,00E+00	1,12E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
060. Photochemical ozone formation	kg NMVOC eq	3,66E-05	6,92E-06	9,80E-08	0,00E+00	2,96E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
061. Resource use, minerals, metals	kg Sb eq	4,59E-08	3,74E-08	8,37E-10	0,00E+00	7,63E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
062. Resource use, fossils	MJ	1,06E-01	1,01E-01	2,43E-04	0,00E+00	4,64E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
063. Water use	m3 depriv.	6,74E-04	5,02E-04	4,35E-06	0,00E+00	1,68E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
064. Particulate matter	disease inc.	1,26E-10	7,48E-11	1,53E-12	0,00E+00	4,95E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
065. Ionising radiation	kBq U-235 eq	2,80E-05	1,65E-05	2,88E-07	0,00E+00	1,12E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
066. Ecotoxicity, freshwater	CTUe	3,42E-02	2,99E-02	5,36E-04	0,00E+00	3,80E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
067. Human toxicity, cancer	CTUh	4,16E-12	1,35E-12	3,93E-14	0,00E+00	2,77E-12	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
068. Human toxicity, non-cancer	CTUh	4,52E-11	3,00E-11	9,12E-13	0,00E+00	1,43E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

069. Land use	Pt	8,56E-02	8,33E-02	2,84E-04	0,00E+00	2,09E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Tabel 102: Resultaten transport, vrachtschip, bulk-droog, zee Hydrogen Liquid SMR Grey), verbrandingsmotor TIER III Set

Impact category	Eenheid	Totaal	A1-A3	A4	A5	B	C1	C2	C3	C4	D
001. abiotic depletion, non fuel (AD)	kg Sb eq	9,93E-08	4,16E-08	9,61E-10	0,00E+00	5,68E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
002. abiotic depletion, fuel (AD)	kg Sb eq	6,12E-05	5,87E-05	1,13E-07	0,00E+00	2,42E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
004. global warming (GWP)	kg CO2 eq	7,71E-03	7,27E-03	1,65E-05	0,00E+00	4,21E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
005. ozone layer depletion (ODP)	kg CFC-11 eq	6,77E-10	6,53E-10	2,49E-12	0,00E+00	2,13E-11	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
006. photochemical oxidation (POCP)	kg C2H4	3,04E-06	1,50E-06	1,07E-08	0,00E+00	1,53E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
007. acidification (AP)	kg SO2 eq	2,33E-05	8,81E-06	8,79E-08	0,00E+00	1,44E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
008. eutrophication (EP)	kg PO4--- eq	4,82E-06	1,29E-06	1,59E-08	0,00E+00	3,52E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
009. human toxicity (HT)	kg 1,4-DB eq	1,53E-03	5,96E-04	1,81E-05	0,00E+00	9,20E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
010. Ecotoxicity, fresh water (FAETP)	kg 1,4-DB eq	2,45E-05	1,24E-05	3,55E-07	0,00E+00	1,18E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
012. Ecotoxcity, marine water (MAETP)	kg 1,4-DB eq	8,52E-02	4,43E-02	9,12E-04	0,00E+00	3,99E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
014. Ecotoxicity, terrestric (TETP)	kg 1,4-DB eq	2,49E-05	1,54E-05	8,38E-07	0,00E+00	8,72E-06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

9. Appendices Changes register EcoInvent 3.6 versus 3.6

Tabel 103: Adjusted Market mix Petroleum {Europe without Switzerland}| market for petroleum | Cut-off, U

Process	Environmental profile E.I. 3.9	Environmental profile E.I. 3.6
Production Brazil	Petroleum {BR}| petroleum and gas production, offshore | Cut-off, U	Petroleum {RoW}| production, onshore | Cut-off, U
Production Brazil	Petroleum {BR}| petroleum and gas production, onshore | Cut-off, U	Petroleum {RoW}| production, onshore | Cut-off, U
Production Great Britain	Petroleum {GB}| petroleum and gas production, offshore | Cut-off, U	Petroleum {GB}| petroleum and gas production, offshore | Cut-off, U
Production Great Britain	Petroleum {GB}| petroleum and gas production, onshore | Cut-off, U)	Petroleum {GB}| petroleum and gas production, offshore | Cut-off, U
Production Iraq	Petroleum {IQ}| petroleum and gas production, onshore | Cut-off, U	Petroleum {RoW}| production, onshore | Cut-off, U
Production Nigeria	Petroleum {NG}| petroleum and gas production, offshore | Cut-off, U	Petroleum {NG}| petroleum and gas production, onshore | Cut-off, U
Production Norway	Petroleum {NG}| petroleum and gas production, onshore | Cut-off, U	Petroleum {NO}| petroleum and gas production, offshore | Cut-off, U
Production Norway	Petroleum {NO}| petroleum and gas production, offshore | Cut-off, U	Petroleum {NO}| petroleum and gas production, offshore | Cut-off, U
Production Russia	Petroleum {RU}| petroleum and gas production, offshore | Cut-off, U	Petroleum {RU}| production, onshore | Cut-off, U
Production Russia	Petroleum {RU}| petroleum and gas production, onshore | Cut-off, U	Petroleum {RU}| production, onshore | Cut-off, U
Production U.S.A.	Petroleum {US}| petroleum and gas production, offshore | Cut-off, U	Petroleum {US}| petroleum and gas production, onshore | Cut-off, U
Production U.S.A.	Petroleum {US}| petroleum and gas production, onshore | Cut-off, U	Petroleum {US}| petroleum and gas production, onshore | Cut-off, U
Production other	Petroleum {RoW}| petroleum and gas production, onshore | Cut-off, U	Petroleum {RoW}| production, onshore | Cut-off, U

Tabel 104: A1-A4 GTL, per ton

Process	Environmental profile E.I. 3.9	Environmental profile E.I. 3.6
Feedstock	Natural gas, high pressure {QA}| petroleum and gas production, offshore | Cut-off, U	Natural gas, high pressure {RoW}| natural gas production | Cut-off, U