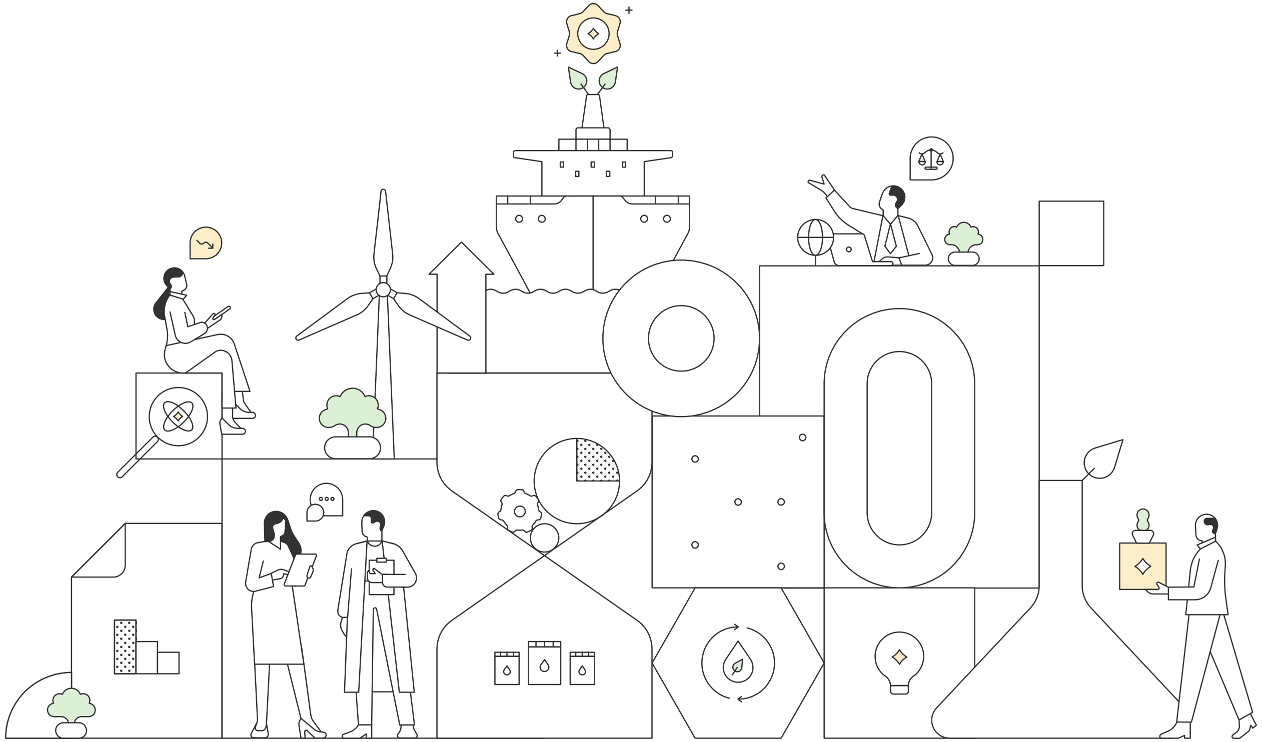
Propelling policy: LCA take-off for maritime fuels

Ann O'Connor
Dr. Loïc Francke



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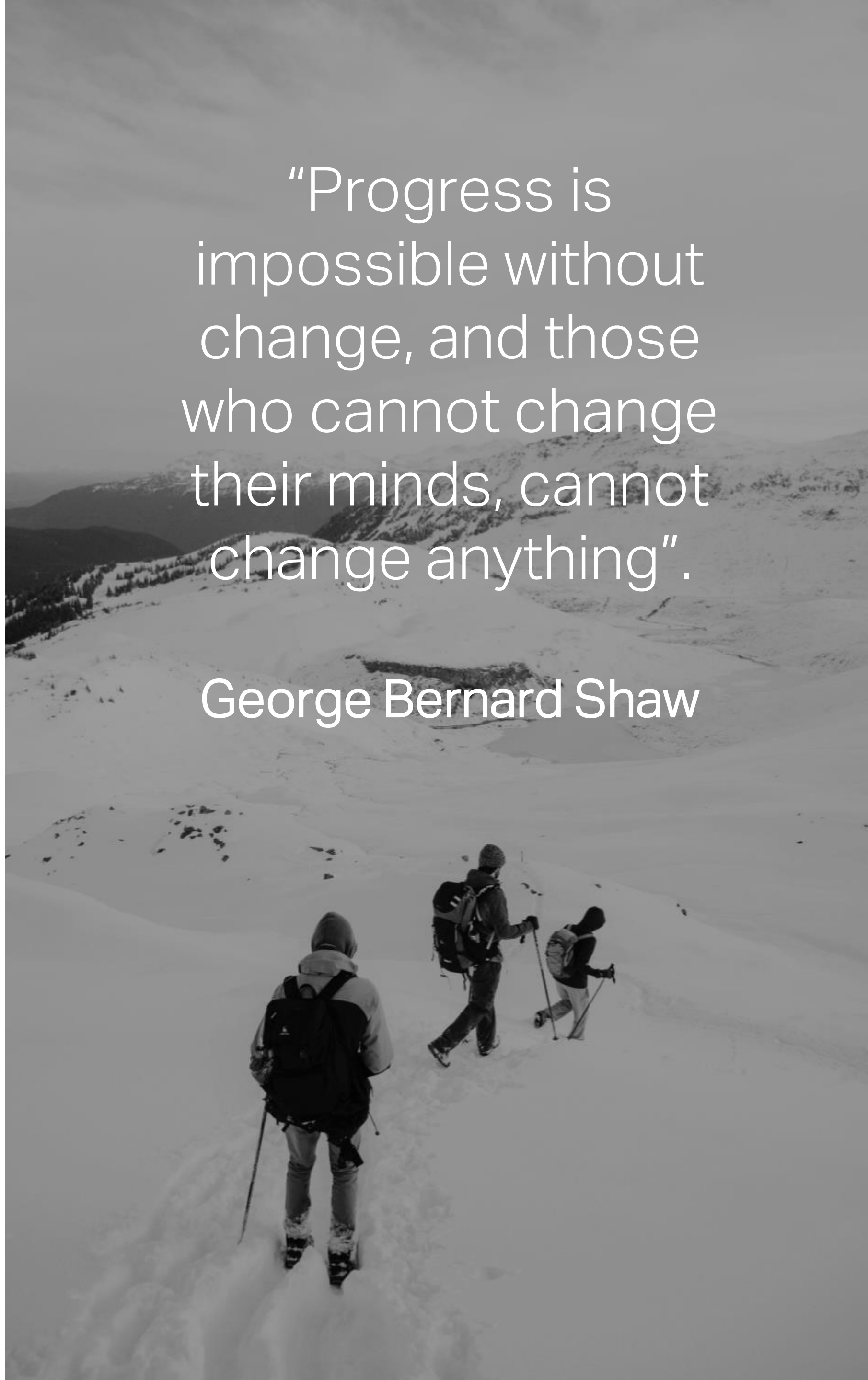
Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Agenda

1. Introduction and housekeeping
2. The role of LCA in the energy transition
3. LCA and policy insights
4. Methodology overview

5. Goal and System boundary
6. Impact assessment
7. Well-to-Tank
8. Tank-to-Wake
9. Focus areas

10. Panel discussion
11. Q&A
12. Wrap up



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#LCA

Contextual setting

LCA as a tool for positive change in the energy transition

Creating clarity
LCA is the tool policymakers use to assess the potential GHG Intensity of alternative fuels. The IMO is developing a methodology by processing inputs from member states to reach a consensus. The challenge with this approach is more clarity on complex aspects.

Improve standardization and consistency
Standardizing how LCA is used can improve the consistency of assessing the potential GHG intensity of alternative marine fuels.

Accelerate decision making
Decarbonization relies on selecting fuels that deliver the GHG savings needed to reach 2050 and interim targets. By improving clarity and consistency, decision-makers can improve their fuel selection process, thereby accelerating decarbonization.

LCA is an enabler of the energy transition

Policy

Effective policy is needed to send demand signals for alternative marine fuels with low GHG intensity.

Investment

Fuel demand certainty begins to increase, lowering the investment risks in low GHG intensity fuels

Enabling fuel production

Fuels that offer reductions in GHG intensity begin to make it to the market.

Market formation

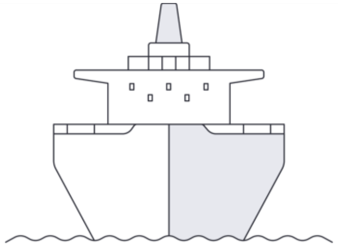
Fuel users can select fuels based on their GHG intensity, leading to a green premium for clean fuels

A global snapshot of lifecycle methodologies used in policy

These methodologies were used in our qualitative assessment of LCA methodologies.. Methods were selected based on providing good regional coverage.

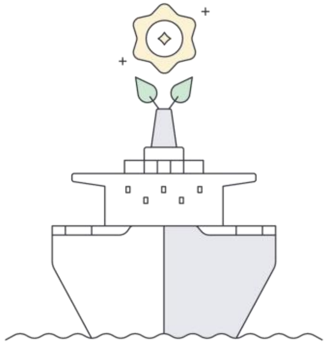
Lifecycle methodology	Fuels	Implementation coverage	Feedstock methodology
RSB Standard Certification	All transport sectors	Global	Global
RFTO Regulation	All transport sectors	UK	UK
RED II Directive	All transport sectors	Europe	Europe
GREET Model	All transport sectors	North America	North America and global
ICAO-CORSIA Certification	Aviation fuels	EU 28 + 29 regions	Europe and global
JEC Well-to-Wheel study	All transport sectors	Europe-global	Global
RenovaBio Regulation	All transport sectors	Brazil	Brazil

Methodological aspects covered in the assessment



Methodological aspects

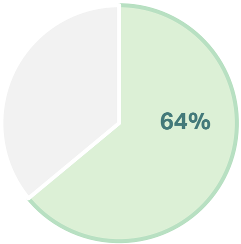
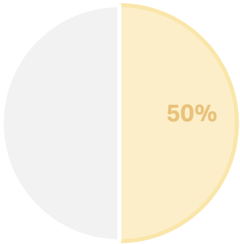
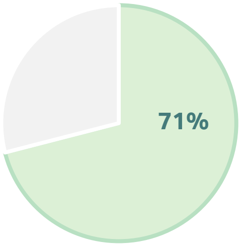
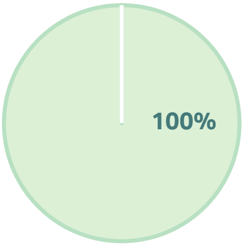
Fuel coverage	How well are the various fuel pathways covered in the selected methods and what are the system boundaries.
Fugitive emissions (including engine slips)	Emissions that occur in WTT activities as unintentional releases or leakages to the environment. Along with the engine slip emissions that occur during fuel combustion.
Direct Land Use Change / indirect Land Use Change (dLUC/ILUC)	Refers to the change in the use or management of land by humans that impacts on surface albedo, sources and sinks of GHG gases and other properties of the climate system that increases radiative focrcing[1]
Treatment of co-products	This aspect refers to how input and output flows to the system boundary are partitioned between the products. Biofuels are a good example, whereby production of biofuel leads to the production of by-products such as biochar and digestate. The emissions need to be allocated across all the products



Baseline of ambitions

1 IPCC. Definition of terms.

Summary of key findings

Technical aspect	Fuel Coverage	Fugitive emissions	Direct land use change	Treatment of co-products
% Coverage	 64%	 50%	 71%	 100%

Well covered
Aspect is mature and well covered in the methodologies. Only minor challenges outstanding.

Requires greater implementation
Aspect is not well covered in the methodologies. Median challenges remain.

Implementation lagging
Major challenges remaining for implementation. Clear guidance on how to implement is needed

Features of the methodology

Based on technical stds

2006 Intergovernmental Panel on Climate Change

ISO14040:2006 – Environmental management – Life cycle assessment, principles, and framework

ISO14044:2006 – Environmental management – Life cycle assessment – Requirements and guidelines

ISO14067:2018 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification

GHG Protocol Product Life Cycle Accounting and Reporting Standard

Agnostic

Policy and technology agnostic

The methodology doesn't favour any fuels or production technologies. Instead, it aims to evaluate all fuels on their associated climate burdens.

It doesn't aim to achieve any policy outcome but merely drive consistency and standardisation.

Detailed

Technical detailed

It is sufficiently detailed to ensure consistency in the results – aiding fuel GHG intensity comparisons. Differentiating climate performance.

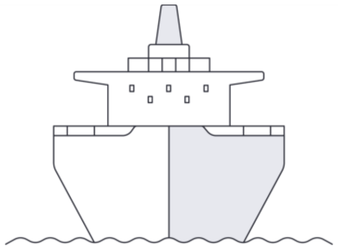
Supports effective implementation.

Credit mechanisms

Credit mechanisms for avoided climate burdens

The methodology identify potential credit mechanisms that can be achieved by the fuels. We have done this to support good fuel production practices and aid market development.

Future development of the methodology – industry "gold standard"



Lack of clarity and certainty on fuel lifecycle emissions

Reflective of the Centers mission

Reflective of emerging science on climate impacts

Reflective of sustainability risks that we identify through our work

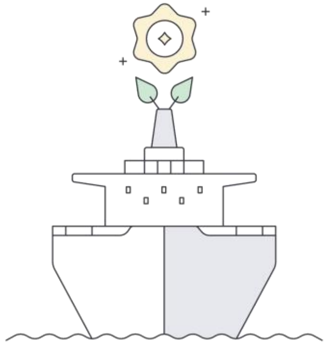
Support certification and regulation of fuels

Expanding the scope of the method to include environmental, social and economical aspects – in line with a sustainable transition

The debate around the metrics used to quantify climate change is constantly developing – GWP bio, GWP 100 V GWP 20, displacement effects and indirect impacts.

Some sustainability aspects are difficult to quantify and need a risk-based approach until certainty of quantification improves.

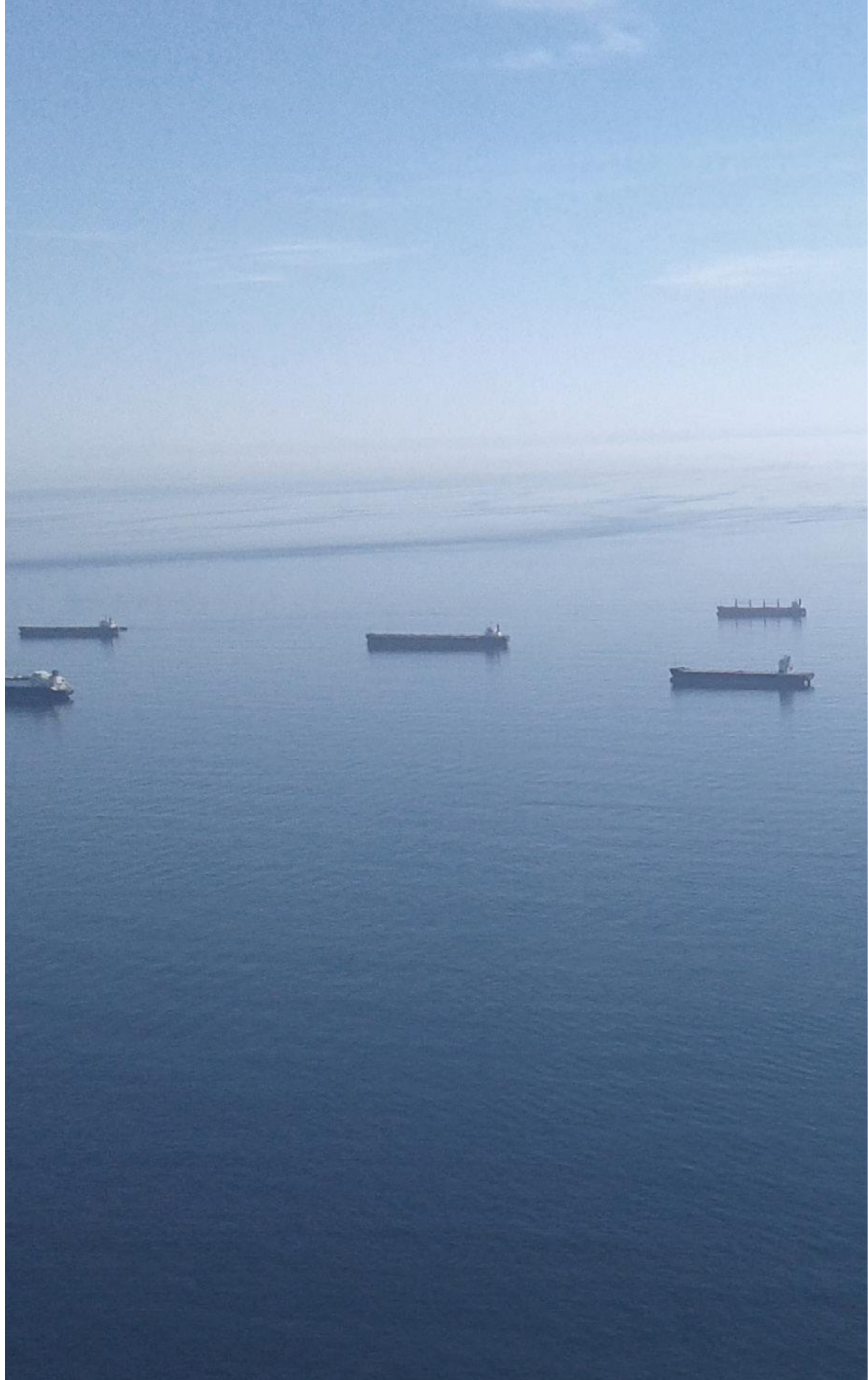
If adoption of the Centers methodology achieves high uptake, then there is a need to expand the scope of the methodology to support the verification of GHG savings and certify fuels.



Raising the bar and delivering clarity to increase the uptake of alternative marine fuels

MMMCZCS LCA methodology

Goal and Scope



A methodology to support all actors of the maritime fuels

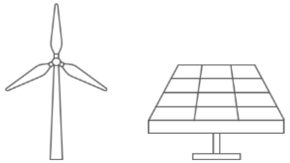
Maritime fuel producers	The methodology provides a framework for documenting the life cycle GHG intensity of marine fuels, which is a major part of the fuels' climate performance
Maritime industry stakeholders	The methodology helps stakeholders to document climate performance of their chosen fuels and to identify suitable alternative fuels to support their decarbonization
Technology providers	The methodology helps identify sources of both GHG emissions and avoided emissions throughout the fuel life cycle, with specific attention to production pathways of alternative maritime fuels (e.g., byproducts, CCS, renewable power)
Policy makers	The methodology quantifies the life cycle GHG intensity of various maritime fuels to help inform regulatory decisions that will best support decarbonization

Assess GWP of alternative maritime fuels

Biofuels

Biofuels are liquid or gaseous maritime fuels, such as bio-oils, bio-methane or bio-methanol, produced using feedstock from a biological source.

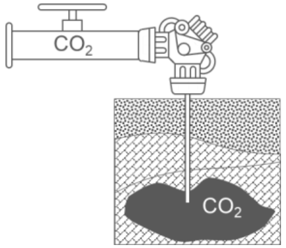
- Bio-oils
- Bio-diesels
- Bio-methanol
- Bio-methane



e-fuels

E-fuels, like e-methane, e-ammonia or e-methanol, are fuels in gas or liquid form that are produced using electrolytic hydrogen via renewable (e.g., solar or wind power) or decarbonized electricity source (low emission intensity grid).

- e-methanol
- e-methane
- e-ammonia



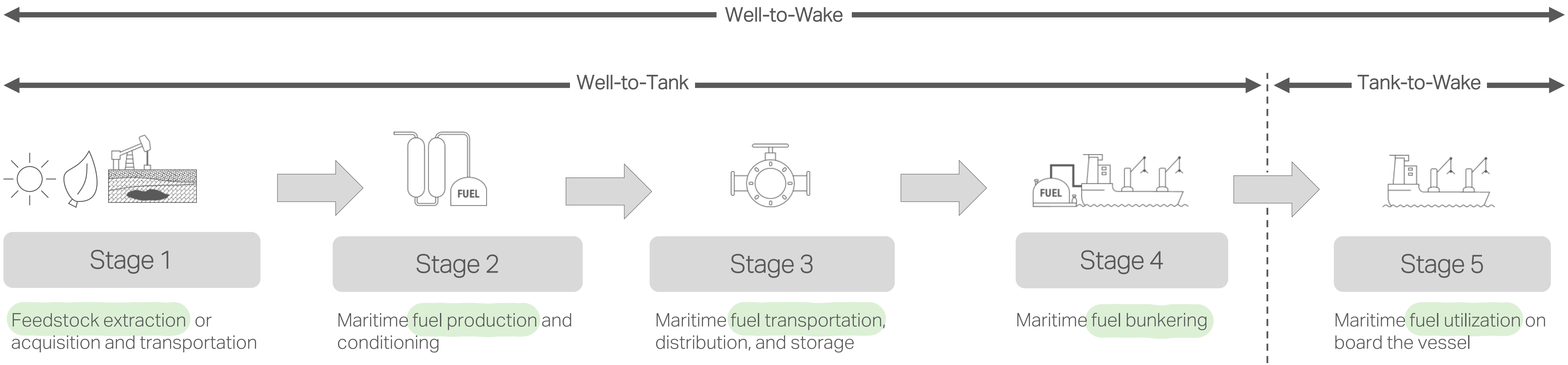
Blue fuels

Blue fuels are liquid or gaseous maritime fuels, such as blue-ammonia produced from fossil sources of hydrogen combined with CO_2 capture, transport and storage (CSS)

- Blue-ammonia

System boundary

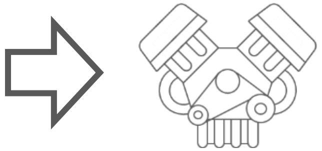
The methodology covers the entire life cycle of the fuel, from the Well up to fuel utilization on board the vessel, expressed as fuel utilized in fuel converter (Wake)



A functional unit to assess fuel utilization onboard

FU = 1MJ of fuel LHV used in maritime vessel by the maritime fuel converter

1MJ fuel stored in vessel

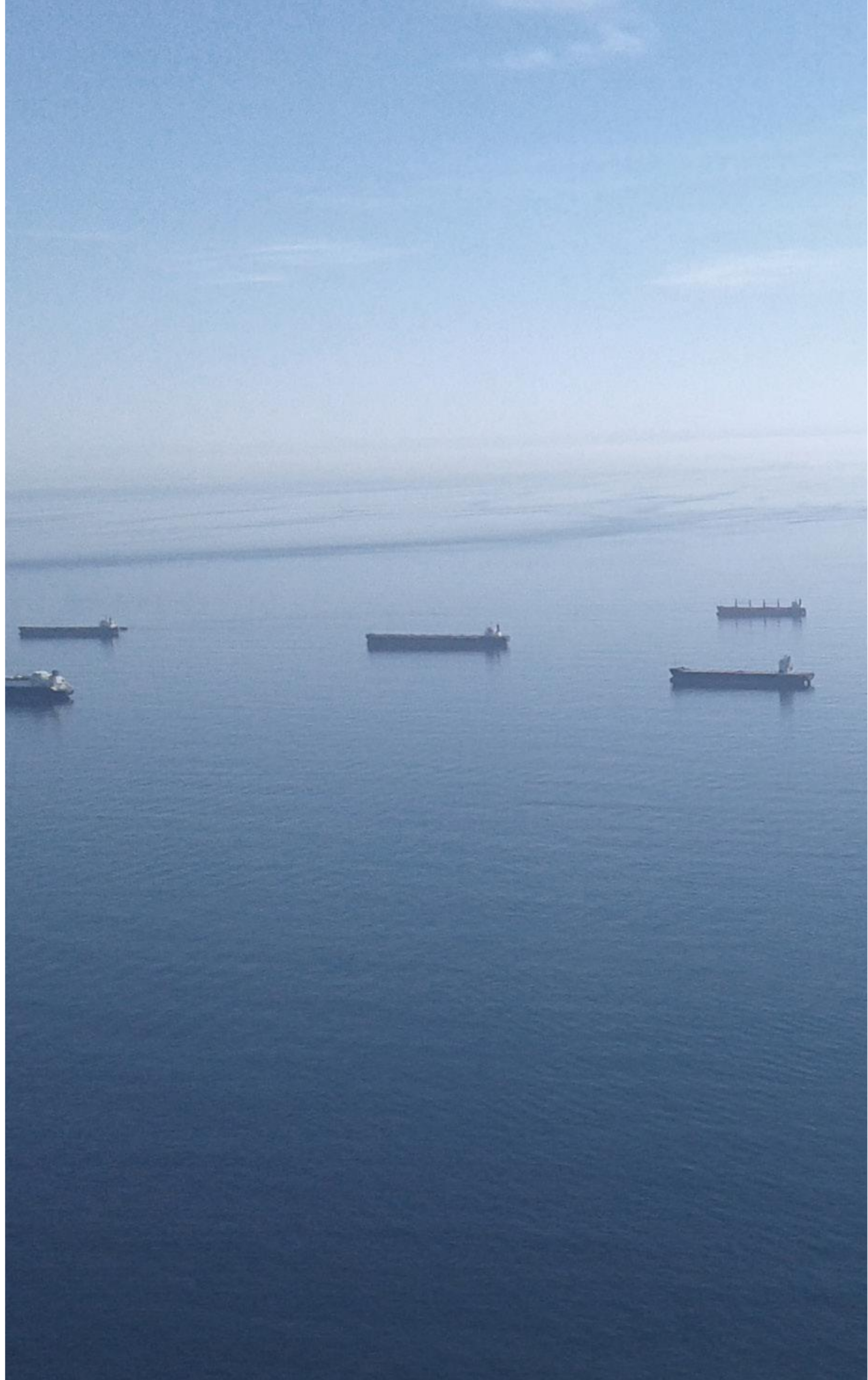


This **global warming potential impact** is expressed as grams CO_2eq per functional unit:

gCO_2eq/MJ fuel LHV used in maritime vessel by the maritime fuel converter

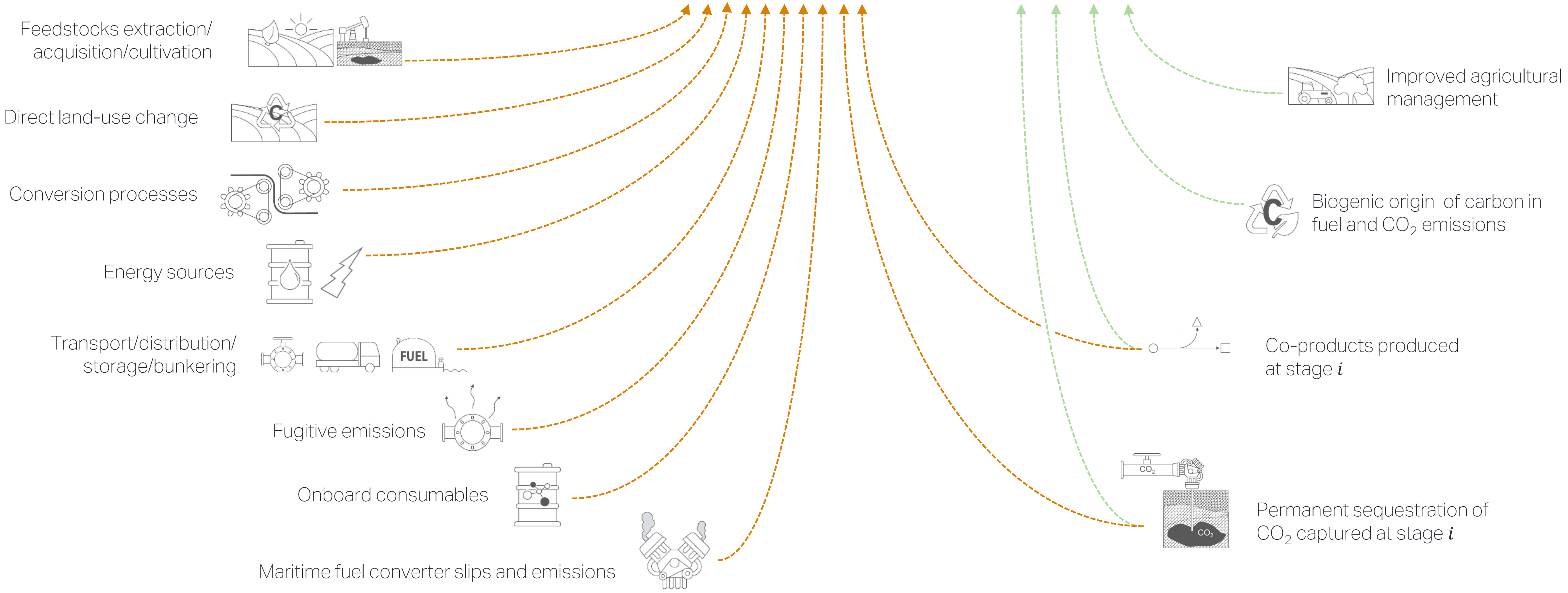
MMMCZCS LCA methodology

Impact assessment



Global warming potential (GWP) impact assessment

$$E_{Stage\ i} = \underbrace{\sum GHG\ Emissions}_{} - \underbrace{\sum GHG\ Emission\ credits}_{}$$



Internal

Global warming potential (GWP) impact assessment

Total life cycle GWP is estimated using the life cycle emissions of different GHGs (including but not limited to CO_2, CH_4, and N_2O) combined with the corresponding GWP over 100 years (GWP100) extracted from the IPCC Sixth Assessment Report or a subsequent IPCC assessment report.

$$GWP_i = \sum_{j=1}^{n} mass\ GHG_i \times GWP_i$$

Greenhouse gas	GWP100 ($gCO_2eq/gGHG$)
Carbon dioxide (CO_2)	1
Methane (CH_4)	29.8
Nitrous oxide (N_2O)	273

Internal

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Global warming potential (GWP) impact assessment

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$$GWP_i = \sum_{j=1}^{n} mass\ GHG_i \times GWP_i$$

Life cycle impact as GWP over a 20-year horizon (GWP20) may also be calculated separately if desired and subject to data availability for GWP20 emissions factors

Greenhouse gas	GWP100 ($gCO_2eq/gGHG$)	GWP20 ($gCO_2eq/gGHG$)
Carbon dioxide (CO_2)	1	1
Methane (CH_4)	29.8	82.5
Nitrous oxide (N_2O)	273	273

A detailed accounting of emissions and credits

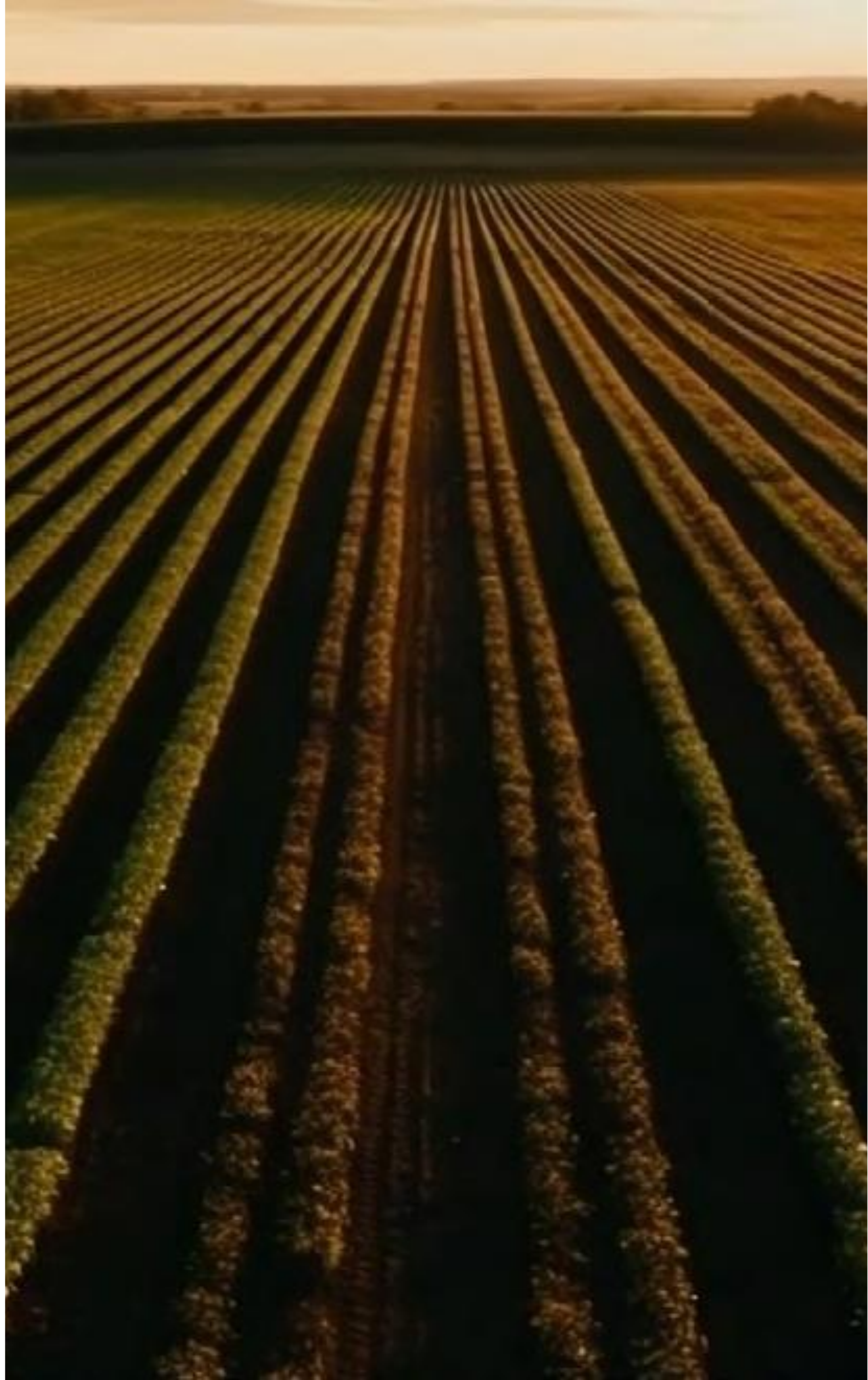
Well-to-Tank

1	Feedstock extraction	$E_{Stage\ 1} = e_{fecu} + e_l + e_{1,t} + e_{1,p} + e_{1,fug}$
2	Fuel production	$E_{Stage\ 2} = e_{2,p} + e_{2,fug}$
3	Fuel transport & storage	$E_{Stage\ 3} = e_{3,t} + e_{3,p} + e_{3,fug}$
4	Fuel bunkering	$E_{Stage\ 4} = e_{4,p} + e_{4,fug}$

Tank-to-Wake

5	Fuel utilization	$E_{Stage\ 5} = e_{5,fug} + e_{slip} + e_{fc} + e_{fu}$

Accounting emission from the Well-to-Tank stages



Well-to-tank activities associated with biofuels

Feedstock cultivation	Direct land use change (dLUC)	Feedstock collection and transport	Feedstock conditioning	Biofuel production	Fugitive emissions	Biofuel production emission credits	Biofuel distribution (transport, storage, and bunkering)
Agriculture processes	Emissions from carbon stock changes caused by a default 20-year transition period following conversion	Fuels and energy sources use during feedstock extraction/collection	Fuels and energy sources use during pre-processing	Energy sources use for biofuel production	Unintentional or accidental releases of GHGs, such as CH_4 and CO_2	Improved agricultural management	Fuels and energy source use for biofuel transport, distribution, and bunkering
Fertilizer application		Fuels and energy sources use during intermediate transport		Consumable use for biofuel production, such as chemicals	Unintentional or accidental GHG releases from biofuel during the WTT stages	Improved manure handling	Fuels and energy sources use during biofuel storage
Pesticide application				Fuel and energy sources use for biofuel temporary storage		Application of digestate to land	Fugitive emissions during biofuel transport, distribution, and bunkering
Water extraction and irrigation				GHG emissions during biofuel production processes		Biochar application to land	Boil-off emissions to air during liquified fuel storage
Fuel use during harvesting, tillage				Emission of CO_2 due to incomplete CO_2 capture		Provision of excess heat or electricity to the local grid	
Fuels and energy use during onsite feedstock storage				Emissions for biofuel conditioning for transportation (compression, liquefaction)		CO_2 emissions from carbon biogenic origin	
Biogenic CO_2 sequestration during plant growth						Permanent storage of captured CO_2	

Well-to-tank activities associated with e-fuels

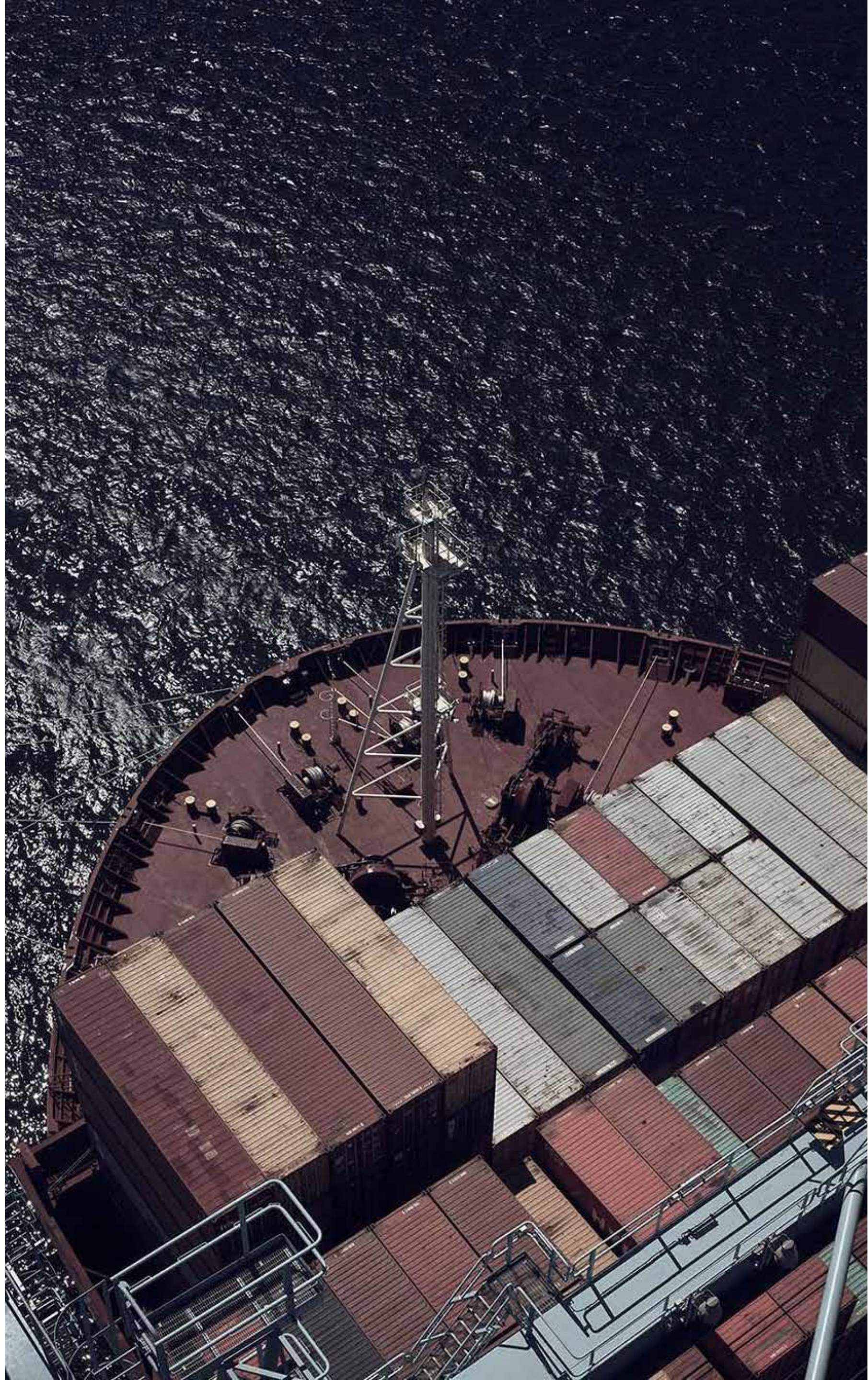
Feedstocks extraction/ production	Fugitive emissions during feedstocks extraction/production	Feedstock collection and transport	e-fuel production	Fugitive emissions during e-fuel production	e-fuel production emission credits	e-fuel distribution (transport, storage, and bunkering)
GHG emissions from biogenic carbon feedstock acquisition for e-fuel production GHG emissions from direct air capture (DAC) operations for e-fuel production GHG emissions from nitrogen extraction and processing for e-fuel production GHG emissions from water extraction and processing for e-fuel production Off-grid electricity production (emissions associated with the operational part of the life cycle) Use of consumables	Unintentional or accidental releases of GHGs relating to feedstocks extraction, production, and transport	Fuels and energy sources use during feedstocks pre-processing for transportation to e-fuel production site Fuels and energy sources use during feedstocks transport to e-fuel production site	Consumable use for e-fuel production, such as chemicals Fuels and energy sources use for e-fuel production GHG emissions during e-fuel production processes Fuels and energy sources use for e-fuel temporary storage e-fuel conditioning for transportation (compression, liquefaction)	Unintentional or accidental releases of GHGs, such as CH_4 and CO_2 Unintentional or accidental GHG releases from e-fuel during the WTT stages	Provision of excess electricity to the local grid Permanent storage of captured CO_2 CO_2 emissions from carbon of biogenic origin	Fuels and energy sources use for e-fuel transport, distribution, and bunkering Fuels and energy sources use during e-fuel storage Fugitive emissions during e-fuel transport, distribution, and bunkering Boil-off emissions to air during liquified fuel storage

Well-to-tank activities associated with blue fuels

Feedstocks extraction/ production	Fugitive emissions during feedstock extraction/production	Feedstock collection and transport	Blue fuel production	Fugitive emissions during blue fuel production	Blue fuel production emissions credits	Blue fuel distribution (transport, storage, and bunkering)
Natural gas extraction, flaring, venting, processing, and transport	Unintentional or accidental releases of GHGs relating to feedstock extraction, production, and transport	Fuels and energy sources use during feedstocks pre-processing for transportation to blue fuel production site	Energy source use for blue fuel production	Unintentional or accidental releases of GHGs, such as CH_4 and CO_2	Provision of excess electricity to the local grid	Energy source use for blue fuel transport, distribution, and bunkering
Water and oxygen extraction and processing		Fuels and energy sources use during feedstocks transport to blue fuel production site	Consumables use for blue fuel production, such as chemicals	Unintentional or accidental GHG releases from blue fuel during the WTT stages	Permanent storage of captured CO_2	Energy sources use during blue fuel storage
Off-grid electricity production (emissions associated with the operational part of the life cycle)			Emission from CO_2 capture, temporary storage, transport, and sequestration	Unintentional or accidental releases of GHG relating to captured CO_2 temporary storage, transport, and sequestration	CO_2 emissions from carbon of biogenic origin	Fugitive emissions during blue fuel transport, distribution, and bunkering
Fuels and energy sources use			GHG emissions during blue-fuel production processes			Boil-off emissions to air during liquified fuel storage
Use of consumables			Fuel and energy sources use for blue fuel temporary storage			
			Blue fuel conditioning for transportation (compression, liquefaction)			

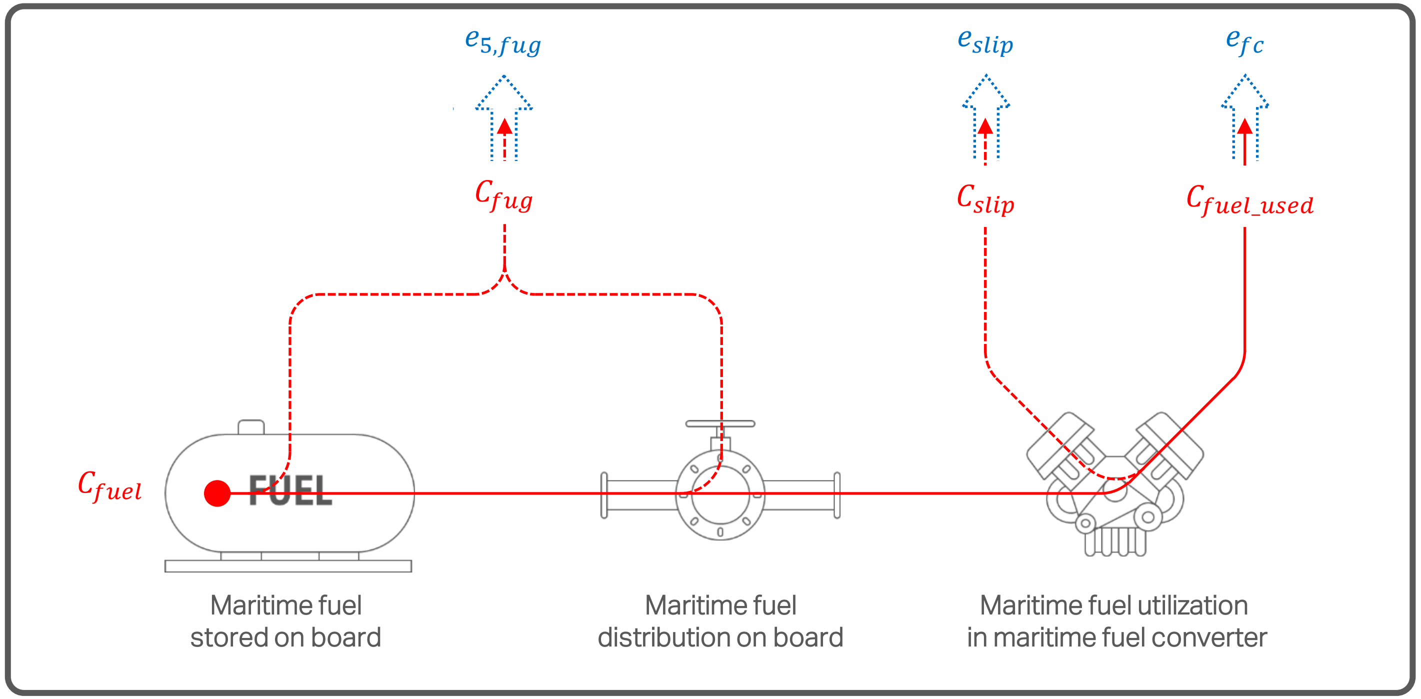
Tank-to-Wake

GHG emission details



Accounting fuel emission in Tank-to-Wake stage

5



$$C_{fuel} = 100\% = C_{fuel\_used} + C_{fug} + C_{slip}$$

$$C_{fuel\_used} = 1 - \frac{(C_{fug} + C_{slip})}{100}$$

Accounting fuel emission in Tank-to-Wake stage

5

$$E_{Stage\ 5} = e_{5,fug} + e_{slip} + e_{fc} + e_{fu} + \left(e_{ccsp} - e_{ccs}\right)_5 + \left(e_{cpm} - e_{cpc}\right)_5 - e_{5,c}$$

$$e_{5,fug} = \frac{C_{fug}}{100} \times \frac{GWP_{fuel}}{LHV_{fuel}}$$

$$e_{slip} = \frac{C_{slip}}{100} \times \frac{GWP_{fuel}}{LHV_{fuel}}$$

$$e_{fc} = \frac{C_{fuel\_use}}{100} \times \frac{(C_{fc,CO_2} \times GWP_{CO_2} + C_{fc,CH_4} \times GWP_{CH_4} + C_{fc,N_2O} \times GWP_{N_2O})_{fc}}{LHV_{fuel}}$$

Internal

Accounting emission from consumables used onboard

5

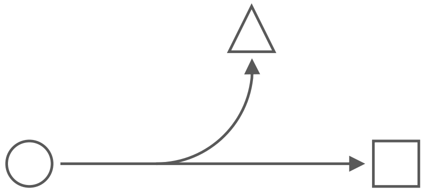
$$E_{Stage\ 5} = e_{5,fug} + e_{slip} + e_{fc} + \boxed{e_{fu}} + \left(e_{ccsp} - e_{ccs}\right)_5 + \left(e_{cpm} - e_{cpc}\right)_5 - e_{5,c}$$

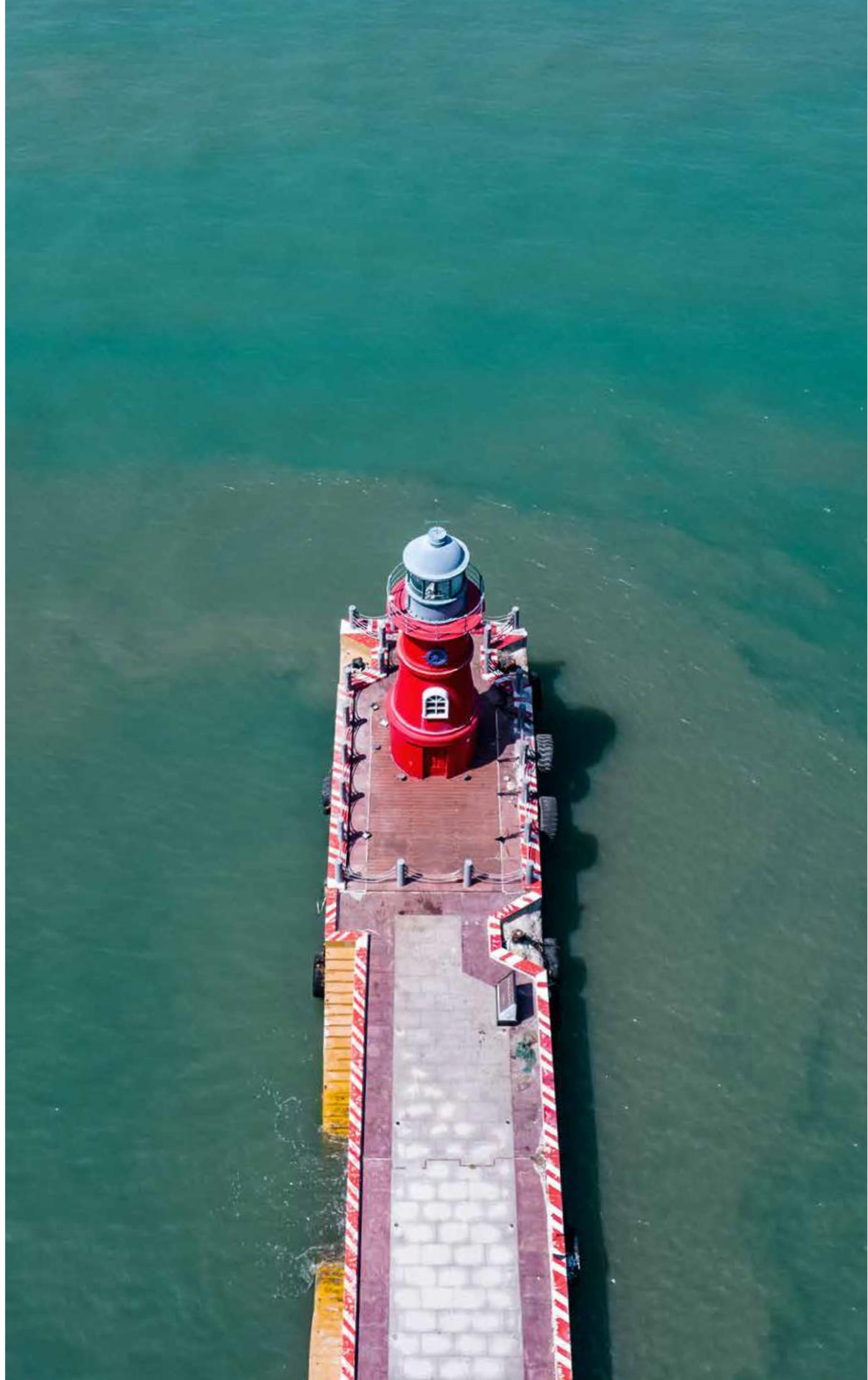
$$e_{fu} = \sum_k e_{fu,k} = \sum_k (C_{consumable\ k} \times GWP_{consumable\ k})$$

The conversion of maritime fuel in the energy converter may require the utilization of specific consumables (pilot fuel, additives, oils and lubricants).

The emissions from these consumables required for the utilization of the maritime fuel in the maritime fuel converter must be included in e_{fu}.

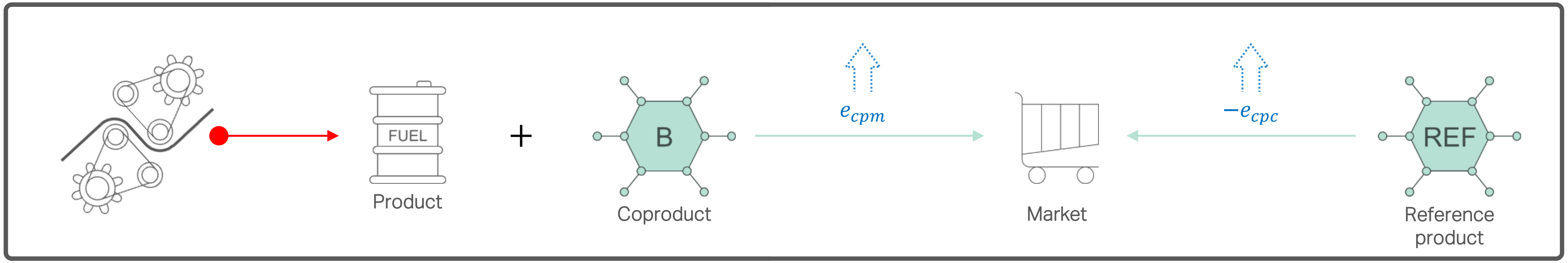
Focus on multifunctionality consideration





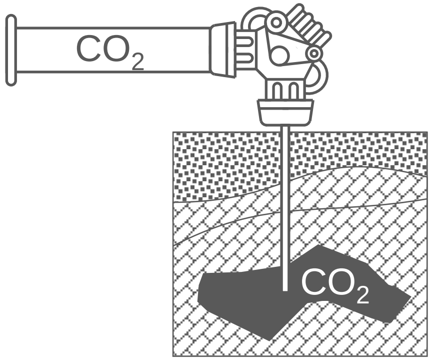
Considering multifunctionality

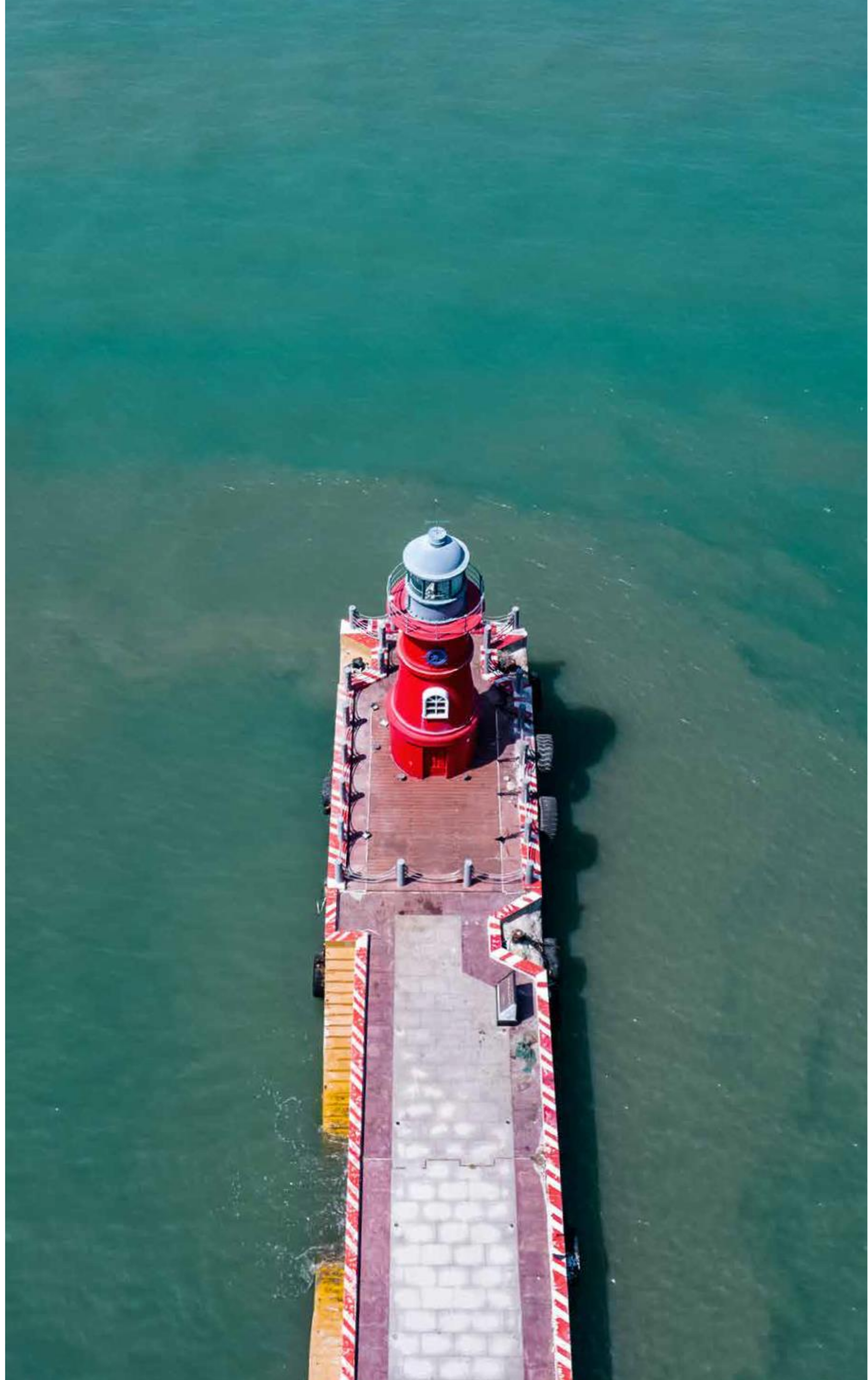
Multifunctionality refers to a situation where a product or process provides multiple outputs simultaneously.



Internal

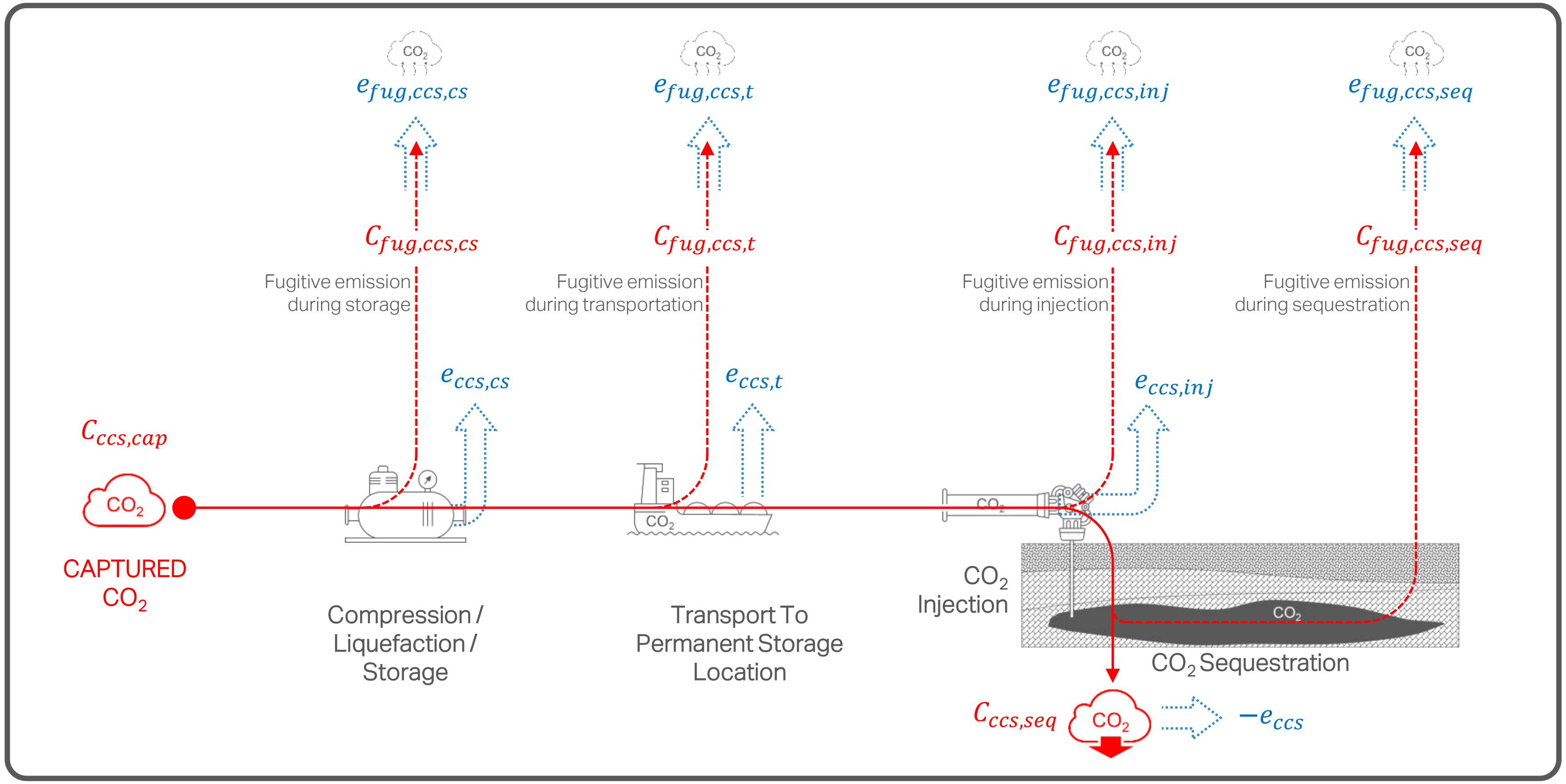
Focus on CCS chain consideration



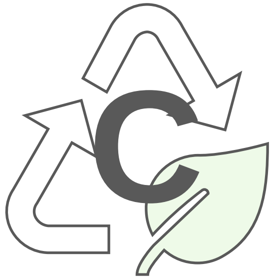


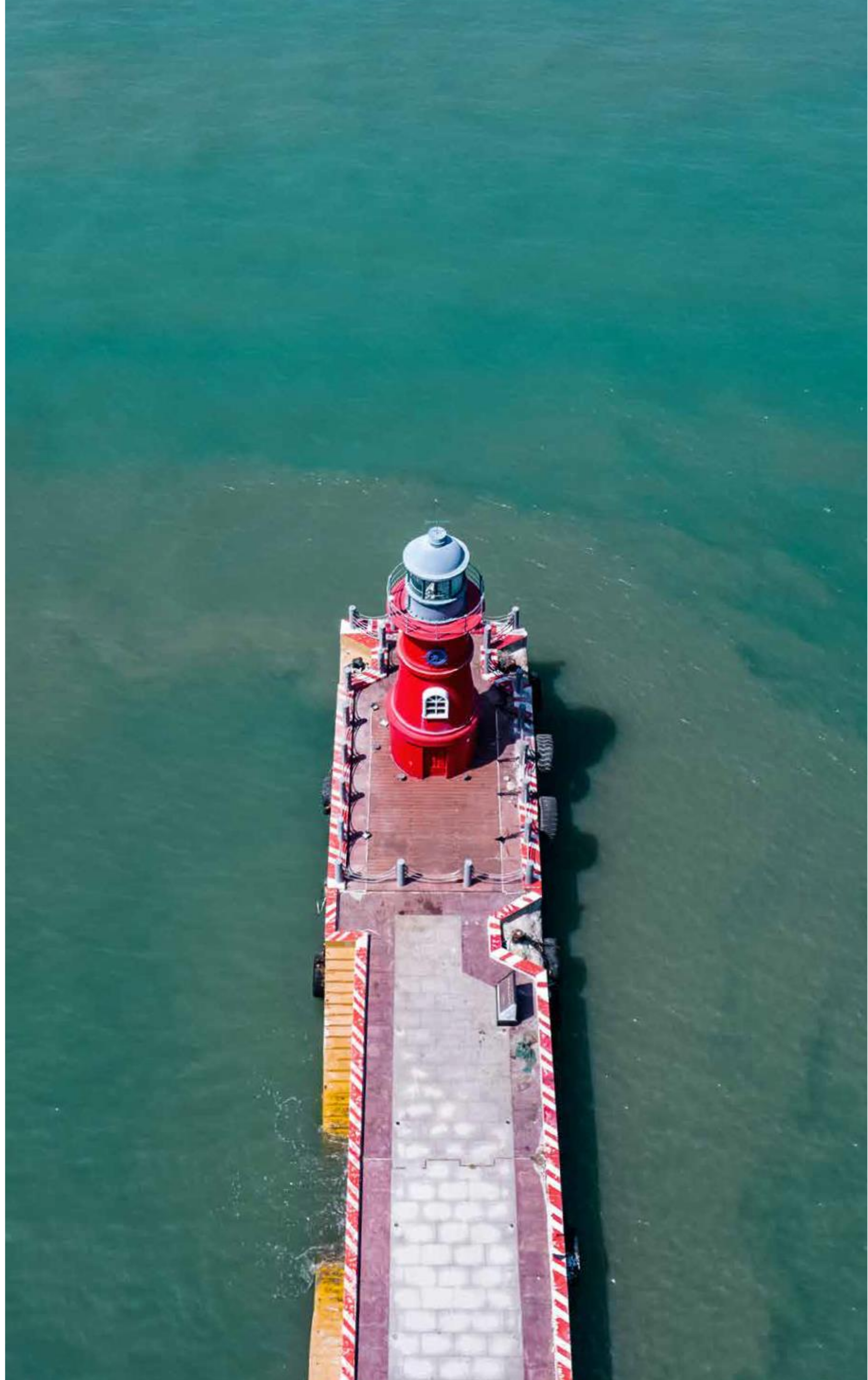
Captured CO_2 transport and storage consideration

$$E_{i,ccs} = (e_{ccsp} - e_{ccs})_i = [(e_{ccs,cs} + e_{fug,ccs,cs}) + (e_{ccs,t} + e_{fug,ccs,t}) + (e_{ccs,inj} + e_{fug,ccs,inj}) + e_{fug,ccs,seq} - e_{ccs,c}] - e_{ccs}$$



Focus on carbon biogenic origin credit



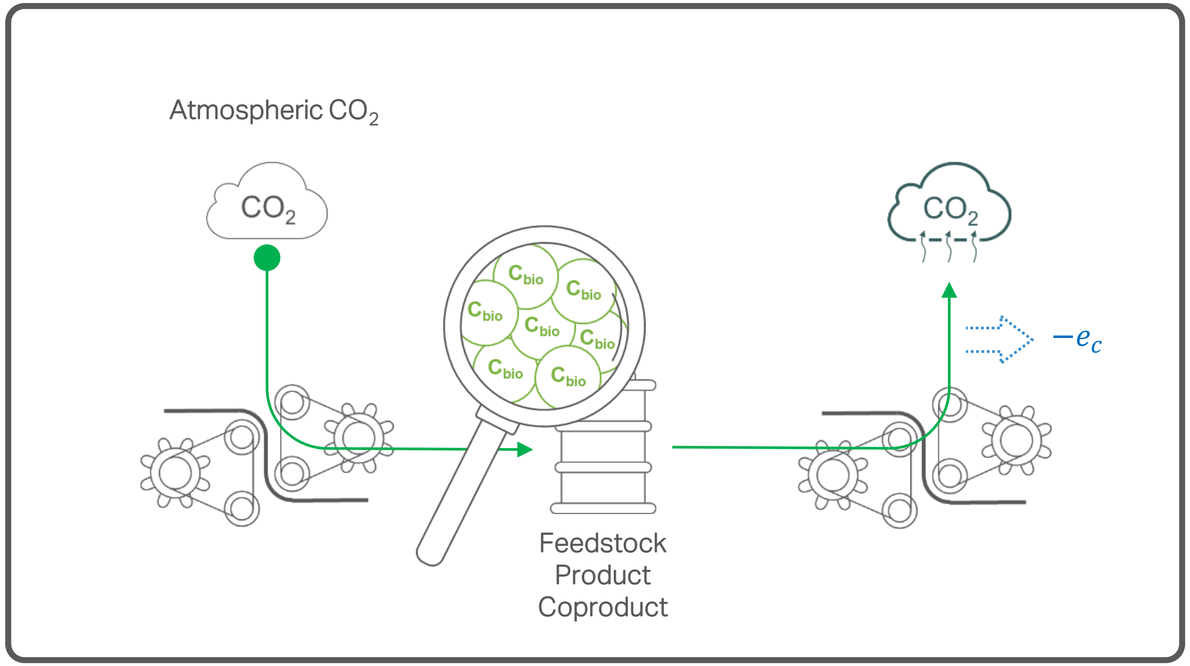


Accounting emission credit from carbon origin

When biogenic carbon is used as feedstock, this biogenic carbon is incorporated in the feedstock, the product or co-products.

When oxidized, this biogenic carbon mays be released as CO_2 and leads to net zero climate impact of biogenic carbon emitted since the biogenic carbon is released to atmosphere.

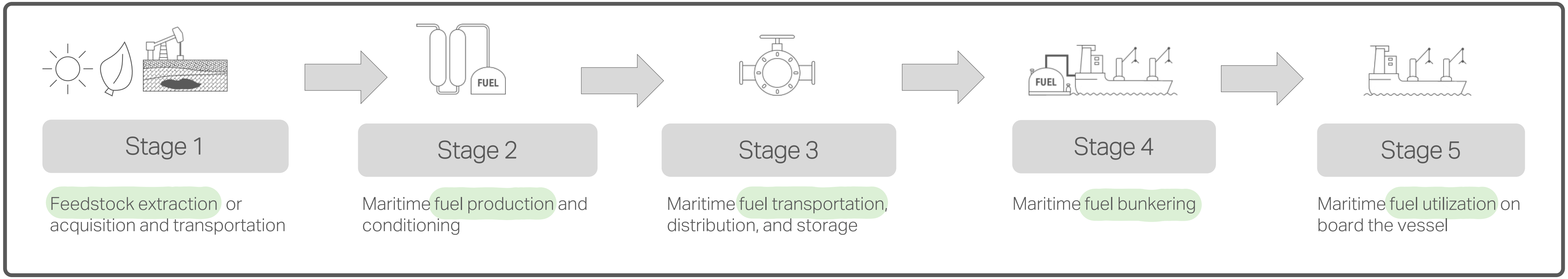
To reflect this neutral biogenic carbon cycle, an emission credit , e_c , must be applied for any CO_2 emission to atmosphere, resulting from oxidation of biogenetic carbon



$$e_{i,c} = (C_{fCO_2\,BIO} \times GWP_{CO_2})_i$$

Pending further methodological refinement of this parameter, $e_{i,c}$ value should be set to zero, when C in CO_2 emission is sourced from fossil CCU pathways or recycled carbons

Summary



Well-to-Tank

1 Feedstock extraction

$$E_{Stage\ 1} = e_{fecu} + e_l + e_{1,t} + e_{1,p} + e_{1,fug} - e_{sca} + \left(e_{ccsp} - e_{ccs}\right)_1 + \left(e_{cpm} - e_{cpc}\right)_1 - e_{1,c}$$

2 Fuel production

$$E_{Stage\ 2} = e_{2,p} + e_{2,fug} + \left(e_{ccsp} - e_{ccs}\right)_2 + \left(e_{cpm} - e_{cpc}\right)_2 - e_{2,c}$$

3 Fuel transport & storage

$$E_{Stage\ 3} = e_{3,t} + e_{3,p} + e_{3,fug} - e_{3,c}$$

4 Fuel bunkering

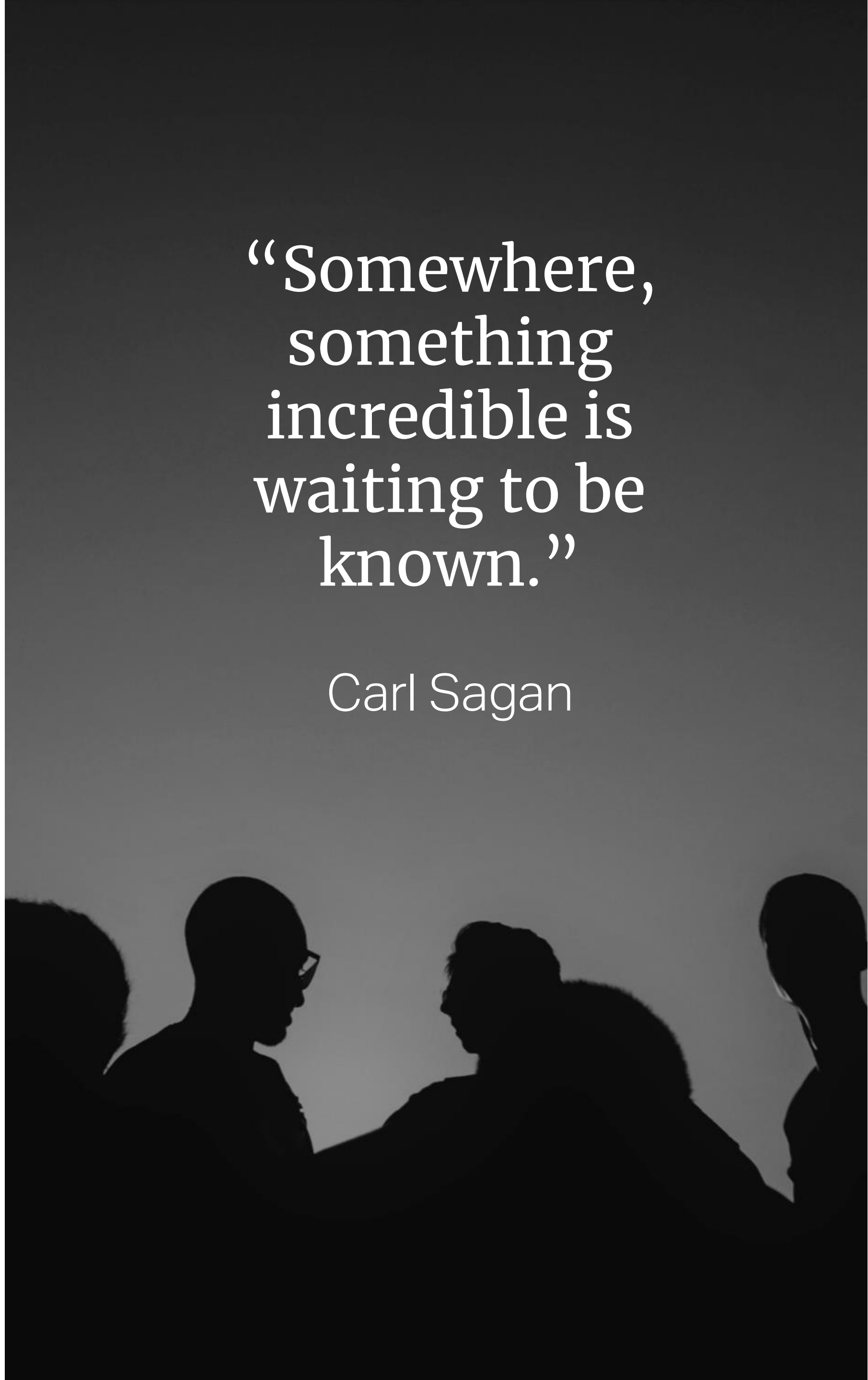
$$E_{Stage\ 4} = e_{4,p} + e_{4,fug} - e_{4,c}$$

Tank-to-Wake

5 Fuel utilization

$$E_{Stage\ 5} = e_{5,fug} + e_{slip} + e_{fc} + e_{fu} + \left(e_{ccsp} - e_{ccs}\right)_5 + \left(e_{cpm} - e_{cpc}\right)_5 - e_{5,c}$$

Panel discussion



Panellists

Dr Selma Brynolf

Researcher and Head of Department, Mechanics and Maritime Sciences at Chalmers University

Professor Michael Hauschild

Department of Environmental and Resource Engineering at DTU

Dr Don O'Connor

Developer of GHG Genius and President of S&T Consultants

Dr Carl Vadenbo

Project Manager at ecoinvent

Dr Michael Wang

Director of the Systems Assessment Center, and interim director of the Energy Systems and Infrastructure Analysis division at Argonne National Laboratory, USA

Discussion points

1. Importance of policy incentivizing calculation and measurement over default emission factors
2. Regulation of fuel emissions; Well-to-Wake or Tank-to-Wake.
3. LCA and academic trade-offs when implemented in policy
4. The policy landscape; centralized and decentralized policies – risks and opportunities.
5. Risks associated with double accounting

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#LCA

Thank you

Stay in touch:

ann.oconnor@zerocarbonshipping.com
loic.francke@zerocarbonshipping.com

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