CLEVER

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ABBREVIATION	DEFINITION
DoA	Description of Action
EC	European Commission
GA	Grant Agreement
HEU	Horizon Europe

Short name and name of beneficiaries

SHORT NAME	NAME
PNO	PNO Innovation S.l.
SFC	Smart Freight Centre
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
IFEU	Institut Fur Energie – Und Umweltforschung Heidelberg GGMBH
GR	Greenrouter Srl
EMI	Emisia SA - Anonino Etairia Perivallontikon Kai Energiakon Meleton Kai Anaptixis Logismikou
MEO	Meo Carbon Solutions GmbH
ZN	ZN
3OC	Three O’Clock
UITP	Union Internationale des Transports Publics
Ricardo	RICARDO-AEA LTD

1 INTRODUCTION

1.1 GENERAL INTRODUCTION TO THE CLEVER PROJECT

The CLEVER project, funded by the European Union's Horizon Europe programme, aims to develop standardized, accurate, and future-proof emission factors and methodologies for the global transport and logistics sector. By building a comprehensive, harmonized framework for emissions accounting across all transport modes, CLEVER supports more consistent reporting, informed decision-making, and the adoption of sustainable practices in line with European and international climate goals.

The CLEVER project aims to achieve the following key objectives:

- Enable international collaboration by developing common tools and methods that support alignment across organizations involved in emission factor development and application throughout the energy lifecycle (Well-to-Wheel).
- Identify critical gaps in current emission factors and accounting methodologies, covering both conventional and alternative fuels across all modes in the transport and logistics sector.
- Develop a unified, transparent methodology with clear calculation rules and aligned fuel specifications that can be widely accepted and used across industries.
- Create a reliable and globally applicable framework with a validated set of default emission factors to ensure consistent and accurate emissions reporting.
- Support real-world implementation by increasing industry understanding of the methodology's benefits and practical use in operations.
- Drive long-term impact by promoting the adoption of CLEVER outputs through policy engagement, stakeholder collaboration, and alignment with international standards and regulations.

Within the first phase of the CLEVER project, an in-depth work was conducted, including compilation of the relevant initiatives, emission factor reference sources and regulatory frameworks that are collected in the CLEVER Repository, a further survey of value chain stakeholders, and the conclusions drawn from the Emission Factor Knowledge Database in the State-of-the-Art Review, and an exhaustive gap analysis.

As part of its Scientific State-of-the-Art analysis, CLEVER examined existing emission factor databases, tools, and scientific literature, uncovering significant gaps including inconsistent methodologies, limited information on emerging fuels, and insufficient tools for assessing emissions from fuel blends. A stakeholder survey with over 160 participants highlighted the critical need for standardized approaches, detailed fuel-specific data, regular updates, and dedicated support for fuel blend calculations. Based on these findings, CLEVER is focused on developing rigorous methodologies, expanding its fuel data collection, designing specialized tools for blended fuels, and maintaining continuous stakeholder engagement to ensure its outputs are relevant and actionable.

The Gap Analysis, informed by extensive input from CLEVER Expert Forum members and broader stakeholder consultation, identifies major challenges such as methodological inconsistencies, complex fuel classifications, and a lack of transparency that undermines confidence in emission data. It emphasizes the necessity of creating harmonized, clear, and adaptable methodologies that address a wide range of fuel types and lifecycle stages while ensuring alignment with regulatory frameworks. Drawing on these insights and ongoing collaboration with Expert Forum members, CLEVER aims to deliver a transparent and comprehensive methodology. To support widespread adoption, the project will develop practical use cases, offer trainings, and engage with regulators and certification bodies, recognizing that timely stakeholder buy-in is crucial for the global impact of CLEVER project.

Building upon the insights from the Scientific State-of-the-Art review and the Gap Analysis, this task will focus on defining the goal, scope, and system boundary needed to develop robust and harmonized emission factors.

1.2 INTRODUCTION TO GOAL AND SCOPE

This document introduces and defines the Goal and Scope of the CLEVER framework. In accordance with ISO 14040/44:2006, both Goal and Scope are the key initial elements of any LCA. Together with inventory analysis, impact assessment and finally the interpretation of results, they form the basic structure. The purpose of the Goal in the sense of an LCA is to describe the overall purpose of the assessment at hand, from which all other major relevant elements, in particular the functionality/functional unit, are derived. The Scope determines the framework for the assessment, both in conceptual as well as technical terms. A key element of the Scope is the applied system boundary, which further specifies key criteria and methodical decisions.

The CLEVER framework has a specific role in the overall scope of the CountEmissionsEU regulation, covering major parts of the overall logistics value chain with an emphasis on the upstream energy carrier provision and utilization within vehicles. CLEVER Emission Factors (EF) are generated by applying this CLEVER framework.

This document specifies key methodical aspects for compliance with the CLEVER framework and refines more generalized LCA procedures and elements with the specific aim of fulfilling the requirements of CountEmissionsEU. Chapter 3 provides some background to the development of the CLEVER framework and defines the Goal, while Chapter 4 introduces the Scope.

2 BACKGROUND AND GOAL

2.1 BACKGROUND AND POLICY CONTEXT

With the adoption of the European Green Deal (2021), the European Climate Law as well as further legislative steps outlined in the “Fit for 55” legislative package (as of Oct. 9th 2023), the European Union (EU) moves ahead in order to accelerate the transition toward achieving the goal of becoming the first climate-neutral continent (EU Climate Law, Green Deal). In combination with supplementary / complementary legislative tools / instruments, such as the revised Renewable Energy Directive (Directive (EU) 2023/2413) or the ReFuelEU initiative, all sectors of Europe’s economies are covered, with sector-specific commitments.

Whereas some key sectors, such as power generation or heating, are well on their way to meet (or even exceed) their respective sectorial goals, the transport sector still faces notable challenges to reduce emissions. In 2022, transport activities accounted for roughly 25 % of all GHG emissions (EEA, Sustainability of Europe’s mobility systems), and as such, remains one of the largest contributing sectors, with GHG emissions in excess of the reference year 1990.

To meet the specific challenges of the transport sector, the EU adopted or proposed additional legislative instruments and strategies, such as the Commission's *Sustainable and Smart Mobility Strategy*[1] (SSMS, outlined within the Green Deal), to address freight and passenger specific issues. One key aim of the SSMS is, inter alia, to provide a *framework for the harmonized measurement of greenhouse gas emissions from transport and logistics.* This initiative is meant to confirm the use of a single calculation methodology based on the relevant international standard (ISO 14083), so avoiding methodological dissonance within calculations, and providing a focal point of a single database of emission factors, again based on a single, consistent methodology. This key part of the SSMS is currently in the process of implementation as the *CountEmissionsEU* regulation (proposal for a regulation of the European Parliament and of the Council on the accounting of greenhouse gas emissions of transport services), introduced in July 2023.

At its core, the CountEmissionsEU initiative aims at a single / universal methodology for the calculation / assessment of GHG emissions from transport services (EU Legislation in Progress Briefing on CountEmissionsEU, September 2024). Both, freight and passenger transport are addressed, as are hub operations, allowing for a comprehensive calculation of emissions from logistics services. The goal of the methodology to be established is to allow for a comparison of the GHG emissions of different transport services, while ensuring that the underlying data is reliable, precise and robust. The CLEVER framework, outlined within this document, is a key element of the overall CountEmissionsEU methodology package and focuses primarily on fuel provision and utilization, while hub operations are out of scope and subject to a complementary framework. Together with the CLEVER framework, the CountEmissionsEU scope is realized.

This document entails the goal and scope of the CLEVER framework. One key aim of CLEVER is harmonization with existing best practice and guidelines, frameworks and standards in the context of transport sector and logistics emission accounting. As such, the reference methodology of CountEmissionsEU and CLEVER is the ISO 14083 standard on "Quantification and reporting of GHG emissions arising from transport chain operations". In this ISO standard, key rules for the calculation of climate impacts from transport operation are outlined. However, while ISO 14083 also covers GHG emission factors from different energy carriers through outline guidance in Annex J, a further elaboration of rules on how to calculate these emission factors is still lacking. Additionally, the CLEVER project aims at demonstrating and applying the CLEVER framework in order to thus provide a set of up-to-date, transparent, reliable and ready-to-use GHG emission factors of all commonly used energy carriers.

The document at hand describes Goal (Chapter 3.2) and Scope (Chapter 4) definition of the CLEVER framework.

2.2 GOAL OF CLEVER GHG EMISSION FACTORS

CLEVER aims at supporting CountEmissionsEU by establishing the methodology to accurately assess the GHG emission factors of current or emerging energy carrier pathways. These GHG emission factors are intended to be used in the subsequent calculation of the climate impacts (GHG emission intensities) from transport operations, thus depicting the whole logistics value chain, including hub operations. As a result of CountEmissionsEU, a fair comparison of different transport services per tonne-kilometre or person-kilometre is possible.

[1] Among other goals outlined in the SSMS, a key objective described is an emission reduction of the transport sector by 90 % in 2050

The CLEVER framework covers key elements of the overall scope of CountEmissionsEU, but does not aim at covering the whole scope. Therefore, CLEVER GHG emission factors cannot be used as a stand-alone metric to determine the GHG-intensity of transport services, because other key elements determining the overall GHG-intensities are not accounted for within the CLEVER framework. CLEVER values constitute the basis, and in combination with further supplementing information and data covering complexities related to logistics hub operations and vehicle usage, a holistic calculation of GHG-intensities of singular pathways per tonne-kilometre or passenger-kilometre becomes possible, which depicts the overall CountEmissionsEU scope. Thus, a fair comparison of different logistics options becomes possible. Only if the operational conditions of using different energy carriers were to be exactly the same (for example, if the energy demand of the vehicles and exhaust gas treatment as well as the operating conditions such as load factor or maximum load are not impacted by the chosen energy carrier pathway), does a direct comparison of CLEVER values for different energy carrier pathways lead to a fully meaningful assessment of the climate impacts of the overall transportation service. Nonetheless, it provides an indispensable input to such an assessment, especially in the context of decarbonization options.

The goal is to quantify all relevant contributions to climate change by using the global warming potential in the form of CO_2-equivalents (CO_2-eq.). In accordance with the cut-off criteria (Chapter 3.4), all climate impacts from the production and utilization of energy carriers within vehicles for passenger and freight transport are assessed. This includes liquid and gaseous fuels of fossil, biogenic or other origins as well as electricity used in transportation. To accurately assess these impacts, the whole energy carrier lifecycle must be considered and included into the GHG emission factor for all energy carrier pathways.

CLEVER can be used in two ways: Firstly, the derived default GHG emission factors for the different energy carriers from the CountEmissionsEU reference data base may directly be utilized within any calculation and assessment of climate impacts from transport operations, especially in the context of CountEmissionsEU. Secondly, instead of using default values, economic operators may calculate their own actual GHG emission factors for specific energy carrier pathways or energy carrier pathways not yet covered by the default GHG emission factors within CountEmissionsEU reference database. Whenever the second option is chosen, the specific energy carrier pathway must be stated unambiguously and the CLEVER framework / methodology must be followed.

In addition, the aim of CLEVER is to foster understanding of the GHG emission factors for different energy carrier pathways and different uses, to ensure a level playing field for all energy carrier pathways. This will enable users to report on the climate impacts of their transport operations using consistent, reliable and transparent GHG emission factors. It also helps to understand the calculation of climate impacts from transport operations and the GHG emission factors behind them.

Following this, CLEVER GHG emission factors are limited to one singular environmental impact metric – climate change. No other conclusions with respect to environmental impacts beyond climate change may be drawn upon CLEVER values, nor are general assessments of sustainability of specific pathways possible.

Thus, the intended audience of the CLEVER framework and CLEVER emission factors are primarily economic operators with the intention of conducting calculations of the GHG-intensity and total GHG emissions as well as disclosing data and information on the climate impact of their transport services (compliance with CountEmissionsEU). Furthermore, the intended audience constitutes a range of interested parties, decision makers and consumers in the field of transport and logistics, as well as suppliers of energy carriers used in transport.

CLEVER will focus on existing and emerging energy carrier pathways and is intended to be used for accounting/ reporting or verification purposes, only. It will thus provide average values using an attributional approach and will not directly assess impacts from changes to the global system. A comparison between different energy carrier pathways (including their usage) can still be made and can be used to inform potential changes (e. g. switching from a crop-based biofuel to a waste-based biofuel) by comparing the factors produced through the attributional approach, provided the operational conditions for the vehicle(s) are the same.

3 SCOPE OF CLEVER GHG EMISSION FACTORS

The objective of the CLEVER framework is to provide guidance to calculate CLEVER emission factors (EF). In accordance with the principal LCA ISO norms ISO 14040/44:2006, the scope of any CLEVER assessment must be consistent with the defined goal. Its outline must accurately reflect all relevant aspects in accordance with the cut-off criteria (chapter 3.4) of the energy carrier's lifecycle. The following aspects are elements of the overall scope and shall be considered:

a) A clear description of the product system under investigation (fuel pathway / energy carrier pathway utilized within a vehicle) shall be given. In particular, all relevant characteristics and technical aspects of the value chain shall be described.
b) Classification of fuel pathways. The CLEVER framework provides a classification metric to facilitate identification of energy carriers as well as some further methodical aspects that can be specific to a category, but might not apply to another.
c) The functionality of CountEmissions.EU is tonne-kilometre or person-kilometre as basis for any assessment or comparison, defined a priori by the specific purpose (chapter Goal) of CountEmissionsEU. Due to the fact that the CLEVER framework only covers a part of the CountEmissionsEU scope, CLEVER specifies a declared unit of one MJ (Megajoule) of an energy carrier utilized within a vehicle.
d) In particular, the applied system boundary (chapter 4.4) shall be described in detail. By default, any CLEVER assessment shall consider a WtW system boundary, covering both, emissions and expenditures associated with energy carrier provision, including distribution and supply as well as operational emissions from fuel utilization and vehicle operation, taking into account expenditures and emissions e.g. from fuel utilization ("tailpipe" emissions), emissions from exhaust gas treatment and additional climate impacts from vehicle operation. Assessed elements of the system boundary shall be described, disaggregated into WtT (focussing on fuel production) & TtW (focussing on fuel utilization and vehicle operation) specific parts. This further entails information on the geographical and temporal scope, and the applied cut-offs.
e) Life cycle inventory modelling and multifunctionality: Any assessment applying the CLEVER framework shall follow an attributional ('descriptive') approach to inventory modelling. Furthermore, multifunctionality shall be solved applying the hierarchy as defined in ISO 14044:2006 (Chapter 4.3.4.2). Further key methodical choices / settings to be described are (among others):
    a. Co-product allocation i.e., energy based (LHV) allocation as a default,
    b. Consideration of end-of-life modelling (allocation methodology) i.e. the 'Cut-Off-method', and
    c. Definition of material flows, i.e., waste vs co-product classification and respective methodical handling.
f) To contextualize the applied data as the basis for the calculation of a CLEVER EF, their origin and quality shall be described. Furthermore, applied data shall be appropriate to the investigated product system and moreover consistent with the geographical and temporal scope. Any deviations shall be stated and justified, as well as any resulting limitations disclosed.
g) Assumptions and limitations: When assumptions are made, especially ones with substantial influence or impact on results, they shall be mentioned, described and justified. Furthermore, the influence of assumptions and limitations shall be reflected when results are described and interpreted.
h) If carbon (dioxide) removals occur as a part of the energy carrier lifecycle, they shall be reported separately and specific to the origin of the carbon (fossil, renewable). Likewise, if carbon (dioxide) emissions from LUC occur, they shall be assessed and reported separately (Chapter 4.12). Special attention shall be paid in order to avoid any double counting of removals and overall on consistency regarding the system boundary.

i) Attribution of biogenic carbon in multi-outputs: If biogenic and fossil carbon containing feedstocks are processed together (i.e. co-processing within a conversion unit of a conventional petrochemical refinery) and multiple outputs result from this process, the biogenic carbon shall be attributed to all outputs according to physical causalities, based on rules laid out in Delegated Regulation (EU) 2023/1640.

j) Emissions from land use / land use change. When land is required to produce fuels, e.g. to cultivate biomass, direct or indirect land use change and associated emissions can occur.[2] This pertains in particular crop-based biofuels. Emissions from direct and indirect land use change shall be considered within CLEVER emission factors, but reported separately to the base emission factor (see concept of scope modularity further below). Direct land use change shall be based on current IPCC guidelines, more specifically Volume 4: Agriculture, Forestry and Other Land Use, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Indirect land use-change shall be assessed according to the ICAO CORSIA approach (extended to cover also others fuels apart from only SAF) for induced land use-change.

k) Impact assessment methodology. The scope of CountEmissionsEU, and therefore also of the CLEVER framework, is limited to the climate impact of transport services, expressed via the impact category "Climate Change". As default metric and indicator for the impact assessment in CLEVER, the latest characterization factors for GHG emissions from the IPCC Assessment Reports (currently, Assessment Report 6, IPCC 2023) using the GWP100 (global warming potential with a 100-year perspective without feedback) shall be utilized. The total climate change impacts are the sum of all GHG emissions multiplied with their respective GWP_{100y} factor. Biogenic carbon uptakes and emissions shall be included, utilizing a characterization of -1 for biogenic carbon dioxide sequestration and +1 for biogenic carbon dioxide emissions.

l) Verification and certification requirements. When economic operators calculate and report their own values applying the CLEVER framework instead of using CLEVER default values, additional requirements regarding verification of results as well as certification of claimed feedstocks or fuels have to be met. Verification in the form of a Conformity Assessment ensures plausibility of calculated results and assesses compliance with the CLEVER framework. Certification is required, when specific feedstocks or fuels are claimed, instead of utilizing respective defaults and aims at ensuring that no false claims are made as regards in particular limited alternative fuels.

m) Reporting requirements. Any calculation of CLEVER values shall be accompanied by a report describing all relevant aspects.

[2] These LUC related emissions can be substantial, depending on a range of factors, such as agricultural circumstances or the characteristics of local/regional (soil) conditions.

MODULARITY PRINCIPLE OF THE CLEVER FRAMEWORK

In order to allow for a flexible utilization of CLEVER values for multiple purposes, CLEVER emission factors are modularly structured. The concept of modularity in principle aims at partitioning the overall CLEVER scope into smaller, modular components to reflect the contributions of specific elements (such as e.g. impacts from iLUC or additional climate impacts from operation).

$$EF_{Total} = EF_{Core} + EF_{iLUC} + EF_{ACI}$$

With EF_{Total} constituting the total CLEVER emission factor, EF_{Core} includes all relevant commonly assessed energy provision (also called well-to-tank or WtT) and operational (also called tank-to-wheel or TtW) elements, and thus includes some disaggregated values, such as values for dLUC EF_{dLUC}, or methane $EF_{Methane}$ and N_2O emissions EF_{N2O}.

EF_{iLUC} represents contributions from iLUC (indirect land use change).

EF_{ACI} comprises additional climate impacts (not uniformly assessed across different frameworks), such as values for the GWP of hydrogen $EF_{Hydrogen}$, impacts from high altitude emissions of air planes EF_{HAE}, and for the GWP of black carbon $EF_{Black\ Carbon}$. The individual components are introduced in the chapters to follow, in particular chapter 4.4. Further information on how CLEVER results must be reported and the requirements for the breakdown into different components can be found in chapter 3.14.

Generally, the CLEVER framework distinguishes between different types of requirements. 'Must' or 'shall' inclusions are mandatory requirements for the calculation of any emission factor under the CLEVER methodology. 'Should' inclusions are also mandatory requirements, but when a clear justification is given, an alternative approach can be described and followed. Not all requirements are relevant for all energy carrier pathways, thus CLEVER also distinguishes between 'universal' requirements (relating to all energy carrier pathways) and 'specific' requirements (only relating to the specifically mentioned energy carrier pathways).

3.1 DESCRIPTION OF THE PRODUCT SYSTEM

A clear and comprehensive description of the product system (and its value-chain) that is subject of a CLEVER assessment, including all relevant technical properties / characteristics (e.g. lower heating value, density or carbon content) of the fuel / energy carrier shall be provided. Moreover, the general technological, geographical and temporal context of the assessed energy carrier pathway shall be defined, with the goal of identification of the specific situation for which the derived results apply[3] and how they might compare to other values. If the emission factor to be calculated has a temporal limitation / time boundary, the period of time for which the emission factor is representative shall be specified. Other limitations shall also be clearly stated.

3.2 CLASSIFICATION OF ENERGY CARRIER PATHWAYS

It is recognised above that certain scope requirements may not be relevant to all energy carriers, for example, land use change.

[3] This can be the specific real situation of an economic operator, but also an average (default) value.

CLEVER follows similar terminology to the **R**enewable **E**nergy **D**irective (Directive (EU) 2018/2001, in short RED) to delineate different groupings. In any CLEVER assessment, a classification of the fuel pathway under investigation shall be conducted to help identification and comprehensibility. CLEVER groups all energy carriers under the categories of 'fossil', 'renewable electricity', 'biogenic', 'RFNBO', and 'RCF', and one additional group, 'Other low-carbon fuels', referring to possible fuel pathways that differ from the RED categories, because they do not fulfil the respective requirements (e.g. a production of an e-fuel is conceivable with grid-electricity, thus not complying with RED definitions for a RFNBO). Moreover, a combination of different categories is technically possible. Here, the respective rules apply for the different elements of the fuel according to their classification of their 'parent' categories (e.g. a fuel is parts advanced biofuel and part RFNBO, then the respective rules apply).

Energy Carrier Category	Identification Code	Definition	Examples
Fossil	FOS	Liquid, gaseous or electrical non-renewable energies produced from fossil reserves such as natural gas, coal and oil.	• Fossil diesel, gasoline, kerosene or natural gas • Hydrogen via steam methane reforming or electrolysis from natural gas.
Renewable Electricity (non-biogenic)	REE	Electrical power generation from primary renewable energy sources. This does not include nuclear energy.	• Onshore and offshore wind electricity • Solar electricity • Water electricity • Geothermal electricity
Biogenic	BIO	Liquid and gaseous fuels produced from biomass such as food and feed crops, wastes, animal fats, and non-agricultural residues.	• Biogas and biomethane • Biodiesel in the form of HVO or FAME. • Bioethanol
RFNBO (Renewable Fuels from Non-Biological Origin)	RNB	Liquid or gaseous fuels that do not derive any of their energy content from biogenic or non-renewable sources. Hydrogen used in the production of RFNBOs must also be derived from renewable and non-biological sources. This will most commonly mean via electrolysis. Electricity supplied in the production of RFNBOs must also be considered fully renewable as defined by the delegated act on RFNBOs. The carbon source used in production also has specific rules defined in the delegated act, which require it to not hold any energy content that feeds into the final fuel.	• Hydrogen from renewable non-biological sources • E-fuels such as e-gasoline or e-kerosene produced using non-biological energy sources
RCF (Recycled Carbon Fuels)	RCF	Liquid or gaseous fuels produced from liquid or solid waste streams of non-renewable origin that are not suitable for material recovery, or from waste	• Synthetic gas produced from non-biological waste

		processing or exhaust gas of non-renewable origin which is an unavoidable and unintentional consequence of the production process in industrial installations.	• Diesel, gasoline or SAF produced via Fischer Tropsch with a carbon source of non-recyclable and non-biological refuse.
Other low-carbon fuels	OTH	Includes all other fuels which may not suit any of the categories above.	• E-fuels generated from electricity grid mixes • Grid electricity • Other fringe cases

In addition to the above energy carrier categories, CLEVER recognises a need to further subdivide energy carriers according to their feedstock type to account for the associated specific scope requirements. CLEVER does not give direction for the selection of certain feedstocks for use in energy production, though the user should note that restrictions exist under different regulations e.g., RED. For biofuels, a distinction between feedstocks is made using the categories of "food or feed crops", "agricultural or forestry residues" and "waste", as different methodology aspects can apply. Furthermore, the carbon source for RFNBOs, RCFs or other low-carbon fuels is distinguished between direct air capture (DAC) and carbon capture and utilisation from a point source.

3.3 FUNCTION, FUNCTIONAL UNIT AND DECLARED UNIT

The functionality of CountEmissionsEU (as defined in the goal and scope section) is always the transportation of passengers or freight, and the functional unit is either the person-kilometre (pkm) or the tonne-kilometre (tkm) in line with any GHG assessment following ISO 14083. The CLEVER factors provide the needed energy provision GHG emission factors as well as the total GHG emission factors of a wide range of possible energy carrier pathways to convert from an amount of energy carrier consumed per tkm or pkm to a GHG emission intensity per tkm or pkm. To arrive at a more accurate assessment, they may be supplemented by operational emissions of greenhouse gases or air pollutants for very specific vehicle/ engine/ exhaust gas after-treatment configurations for different driving patterns (e. g. street categories or engine loads).

Thus, the functionality of CLEVER is always the provision and usage of an energy carrier coming from a specific energy carrier pathway for transportation purposes used in a certain vehicle and engine type. It is a sub-function of an assessment of total transport GHG emissions according to CountEmissionsEU and does not reflect the complete lifecycle of the transport, nor does it take into account other aspects of the broader CountEmissionsEU scope (e.g. vehicle lifecycle or hub operations). Following this, the CLEVER framework cannot depict the functionality of CountEmissionsEU. To reflect this, CLEVER always operates using a declared unit (or reference flow) of 1 MJ of a certain energy carrier used in a specific vehicle (instead of the functional unit of CountEmissionsEU of pkm or tkm).

The reference flow of CLEVER thus encompasses both the information on the energy carrier type and its production pathway as well as further information on the use as a transportation energy carrier. For some energy carrier pathways, a broad range of uses can be covered by the same factor (e. g. gasoline for road), while for some, a more granular approach is needed to correctly capture the impacts from the operational phase. By adding information on the production pathway, a distinction between different ways of producing the same energy carrier can be given.

Some (simplified) examples are:

- Fossil compressed natural gas used in a truck with an SI engine

- Fossil kerosene used in an airplane
- Fossil diesel used in a truck fitted with an SCR system
- Biogenic liquefied natural gas produced from biowaste (using a closed digestate storage) used in a sea ship with an Otto engine at medium speed

Depending on the energy carrier pathway, the declared unit may also refer to a specific fuel volume (e.g. litre) or a specific fuel mass (e.g. kg) as well as to an amount of energy directly. At the end of the calculation, however, a conversion to 1 MJ is done using the density and the lower heating value.

It is important to note that CLEVER EF cannot guarantee functional equivalence regarding the functional unit of CountEmissionsEU. Thus, when interpreting the results for different CLEVER EF, no conclusions can be drawn regarding the impacts on a tkm or pkm basis.

3.4 SYSTEM BOUNDARY

The system boundary shall be cradle-to-grave and shall include all significant contributions associated with the energy provision (well to tank or WtT) of the energy carrier as well as the operational (tank to wheel or TtW) processes specified in Figure 1.

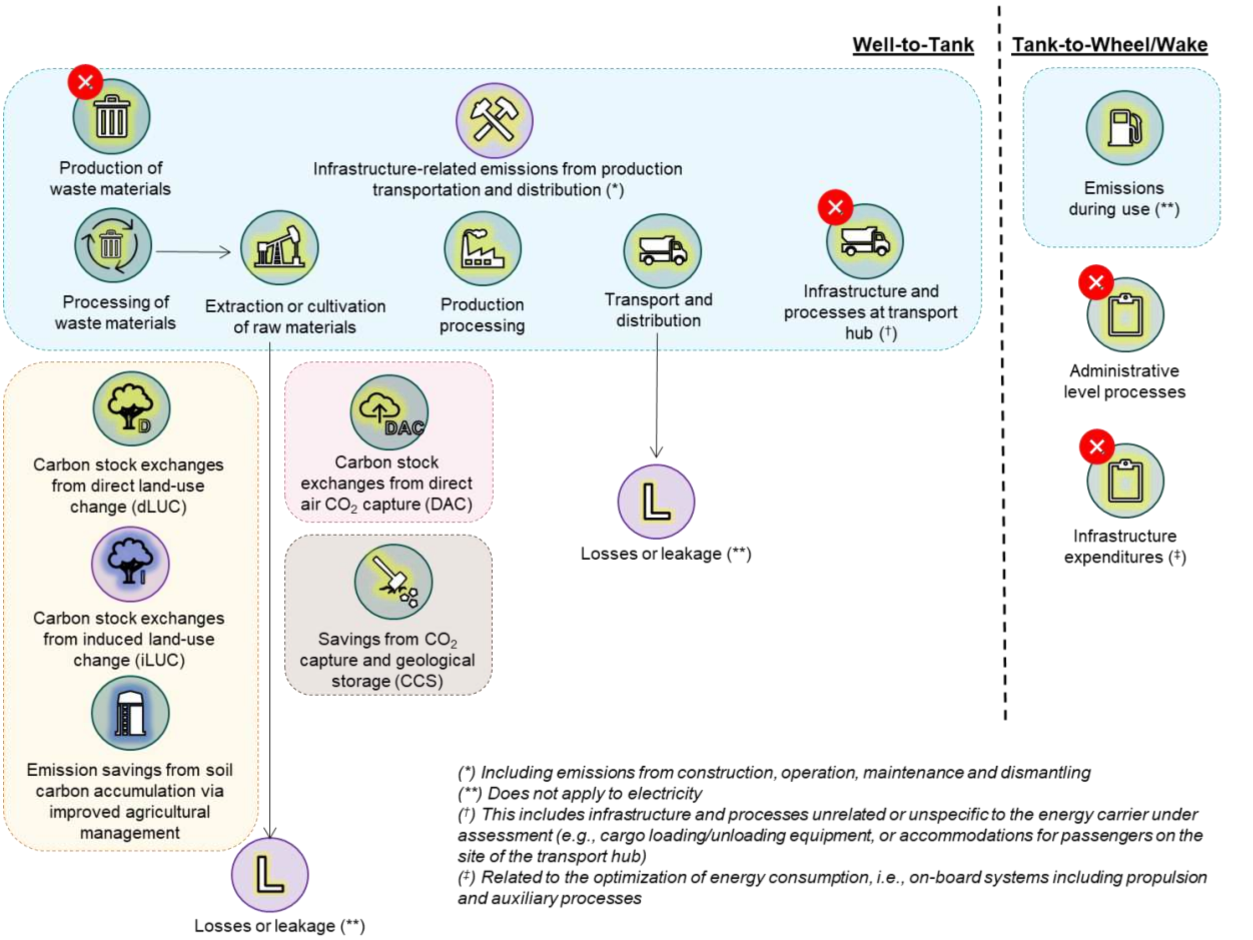

Figure 1 Simplified depiction of the CLEVER system boundary

Colour:	Key:
	Baseline process. The process requirement is considered “baseline” and as such its inclusion is always required for compliance.
	Advanced process. The process is required by CLEVER but is considered “advanced” as it is not included within RED methodology.
	The process is always excluded from the system boundary.
	Process is considered a “must”.
	Process is considered a “should”.
	Process is considered “universal” and is thus applicable to all energy carriers.
	Process is considered specific to bio-fuels, and to biomass used for electricity generation.
	Process is considered specific to some RFNBO pathways.
	Process is considered specific to some thermal electricity generation pathways (e.g. from coal, natural gas and biomass).

Processes Included

The CLEVER system boundary for the life cycle of an energy carrier (split into energy provision or **WtT** and operational or **TtW** stages) should include all of the processes listed in Table 1 below. Two levels of process requirement are possible ("**must**" and "**should**, as previously defined under "**Scope modularity**"). Additionally, for each process, indications are provided on:

- Whether the process requirement is to be considered "baseline" (its inclusion always required for compliance) or "advanced" (required by CLEVER, but flagging divergence in other related methodologies, such as e.g., RED);
  Whether the process requirement is "**universal**" (i.e., applicable to all energy carriers), or "**specific**" (only pertaining to some specific energy carrier types).

Table 1: CLEVER system boundary inclusions

WtT or TtW	Process	"must" or "should"	"Baseline" or "advanced" (with notes)	"universal" or "specific" (with notes)
WtT	Extraction or cultivation of raw materials (including processing of waste as an input)	Must	Baseline	Universal
WtT	Carbon stock exchanges caused by direct land-use change (dLUC)	Must	Baseline	Specific (only applies to bio-fuels, and to biomass used for electricity generation)
WtT	Carbon stock exchanges caused by induced land-use change (iLUC)	Should	Advanced (not included in RED)	Specific (only applies to bio-fuels, and to biomass used for electricity generation)
WtT	Emission savings from soil carbon accumulation via improved agricultural management	Should	Baseline	Specific (only applies to bio-fuels, and to biomass used for electricity generation)
WtT	Carbon stock exchanges from direct air CO_2 capture (DAC)	Must	Baseline	Specific (only applies to some RFNBO pathways)
WtT	Emission savings from CO_2 capture and geological storage (CCS)	Must	Baseline	Specific (only applies to some thermal electricity generation pathways, e.g., from coal, natural gas, biomass or hydrogen production with CCS)
WtT	Production processing	Must	Baseline	Universal
WtT	Transport and distribution	Must	Baseline	Universal

WtT or TtW	Process	"must" or "should"	"Baseline" or "advanced" (with notes)	"universal" or "specific" (with notes)
WtT	Losses or leakage as a result of extraction, transport and distribution	Must	Advanced (not included in RED)	Specific (does not apply to electricity)
WtT	Infrastructure-related emissions from production, transportation and distribution (including construction, operation, maintenance and dismantling)	Must	Advanced (not included in RED)	Universal
TtW	Emissions from the fuel during use and other operational emissions	Must	Baseline / Advanced (in parts not included in RED)	Specific (does not apply to non-ICE drivetrains)

In particular, it is acknowledged that carbon stock exchanges caused by induced land-use change (iLUC) inevitably entail a degree of consequentiality in the approach (in contradiction to the overarching intent to always adhere to a strictly attributional approach in CLEVER). However, given the potentially very large relevance of these emissions for bio-fuel pathways, sometimes to the point where iLUC becomes the key determinant of whether the total GHG emission factor of the biofuel in question ends up being lower or higher than that of its fossil counterpart, the inclusion of this process is considered mandatory in CLEVER ("should" designation). For further detail on the methodological approach and underlying general/partial equilibrium models to be used for the quantification of iLUC emissions, see Section 4.12 below.

Processes Excluded

The CLEVER system boundary[4] shall always exclude the following processes:

- Production (as opposed to processing) of materials entering the system as a waste from a previous system;
- Infrastructure and processes at transport hubs unrelated or unspecific to the energy carrier under assessment (e.g., cargo loading/unloading equipment, or accommodations for passengers on the site of the transport hub);
- Processes at the administrative level of the organisations involved in any stage of the boundary;
- Infrastructure expenditures related to the optimization of energy consumption, i.e., on-board systems including propulsion and auxiliary processes.
- Vehicle manufacturing, maintenance and end-of-life (including also batteries for electric vehicles)
- Some operational processes with minor importance for overall GHG emissions not directly linked to use of the energy carrier in a vehicle (see sub-section on 'Handling of operational emissions with a minor relevance for the overall climate impacts' below)

[4] This excludes elements that are included in the broader CountEmissionsEU scope, but are not subject to CLEVER.

General Cut-offs

All processes, flows and activities attributable to the energy carrier system under assessment must be included in the system boundary, and associated data collection must aim for completeness. Where quantitative data are available, these shall be included, in line with ISO 14044:2006, CLEVER permits the exclusion (or ‘cut-off’) of inputs or outputs, if necessary, but only if they contribute less than a specified proportion of the overall environmental significance. To ensure consistent cut-off rules are followed, CLEVER defines the cut-off criteria below.

More specifically, a CLEVER emission factor may only cut-off flows from its calculation which cumulatively contribute to 3% or less of the total life-cycle impact of the energy carrier under assessment. In other words, cumulatively, all excluded flows must remain below this threshold, thereby ensuring at least 97 % coverage of total GWP. The use of a cut-off criterion must always be clearly stated and justified.

This cut-off criterion therefore implicitly permits differences in system boundary across different energy carrier categories, i.e., where a process or a certain list of processes cumulatively contribute less than 3 % of the total impact, then such process(es) may be excluded from the system boundary. It is common that certain upstream infrastructures get cut-off from the boundary on this basis, e.g. in the case of the infrastructure of a thermal fossil powerplant.

Handling of operational emissions with a major relevance for the overall climate impacts

The scope of CountEmissionsEU and therefore the CLEVER framework covers the whole value chain needed to depict the impacts of different transport services, including emissions from vehicle / vessel operation. Some elements of the operational phase are comprised within the ‘core’ emission factor of CLEVER, in particular those related to fuel combustion, nitrous oxide and methane emissions (including slip). Others, less uniformly considered elements, such as consideration of hydrogen losses or climate impacts from high altitude emissions of airplanes or black carbon emissions from e.g. sea ships are reported separately to the ‘core’ value, given their novelty. A core principle of the CLEVER project is its modular approach to emission factor development.

Crucially, this modularity strongly encourages and facilitates the use of primary, specific data by users. For example, where operators have access to reliable data on methane slip for their specific gas engine fleet, or measured N_2O emissions from their particular ammonia-fuelled engines or SCR systems, the CLEVER framework is designed to allow these primary values to seamlessly replace the default factors provided. This prioritizes accuracy and reflects the actual performance of the technology in use, supporting more robust GHG accounting and targeted emission reduction efforts

EMISSIONS FROM METHANE SLIP AND EXHAUST GAS TREATMENT

Accurately quantifying the full climate impact of transport operations requires looking beyond the CO_2 emissions resulting from ideal fuel combustion. The generation of non-CO_2 GHGs, notably methane (CH_4) and nitrous oxide (N_2O), during vehicle operation is often highly dependent on the specific energy carrier and, crucially, the engine type, combustion conditions, and aftertreatment technology employed. The CLEVER methodology will address these complexities by incorporating the potential to develop technology-specific emission factors for CH_4 and N_2O within its modular framework.

Methane emissions during the operational phase primarily arise from 'methane slip' in engines utilizing gaseous fuels like natural gas (CNG/LNG) or biomethane. Methane slip refers to the release of uncombusted methane fuel through the exhaust. Given methane's high GWP (both, fossil and biogenic), even small amounts of slip can significantly increase the overall TTW GHG emissions, potentially offsetting the CO_2 benefits compared to liquid fuels. The extent of methane slip varies considerably depending on the engine technology (e.g., spark-ignition vs. high-pressure direct injection, lean-burn vs. stoichiometric, specific dual-fuel engine designs) and potentially its age and maintenance condition. Recognizing this variability, the CLEVER methodology will provide default methane slip factors differentiated by major engine technology categories relevant to road, maritime, and other transport applications.

N_2O is also formed during combustion processes. While present in the exhaust of conventional fuel engines, its emission levels can be particularly significant and variable when using alternative fuels like ammonia (NH_3). The combustion chemistry of ammonia is complex, and under certain conditions (influenced by temperature, pressure, fuel/air mix, catalysts), significant amounts of N_2O can be produced, alongside desired N_2 and water. Furthermore, Selective Catalytic Reduction (SCR) systems, commonly used to reduce NO_X emissions (especially in modern diesel engines, and potentially future ammonia engines), can also inadvertently generate N_2O as a by-product. The CLEVER methodology will therefore account for operational N_2O emissions, aiming to provide differentiated factors based on fuel type, primary engine technology, and the presence/type of relevant aftertreatment systems (like SCR), while acknowledging the higher uncertainty and data scarcity, especially for emerging pathways like ammonia combustion.

Within a CLEVER assessment, values for methane (incl. slip) are represented by $EF_{Methane}$, while N_2O emissions are covered under EF_{N2O}. Both must be included into the ‘core’ emission factor.

GLOBAL WARMING POTENTIAL OF HYDROGEN

The use of hydrogen as a transport fuel, either in Internal Combustion Engines (ICEs) or Fuel Cells (FCs), introduces operational emission considerations beyond the primary water vapor output. Specifically, "hydrogen slip" – the release of uncombusted or unreacted hydrogen from the energy converter (engine or fuel cell stack) during operation – needs to be accounted for. While distinct from fugitive hydrogen losses from storage tanks or distribution infrastructure (which are considered in the energy provision phase or as separate operational fugitive emissions), hydrogen slip contributes directly to the operational emissions profile.

Hydrogen itself is not a direct GHG, but it acts as an indirect one, influencing the atmospheric concentrations of methane, ozone, and stratospheric water vapor, ultimately contributing to warming. Based on recent scientific assessments, although not yet formally adopted in IPCC GWP tables, hydrogen exhibits a significant climate impact. For the purposes of the CLEVER methodology, a GWP100 of 11.6 kg CO_2e per kg H_2 will be utilized, reflecting current scientific understanding[5]. Recognizing that official GWP values for hydrogen will further evolve, the climate impact associated with hydrogen emissions (both slip and any upstream fugitive losses allocated to the operational phase) will be reported as a separate H_2-specific CO_2e value within the CLEVER framework, as part of the additional climate impacts covered in CLEVER. This approach ensures transparency and allows users to easily adjust the total GHG impact in the future should the official GWP100 for hydrogen be updated by bodies like the IPCC.

[5] For reference, see Sand, M., Skeie, R.B., Sandstad, M. *et al.* A multi-model assessment of the Global Warming Potential of hydrogen. *Commun Earth Environ* **4**, 203 (2023). https://doi.org/10.1038/s43247-023-00857-8

Consistent with its overall approach, the CLEVER methodology will adopt a modular structure for hydrogen emission factors. This will involve providing default operational emission factors that account for hydrogen slip, differentiated where possible based on the energy conversion technology (ICE vs. FC) and potentially sub-categories, if data allows.

This modularity enables and encourages the integration of primary data. Operators who have access to specific, measured data regarding hydrogen slip or total operational hydrogen losses for their fleet or equipment are strongly encouraged to use these primary values within the CLEVER framework. Substituting default values with verified, specific data will significantly enhance the accuracy and relevance of the resulting GHG emission calculations, providing a truer picture of operational performance.

Within a CLEVER assessment, values for the GWP of hydrogen emissions are represented by $EF_{Hydrogen}$ and will be grouped under the emission factor for additional climate impacts.

IMPACTS FROM HIGH ALTITUDE EMISSIONS

Aircraft operating at high altitudes generate climate impacts beyond their direct CO_2 emissions. These "non-CO_2 aviation effects" include the formation of persistent condensation trails (contrails) and contrail-cirrus clouds, and the impact of nitrogen oxides on atmospheric ozone and methane concentrations, as well as direct emissions of water vapor, black carbon, and sulphate aerosols. Collectively, these effects contribute significantly to aviation's overall climate forcing, particularly on shorter time scales, but their quantification is associated with considerable variations in the values due to complex dependencies on altitude, geographical location, atmospheric conditions, time of day, and aircraft/engine technology. Thus, any generalised factor will be associated with a certain uncertainty.

Despite the uncertainties, the magnitude of these effects (an increase in the climate impacts from aircrafts of 40 % to 70 %) necessitates their consideration in a comprehensive assessment of aviation's climate impact. Many current emission factor systems either omit these effects or use highly simplified approaches. The CLEVER methodology aims to provide a transparent way to acknowledge these effects within its emission factor framework, balancing the need for inclusion with the current scientific complexities.

The precise methodology for integrating these non-CO_2 effects within the CLEVER emission factors is currently under development. The strategy being explored aims to accommodate different levels of assessment detail and user needs. For users needing detailed analysis of non-CO_2 aviation effects, especially for specific flights, CLEVER will refer to the EU MRV system (Monitoring, Reporting and Verification of CO_2 emissions) under the ETS II (European Union Emissions Trading System) and the NEATS (Non-CO_2 Aviation Effects Tracking System) IT tool for quantification[6]. To ensure these impacts are considered in more general applications, CLEVER will use a standardized approach to represent the average climate impact of these non-CO_2 effects.

The CO_2-equivalent impact derived from this standardized CLEVER approach will be reported as a separate, distinct component alongside the other factors depicting parts of the value chain, such as the ‘core’ value. This will allow users to:

- Clearly identify the contribution of non-CO_2 aviation effects.

6 https://climate.ec.europa.eu/document/download/2efafc7e-8b25-4763-906f-a7ba23b466d2_en?filename=policy_ets_avaiation_explainer_non-co2_mrv_tasks_for_ao_en.pdf

- Adapt their reporting, if operators want to utilize a CLEVER value for other specific frameworks (e.g., a corporate reporting scheme) that can have different scopes or requirements for non-CO_2 effects.
- Facilitate future updates. As scientific understanding improves and more refined GWP-like metrics or consensus approaches for non-CO_2 aviation effects are established by authoritative bodies, this separate component can be readily adjusted without altering the other modular emission factors.

Within a CLEVER assessment, values for the non-CO_2 climate impacts from high altitude emissions are represented by EF_{HAE} and will be grouped under the emission factor for additional climate impacts.

GLOBAL WARMING POTENTIAL OF BLACK CARBON FORMATION

Black Carbon (BC), a component of particulate matter also known as soot, is a potent short-lived climate pollutant with significant atmospheric warming effects. It impacts climate through various mechanisms, including the absorption of sunlight in the atmosphere and the reduction of reflectivity when deposited on snow and ice, accelerating melting.

Despite its recognized climate impact, BC is not currently assigned a Global Warming Potential by the IPCC, and its comprehensive integration into standardized GHG emission factor methodologies remains a challenge. Most existing emission factor databases do not systematically include BC's climate effects in CO_2-equivalent terms, often due to the complexities in quantifying its diverse impacts and the lack of a universally agreed metric.

The CLEVER project acknowledges the importance of addressing the climate impact of BC emissions from transport operations. The specific methodology for quantifying and incorporating the climate effects of BC within the CLEVER emission factors will be guided by the practical guidelines developed by the Stockholm Environment Institute (SEI) and Climate and Clean Air Coalition (CCAC) (Stockholm Environment Institute and Climate and Clean Air Coalition, 2022) , and forthcoming guidance on addressing air pollutant emissions and BC as an annex to the GLEC Framework This updated guidance is anticipated for publication around autumn 2025.

Consistent with the approach for other climate forcers with evolving metrics or significant uncertainties, it is envisaged that any climate impact attributed to BC emissions, based on the GLEC guidance or other emerging scientific consensus, will be reported as a separate component within the CLEVER emission factor. This will ensure transparency and allow for straightforward adjustments in the future as scientific understanding and standardized metrics for BC's climate impact mature and become more widely adopted.

Within a CLEVER assessment, values for the GWP of black carbon emissions are represented by $EF_{Black\ Carbon}$ and will be grouped under the emission factor for additional climate impacts.

Handling of operational emissions with a minor relevance for the overall climate impacts

Not included (and thus cut- off) are:

- *Emissions from unintentional lubricant oil combustion*:
  The emissions from unintentional lubricant oil combustion constitute a small fraction compared to the substantial CO_2 emissions generated from fuel combustion (only about 0.19% of the CO_2 emissions from the road transport sector are due to unintentional lubricant oil consumption). Additionally, lubricant oil is not intended for energy conversion like fuel, hence its emissions are not a primary focus in efforts to manage energy-related impacts. Furthermore, the methodologies

for estimating emissions from lubricant oil combustion are subject to high uncertainties and variability, potentially leading to inaccuracies in the overall GHG inventory.

- *Emissions from fuel evaporation for gasoline engines*:
  Fuel evaporation losses typically account for only about 1% to 2% of total annual fuel consumption of gasoline vehicles. While evaporative emissions contribute to air pollution, their presence signifies a reduction in CO_2 emissions, as the fuel is not burned in the engine. Additionally, methodologies for estimating evaporative emissions are complex, incorporating factors such as emissions control technology, fuel specifications, driving dynamics, and even ambient conditions like temperature, and are subject to high uncertainties, potentially leading to inaccuracies in the overall GHG inventory.

CLEVER GHG emissions factors must always differentiate not only the energy carrier pathway, but also the usage of this energy carrier. However, to make things easier, for some energy carrier types, a range of different engine/ vehicle types can be captured using the same factor by using an average over a range of different applications. This might lead to a possible over or underestimating of certain impacts, whenever an underestimation occurs this must always stay below the overall cut-off criteria specified.

For instance, the nitrous oxide emission factors of a typical medium-sized heavy-duty truck (weighing between 14 to 20 tonnes) vary depending on the Euro vehicle standard, reflecting the developments in regulatory measures and technology. Specifically, the emission factors, as calculated with COPERT (Calculations of Emissions from Road Transports – tool), are as follows: 0.0015 g/MJ for Euro I and II, 0.0007 g/MJ for Euro III, 0.0016 g/MJ for Euro IV, 0.0044 g/MJ for Euro V, 0.0054 g/MJ for Euro VI, and 0.0025 g/MJ for Euro VII. The increase at Euro IV and Euro V is largely due to the use of SCR to comply with the strict NO_X emissions standards. This example illustrates the importance of tailoring emission factors to capture the differentiation between energy carrier pathways and vehicle usage within the CLEVER framework.

3.5 LIFE CYCLE INVENTORY (LCI) MODELLING

As the approach to life cycle inventory modelling, an attributional approach shall always be utilized (as described in the goal section). This extends to all data sets and processes utilized within the inventory modelling, and with the exemption of the iLUC-value (see chapter 4.12), which is in its nature consequential, all other elements shall strictly follow attributional modelling principles. This includes specifically the addressing of multifunctionality (see chapter 3.8). Another key influencing factor for the appropriate modelling of the LCI, data appropriateness and quality is described in the following chapter.

3.6 DATA AND DATA QUALITY

Data must be collected for all unit processes within the system boundary, and the sources and quality of data used in the generation of emission factors must be documented and assessed. A CLEVER assessment shall utilize the best data available. Moreover, utilized data shall be characterized both quantitatively and qualitatively. Data used in the generation of energy carrier impact calculation will stem from a combination of sources. This section provides guidance on the assessment of data in the context of the CLEVER framework.

CLEVER identifies the following types of data:

1. **Primary data** – foreground activity data collected by a specific organisation for the production of a product under its own operation for which the immediate LCA is being undertaken. For example, the quantity of electricity required to manufacture the assessed product.
2. **Secondary data** – either foreground or background data, which has been derived from an existing database, literature source or supplier. For example, emissions factor profile for producing 1 kg of low-alloyed steel.

Where the use of secondary data is required, CLEVER defines the following hierarchy to be followed in order of preference:

1. Verified foreground or background data from an organisation in the direct value chain
2. Verified industry average life-cycle data from LCI databases, industry association reports, government statistics, etc.
3. Foreground or background data from literature or scientific papers, including proxies
4. Foreground data based on assumptions

General Data Quality Requirements

Data quality of the study must be specified for both, primary and secondary data, and minimum requirements exist under certain circumstances.

ISO 14044:2006 requires data quality to be assessed and provides recommended aspects to consider (for reference, see chapter 4.2.3.6 of ISO 14044:2006), however, it does not explicitly state, how to undertake the assessment. The European Commission's Product Environmental Footprint (PEF) methodology on the other hand provides specific requirements for undertaking a data quality assessment. CLEVER's requirement for data quality therefore combines both approaches to ensure a robust and standardised assessment takes place.

CLEVER requires that the ten data quality aspects listed in ISO 14044:2006, and repeated below in Table 2, must be considered for all studies, regardless of whether the study is comparative.

Table 2: Data quality aspects and definitions to be considered for a CLEVER study.

Data Quality Aspect	Description
Time-related coverage	Desired age of data and the minimum length of time over which data should be collected.
Geographical coverage	Area from which data for unit processes should be collected to satisfy the goal of the study.
Technology coverage	Type of technology (specific or average mix).
Precision	Measure of the variability of the data values for each data expressed (e.g., variance).

Completeness	Percentage of flow that is measured or estimated.
Representativeness	Assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage).
Consistency	Assessment of whether the study methodology is applied uniformly to the various components of analysis.
Reproducibility	Assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study.
Sources of the data	Assessment of the data sources used.
Uncertainty of the information	Uncertainty associated with e.g., data, models, assumptions.

The assessment for each aspect is either undertaken qualitatively or quantitively, depending on the aspect. Where PEF has established a quantitative scoring procedure for a specific aspect, this shall be utilised, otherwise, a qualitative assessment is sufficient.

Table 3: Assessment format for data quality aspects

Aspect	Primary data assessment	Secondary data assessment
Time-related coverage	Quantitative using PEF matrix	Quantitative using PEF matrix
Geographical coverage	Quantitative using PEF matrix	Quantitative using PEF matrix
Technology coverage	Quantitative using PEF matrix	Quantitative using PEF matrix
Precision	Quantitative using PEF matrix	Qualitative
Completeness	Qualitative	Qualitative
Representativeness	Qualitative	Qualitative
Consistency	Qualitative	Qualitative
Reproducibility	Qualitative	Qualitative
Sources of the data	Qualitative	Qualitative
Uncertainty of the information	Qualitative	Qualitative

Quantitative Assessment

The PEF guidelines provide detailed scoring criteria for each associated data quality aspect, which results in a score/rating, ranging from 1 to 5 (with 1 being the best and 5 being the worst) for each data quality aspect and data type. PEF provides specific requirements for a data point to achieve a certain score, with different requirements noted for primary and secondary data points.

Once all data points have been assessed individually using the PEF scoring criteria for all relevant aspects, PEF requires an additional step to calculate an overall primary and overall secondary data quality rating (DQR) score. These scores are calculated via a weighted average, which considers the individual data point's contribution to the overall climate impact[7]. Once a DQR is achieved for the primary and secondary data, both of these scores are to then to feed into a further calculation of overall DQR for the study.

Qualitative Assessment

Whilst PEF does not provide quantitative scoring for all data quality aspects, CLEVER requires the remaining aspects to be assessed qualitatively. This must take the form of a written statement for each aspect which includes:

- The data quality requirement set for the aspect during the scope definition
- Identification and discussion of the key factors influencing the data quality aspect
- Evaluation statement of how the study data (primary and secondary) compares to the data quality requirement set
- Identification of any data points that have been assessed as not meeting the data quality requirement for the aspect and discussion of the limitations it imposes on the study

Every CLEVER-compliant study must state the primary and secondary data quality requirements for each aspect, as well as undertake evaluation and scoring for the data quality assessment, concluding with an overall data quality rating.

Default Factors Minimum Requirement

The above process to data quality definition and assessment must be followed for all assessments using the CLEVER methodology, e.g., actual factors calculated by economic operators, and provides flexibility to the practitioner creating actual values to define their own data quality requirements.

In instances where the methodology is followed with the intention of adding to the list of default emission factors within the CountEmissionsEU reference database, minimum data and data quality requirements exist and are stated in Table 4 below.

CLEVER requires that any data point used in the study (foreground, background, primary or secondary) must conform to the below data quality requirements if it contributes 10 % or more to the total GWP impact of the study. Should a single data point contribute less than this, the Table 4 data quality requirements should still be considered a minimum target, however, quantitative scores may be higher if appropriate explanation is provided demonstrating the minimal influence on the overall results.

If a single data point contributes equal to or greater than 10% of the total GWP impact yet cannot meet the minimum data quality requirements below, the generated result should not be added to the CountEmissionsEU reference database.

[7] This weighting diverges from PEF as the guidelines instead focus on weighting based on an 80% impact threshold which considers impact categories beyond ”Climate Change”.

Table 4: Data quality requirements set for a CLEVER default emission factor

Aspect	Primary data quality requirements	Secondary data quality requirements
Time-related coverage	Min score: 3 Data should represent the current situation of the date of study, or as close as possible. It should be no more than three annual administration periods dated.	Min score: 5 Data should aim to be no older than two years beyond the time validity of the dataset. No data should be older than 10 years old beyond the time validity of the dataset.*
Geographical coverage	Min score: 2 Data should be representative of the geographical areas where the individual unit processes occur. The activity data and elementary flows must partly reflect the geography. where the process modelled takes place.	Min score: 3 Data should be representative of the geographical areas where the individual unit processes occur. The process modelled in the study takes place in one of the geographical regions for which the dataset is valid.
Technology coverage	Min score: 2 Data should be representative of the technology used in the process being represented. It should be the exact technology but – at minimum – a proxy.	Min score: 4 Data should be representative of the technology used in the process being represented. The technologies used in the study must be similar to those included in the scope of the dataset.
Precision	Min score: 3 Measured/calculated /literature data and plausibility not checked by reviewer OR qualified estimate based on calculations plausibility checked by reviewer.	Data that has been derived based on measurements or qualified calculations / estimates will be used for this study.
Completeness	All environmentally relevant material/energy flows and other environmental interventions as required for adherence to the system boundary, the data requirements and the impact assessment method shall be included in the study.	
Representativeness	The data should fulfil the defined time-related, geographical and technological scope.	
Consistency	All methods and assumptions shall be applied in a sufficiently consistent way to all life cycle stages, parameters, and flows of the analysed system(s), including across foreground and background systems. All LCI data shall be sufficiently consistent regarding accuracy, precision, and completeness, in line with the goal of the study.	
Reproducibility	Information about the method and data will be provided.	
Sources of the data	Data will be derived from the company and or suppliers.	Data will be derived from credible sources and references will be provided e.g. literature or databases
Uncertainty of the information	A sensitivity and qualitative uncertainty analysis will be conducted on the key area(s) of uncertainty of environmental significance.	

* This timescale of 10 years diverges from PEF requirements due to CLEVER's understanding that widely used LCA databases for emission factors tend to have longer periods of validity but are accompanied by regular checks to ensure they still appropriately reflect present-day practices.

Comparisons of CLEVER outputs

Under circumstances where two or more energy carrier emission factors are compared, the equivalence of the systems and associated data quality must be evaluated before interpreting the results. This must be enacted for both CLEVER default factors and actual values. Whilst CLEVER default factors intend to be developed with consideration of likely comparison by users, it cannot be guaranteed that the system boundary and data quality associated with each factor will be exactly aligned to make them comparable. Therefore, as mentioned, consideration of system boundary and data quality should be taken prior to consideration of results. CLEVER follows the recommendation by ISO 14044:2006 that a critical review should be performed if comparative assertions are intended to be disclosed to the public.

3.7 ASSUMPTIONS AND LIMITATIONS

Any key assumption that was made must be clearly stated and described. Moreover, if an assumption greatly / significantly influences overall results, a sensitivity analysis shall be performed to assess the significance of the assumption. Where assumptions have significant influence on results, they shall be assessed by means of a sensitivity analysis[8]. Key assumptions pertain methodical choices as well as both fore- and background data.

If limitations to the investigated fuel pathway exist, they must be stated and described clearly to allow for the reader to draw correct conclusions. Limitations might pertain:

- General methodological limitations (e.g. which key methodical choices or assumptions were taken and how they might limit the interpretation of results)
- General context (e.g. with respect to the utilized technology and / or specifics of the fuel production and utilization, see chapter 4.1)
- Geographical coverage
- Temporal coverage
- Limitations to the utilized data: Inconsistencies of applied data, e.g. as regards their temporal coverage, or their general appropriateness for the investigated product system shall be stated;

The consequences of the limitations, especially with regard to the interpretation of results and their comparability with other values shall be stated within the report / documentation.

[8] For example, the choice of electricity mix can have significant influence on results. If the electricity mix is not based on official data or calculations based on official data, but rather assumed (e.g. to depict changes over time), and choice of carbon intensity of the consumed electricity shows significant impact on overal results, a sensitivity analysis with a different assumed electricity mix helps contextualize results and put them into perspective.

3.8 HANDLING OF MULTIFUNCIONALITY

During LCI modelling, some processes, referred to as “multifunctional” or “multi-output” processes, deliver multiple useful outputs, usually multiple products. Of these, one is sometimes referred to as the main (intended) product, and the others are classified as secondary co-products (i.e., other valuable outputs), while others are classified as wastes.

Systems involving multi-functionality of processes must be modelled in line with the decision hierarchy defined by ISO 14044:2006 and then also adopted within the EF method (Recommendations 2279/2021 - Annex I – section 4.5). This hierarchy lists the following options:

1. **Subdivision or system expansion (with or without substitution)**
2. **Allocation based on a relevant underlying physical relationship (mass or energy), or**
3. **Economic allocation**

According to this hierarchy, wherever possible, **subdivision or system expansion (with or without substitution)** should be used to avoid allocation.

Subdivision is straightforward, and it works by breaking down a single multifunctional process into smaller, monofunctional sub-processes, each responsible for a distinct output or function. Where subdivision is possible, inventory data is collected only for those unit processes directly attributable to the goods/services of concern. Emissions and burdens can thus be attributed to the distinct product or function directly, and no other metric of allocating burdens is needed.

System expansion refers to expanding the system boundary by including additional functions related to the co-products. If the system boundary may be expanded, the additional co-products/functions can be included in the analysis, and the cumulative life-cycle impacts communicated for the expanded system as a whole rather than for one individual product only. However, if the aim of the study is to focus on one single product (e.g., one specific energy carrier or fuel, as is the case in CLEVER), then system expansion is not a suitable approach, unless substitution can be applied in a very tightly defined manner, as discussed below.

System expansion with substitution is an approach that may be used when the co-product(s) of a multifunctional process result in a reduced need for the production of one or more alternative product(s). However, system expansion with substitution should only be applied when there is a clearly defined and widely recognised “dominant” primary product and production pathway that each co-product replaces, as agreed by sector consensus. In terms of its possible application to CLEVER-relevant energy carriers, system expansion with substitution may be considered as an option in selected cases, like for instance:

- Electricity and heat co-generation by a thermal power plant, where an alternative “dominant” process may be identified to generate the heat, which is considered as the “substitutable” co-product
- Fatty Acid Methyl Esters (FAME) biofuel production, where an alternative “dominant” may be identified for the production of the glycerol (chemical), which is considered as the “substitutable” co-product (however, care should be exercised in these cases, as beyond a certain level of production, there may no longer be a viable market for the co-product, thereby essentially turning the latter into a waste).

In most cases, however, neither subdivision nor system expansion (not even with substitution) are possible options, and therefore **allocation** cannot be avoided. Thus, allocation is the preferred approach to address multifunctionality in CLEVER assessments.

The preferred option for allocation in CLEVER, consistently with the ISO hierarchy, is then **physical allocation**, whereby all the inputs and outputs to/from the multifunctional process are partitioned (allocated) between the various co-products. The physical relationship may be established using metrics such as:

- Produced mass (e.g., kg of steel vs. aluminium);
- Number of units (e.g., parts per batch);
- Energy or exergy content (e.g., MJ in fuel co-products).

The latter option (**physical allocation based on energy or exergy content**) is used as the default in CLEVER for all multifunctional processes directly responsible for the (co)-production of energy carriers. More specifically, energy-based allocation with the lower heating value (LHV) shall be the preferred allocation metric, with the exception of power and heat co-generation, where exergy-based allocation is recommended. When a process results in more than one product[9], process expenditures shall be allocated among products according to their respective LHV. Exergy is the theoretically maximum amount of energy that can be reversibly converted into work, with reference to a conventional "reference environment". As such, the exergy of an energy carrier is always lower than its energy, and more significantly so when dealing with thermal fuels. The most applicable example is electricity and heat generation (CHP), where electricity has a considerably higher exergy (comparable to its energy), compared to heat (for which exergy << energy).

For specific multifunctional processes for which physical allocation may lead to underestimation of the impact to some co-products and allocation based on energy (or exergy) does not apply[10], **economic allocation** is recommended instead. A typical case in point where this condition applies is that of metal co-production, where often the higher-value metal(s) are co-produced in smaller quantities together with their respective "parent" metals (e.g., silver and copper as co-products of zinc from zinc ore mining). In these cases, economic allocation (based on the relative market values of the co-products) is better suited than physical allocation (based on the relative masses) to reflect the actual economic driving forces that underpin the mining activities. In the case of metals co-production, this same logic (and choice of economic allocation) is also almost universally adopted by most widely-used LCI databases (e.g. ecoinvent)

Finally, two specific types of multifunctional processes need to be mentioned and discussed specifically:

Allocation of biogenic carbon in multi-outputs (i.e. co-processing), covered in chapter 4.11. Allocation of captured fossil carbon as a co-product of systems equipped with Carbon Capture and Utilization (CCU) equipment. When CCU is employed, if CO_2 from fossil fuel combustion is captured (e.g., at a power plant stack) and later "utilized" to produce a synthetic fuel, the captured CO_2 can only be accounted for as either (i) reducing the CO_2 emission intensity of the CCU-equipped emitter (e.g., as reduced GHG emissions assigned to the electricity generated by the power plant), or (ii) as a negative

[9] Wastes are by definition not intended and thus, not responsible for any burdens.

[10] This can be the case, when products either do not have a LHV or the produced products generate their value based on other characteristics than their function as energy carriers.

contribution to the GHG emission accounting along the (WtT) supply chain of the synthetic fuel, but not both.

In most real-world situations, whenever CCU equipment is implemented, the former accounting (i) may be reasonably assumed to have already been applied to the CCU-equipped emitter (e.g., credited to electricity generation), and hence no negative fossil CO_2 emission contribution should be assigned to the synthetic fuel pathway. Doing otherwise (i.e., accounting for and reporting – even separately – CCU-derived CO_2 negative emissions in the supply chain of the synthetic fuel) would convey a misleading message that would implicitly equate to double counting.

An identical argument also applies to biogenic CO_2 removals, if/when they arise from CCU implemented at bio-energy power plants (where a net negative CO_2 emission contribution would likely already have been accounted for as a co-product of the electricity generated by those same plants). Hence, in these cases, too, no biogenic CO_2 removal should be assigned to the synthetic fuel pathway, nor reported (not even separately).

Most processes along the energy provision (WtT) supply chain of an energy carrier usually produce some waste flows (unintended residues with no certain further use). The term “waste” refers to materials discarded in compliance with legal requirements or without assured reuse, e.g., paint sludge. The downstream treatment processes for these waste materials (and the associated emissions) are modelled as contributing to the emissions burden of the main (primary) product (i.e., the wastes themselves are not assigned any emissions/impacts, unless they are reprocessed into recycled feedstock through methods exceeding standard industrial practices, e.g., chemical recycling or advanced purification, as in the case of metal shavings). For further discussion of waste modelling, see **Section 3.10.**

3.9 END-OF-LIFE

CLEVER uses the cut-off approach, as applied among others within the ecoinvent database for waste treatment. Thus, the primary production of a material is always allocated to the primary user. Whenever a material is recycled at the end of life of a product system’s life cycle, that same product system does not receive any type of credit for the provision of this recyclable material. These recyclable materials are then available burden-free for any subsequent product system which may utilise them, and which will only bear the impacts from the recycling processes themselves. The responsibility for the waste treatment instead always stays with the first product system.

In many cases, the impact of this End-of-Life modeling is fairly small. Whenever the input of secondary material and the output of recyclable material are similar to each other, the results resemble a closed-loop recycling approach. The approach favors the use of secondary material while not incentivizing the provision of recyclable material at end of life.

3.10 WASTE DEFINITION

In CLEVER, different material flows are distinguished, such as for example products, co-products / by-products and wastes. In line with the EU’s Waste Framework Directive (Directive 2008/98/EC), wastes are defined as ‘any substance or object which the holder discards or intends or is required to discard’ (Art. 3 (1)). Key for classification of a material flow as waste is therefore primarily the intent to discard, or the act of (or requirement to), discarding said material, irrespective of the fate of the material or the subsequent treatment / handling. Wastes can moreover have a positive market value (e.g. UCO) which can be closely linked to waste characteristics[11].

When a material flow is identified as waste, it shall not bear any burdens from the waste-generating process. Following this, all burdens from a process shall only be allocated among products and co-products (by-products) from the process, if a process results in both, products and wastes. Co-products are generated, if a process results in more than one product output.

If a waste is utilized as a feedstock or input to a process, only emissions at the point of waste collection and onward shall be attributed / allocated to the waste and subsequently, the waste utilizing process. Following this, wastes feedstocks don't carry any burdens associated with the primary life cycle of the product-turned-waste (100:0 system allocation[12]).

Challenges of fraudulent practices in the European biofuels market with waste-based feedstocks

Waste-based biofuels, defined and mandated by the RED (more specifically within Annex IX, part a and part b) saw substantial growth within the European biofuels market, primarily due to their high emission saving potential. However, especially UCO (used cooking oil) and increasingly POME (palm oil mill effluent) as well as other waste-based feedstocks, mainly biogenic oils from industrial waste, sometimes also referred to as 'brown grease', are suspect of fraudulent practices, such as re-declaring virgin vegetable oil, like palm oil as wastes. These challenges are especially pronounced when these feedstocks are imported from third countries with limited market access for auditors. This has led to these feedstocks being heavily scrutinized in Europe in the last years, with some certification schemes assessing them as high risk. However, so far, no credible mitigation strategy to avoid criminal activities was successful. Special attention shall thus be paid regarding the credibility of waste-based feedstocks when they are subject of a CLEVER assessment.

3.11 ATTRIBUTION OF BIOGENIC CARBON IN MULTI-OUTPUTS

The attribution of biogenic carbon in multi-output systems shall be in line with the principles of Delegated Regulation (EU) 2023/1640).

If within a process or process stage, both a fossil and a biogenic carbon source are utilized (e.g. during co-processing of fossil and biogenic intermediates / feedstocks within a shared process) and the product or products from this process contain carbon, the biogenic carbon shall be attributed to all resulting products in accordance with physical reality. To this end, the carbon content and origin of carbon shall be determined by measurement for all products from the process, while the total biogenic carbon amount in products together with potential process losses (e.g. in the form of biogenic CO_2 emissions, solid wastes, waste water) shall equal the biogenic carbon fed to the process.

[11] The positive market value is caused primarily by UCO's waste characteristics and thus applicability for different purposes.

[12] Moreover, no credits for waste utilizations apply, e.g. for 'avoided emissions' in the case of a waste stream utilized to produce fuels no longer needs to be treated in a different manner.

As a method of choice, the radiocarbon method (^{14}C) as outlined in Delegated Regulation (EU) 2023/1640) shall be chosen as primary main methods[13]. Moreover, the exemptions regarding the choice of main testing method for the attribution of carbon laid out in Article 1 et seq. apply.

3.12 HANDLING OF LAND USE AND LAND-USE CHANGE

When land is converted from one use form, defined and classified in land-use categories (for reference, see IPCC Good Practice Guidance for LULUCF, Chapter 2.2) to arable land / "cropland" for the purpose of producing biomass as feedstock for the production of biofuels, associated land use-change emissions shall be calculated and accounted for. Reference date for consideration of LUC associated emissions is January 1st 2008.

In principle, two forms of land-use change are distinguished: direct land-use change (dLUC) and indirect land-use change (iLUC). Direct land-use change occurs if the change in utilization of land from one category to arable land / ["cropland"] occurs directly with the purpose of producing biofuels[14]. Indirect land-use change occurs, if the change in utilization of land from one category to arable land / ["cropland"] occurs as an induced result, following an introduction / uptake or expansion of biomass cultivation for the purpose of biofuel production on already established arable land and thus, previous agricultural activities (e.g. for the production of food or feed crops) are being displaced, leading to said land-use change. For both, dLUC and iLUC, emissions occurring due to LUC are annualized over a 20-year time horizon[15].

Within the CLEVER framework, both dLUC and iLUC are assessed in a quantified approach[16], leading to specific emission factors that are part of the total CLEVER emission factor. If dLUC occurs, the respective emission factor EF_{dLUC} shall be grouped under the 'core' emission factor. If iLUC occurs, the respective emission factor EF_{iLUC} shall be reported separately, following the modularity concept (see section Modularity principle of the CLEVER framework).

If dLUC occurs, emissions shall be calculated based on current IPCC guidelines, more specifically Volume 4: Agriculture, Forestry and Other Land Use, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

If iLUC occurs, emissions shall be calculated following ICAOs CORSIA methodology "Calculation of induced Land Use Change vales" (Part III CORSIA supporting document – Life cycle assessment methodology).

[13] Article 6 of Delegated Regulation (EU) 2023/1640 specifies AMS – Accelerator Mass Spectrometry or LSC – Liquid Scintillation Counting as reference methods.

[14] In other words: the land where cultivation of biomass takes place is part of the system or within the system boundary.

[15] Corresponding to utilizing IPCC's Tier 1 approach, in other words: total LUC related emissions are spread over a 20y period, with each year being attributed 1/20 of total emissions. For example, if LUC occured in 2010, all sourced biomass from this land will be attributed respective emissions / removals until 2030.

[16] As alternative to quantifying LUC contributions, a risk-based assessment of feedstocks and subsequent exclusion of specific feedstocks assessed as high-LUC risk exists and is utilized e.g. within the EC's Renewable Energy Directive (Directive (EC) 2001/2018)

If in the future, a different approach to the assessment of emissions/removals from iLUC will be the scientific and political consensus, the CLEVER framework shall consider the consensus approach and adopt it if considered suitable for the context of CLEVER / CountEmissionsEU.

3.13 LIFE CYCLE IMPACT ASSESSMENT (LCIA) METHODOLOGY

CLEVER GHG emission factors must include all relevant climate impacts from the provision and the usage of the energy carriers in transportation. The scope is limited to the impact category of "Climate Change" (at midpoint level). At its core, any CLEVER assessment must include all climate impacts given in the latest IPCC guideline [17] using the GWP_{100} (global warming potential with a 100-year perspective without feedback) since it is the most widely used and accepted metric. In addition, a GWP_{100} factor for hydrogen of 11.6 kg CO_2e/kg (Warwick, et al., 2022; Ocko & Hamburg, 2022; European Commission, et al., 2022) should be used, as this GHG will probably be added in the next IPCC assessment report. Other metrics may also be used in addition (e. g. the GWP_{20} with a 20-year timeframe or the GTP_{100}).

Any CLEVER assessment must not only assess the GWP_{100} but also list the main greenhouse gases separately, which covers carbon dioxide (fossil and biogenic), methane (biogenic and fossil) and nitrous oxide, as well as hydrogen.

In addition to the core GHG emission factors, a CLEVER assessment must also include values for climate impacts not directly linked to the classical greenhouse gases (high altitude emissions from airplanes as well as black carbon).

Handling of biogenic carbon

For biogenic carbon dioxide a -1/+1 accounting method is chosen. Thus, carbon uptake must be modelled as a negative emission, whereas the carbon release during the fuel combustion must be modelled as a positive emission. However, for biofuels, as well as RFNBOs using carbon dioxide from direct air capture, the uptake and the subsequent release of the carbon dioxide cancel each other out when looking at the full energy carrier lifecycle. Emissions of biogenic carbon dioxide should also be reported separately from the other greenhouse gases, since the CSRD directive mandates to report biogenic carbon dioxide while following the carbon neutral approach.

Handling of carbon dioxide removals

Carbon dioxide removals may only be considered, if they are directly and physically linked to the fuel production process. This can entail carbon dioxide uptake by plant growth via synthesis or direct air capture (DAC) of CO_2. Here, the fuel itself acts as a (short-term)[18] carbon sink with corresponding carbon dioxide emission, when the fuel is converted/used/utilized. Overall, both these options do not result in a net carbon removal with respect to the carbon within the fuel, but a neutral carbon balance. A second option for carbon dioxide removals to be applicable within the CLEVER framework pertains permanent carbon dioxide removed and stored via CCS (carbon capture and storage) that would otherwise have been emitted (e.g.

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[17] IPCC, 2023: *Climate Change 2023: Synthesis Report.* Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647.

[18] Since the carbon is sequestered within a fuel, no intermediate nor long-term storage are assumed and thus, no storage effects of this sink may be considered within the GHG emission calculation, irrespective of the origin of the carbon.

as part of the production process). If this carbon is stored in a permanent technical sink (for 100 years or more, with any losses accounted for), and it is biogenic in its origin, it may be counted as a negative emission (-1 kg C / kg C removed). Besides real carbon dioxide removals described above, no carbon offsetting/ compensation shall be considered when calculating CLEVER GHG emission factors.

In general, double counting of potential carbon dioxide removals shall be avoided and special attention paid by the calculation of CLEVER compliant values. This pertains in particular carbon dioxide removals that are claimed by any third-party involved within the carbon dioxide removing process for regulatory compliance. These removals shall either be attributed to the CO_2 producing process or to the fuel producing process, but cannot be counted twice (for reference, see also chapter 4.5.3 and chapter 4.8).

3.14 RESULTS AND INTERPRETATION

Results and their interpretation shall be reflective of the goal and scope of the assessment and the specific pathway under investigation. Moreover, they shall consider limitations and assumptions made, and cannot make any generalized claim regarding the environmental impact beyond the impact on climate change, Furthermore, the interpretation of results shall also reflect on the data quality, appropriateness and completeness as well as the influence of potential cut-offs.

Whenever a result of a CLEVER assessment is communicated, it must include all information on the chosen energy carrier pathway as well as the usage (vehicle type and engine/ aftertreatment, if relevant) and shall be given per MJ of fuel consumed.

Results shall always be given in the following format:

$$EF_{Total} = EF_{Core} + EF_{iLUC} + EF_{ACI}$$

with EF_{Total} constituting the total CLEVER GHG emission factor

with EF_{Core} including all GHG emissions and processes inside of the system boundary (apart from iLUC and additional climate impacts)

with EF_{iLUC} representing contributions from iLUC (indirect land use change)

with EF_{ACI} representing additional climate impacts (divided into impacts of hydrogen $EF_{Hydrogen}$, impacts from high altitude emissions of airplanes EF_{HAE}, and black carbon $EF_{Black\ Carbon}$)

Both the total GHG emissions (formerly also called Well-to-Wheel, $EF_{Total\ WTW}$) and the energy provision GHG emissions (formerly called well-to-tank, $EF_{Total,WtT}$) as well as the operational GHG emissions (formerly called Tank-to-Wheel, $EF_{Total,TtW}$) shall be reported.

In addition to the GWP100 following the latest IPCC guideline, the operational GHG emissions of the main greenhouse gases (carbon dioxide, methane and nitrous oxide) shall also be reported separately and the used characterisation factors (or their source) shall be clearly stated.

Any result presentation thus includes values for the following:

- Information on energy carrier pathway and usage
- Lower heating value (MJ/kg)
- Density (l/kg), for liquid fuels only
- Overall data quality rating (DQR) (section 3.6)

- GHG emissions total ($EF_{total, WTW}$) (g CO_2e/MJ)
- GHG emissions energy provision ($EF_{total, WTT}$)
- GHG emissions operational ($EF_{total, TTW}$) (g CO_2e/MJ)
- GHG emissions operational from CO_2 (g CO_2e/MJ)
- GHG emissions operational from CH_4 (g CO_2e/MJ)
- GHG emissions operational from N_2O (g CO_2e/MJ)
- GHG emissions operational from H_2 (g CO_2e/MJ)
- GHG emissions operational from biogenic CO_2 (g CO_2e/MJ)
- GHG emissions total from H_2 (EF_{H2}) (g CO_2e/MJ)
- Climate impacts total from iLUC (EF_{iLUC}) (g CO_2e/MJ), from energy provision only
- Climate impacts total from black carbon (EF_{BC}) (g CO_2e/MJ), from operation only
- Climate impacts total from high altitude emissions (EF_{HAE}) (g CO_2e/MJ), from operation only

Following ISO 14083, any GHG emission factor shall be complemented by further information on the density (for liquid fuels) as well as the lower heating value (for gaseous and liquid) fuels as well as the information given in the reporting.

3.15 VERIFICATION AND CERTIFICATION REQUIREMENTS

The CountEmissionsEU reference value database (CERVD) covers a comprehensive range of different energy carriers / fuel pathways. Additionally, transport service providers may opt for calculating own / actual values in compliance with calculation requirements defined by the CLEVER framework within this document. In case of own calculation of values, an independent third-party Conformity Assessment shall be conducted to verify compliance with calculation principles and rules laid out in the CLEVER framework.

Furthermore, in the case of calculation of own / actual values, if a specific (sustainable) fuel is subject of the assessment, the assessed fuel must be certified to ensure credibility of characteristics, like e.g. emission savings or other sustainability criteria, e.g. waste status of the feedstock. This furthermore extends to any energy carrier utilized within the production process of the fuel and their respective market instruments, such as e.g. renewable electricity[19].

Certificates shall be subject of a rigid chain of custody system, where fuel suppliers or energy providers can emit certificates according to their total real / physical[20] fuel volumes supplied to a specific market. If a unit of fuel is sold and claimed by a transport service provider TSP, the certificate shall be deleted, as this unit no longer is available to the market.

When a fuel consumer (economic operator) utilizes RED-certified fuels – such as biofuels, Renewable Fuels of Non-Biological Origin (RFNBOs), or Recycled Carbon Fuels (RCFs) or any type of certified fuel to be sold against a mandate – in their transport fleet, particular attention must be paid to avoid any risk of double counting the sustainability characteristics of these fuels. This scope of double counting can be

[19]With respect to RFNBO, rules laid out in the RED and in particular Commission Delegated Regulation (EU) 2023/1184 apply.

[20] Other regulation, especially RED and the national implementations allow for some multiplication factors to foster market uptake of certain fuel types. This is explicitly ruled out within CLEVER.

extended to any certified fuel under any type of mandate. This concern becomes critical in the context of developing a harmonized and transparent methodology for calculating transport and logistics-related greenhouse gas (GHG) emissions, as is the objective of CLEVER. Furthermore, the GHG value from a fuel supplier can only serve as a basis for a CLEVER compliant emission factor, given the differences in scope and calculation rules of both RED and the CLEVER framework / CountEmissionsEU.

To maintain the integrity of sustainability claims and to avoid inflating emission savings, this issue must be addressed with the utmost rigor and methodological consistency.

3.16 REPORTING REQUIRMENTS

When calculating a CLEVER GHG emission factor, a comprehensive and transparent report shall be produced in addition. The aim of the report shall be firstly, to demonstrate compliance with the applied CLEVER framework and secondly, to describe the pathway under study and additionally document and inform about all relevant aspects pertaining – in particular – applied methodical approach and methodical decisions taken as well as disclose and provide information on utilized data and its data quality.

As a basis, the items listed above from section 4.1 to 4.15 shall be addressed within any CLEVER reporting. Furthermore, if compliance is sought also with ISO 14067:2018, cross-reference with chapter 7 (in particular section 7.3) of ISO 14067:2018, regarding reporting requirements is advised.

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