TECHNICAL SPECIFICATION

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Hydrogen technologies — Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate

Technologies de l'hydrogène — Méthodologie pour déterminer les émissions de gaz à effet de serre associées à la production, au conditionnement et au transport de l'hydrogène jusqu'au point de consommation

Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*, Subcommittee SC 1, *Hydrogen at scale and horizontal energy systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The Paris Agreement was adopted at the UN Climate Change conference (COP21) with the aims of: strengthening the global response to the threat of climate change, restricting global temperature rise to below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1,5 °C above pre-industrial levels. To meet these goals, greenhouse gas (GHG) emissions need to be reduced by about 45 % from 2010 levels by 2030, reaching net zero in 2050 (IPCC, 2018; UNFCCC, 2021).

GHG initiatives on mitigation rely on the quantification, monitoring, reporting and verification of GHG emissions and/or removals. International Standards that support the transformation of scientific knowledge into tools can help in reaching the targets of the Paris Agreement to address climate change.

ISO 14040 and ISO 14044 define the principles, requirements and guidelines identified in existing International Standards on life cycle assessment (LCA). The ISO 14060 series provides clarity and consistency for quantifying, monitoring, reporting and validating or verifying GHG emissions and removals to support sustainable development through a low-carbon economy. It also benefits organizations, project proponents and stakeholders worldwide by providing clarity and consistency on quantifying, monitoring, reporting and validating or verifying GHG emissions and removals.

ISO 14067 is based on the principles, requirements and guidelines on LCA identified in ISO 14040 and ISO 14044 and aims to set specific requirements for the quantification of a carbon footprint (CFP) and a partial CFP.

ISO 14067 defines the principles, requirements and guidelines for the quantification of the carbon footprint of products. Its aim is to quantify GHG emissions associated with the lifecycle stages of a product, beginning with resource extraction and raw material sourcing and extending through the production, use and end-of-life stages of the product.

Figure 1 illustrates the relationship between ISO 14067 and other ISO documents on LCA.

PCR   Product category rule
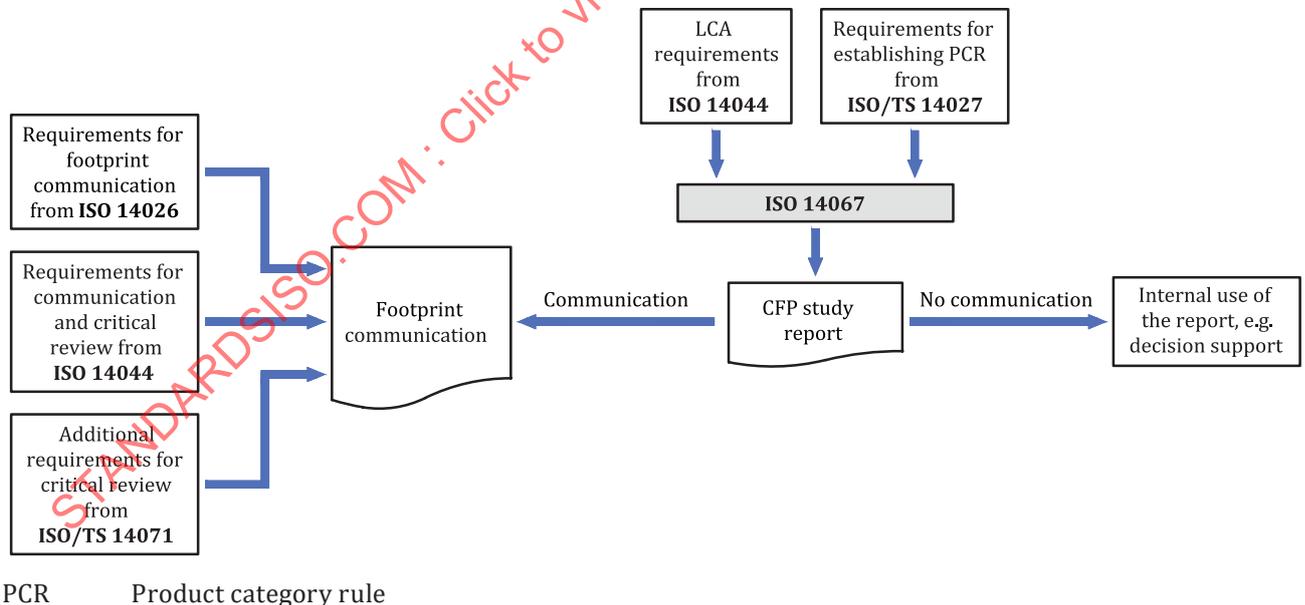
Figure 1 — Relationship between standards beyond the GHG management family of standards (source ISO 14067:2018)

Hydrogen can be produced from diverse sources including renewables, nuclear and fossil fuels using carbon capture, utilization and storage (CCUS) to reduce the emissions associated with its production. Hydrogen can be used to decarbonize numerous sectors including transport, industrial manufacturing and power generation.

A particular challenge is that identical hydrogen molecules can be produced and combined from sources that have different GHG intensities. Similarly, hydrogen-based fuels and derivatives will be indistinguishable and can be produced from hydrogen combined with a range of fossil and low-carbon inputs. Indeed, some of the products made from hydrogen (e.g. electricity) can themselves be used in the production of hydrogen. Accounting standards for different sources of hydrogen along the supply chain (see Figure 2) will be fundamental to creating a market for low-carbon hydrogen, and these standards need to be agreed upon internationally. Additionally, there is the possibility that consumption gates are not located in proximity to hydrogen production gates, requiring hydrogen transport. ISO 14083 gives guidelines for the quantification and reporting of GHG emissions arising from transport chain operations.

A mutually recognized international framework that is robust, avoids miscounting or double counting of environmental impacts is needed. Such a framework will provide a mutually agreed approach to "guaranties" or "certificates" of origin, and cover greenhouse gas inputs used for hydrogen production, conditioning, conversion and transport.

This document aims at increasing the methodologies that should be applied, in line with ISO 14067, to the specific case of the hydrogen value chain, covering different production processes and other parts of the value chain, such as conditioning hydrogen in different physical states, conversion of hydrogen into different hydrogen carriers and the subsequent transport up to the consumption gate.
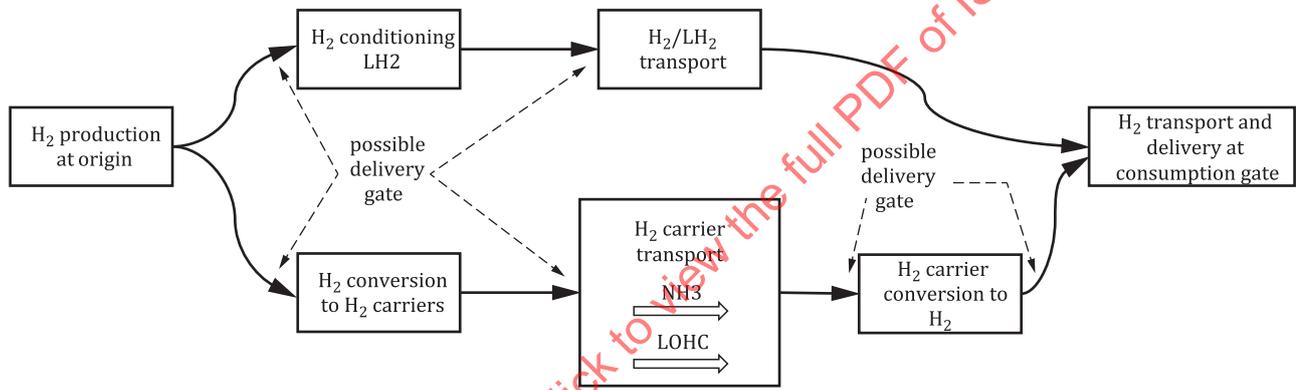

Figure 2 — Examples of hydrogen supply chain

Hydrogen technologies — Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate

1 Scope

ISO 14044 requires the goal and scope of an LCA to be clearly defined and be consistent with the intended application. Due to the iterative nature of LCA, it is possible that the LCA scope needs to be refined during the study.

This document specifies methodologies that can be applied to determine the carbon footprint of a product (CFP) or partial CFP of a hydrogen product in line with ISO 14067. The goals and scopes of the methodologies correspond to either approach a) or b), given below, that ISO 14040:2006, A.2 gives as two possible approaches to LCA.

a)   An approach that assigns elementary flows and potential environmental impacts to a specific product system, typically as an account of the history of the product.

b)   An approach that studies the environmental consequences of possible (future) changes between alternative product systems.

Approaches a) and b) have become known as attributional and consequential, respectively, with complementary information accessible in the ILCD handbook.[1]

There are numerous pathways to produce hydrogen from various primary energy sources. This document describes the requirements and evaluation methods applied to several hydrogen production pathways of interest: electrolysis, steam methane reforming (with carbon capture and storage), co-production and coal gasification (with carbon capture and storage), auto-thermal reforming (with carbon capture and storage), hydrogen as a co-product in industrial applications and hydrogen from biomass waste as feedstock.

This document also considers the GHG emissions due to the conditioning or conversion of hydrogen into different physical forms and chemical carriers:

—   hydrogen liquefaction;

—   production, transport and cracking of ammonia as a hydrogen carrier;

—   hydrogenation, transport and dehydrogenation of liquid organic hydrogen carriers (LOHCs).

This document considers the GHG emissions due to hydrogen and/or hydrogen carriers' transport up to the consumption gate.

It is possible that future revisions of this document will consider additional hydrogen production, conditioning, conversion and transport methods.

This document applies to and includes every delivery along the supply chain up to the final delivery to the consumption gate (see Figure 2 in the Introduction).

This document also provides additional information related to evaluation principles, system boundaries and expected reported metrics in the form of Annexes A to K, that are accessible via the online ISO portal (https://standards. iso. org/iso/ts/19870/ed-1/en).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14040:2006, *Environmental management — Life cycle assessment — Principles and framework*

ISO 14044, *Environmental management — Life cycle assessment — Requirements and guidelines*

ISO 14067:2018, *Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification*

ISO 14083:2023, *Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations*

ISO/TS 14071, *Environmental management — Life cycle assessment — Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Quantification of the Carbon Footprint of a Product

3.1.1
allocation
partitioning the *input* (3.2.8) or *output* (3.2.10) flows of a process or a *product system* (3.2.3) between the product system under study and one or more other product systems

[SOURCE: ISO 14040:2006 and ISO 14040:2006/AMD 1:2020]

3.1.2
carbon footprint of a product
CFP
sum of *greenhouse gas emissions* (3.1.12) and *greenhouse gas removals* (3.1.4) in a *product system* (3.2.3), expressed as CO_2 *equivalent* (3.1.10) and based on a *life cycle assessment* (3.4.5) using the single impact category of climate change

Note 1 to entry: A CFP can be disaggregated into a set of figures identifying specific *GHG emissions* (3.1.12) and *removals* (3.1.4). A CFP can also be disaggregated into the stages of the *life cycle* (3.4.4).

Note 2 to entry: The results of the *quantification of CFP* (3.1.8) are documented in the CFP study report expressed in mass of CO_2e (3.1.11) per *functional unit* (3.2.14).

[SOURCE: ISO 14067:2018, 3.1.1.1]

3.1.3
partial CFP
sum of *greenhouse gas emissions* (3.1.12) and *greenhouse gas removals* (3.1.4) of one or more selected process(es) in a *product system* (3.2.3) expressed as *CO₂ equivalents* (3.1.10) and based on the selected stages or processes within the *life cycle* (3.4.4)

Note 1 to entry: A partial CFP is based on or compiled from data related to (a) specific process(es) or footprint information modules (defined in ISO 14026:2017, 3.1.4), which is (are) part of a *product system* (3.2.3) and can form the basis for quantification of a carbon footprint of a product (CFP). More detailed information on information modules is given in ISO 14025:2006, 5.4.

Note 2 to entry: The results of the quantification of the partial CFP are documented in the CFP study report expressed in mass of CO_2e (3.1.10) per declared unit.

3.1.4
greenhouse gas removal
GHG removal
withdrawal of a *greenhouse gas* (3.1.9) from the atmosphere

[SOURCE: ISO 14067:2018, 3.1.2.6]

3.1.5
CFP study
all activities that are necessary to quantify and report the *carbon footprint of a product* (3.1.2) or a *partial CFP* (3.1.3)

[SOURCE: ISO 14067:2018, 3.1.1.4]

3.1.6
product category
group of products that can fulfil equivalent functions

[SOURCE: ISO 14025:2006, 3.12]

3.1.7
production batch
amount of products produced by a device between any two points in time selected by the operator

3.1.8
quantification of CFP
activities that result in the determination of the *carbon footprint of a product* (3.1.2) or a *partial CFP* (3.1.3)

Note 1 to entry: Quantification of the *CFP* (3.1.2) or the *partial CFP* (3.1.3) is part of the *CFP study* (3.1.5).

[SOURCE: ISO 14067:2018, 3.1.1.6]

3.1.9
greenhouse gas
GHG
gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds

Note 1 to entry: For a list of *greenhouse gases* (3.1.9), see the latest IPCC Assessment Report (currently carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O)). Other GHGs are not considered relevant for this document.

Note 2 to entry: Water vapour and ozone, which are anthropogenic as well as natural *greenhouse gases* (3.1.9), are not included in the *carbon footprint of a product* (3.1.2).

Note 3 to entry: The focus of this document is limited to long-lived GHGs and it therefore excludes climate effects due to changes in surface reflectivity (albedo) and short-lived radiative forcing agents (e.g. black carbon and aerosols).

[SOURCE: ISO 14067:2018, 3.1.2.1]

3.1.10
carbon dioxide equivalent
CO$_2$ equivalent
CO$_2$e
unit for comparing the radiative forcing of a *greenhouse gas* (3.1.9) to that of carbon dioxide

Note 1 to entry: Mass of a greenhouse gas is converted into *CO$_2$ equivalents* by multiplying the mass of the *greenhouse gas* (3.1.9) by the corresponding *global warming potential* (3.1.11) or global temperature change potential (GTP) of that gas.

Note 2 to entry: In the case of GTP, *CO$_2$ equivalent* is the unit for comparing the change in global mean surface temperature caused by a greenhouse gas to the temperature change caused by carbon dioxide.

[SOURCE: ISO 14067:2018, 3.1.2.2]

3.1.11
global warming potential
GWP
index, based on radiative properties of *greenhouse gases* (3.1.9) (GHG) measuring the radiative forcing following a pulse emission of a unit mass of a given GHG in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide (CO$_2$)

Note 1 to entry: "Index" as used in this document is a "characterization factor" as defined in ISO 14040:2006, 3.37.

Note 2 to entry: A "pulse emission" is an emission at one point in time.

[SOURCE: ISO 14067:2018, 3.1.2.4]

3.1.12
greenhouse gas emission
GHG emission
release of a *greenhouse gas* (3.1.9) into the atmosphere

[SOURCE: ISO 14067:2018, 3.1.2.5]

3.1.13
greenhouse gas emission factor
GHG emission factor
coefficient relating activity data with the *greenhouse gas emission* (3.1.3)

[SOURCE: ISO 14067:2018, 3.1.2.7]

3.1.14
capital goods emission
CAPEX emission
GHG emissions (3.1.12) related to the manufacturing of capital goods

3.1.15
subdivision
virtual subdivision
decomposition of the analysed unit process into physically or virtually distinguishable sub-process steps with the possibility to collect data exclusively for those sub-processes

3.2 Products, product systems and processes

3.2.1
product
any goods or service

Note 1 to entry: The product can be categorized as follows:

— services (e.g. transport);

— software (e.g. computer program, dictionary);

— hardware (e.g. engine mechanical part);

— processed materials (e.g. lubricant).

[SOURCE: ISO 14040:2006, 3.9]

3.2.2
product flow
products (3.2.1) entering from or leaving to another *product system* (3.2.3)

[SOURCE: ISO 14040:2006, 3.27]

3.2.3
product system
collection of unit processes with *elementary flows* (3.2.16) and *product flows* (3.2.2), performing one or more defined functions and which models the *life cycle* (3.4.4) of a *product* (3.2.1)

[SOURCE: ISO 14044:2006, 3.28]

3.2.4
co-product
two or more *products* (3.2.1) coming from the same unit process or *product system* (3.2.3)

[SOURCE: ISO 14040:2006, 3.10]

3.2.5
conditioning
means changing the physical conditions (temperature, pressure) of a species

Note 1 to entry: In this document, examples are changing the pressure of gaseous hydrogen or liquefying gaseous hydrogen.

3.2.6
conversion
means changing the chemicals conditions of a species

Note 1 to entry: In this document, examples are changing hydrogen molecules into ammonia or LOHCs.

3.2.7
heating value
amount of energy released when a fuel is burned completely

Note 1 to entry: Care must be taken not to confuse higher heating values (HHVs) and lower heating values (LHVs).

3.2.8
input
product (3.2.1), material or *energy flow* (3.2.17) that enters a unit process

Note 1 to entry: *Products* (3.2.1) and materials include raw materials, *intermediate products* (3.2.9) and *co-products* (3.2.4).

[SOURCE: ISO 14040:2006, 3.21]

3.2.9
intermediate product
output from a unit process that is input to other unit processes that require further transformation within the system

[SOURCE: ISO 14040:2006, 3.23]

3.2.10
output
product (3.2.1), material or *energy flow* (3.2.17) that leaves a unit *process* (3.2.13)

Note 1 to entry: *Products* (3.2.1), and materials include raw materials, *intermediate products* (3.2.9), *co-products* (3.2.4) and *releases* (3.4.11).

[SOURCE: ISO 14040:2006, 3.25]

3.2.11
system boundary
boundary based on a set of criteria representing which unit *processes* (3.2.13) are a part of the system under study

[SOURCE: ISO 14040:2006/AMD 1:2020, 3.32]

3.2.12
system expansion
concept of expanding the *product system* (3.2.3) to include additional functions related to the *co-products* (3.2.4)

Note 1 to entry: The *product system* (3.2.3) that is substituted by the *co-product* (3.2.4) is integrated in the *product system* (3.2.3) under study. In practice, the *co-products* (3.2.4) are compared to other substitutable products, and the environmental burdens associated with the substituted product(s) are subtracted from the *product system* (3.2.3) under study. The identification of this substituted system is done in the same way as the identification of the upstream system for *intermediate product* (3.2.9) *inputs* (3.2.8). See also ISO/TR 14049:2012, 6.4

Note 2 to entry: The application of *system expansion* (3.2.12) involves an understanding of the market for the *co-products* (3.2.4). Decisions about *system expansion* (3.2.12) can be improved through understanding the way *co-products* (3.2.4) compete with other products, as well as the effects of any product substitution upon production practices in the industries impacted by the *co-products* (3.2.4).

Note 3 to entry: Can be referred to as *system expansion* (3.2.12) and also as expanding the *system boundary* (3.2.11).

[SOURCE: ISO 14044:2006/AMD 2:2020, D.2.1]

3.2.13
process
set of interrelated or interacting activities that transforms *inputs* (3.2.8) into *outputs* (3.2.10)

[SOURCE: ISO 14044:2006, 3.11]

3.2.14
functional unit
quantified performance of a *product system* (3.2.3) for use as a reference unit

Note 1 to entry: As the carbon footprint of a product treats information on a product basis, an additional calculation based on a declared unit can be presented.

[SOURCE: ISO 14040:2006, 3.20]

3.2.15
reference flow
measure of the *inputs* (3.2.8) to or *outputs* (3.2.10) from *processes* (3.2.13) in a given product system (3.2.3) required to fulfil the function expressed by the functional unit (3.2.14)

Note 1 to entry: In the case of a *partial CFP* (3.1.3), the *reference flow* (3.2.15) refers to the declared unit.

[SOURCE: ISO 14067:2018, 3.1.3.9]

3.2.16
elementary flow
material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation

Note 1 to entry: "Environment" is defined in ISO 14001:2015, 3.2.1.

[SOURCE: ISO 14044:2006, 3.12]

3.2.17
energy flow
input (3.2.8) to or *output* (3.2.10) from a unit process or *product system* (3.2.3), quantified in energy units

Note 1 to entry: Energy flow that is an input can be called an energy input; energy flow that is an output can be called an energy output.

[SOURCE: ISO 14040:2006, 3.13]

3.3 Transport

3.3.1
cargo
goods or sets of goods (liquid, solid or gaseous) transported from one place to another on a means of transport (3.3.5)

3.3.2
consignment
separately identifiable amount of *freight* (3.3.3) transported from one consignor to one consignee via one or more modes of transport

Note 1 to entry: Although "consignment" and "shipment" are common terms often considered as synonyms, in this document and other technical publications, a consignment is differentiated to a shipment. Indeed, a shipment refers to a grouping of freight corresponding to the shipper needs, whereas a consignment refers a grouping of freight according to a carrier or freight forwarder's transport solutions.

[SOURCE: ISO 14083:2023, 3.1.4]

3.3.3
freight
goods, materials, commodities, parcels, etc. being transported from one location to another

[SOURCE: ISO 14083:2023, 3.1.7]

3.3.4
fuel consumption
amount of energy used by a means of *transport* (3.3.5) to fulfil a given task

3.3.5
means of transport
modes of transport such as inland waterway, pipeline, rail and road that are used for the transport of freight

3.3.6
route
journey (to be) taken to get from one point to another point

3.3.7
delivery gate
location where products have their custody transferred according to contractual arrangements between the purchaser and the provider.

3.3.8
consumption gate
location of the final delivery of the product along its complete supply chain.

3.3.9
transport
movement of *freight* (3.3.3) from one location to another performed by modes of transport

Note 1 to entry: The term "transport" in general is used for movement supported by means.

3.3.10
vehicle
any *means of transport* (3.3.5)

Note 1 to entry: Within this standard, this definition includes vessels (watercraft and aircraft like ships, boats, and planes), for reasons of simplification only. Pipelines (see 3.3.24) are not considered a vehicle.

[SOURCE: ISO 14083:2023, 3.1.35, modified Note 1 to entry]

3.3.11
empty trip
section of the route of a *vehicle* (3.3.10) during which no freight or passenger is transported

[SOURCE: ISO 14083:2023, 3.1.5]

3.3.12
distance adjustment factor
DAF
ratio between the actual distance and the transport activity distance, related to the same origin and destination locations

EXAMPLE   Ratio between "actual distance" and "*shortest feasible distance* (3.3.31)"

[SOURCE: ISO 14083:2023, 3.3.5]

3.3.13
fleet
set of *vehicles* (3.3.10) operated by one transport service operator

[SOURCE: ISO 14083:2023, 3.1.6]

3.3.14
great circle distance
GCD
transport distance determined as the shortest distance between any two points measured along the surface of a sphere

[SOURCE: ISO 14083:2023]

3.3.15
hub
DEPRECATED: node
DEPRECATED: site
DEPRECATED: station
DEPRECATED: facility
DEPRECATED: centre
DEPRECATED: depot
location where passengers transfer and/or *freight* (3.3.3) is transferred from one *vehicle* (3.3.10) or mode of transport to another before, after or between different elements of a transport chain

Note 1 to entry: Hubs include, but are not limited to, rail/road terminals, cross-docking sites, airport terminals, terminals at seaports and distribution centres.

[SOURCE: ISO 14083:2023, 3.1.8]

3.3.16
hub activity
parameter that quantifies the *throughput* (3.3.29) of a *hub* (3.3.15)

[SOURCE: ISO 14083:2023, 3.1.9]

3.3.17
hub equipment
equipment and facilities used within a *hub* (3.3.15) to transfer *freight* (3.3.3) or passengers

[SOURCE: ISO 14083:2023, 3.1.10]

3.3.18
hub operation
operation in order to transfer *freight* (3.3.3) or passengers through a *hub* (3.3.15)

[SOURCE: ISO 14083:2023, 3.1.11]

3.3.19
hub operation category
HOC
group of *hub operations* (3.3.18) that share similar characteristics

Note 1 to entry: ISO 14083:2023, Annex H contains examples of HOCs.

[SOURCE: ISO 14083:2023, 3.1.12]

3.3.20
hub operator
entity that carries out *hub operations* (3.3.18) involving carriage of *freight* (3.3.3) or passengers or both

[SOURCE: ISO 14083:2023, 3.1.13]

3.3.21
hub service
service provided within a hub transport chain element

[SOURCE: ISO 14083:2023, 3.1.14]

3.3.22
load
quantity or nature of is the freight being carried by a *vehicle* (3.3.10)

3.3.23
load factor
ratio of the actual *load* (3.3.22) and the maximum authorized load of one *means of transport* (3.3.5)

Note 1 to entry: Different dimensions are used for the measurement of the capacity, such as mass and volume.

[SOURCE: ISO 14083:2023, 3.1.15]

3.3.24
packaging
materials used for the containment, protection, handling, delivery and presentation of *freight* (3.3.3)

Note 1 to entry: Packaging may be further categorized into:

— primary packaging, which is designed to come into direct contact with the product;

— secondary packaging, which is designed to contain one or more products together with any primary packaging required;

— transport packaging

[SOURCE: ISO 14083:2023, 3.4.2]

3.3.25
pipeline
long continuous line of pipes, including ancillary equipment, used for transporting *freight* (3.3.3).

[SOURCE: ISO 14083:2023, 3.1.17]

3.3.26
pipeline transport
movement of a medium (liquid, gas, liquefied gas, slurry) through a system of pipes from one location to another

[SOURCE: ISO 14083:2023, 3.1.18]

3.3.27
round trip
group of sequential journeys that start and end in the same place, whatever the intermediate routing

[SOURCE: ISO 14083:2023, 3.1.19]

3.3.28
shipment
identifiable collection of one or more *freight* (3.3.3) items (available to be) transported together from the original shipper to the ultimate consignee

Note 1 to entry: A shipment may be transported in one or a multiple number of consignments

Note 2 to entry: A shipment can be aggregated or disaggregated to different consignments according to the requirements of the means of transport on any one element of the transport chain, e.g. single bulk units and packages can be aggregated on a pallet and such pallet can be handed over as a unit for aggregation in a container, which in turn is treated as a consignment in a *vehicle* (3.3.10)

Note 3 to entry: Although "consignment" and "shipment" are common terms often considered as synonyms, in this document and other technical publications, a consignment is differentiated to a shipment. Indeed, a shipment refers to a grouping of *freight* (3.3.3) corresponding to the shipper needs, whereas a consignment refers a grouping of *freight* (3.3.3) according to a carrier or *freight* (3.3.3) forwarder's transport solutions.

[SOURCE: ISO 14083:2023, 3.1.20]

3.3.29
throughput
quantity of passengers or *freight* (3.3.3) handled, sorted, cross-docked or transferred within and between modes at a *hub* (3.3.15)

[SOURCE: ISO 14083:2023, 3.1.21]

3.3.30
transhipment
action by which *freight* (3.3.3) is transferred from one *means of transport* (3.3.5) to another during the course of one transport chain

[SOURCE: ISO 14083:2023, 3.1.22]

3.3.31
shortest feasible distance
SDF
DEPRECATED: planned distance
DEPRECATED: network distance
transport distance determined as the distance achievable by the shortest practical route available according to the infrastructure options for a particular *vehicle* (3.3.10) type

Note 1 to entry: "Shortest practical route" implies that small detours from the shortest distance, e.g. to avoid congested city centres or rural roads unsuitable for certain *vehicle* (3.3.10) sizes, can be included.

[SOURCE: ISO 14083:2023, 3.1.27.3]

3.3.32
transport activity
parameter that quantifies passenger or *freight* (3.3.3) transport

[SOURCE: ISO 14083:2023, 3.1.24]

3.3.33
transport activity distance
transport distance related to passengers or *freight* (3.3.3) moved, used as a parameter for calculation of *transport activity* (3.3.32)

[SOURCE: ISO 14083:2023, 3.1.27.4]

3.3.34
transport chain
sequence of elements related to *freight* (3.3.3) or a (group of) passenger(s) that, when taken together, constitutes its movement from an origin to a destination

Note 1 to entry: A passenger or a group of passengers can include their luggage and, if any, their vehicles

Note 2 to entry: Where there are two or more elements, in the majority of cases, one of them implies that the *freight* (3.3.3) or passengers use a *hub* (3.3.15)

[SOURCE: ISO 14083:2023, 3.1.25]

3.3.35
transport chain element
TCE
section of a transport chain within which the *freight* (3.3.3) or a (group of) passenger(s) is carried by a single *vehicle* (3.3.10) or transits through a single *hub* (3.3.15)

EXAMPLE   If a multimodal trip of a passenger includes taking a bus from stop "L4" to stop "L7" of bus line "L", then one TCE is the trip of the passenger from "L4" to "L7".

[SOURCE: ISO 14083:2023, 3.1.26]

11

3.3.36
transport distance
distance between the origin and the destination of a passenger, a consignment or a *vehicle* (3.3.10) along a specified route

Note 1 to entry: For the use of this document, the route followed by the passenger, the *freight* (3.3.3) or the vehicle (3.3.10) may be different from that originally planned. This leads to two categories of transport distances: actual distances, and distances used for calculation of *greenhouse gas emissions* (3.1.12), i.e. *transport activity distances* (3.3.33)

[SOURCE: ISO 14083:2023, 3.1.27]

3.3.37
actual distance
transport distance along the actual route taken by a *vehicle* (3.3.10)

EXAMPLE   Distance measured by an on-board device (odometer).

[SOURCE: ISO 14083:2023, 3.1.27.1]

3.3.38
transport operation
operation of a *vehicle* (3.3.10) in order to transport passengers and/or *freight* (3.3.3)

EXAMPLE   If a multimodal trip of a passenger includes taking a bus from stop "L4" to stop "L7" of bus line "L", this requires a transport operation being the operation of this bus on line "L", from the first stop "L1" to the last stop of this bus line.

Note 1 to entry: It includes cases where the destination is the same as the origin passing through other locations on the way.

[SOURCE: ISO 14083:2023, 3.1.28]

3.3.39
transport operation category
TOC
group of *transport operations* (3.3.38) that share similar characteristics

Note 1 to entry: ISO 14083:2023, Annexes A-G contain recommendations for the characteristics used to specify the TOCs for each transport mode.

[SOURCE: ISO 14083:2023, 3.1.29]

3.3.40
transport operator
entity that carries out *transport operations* (3.3.38) involving carriage of *freight* (3.3.3) or passengers, or both

[SOURCE: ISO 14083:2023, 3.1.30]

3.3.41
transport packaging
tertiary packaging
distribution packaging
protective packaging
packaging (3.3.24) designed to contain one or more articles or packages, or bulk material, for the purposes of transport, handling and/or distribution

Note 1 to entry: Transport packaging does not include road, rail, ship and air containers.

[SOURCE: ISO 14083:2023, 3.4.4]

3.3.42
transport service
service provided to a user for the transport of *freight* (3.3.3) from an origin to a destination

[SOURCE: ISO 14083:2023, 3.1.31]

3.3.43
twenty-foot equivalent unit
TEU
standard unit used to express a number of containers of various lengths and for describing the capacities of container ships or terminals

[SOURCE: ISO 14083:2023, 3.1.34]

3.3.44
vehicle operation
deployment of a *vehicle* (3.3.10) to fully or partially provide a *transport operation* (3.3.38)

[SOURCE: ISO 14083:2023, 3.1.36]

3.4   Life Cycle Assessment

3.4.1
cut-off criteria
specification of the amount of material or *energy flow* (3.2.17) or the level of significance of *greenhouse gas emissions* (3.1.12) associated with unit processes or the *product system* (3.2.3) to be excluded from a CFP study

Note 1 to entry: "Energy flow" is defined in ISO 14040:2006, 3.13.

[SOURCE: ISO 14067:2018, 3.1.4.1]

3.4.2
evaluation
element within the life cycle interpretation phase intended to establish confidence in the results of the *life cycle assessment* (3.4.5)

Note 1 to entry: Evaluation includes completeness check, sensitivity check, consistency check, and any other validation that may be required according to the goal and scope definition of the study

[SOURCE: ISO 14040:2006]

3.4.3
fugitive emissions
emissions that are not physically controlled but result from the intentional or unintentional *releases* (3.4.11) of GHGs (3.1.9)

Note 1 to entry: They commonly arise from the production, processing transmission storage and use of fuels and other chemicals, often through joints, seals, packing, gaskets, etc.

[SOURCE: 2004 GHG protocol, Chapter 4.6]

3.4.4
life cycle
consecutive and interlinked stages related to a product, from raw material acquisition or generation from natural resources to end-of-life treatment

Note 1 to entry: "Raw material" is defined in ISO 14040:2006, 3.15.

Note 2 to entry: Stages of a life cycle related to a product include raw material acquisition, production, distribution, use and end-of-life treatment.

[SOURCE: ISO 14067:2018, 3.1.4.2]

3.4.5
life cycle assessment
LCA
compilation and evaluation of the inputs, outputs and the potential environmental impacts of *a product system* (3.2.3) throughout its *life cycle* (3.4.4)

Note 1 to entry: "Environmental impact" is defined in ISO 14001:2015, 3.2.4.

[SOURCE: ISO 14067:2018, 3.1.4.3]

3.4.6
life cycle inventory analysis
LCI
phase of *life cycle assessment* (3.4.5) involving the compilation and quantification of *inputs* (3.2.8) and *outputs* (3.2.10) for a product throughout its *life cycle* (3.4.4)

[SOURCE: ISO 14044:2006, 3.3]

3.4.7
location-based method
uses the average emissions intensity of the electricity grid in the location in which energy consumption occurs.

[SOURCE: ISO 14064-1:2018, Annex E]

3.4.8
market-based method
uses the emissions intensity from choices a consumer makes regarding its electricity supplier or product

Note 1 to entry: These choices (purchasing energy certificates or differentiated electricity product) are reflected through contractual arrangements between the purchaser and the provider.

[SOURCE: ISO 14064-1:2018, Annex E]

3.4.9
leakage
loss of a product or service that results in changes in *GHG emissions* (3.1.12)

3.4.10
process emissions
emissions generated from manufacturing processes, such as the CO_2 that arises from the breakdown of calcium carbonate ($CaCO_3$) during cement manufacture

Note 1 to entry: Not to be confused with combustion emissions.

[SOURCE: ISO 14064-1:2018, Annex B]

3.4.11
releases
emissions to air and discharges to water and soil

[SOURCE: ISO 14040:2006, 3.30]

3.4.12
sensitivity analysis
systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a *CFP study* (3.1.5)

[SOURCE: ISO 14067:2018, 3.1.4.7]

3.4.13
sensitivity check
process to determine whether the information obtained from a sensitivity analysis is relevant for reaching the conclusions and for giving recommendations

[SOURCE: ISO 14040:2006/AMD1:2020, 3.43]

3.4.14
transparency
open, comprehensive and understandable presentation of information

[SOURCE: ISO 14040:2006, 3.7]

3.4.15
uncertainty analysis
systematic procedure to quantify the uncertainty introduced in the results of a *life cycle inventory analysis* (3.4.6) due to the cumulative effects of model imprecision, input uncertainty and data variability

Note 1 to entry: Either ranges or probability distributions are used to determine uncertainty in the results.

[SOURCE: ISO 14040:2006, 3.33]

3.4.16
waste
substances or objects that the holder intends or is required to dispose of

Note 1 to entry: This definition is taken from the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (22 March 1989), but is not confined in this document to hazardous waste.

[SOURCE: ISO 14040:2006, 3.35]

3.5   Organizations

3.5.1
organization
person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

Note 1 to entry: The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

[SOURCE: ISO 14001:2015, Clause 4]

3.6   Data and Data Quality

3.6.1
data quality
characteristics of data that relate to their ability to satisfy stated requirements

[SOURCE: ISO 14040:2006]

3.6.2
double counting
two or more reporting entities take ownership of the same emissions or reductions

3.6.3
primary data
quantified value of a process or an activity obtained from a direct measurement or a calculation based on direct measurements

Note 1 to entry: Primary data need not necessarily originate from the product system under study because primary data might relate to a different but comparable product system to that being studied.

Note 2 to entry: Primary data can include greenhouse gas emission factors and/or greenhouse gas activity data (defined in ISO 14064-1:2006, 2.11).

[SOURCE: ISO 14067:2018, 3.1.6.1]

3.6.4
secondary data
data which do not fulfil the requirements for primary data

Note 1 to entry: Secondary data can include data from databases and published literature, default emission factors from national inventories, calculated data, estimates or other representative data, validated by competent authorities.

Note 2 to entry: Secondary data can include data obtained from proxy processes or estimates.

[SOURCE: ISO 14067:2018, 3.1.6.3]

3.6.5
site-specific data
primary data obtained within the *product system* (3.2.3)

Note 1 to entry: All site-specific data are primary data but not all primary data are site-specific data because they may be obtained from a different *product system* (3.2.3).

Note 2 to entry: Site-specific data include greenhouse gas (GHG) emissions from GHG sources as well as permanent GHG removals by GHG sinks for one specific unit process within a site.

[SOURCE: ISO 14067:2018, 3.1.6.2]

3.6.6
uncertainty
parameter associated with the result of quantification that characterizes the dispersion of the values that could be reasonably attributed to the quantified amount

Note 1 to entry: Uncertainty can include, for example:

— parameter uncertainty, e.g. *greenhouse gas emission* (3.1.12) factors, activity data;

— scenario uncertainty, e.g. use stage scenario, end-of-life stage scenario;

— model uncertainty.

Note 2 to entry: Uncertainty information typically specifies quantitative estimates of the likely dispersion of values and a qualitative description of the likely causes of the dispersion.

[SOURCE: ISO 14067:2018, 3.1.6.4]

3.7 Abbreviated Terms

ATR	Auto thermal reforming
BT	Benzyltoluene
CCS	CO_2 capture and storage
CCU	CO_2 capture and utilisation
CFP	Carbon footprint of a product
CHP	Combined heat and power
CO_2e	Carbon dioxide equivalent
DAF	Distance adjustment factor
DBT	Di benzyl toluene
GCD	Great circle distance
GHG	Greenhouse gas
GO	Guaranties of origin
GWP	Global warming potential
HFO	Heavy fuel oil
HHV	High heating value
HOC	Hub operation category
LCA	Life cycle assessment
LCIA	Life cycle impact assessment
LCI	Life cycle inventory analysis
LHV	Low heating value
LNG	Liquefied natural gas
LOHC	Liquid organic hydrogen carriers
LPG	Liquefied petroleum gas
MCH	Methyl cyclo hexane
MDEA	Mono-diethanol amine
MDO	Marine diesel oil
MEA	Mono-ethanol amine
NG	Natural gas
PBT	Perhydro-benzyltoluene
PDBT	Perhydro-DBT

PSA	Pressure swing adsorption
SFD	Shortest feasible distance
SMR	Steam methane reformer
TC	Transport chain
TCE	Transport chain element
TEU	Twenty-foot equivalent unit
TOC	Transport operation category

4 Evaluation Methods

4.1 Evaluation Basis

4.1.1 General Principles

The proposed emissions accounting methodology aims at being applied for all hydrogen production, conditioning, conversion and transport pathways, in accordance with ISO 14040, ISO 14044, ISO 14067, ISO 14083, and using guidelines from the GHG protocols and ILCD Handbook which are based on the same ISO standards.

Therefore, referring to ISO 14067, the following criteria shall be applied for the goal and scope definition phase:

a) the product category definition and description of the investigated pathways are identical;

b) the declared unit is identical;

c) the system boundary is equivalent;

d) the description of data is equivalent;

e) the criteria for inclusion of inputs and outputs are equivalent;

f) the data quality requirements (e.g. transparency, coverage, precision, completeness, representativeness, consistency and reproducibility) are the same;

g) assumptions especially for the delivery stage are the same;

h) specific GHG emissions and captures are treated identically;

i) the units (described in Annexes) are identical.

The following criteria shall be applied for the life cycle inventory and LCIA phase:

j) the methods of data collection and data quality requirements are equivalent;

k) the calculation procedures are identical;

l) the allocation of the flows is equivalent;

m) the applied GWPs are identical.

The calculation method for the CFP of hydrogen can differ depending upon the intended use of the result of the evaluation. The present document describes two main situations according to ISO 14040:2006, Annex A.2.

4.1.2 Attributional approach

In this situation, the goal is to define the emissions to be attributed to the production and supply of hydrogen without considering emissions or benefits out of the analysed system. The GHG inventory is established strictly within the border of the H_2 supply chain from well to the delivery point. The accounting of emission is performed for each process along the value chain. Such a case also refers to situation C2 described in the ILCD handbook.

4.1.3 Consequential approach

In this situation, the goal is to evaluate the impact of hydrogen production taking into account emissions which are potentially out of the perimeter of the H_2 supply chain and which happen as a consequence of all stages of the hydrogen production life cycle.

This would be the case when consequences of the hydrogen production, occurring out of the production boundary, are included in the LCA or when the goal of the LCA is to determine avoided emissions on boundaries which exceeds the perimeter of the hydrogen supply chain or where avoided emissions are evaluated including lifecycle stages out of the scope from well to delivery. Such a case also refers to situation C1 described in the ILCD handbook.

Requirement applying to the choice of consequences to be considered:

— The activities to be considered and the corresponding lifecycle stages for these activities shall be clearly stated in the goal and scope of the LCA.

— The baseline/reference scenario according to which the consequence is evaluated shall be clearly stated in the goal and scope of the LCA.

4.2 Product reporting

4.2.1 Product System Boundary

4.2.1.1 General Principles

Analysis methods described in the current document cover a "well-to-consumption gate" system boundary (see Figure 3), including direct and indirect emissions and excluding emissions deemed insignificant per 4.2.2.

Indirect emissions considered include associated impacts from the upstream activities of raw material acquisition phase, raw material transport phase, etc. GHG contributions are defined in terms of carbon dioxide equivalent (CO_2e).
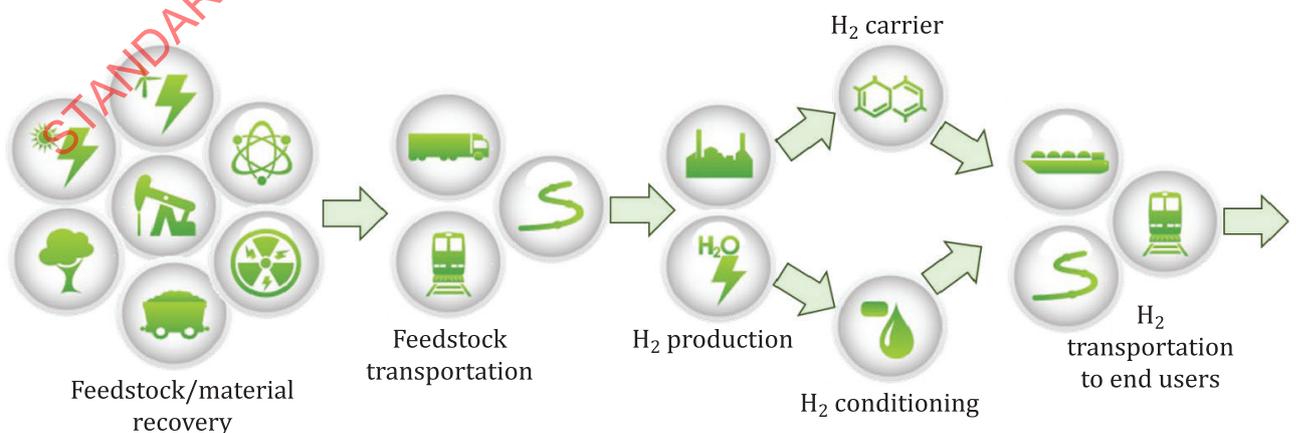

Figure 3 — Schematic of "well-to-consumption gate" system boundary adopted for this document

The emissions from the construction, manufacturing, and decommissioning of the capital goods (including hydrogen production device, etc.), business travel, employee commuting and upstream leased assets are not considered in the well-to-consumption gate system boundary. The rationale for this simplification was motivated by the comparatively small contribution that these emissions add to emissions associated with both fossil and renewable pathways[2], and the fact that they are expected to decrease rapidly in the future[3-5], due to effects of technological progress, and concurrent decarbonisation of upstream energy and material production, such as aluminium, clinker, copper or steel.

However, in some cases these emissions can be significant. Therefore, the quantification of these capital goods emissions, also known as "CAPEX emissions", shall be provided for information separately using relevant values taken from literature or evaluated by calculations following relevant ISO documents (e.g., ISO 14044).

The "well-to-consumption gate" system boundary is divided in three sections considering the hydrogen i) production, ii) conditioning/conversion and iii) transport, as described in Figure 4.
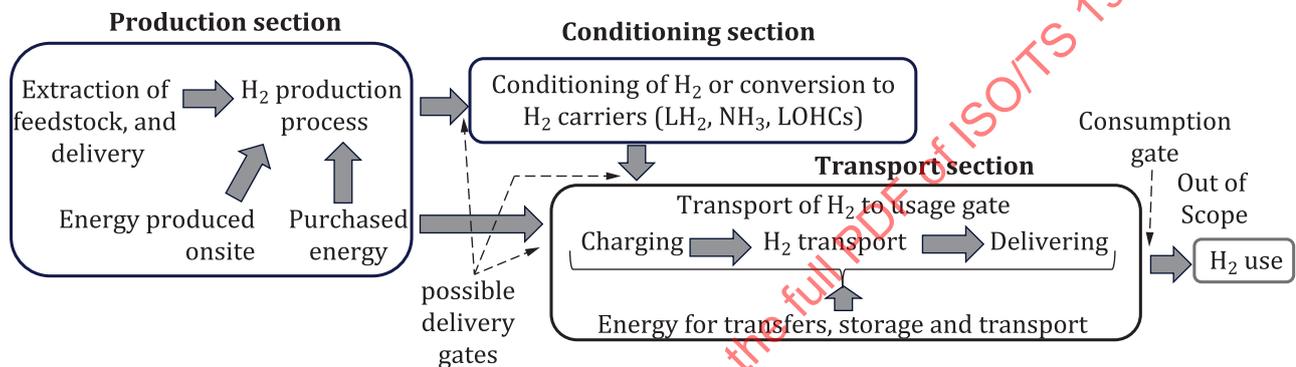

Figure 4 — "Well-to-consumption gate" system boundary divided in three sections (production, conditioning/conversion and transport)

The functional unit for life cycle analysis of hydrogen production is established as 1 kg of hydrogen at a pressure and a purity that corresponds to the inlet requirements of the subsequent stage. For hydrogen purity lower than 99 mol%, refer to Annex K[1], reflecting the impact on GHG emissions at usage (e.g. if balance is 1 % CO_2, this leads to an additional emission of 0,22 $kgCO_2e/kgH_2$).

In the context of life cycle analyses that include multiple consecutive stages depicted in Figure 4, the functional unit for analysis of each stage is recommended to be 1 kg of hydrogen or 1 kg of hydrogen carrier with properties that correspond to the requirements for delivery to the subsequent stage. For example, if a life cycle analysis covers hydrogen conversion into a carrier and cracking followed by hydrogen transport, analysis of the cracking stage should use a functional unit with pressure and purity requirements that correspond to the inlet requirements for the transport stage. As the downstream boundary limit, the delivery gate is considered as the delivery storage point for the functional unit before the next delivery or consumption gate.

The reporting metric recommended for life cycle analysis is $kgCO_2e/kgH_2$ for hydrogen at any delivery gate, and kgH_2 carriers for a hydrogen carrier at any delivery gate, with the exception of the consumption gate, where the carrier will be converted back to hydrogen.

4.2.1.2 Hydrogen production, conversion and conditioning

There are many process routes for hydrogen production, and different processes and methods are being proposed and implemented. This document gives the evaluation principles, system boundaries and expected reported metrics for seven main routes. Annexes A to G[1)] present the system boundaries of typical hydrogen production methods in hydrogen production from electrolysis of water, hydrogen

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1) Annexes A to K can be accessed via https://standards.iso.org/iso/ts/19870/ed-1/en

production from steam reforming of natural gas with CCS, hydrogen as a co-product in industrial applications, hydrogen production from coal gasification with CCS, hydrogen production from biomass, and hydrogen production from auto-thermal reforming of natural gas with CCS. Hydrogen conditioning and conversion

Emissions associated with hydrogen infrastructure past the hydrogen production gate (e.g. liquefaction, hydrogenation in a carrier) are also considered. The upstream boundary limit for the conditioning section is the downstream boundary limit for the previous production pathways. The downstream boundary limit is in this case the point of conditioning/conversion. Annexes H to J present the system boundaries of typical hydrogen conditioning/conversion methods: Annex H - conversion in ammonia production and cracking, Annex I - conditioning in hydrogen liquefaction and Annex J - conversion in hydro- and dehydrogenation of liquid organic hydrogen carriers.

4.2.1.3   Hydrogen transport

Many process routes can be used for hydrogen transport and different processes and methods are being proposed and implemented.

Figure 5 provides an illustrative example of a freight transport chain from the point where freight leaves its last point of production or transformation (Figure 5 Key A, freight consignor) to the point where freight reaches its first non-transport related operation (Figure 5 Key B, freight consignee).

This transport chain consists of five transport chain elements (TCEs), the GHG emissions of which are calculated separately. The first and last TCEs (TCE 1, TCE 5) represent road services (Figure 5 Key C) covering pre- and on-carriage; TCE 2 to TCE 4 represent a maritime freight service (Figure 5 Key D) composed of road/port terminal operations (TCE 2, TCE 4) and main carriage by maritime transport (TCE 3).

Key
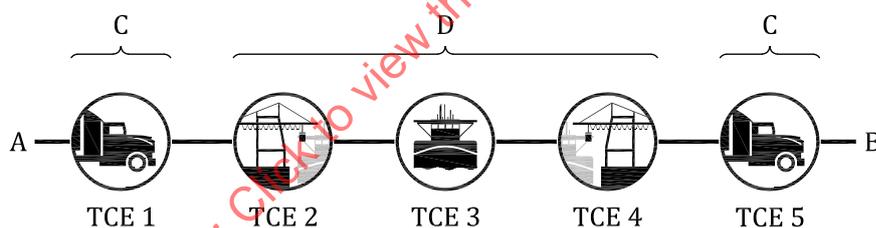
A   freight consignor

B   freight consignee

C   road services

D   shipping service

Figure 5 — Illustrative example of a multi-element freight transport chain [modified from ISO 14083:2023]

The quantification of GHG emissions shall include all transport operations (e.g. fuel consumption for propulsion and on-board activities) by the following modes and means, as well as the hub operations that precede and/or intermediate storages, follow or link them together:

— inland waterway transport;

— pipeline transport;

— rail transport;

— road transport;

— sea transport.

Transport of freight by forklift, pallet truck, etc. shall be part of hub operations. Only freight transports are considered including transport of different goods (hydrogen + X) in the same transport service. Concurrent transport of freight and passengers is not considered. Air transport is not considered in this document.

ISO 14083:2023, Annexes A to H include further specifications that shall be followed for transport modes (inland waterway, pipeline, rail, road, sea) and hubs, respectively. Reference values for GHG emission factors are presented in ISO 14083:2023, Annex K together with guidance on their production in ISO 14083:2023, Annex J.

4.2.2 Selected Cut-Off Criteria

In general, efforts shall be taken to include all processes and flows that are attributable to the analysed system. Completeness based on environmental significance should be tested by including and excluding processes in the system boundary to determine if results change[2].

If individual material or energy flows are found to be insignificant for a particular unit process, these may be excluded and shall be reported as data exclusions considering that if the actual data is known, then it should be included and not considered for exclusion. The cut-off criteria used to exclude certain processes of minor importance shall be clearly and consistently defined within the goal and scope definition phase.

Cut-off criteria for exclusion from analysis include:

a) uncertainty of the measurement equipment;

b) if regular and/or on-line measurements are unavailable, use proxy data derived from the open literature and applicable to the H_2 production location;

The final sensitivity analysis of the inputs and outputs data shall include the mass, energy and environmental significance criteria (expressed in CO_2e/kgH_2 and in CO_2e/kg of H_2 carriers when mentioning at each intermediate stage) and all inputs not considered in the study shall be reported.

4.2.3 Evaluation Elements

4.2.3.1 General Principles

The life cycle assessment of GHG emissions of produced hydrogen selects the impact of climate change as the evaluation element. The characteristic factors are shown in the following Table 1.

Table 1 — Types of environmental impacts and characteristic factors

Environmental impact type	Characterization model	Unit
Climate change	Global warming potential (GWP100)	kgCO$_2$e

The main greenhouse gases considered in this study are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The other GHGs mentioned by IPCC (AR5 WG1:2013, Appendix 8.A)[6] may be used for reporting on the capital goods emissions.

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2) Completeness based on environmental significance is defined by ISO 14044 to be based on three criteria: mass, energy and environmental significance.
Application of cut-off criteria to a given transport chain can rely on the following three possible quantifications:
a) Transport activity: inclusion in the study of all inputs that cumulatively contribute more than a defined percentage of the transport activity within the transport chain;
b) Energy: inclusion in the study of all inputs that cumulatively contribute more than a defined percentage of the transport activity within the transport chain;
c) Environmental significance: inclusion of all GHG sources that cumulatively contribute more than a defined percentage of the GHG emissions of the transport chain.
NOTE This percentage can be specified by national regulations.

The global warming potential (GWP) of the various greenhouse gases is expressed in CO_2e. GWP for other time horizons and GTP, as given by the Intergovernmental Panel on Climate Change (IPCC)., may be used in addition to GWP 100, but should be reported separately.

Table 2 — shows the GWP for a period of 100 years according to the Fourth Assessment Reports of the IPCC.[7] IPCC has released updated values in AR6 WG1[8] documents but AR5 WG1 [6] values are still the values recognised by the United Nations.

Table 2 — Global warming potential (GWP) of various GHGs [IPCC 2013]

	AR5 CO_2e (g/g)
CO_2	1
CH_4	28
N_2O	265

Following these coefficients, the GHG emissions quantity $kgCO_2e$ is:

$$[CO_2e]=[CO_2]+28\,x\,[CH_4]+265\,x\,[N_2O] \tag{1}$$

Following the product system boundaries, the energy requirements and GHG emissions resulting from the construction and decommissioning of manufacturing plants are only considered to inform separately on the capital goods emissions. Furthermore, energy requirements and emissions resulting from the manufacturing and decommissioning of installations or applications (e.g. vehicles) consuming the hydrogen are not considered.

4.2.3.2   Hydrogen production, conditioning and conversion

GHG impact of electricity used for H_2 production shall be restricted to direct emissions and partial indirect emissions assumptions (not including emissions associated with manufacturing of power generation facilities). It shall include extraction and transport of primary energy, transformation, power generation and losses in electricity grids. As a result of this assumption, the GHG impact of electricity generation from wind, solar photovoltaic, hydropower and geothermal will be assumed to be zero. However, as mentioned in 4.2.1, capital goods emission shall be reported for information.

4.2.3.3   Hydrogen transport

The assessment of GHG emissions of a transport service shall include the following, which produce GHG by combustion or by leakage, regardless which organization operates them:

a)   processes implemented by:

1)   external handling or transhipment devices for the movement or transhipments of freight.;

2)   hub equipment operational processes;

3)   vehicle energy provision processes;

4)   hub equipment energy provision processes;

5)   start-up and idling of vehicles, pipelines, transhipment and (de)boarding equipment;

6)   cleaning/flushing operations for pipelines.

b)   both vehicle operational processes and energy operational processes that occur during the operational phase of the lifecycle.

1)   the vehicle operational processes shall include operation of all on-board vehicle systems including propulsion and ancillary services;

2) loaded and empty trips made by vehicle, hence including diversionary and/or out-of-route distance

3) through the use of recommended or best available (e.g. national) GHG emission factors, the energy operational processes shall include:

4) for solid, liquid and gaseous energy carriers: extraction or cultivation of primary energy, chemical processing, transport and distribution (including pipeline) of energy at all steps of the production of the energy carrier used;

5) for electricity: extraction, processing and transport of primary energy, transformation, power generation, losses in electricity grids associated with transmission and distribution of electricity;

c) combustion and/or leakage of energy carriers at vehicle or hub equipment level;

d) leakage of GHG used by vehicles or hubs.

Where best available GHG emission factors do not include production and dismantling of energy source infrastructure this shall be noted in the reporting, in accordance with the cut-off criteria guidance in 4.2.2.

The assessment of GHG emissions of a transport service shall not include, in particular:

— processes consisting of short-term assistance to the vehicle for security or movement reasons, with other devices like tugboats for towing vessels in harbors, etc.;

— processes at the administrative (overhead) level of the organizations involved in the transport services. These processes can be operation of buildings, staff commuting and business trips, computer systems, etc.;

— processes for the construction (e.g. embedded GHG emissions associated with vehicle production), maintenance, and scrapping of vehicles or transshipment and (de)boarding equipment;

— processes of construction, service, maintenance, and dismantling of transport infrastructures used by vehicles (e.g. roads, inland waterways, rail infrastructure) or transshipment and (de)boarding infrastructure;

— non-operational energy processes, like the production or construction of extraction equipment's, of transport and distribution systems, of refinery systems, of enrichment systems, of power production plants, etc. so as their reuse, recycle and scrap;

— production and supply processes of refrigerants;

— waste produced;

— businesses co-located within a hub such as retail and hospitality services, whose functions are severable and incidental to the transport operation of the hub.

The following processes may be included in the calculation:

— storage of freight at hubs, such as warehousing;

— use of information and communications technology (ICT) equipment and data servers related to transport and/or hub operations (see ISO 14083:2023, Annex N);

— (re)packing (see ISO 14083:2023, Annex O).

Outcomes from carbon offsetting actions or GHG emissions trading (e.g. under the European Union Emissions Trading System (EU ETS)) shall not be taken into account for quantification and reporting of GHG emissions from transport operations.

4.2.4 Evaluation cycle

The hydrogen considered should be evaluated for hydrogen produced in an industrial plant as the object.

The evaluation cycle for data is the considered time period of hydrogen production for which the quantified figure for the GHG emissions are representative. The time period for which the GHG emissions are representative shall be specified and justified.

The timing of GHG emissions and captures relative to the year of production of the product shall be specified in the life cycle inventory. The effect of timing of the GHG emissions and captures from the product system (as CO_2e), if calculated, shall be documented separately in the CFP study report. The method used to calculate the effect of timing shall be stated and justified in the CFP study report. The choice of the time period for data collection should consider intra- and inter-annual variability and, when possible, use values representing the trend over the selected period. Where the GHG emissions and captures associated with specific unit processes within the life cycle of a product vary over time, data shall be collected over a time period appropriate to establish the average GHG emissions and captures associated with the life cycle of the product.

4.3 Quantification of greenhouse gas emissions

4.3.1 Process description and data quality

The process, methods and requirements of hydrogen life cycle impact assessment refer to ISO 14067:2018, Clause 5.

A description of the following items is given for each stage of the life cycle of a hydrogen pathway.

As a minimum, a) to m) should be provided for each of the hydrogen production, conditioning, conversion, transport and distribution lifecycle stages:

a) hydrogen process overview and description: production, conditioning and transport;

b) emissions accounting method;

c) emissions inventory;

d) energy supply;

e) upstream emissions relating to the upstream extraction of resources;

f) emissions allocation;

g) results of sensitivity analyses and uncertainty analysis;

h) results of the life cycle interpretation, including conclusions and limitations;

i) disclosure and justification of value choices that have been made in the context of decisions within the study;

j) description of the stages of the life cycle, including a description of the selected use profiles when applicable;

k) assessment of influence of alternative use profiles on the final results;

l) time period for which the partial carbon footprint is representative;

m) reference used in the study.

The methodology should use data that reduces bias and uncertainty by using the highest quality data available. Data quality shall be characterized by both quantitative and qualitative aspects.

Characterization should address the following:

— time-related coverage: age of data and the minimum length of time over which data should be collected;

— geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the partial carbon footprint study;

— technology coverage: specific technology or technology mix;

— precision: measure of the variability of each data value expressed (e.g. variance);

— completeness: percentage of total flow that is measured or estimated;

— representativeness: qualitative 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: qualitative assessment of whether or not the study methodology is applied uniformly to the various components of the sensitivity analysis;

— reproducibility: qualitative 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 partial carbon footprint study;

— sources of the data;

— uncertainty of the information.

4.3.2   Emissions inventory

4.3.2.1   General principles

An overview of the GHG emissions accounting methodology applied to each pathway is summarised below.

Total GHG emissions will be described following Figure 4 as:

$$E_{\text{total emissions inventory}} =$$

$$E_{\text{emissions inventory production}} + E_{\text{emissions inventory conditioning}} + E_{\text{emissions inventory transport}} \tag{2}$$

Emissions include all direct and indirect emissions arising in the "well-to-consumption gate" boundary as defined in 4.2.1.

Formula 3 shows the breakdown of the emissions inventory into its components (emissions categories). Individual countries may use their own emissions inventory that aligns with IPCC guidelines.

$$E_{\text{emissions inventory}} = E_{\text{combustion emissions}} + E_{\text{fugitive emissions}} + E_{\text{industrial process emissions}}$$

$$+ E_{\text{energy supply emissions}} + E_{\text{embodied emissions}} \tag{3}$$

In the case of carbon capture:

— if the captured CO_2 is stored, it shall be considered as Waste and the emissions related to capture and storage shall be considered within the inventory of emissions assigned to the production of hydrogen;

— if the captured CO_2 is used, the emissions resulting from its usage shall be assigned to the life cycle stage in which the GHG emissions occur (see ISO 14067:2018, 6.1).

Such emissions shall be accounted for as follows, depending on the goal of the GHG evaluation:

— if the GHG evaluation goal is attributional (see 4.1.2), the GHG emissions resulting from the use of the captured CO_2 shall not be taken into account in the inventory of emissions of the hydrogen production as they do not occur within the life cycle stage of hydrogen production;

— if the GHG evaluation goal is consequential (see 4.1.3), the boundaries of the system may be expanded to include other lifecycle stages where GHG emissions can be affected as a consequence of hydrogen production.

4.3.2.2 Combustion emissions

This source refers to the combustion of relevant solid, liquid and/or gaseous fuels including (but not limited to) coal, diesel and natural gas. Combustion emissions can be estimated via a variety of approaches including use of emission factors and measurement of fuel (volumetric or gravimetric), and direct measurement.

Combustion emissions should be calculated according to Formula 4:

$$E_{combustion} = \sum_i E_{combustion,i} \qquad (4)$$

where $E_{combustion}$ is the sum of emissions of carbon dioxide, methane and nitrous oxide (as applicable), released from the combustion of fuel type (i) within the module measured and converted in CO_2e tonnes. This covers combustion of solid, liquid, and gaseous fuels calculated using a variety of methods

4.3.2.3 Fugitive emissions

This source intends all structural and operational losses due to the technology deployed and plant management respectively. Therefore, leakages and accidental losses, as well as other losses due to incorrect management plant operations, are considered fugitive emissions.

Fugitive emissions should be calculated according to Formula 5:

$$E_{fugitive} = \sum_i E_{fugitive,i} \qquad (5)$$

where $E_{fugiive}$ is the sum of structural and operational emissions of carbon dioxide, methane and nitrous oxide (as applicable), released from fugitives of source type (i) within the module measured in CO_2e tonnes.

As for most hydrogen producers, fossil fuels are provided by a third party, fugitive emissions associated to its transmission and distribution are taken into account by upstream emissions.

4.3.2.4 Industrial process emissions

Refers to emissions of specific GHG gases used across a number of industry activities (e.g. hydrofluorocarbons (HFCs) used in industrial refrigeration and/or cooling systems, and sulphur hexafluoride (SF_6) used in electrical switchgear). For the purposes of this methodology, this is expected to be limited to emissions of CH_4 and N_2O except for the reporting on the capital goods emissions.

There are a variety of approaches that may be employed to estimate these emissions. Typically, this can be via assumed leakage rates, or changes in stock levels of the relevant substances as measured throughout the relevant production batch period. These items are expected to be extremely minor sources, and estimation should be sufficient in most cases.

Industrial process emissions should be calculated according to Formula 6:

$$E_{\text{industrial process emisisons}} = \sum\nolimits_i E_{\text{industrial process emissions},i} \tag{6}$$

where $E_{\text{industrial process emissions}}$ is the sum of emissions of relevant GHG (as applicable), released from industrial process activity (i) within the module measured in CO_2e tonnes.

4.3.2.5 Energy supply

4.3.2.5.1 General principles

For the location-based emissions accounting approach, energy supply emissions should be calculated according to Formula 7:

$$E_{\text{energy supply emissions,location}} = \sum\nolimits_i E_{\text{energy supply emissions},i} \tag{7}$$

where $E_{\text{energy supply emissions,location}}$ is the emissions of carbon dioxide, methane and nitrous oxide (as applicable), associated with supply of energy (i) within the module measured in CO_2e tonnes (calculated in line with the location-based approach).

For the market-based emissions accounting approach, net energy supply emissions should be calculated according to Formula 8:

$$E_{\text{net energy supply emissions,market}} = \sum\nolimits_i E_{\text{energy supply emissions},i} - E_{\text{applicable energy}} \tag{8}$$

where

$E_{\text{energy supply emissions,market}}$	is the emissions of carbon dioxide, methane and nitrous oxide (as applicable), associated with supply of energy (i) within the module measured in CO_2e tonnes (calculated in line with the market-based electricity approach);
$E_{\text{applicable energy}}$	is the emissions associated with the supply of energy (in MWh) for which relevant energy certificates have been purchased and retired.

4.3.2.5.2 Treatment of electricity

The GHG emissions associated with the use of electricity shall include:

— GHG emissions arising from the life cycle of the electricity supply system, such as upstream emissions (e.g. the mining and transport of fuel to the electricity generator or the growing and processing of biomass for use as a fuel). Following the product system boundaries, emissions associated with capital equipment manufacturing, construction and decommissioning are excluded in this version. However, an indicative value of these emissions shall be provided in line with the requirement of 4.2.1.

— GHG emissions arising from the supply of the electricity including:

  — the supplied electricity counted at the in gate of the hydrogen-production facility;

  — the losses from the electricity generation process and from transmission and distribution.

a) On-site electricity generation

   When electricity is internally generated (e.g. on-site generated electricity) and consumed for the investigated hydrogen production process and no contractual instruments have been sold to a third party, then the emissions would be any direct emissions resulting from generating that electricity.

Following the product system boundaries, direct emissions from electricity use may be considered to be zero when on-site renewable electricity produced from hydro, photovoltaic or wind is used. However, an indicative value of the capital goods emissions shall be provided as per the requirement under 4.2.1

b) Electricity from the grid

The electricity GHG emissions should refer to emissions attributed to electricity consumed by the plant, considering upstream emissions, operational and downstream emissions and all losses in the electricity-generation facility and transmission and distribution losses.

If the GHG evaluation goal is attributional (see 4.1.2):

The electricity emissions reporting method proposed is consistent with ISO 14064-1:2018, Annex E. This approach includes dual reporting requirements consisting of a location-based and market-based method.

The following is adapted from ISO 14064-1:2018, Annex E.

— *A location-based method reflects the average emissions intensity of grids on which energy consumption occurs (using mostly grid-average emission factor data).*

— *A market-based method reflects emissions from electricity that companies have purposefully chosen (or their lack of choice). It derives emission factors from contractual instruments, which include any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims.*

Markets *differ as to what contractual instruments are commonly available or used by companies to purchase energy or claim specific attributes about it, but they can include energy attribute certificates (RECs, GOs, etc.), direct contracts (for both low-carbon, renewable, or fossil fuel generation), supplier specific emission rates, and other default emission factors representing the untracked or unclaimed energy and emissions (termed the "residual mix") if a company does not have other contractual information.*

Provided that market based contractual instrument and default emission factors (residual mix) meet proper quality criteria, the market-based method should be used in priority to determine the emission factor of electricity used to produce hydrogen.

An example of quality criteria for market-based information can be found in the ISO 14064-1:2018, Annex E.

If the GHG evaluation goal is consequential (see 4.1.3):

When electricity is purchased on the generic electricity market, the processes to include are those that are expected to react to a change in demand for electricity. These can be identified from national forecasts of electricity generation capacity as those generation activities that have capacity increase over time, not determined by political quota or resource constraints. When more than one such generation activity is identified, a mix shall be applied, in proportion to the rate of growth in capacity, taking into account the lifetime of the installed capacity.

When electricity is purchased from specific suppliers that expand their capacity in proportion to the specific demand that under Guarantee of Origin is provided in excess of what they deliver to the generic market, the emission factors of these suppliers can be used.

4.3.2.5.3 Treatment of steam

The steam involved in different processes can be either as a heat input (e.g. to ensure the required temperature within different sub processes) or a feedstock (e.g. high temperature electrolysis or gas reforming) or a co-product (e.g. steam co-produced in SMRs).

When steam is an input to the hydrogen production facility, the emissions assigned to its production and supply shall be allocated to the co-products of the Hydrogen production facility as provided for under the 4.3.2.8 emissions allocations.

When steam is a co-product, the fraction from the GHG emissions inventory to be allocated to steam shall be determined as provided for under 4.3.2.8 emissions allocations.

4.3.2.5.4 Treatment of natural gas

Depending on the available data, calculation of the emission factor of the used gas (as energy or feedstock) ($kgCO_2e$ / MWh) for the different pathways considered can be performed by:

a) using a well-documented emission factor of the gas purchased based on independent, third party, public-funded scientific analysis;

b) individual gas suppliers can be given the possibility to prove that their facilities operate at a lower level of leakage than the default level. This can be achieved using Guaranties of Origin schemes;

c) using an emission factor provided by national authority, or data source which is generally used in the country or area where the well is located, or otherwise globally used LCA data base. The system boundary of the data should match that of the gas purchased. GHG emissions from gas transport to consumption gate and leakages from extraction gate to consumption gate shall be accounted for.

4.3.2.5.4.1 Upstream system of a hydrogen-production pathway using natural gas

This covers upstream activities associated with the extraction, processing and delivery of the natural gas feedstock. Potential co-products from the gas extraction and processing steps include natural gas liquids such as ethane, propane, butane and pentane, as well as oil and condensates. These products often co-exist with the gas extracted from the reservoir and are typically separated out from the gas stream as they attract a higher value when sold as separate products.

System expansion is not feasible for this application as an appropriate alternative method for producing these products does not exist. Therefore, since natural gas is valorised for its energy, allocation will be performed for these co-products based on the proportion of energy content of the individual products.

If the GHG evaluation goal is consequential (see 4.1.3), and depending on the boundaries of the consequences considered for the LCA, the product system is expanded to include the marginal consumers of these co-products, i.e. the consumers that will change their consumption when the price of these co-products change; in this case, vehicles that can run on both gasoline and natural gas liquids, so that an increase in availability of natural gas liquids will lead to a reduction in the demand for gasoline.

The net remaining emissions are carried with the gas product stream (as upstream emissions) into the hydrogen production pathway considered.

See Figure 6 for an example of a process diagram for the upstream system to deliver natural gas for hydrogen production.
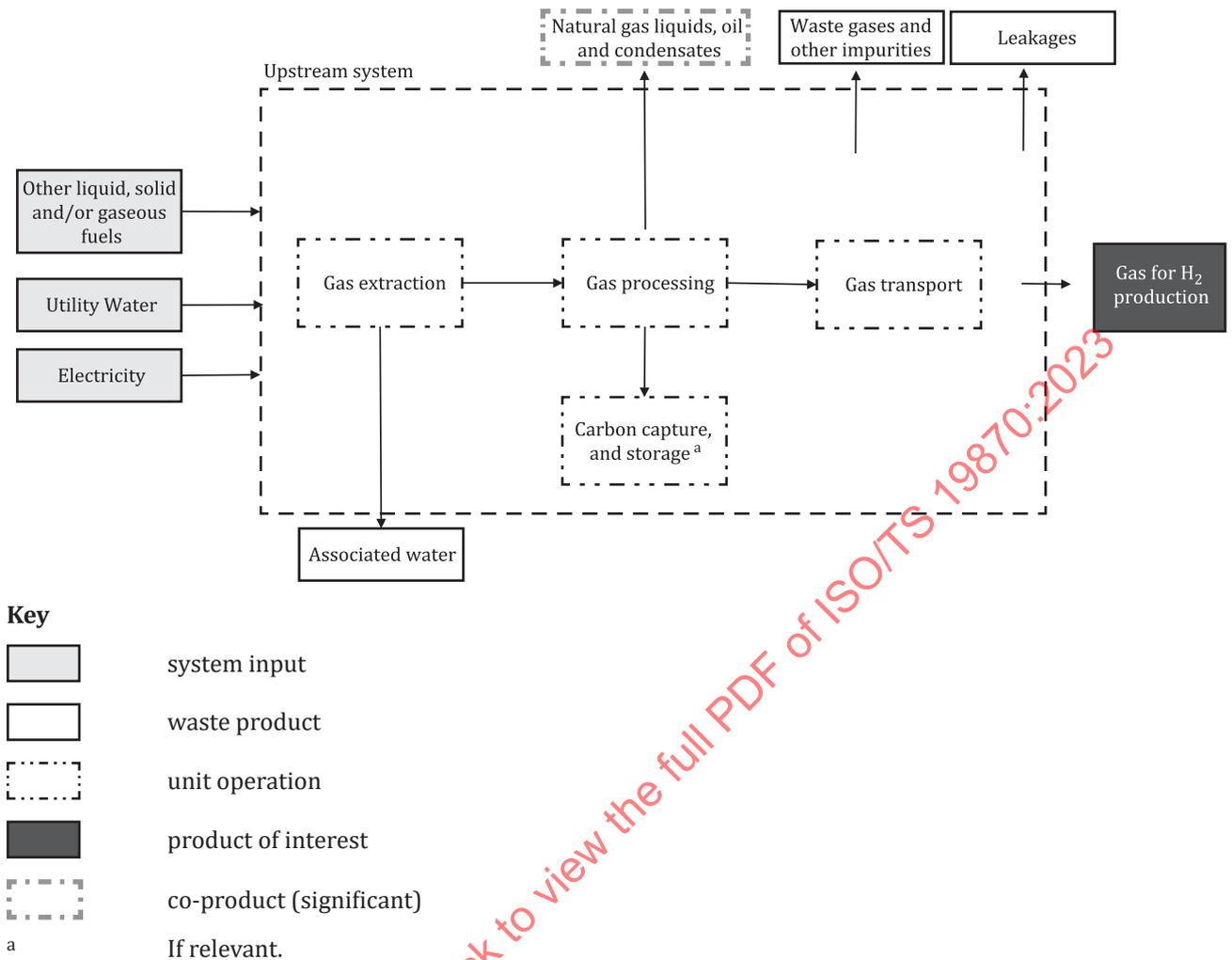
Key

(light grey box)	system input
(white box)	waste product
(dotted box)	unit operation
(dark grey box)	product of interest
(grey dashed box)	co-product (significant)
a	If relevant.

Figure 6 — Example of process diagram for the upstream system to deliver the natural gas for H$_2$ production

4.3.2.6 Treatment of GHG emissions of one transport service

4.3.2.6.1 General Principles

The treatment of GHG emissions of one transport service described in this subclause summarizes the main approaches of ISO 14083:2023 where detailed information is provided.

4.3.2.6.2 Calculation of transport activity

The transport activity for freight transport shall be the quantity of freight multiplied by the transport activity distance in ton.km. The quantity of freight shall be the actual freight mass.

The standard unit for expressing units of mass (e.g. quantities of freight) shall be kg or metric tonnes.

For container transport, the quantity of freight may be the number of twenty-foot equivalent units (TEUs). Where such a choice is made, the mass of freight should be calculated using the actual mass of freight per TEU, if known, or otherwise using an average mass per TEU. Any such choice should be justified and documented. Alternate container types and sizes exist. For example, one standard 40-foot ISO Series container is equivalent to two TEUs; one ISO Series 45-foot container is equivalent to 2.25 TEUs; one high cube 40-foot container is equivalent to 2.25 TEUs.

Where the actual mass of freight per TEU is not known, a standard conversion factor of 10 tonnes per TEU may be used (so 20 tonnes for a 40-foot container). Alternatively, a value of 6 tonnes may be used for lightweight cargo or 14.5 tonnes for heavyweight cargo if the use of these categories can be justified.

The quantity of freight shall include the mass of the packaging initially provided by the organization responsible for sending a consignment, and shall not include any additional transport packaging, pallets or containers used by the transport operator specific to the transport operation in question.

The transport activity distance shall be either the shortest feasible distance (SFD) or the great circle distance (GCD). In cases where the transport operator does not have access to the SFD or the GCD, the actual distance and a distance adjustment factor (DAF), as described in 4.3.2.6.5.5, should be used.

A DAF shall be used each time the actual distance is used in the calculation of transport activity. The DAF is used by multiplication of the actual distance by a specific DAF value. The DAF serves to increase the transport activity distance used in the calculation of GHGs to allow for systematic differences between the actual distance and the SFD or the GCD. Recommended values of the DAF are provided for different modes in ISO 14083:2023, Annexes A to G. In cases where the actual distance and the transport activity distance correspond, the DAF can equal 1.

The standard unit for expressing distance shall be the kilometre (km).

4.3.2.6.3 Calculation of hub activity

The hub activity for freight shall be the quantity of freight (outbound). The quantity of freight shall include the mass of the packaging initially provided by the organization responsible for sending a consignment, and shall not include any additional transport packaging, pallets or containers used by the transport operator specific to the transport operation in question.

4.3.2.6.4 Allocation

Allocation may be implemented when multiple functionalities are fulfilled by the same vehicle or hub, and all freight carried do not benefit equally. Wherever possible, allocation should be avoided by dividing the process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes. In circumstances where it is required, allocation shall partition GHG sources or GHG emissions between the freights that benefit equally from the same functionality. The implementation of the partitioning between these groups shall consider the different needs of GHG sources and the different GHG emissions resulting from these needs.

The transport or hub activity of each group may be used for this partitioning, but other criteria and parameters can be necessary. Once set, the allocation parameter used within a given TOC or hub operation category (HOC) shall remain constant.

4.3.2.6.5 Principles of quantification of GHG emissions related to transport chains (TC), transport chain elements (TCE), transport operation categories (TOC) and hub operation categories (HOC)

4.3.2.6.5.1 General Principles

For the purposes of GHG quantification, the transport chain shall be broken down into the discrete, sequential TCEs that reflect the related vehicle types, pipelines, hubs or hub services that carry, handle or transfer the freight as part of the whole transport chain (e.g. Figure 7).

Calculation for one given transport service shall be implemented through the following three main steps:

— step 1: Identification of the different TCEs of this transport service with the different transport operations and hub operations;

— step 2: Calculation of GHG emissions of each TCE with the different transport operations and hub operations;

— step 3: Sum of the results for each TCE.
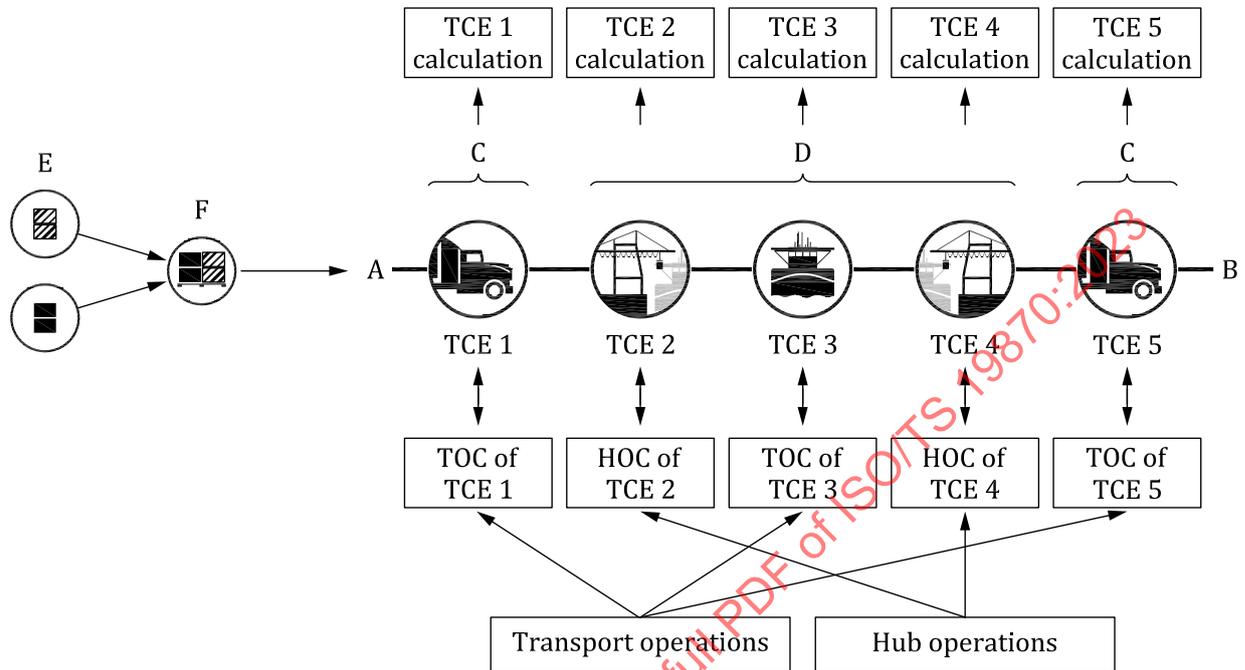
Key

A   cargo consignor

B   cargo consignee

C   road services

D   rail service

E   shipment

F   consignment

Figure 7 — Diagrammatic relationship between operations and TCEs for an example freight transport chain (modified from ISO 14083:2023)

Any single transport operation or hub operation shall always be considered in the context of the overall system in which it takes place. The concept of a TOC or an HOC, as a group of operations sharing similar characteristics, in a defined time period (up to one year), is the key reference point for the calculation of the GHG emissions of a TCE. The characteristics of each TOC/HOC shall reflect the combined characteristics of the transport mode, hub type and the freight/passengers, as required to meet the relevant contractual agreement.

a)   Transport Operation Categories (TOC)

When defining the characteristics of a TOC, consideration shall be given to factors that affect the scale and composition of the TOC, for example:

— number and type of vehicles, or length and type (diameter) of pipeline, to be included in the TOC;

— nature and consistency of the vehicle or pipeline operations included;

— any processes associated with maintaining the condition of the freight (e.g. temperature control);

— nature of the freight carried;

— period of activity of the vehicles or pipelines in the TOC.

ISO 14083:2023, Annexes A to G provide further examples of how such characteristics can be combined to establish TOCs.

TOCs can have different levels of granularity, for example:

— TOC of a single vehicle on a single journey or specific schedule;

— TOC of a single vehicle in multiple schedules/trade lanes, based on network/trade lane characteristics;

— TOC of a specific vehicle type in a single schedule;

— TOC of a specific vehicle type in multiple schedules/trade lanes;

— TOC of a specified fleet in a single schedule;

— TOC of a specified fleet in multiple schedules/trade lanes.

A single TOC can include transport operations with vehicles using different energy carriers for propulsion, e.g. a container line operator uses vessels, some powered by MDO and some powered by liquefied natural gas (LNG), interchangeably on a given trade lane.

Transport operations which constitute a TOC should include entire round trips made by the vehicles in order to balance out GHG emissions within asymmetric transport flows. An exception to this is when a vehicle or vessel is chartered to perform a one-way journey that can be specifically identified within both the transport operator's and transport purchaser's systems. Pipelines are another exception due to the fixed nature of the infrastructure.

The TOC should include loaded trips (possibly with varying load factor) and all the empty trips related to them. Hence, the GHG emissions for a single transport or hub operation cannot be calculated without reference to the TOC or HOC in which it takes place. Where empty containers, roll cages or pallets are transported on behalf of a purchaser of transport services for the purpose of relocation in order to move a new load they become a consignment in their own right and GHG emissions should be assigned to them accordingly.

Each transport operation shall be associated with an existing TOC.

b) Hub Operation Categories (HOC)

When defining the parameters of an HOC, consideration shall be given to factors that affect the scale and composition and characteristics of the HOC such as:

— number and type of hub operations contributing to the HOC;

— for freight: e.g. handling of freight, (un-) loading, (de-) boarding, transport on-site;

— nature and consistency of the hub operations included in the HOC (e.g. electrified or non-electrified);

— inbound and outbound transport mode and relevance of intermodal change;

— any processes essential for maintaining the condition of the freight;

— for freight: e.g. temperature control, repacking;

— nature of the freight handled (e.g. palletized, containerized, piece good).

HOCs can have different levels of granularity, for example:

— HOC of a single hub;

— HOC of a specific hub type.

An HOC shall fully include each hub operation, meaning that a hub operation shall not be split between two HOCs, even if this operation simultaneously benefits different TCEs (e.g. TCEs for ambient and temperature-controlled freight).

A hub may perform different hub operations that form part of different HOCs.

Each hub operation shall be associated with an existing HOC

4.3.2.6.5.2 Establishment of GHG emission intensity of a TOC or a HOC

The implementation of GHG emission quantification can rely on the involvement of different stakeholders and complementary inputs and calculations following several steps, as defined in ISO 14083:

— Each transport chain shall be broken down into TCEs;

— Each TCE shall be related to a transport or hub operation;

— Each transport or hub operation shall be related to a TOC or HOC. The TOC or HOC shall gather operations sharing similar characteristics, implemented over a defined period. This period should be one year or less;

— A GHG emission intensity (in some cases, several GHG emission intensities) shall be established or selected for each TOC or HOC;

— Then the GHG emissions of each TCE shall be calculated based on the corresponding GHG emission intensity and the transport or hub activity of this TCE;

— Finally, the GHG emissions of the transport chain shall be the sum of the GHG emissions of its TCEs.

GHG emission intensities of TOCs and HOCs shall be established using one of the four following options:

— calculation with primary data;

— calculation with a model;

— selection of a value from a database of default values;

— collection of a value from a contracted operator that has used calculation with primary data or with a model.

The values for total GHG activity, the related transport or hub activity, and derived GHG emission intensity shall be prioritized as follows to reflect the level of data access within the transport chain reporting:

— Primary data shall be used. Where this is not available, secondary data may be used. The reasons for using secondary data shall be justified and documented;

— Where secondary data are used, modelled data shall be prioritized over default data.

Commonly combinations of primary and secondary data are needed and used.

Getting the lowest possible value of GHG emission intensity shall not be a criterion for this selection.

a) Calculation of GHG emissions for a transport chain

The following steps shall be followed:

1) Break down the transport chain into its constituent TCEs;

2) Calculate the sum of GHG emissions of all TCEs of the transport chain;

3) Calculate the sum of transport activity of all TCEs of the transport chain;

4) Calculate the GHG emission intensity of the transport chain, with GHG emissions (result of step 2) and transport activity (result of 3).

b) Calculation of GHG emissions of each TCE

The following steps shall be followed:

1) Select a TOC or HOC GHG emission intensity corresponding to this operation;

2) Calculate the transport or hub activity of the TCE;

3) Calculate the GHG emissions of the TCE using transport or hub activity, the selected GHG emission intensity and, for transport, a DAF.

4.3.2.6.5.3 Quantification and calculation of GHG emissions at TOC level

GHG activity data shall encompass all GHG sources of the TOC, and therefore shall consist of the total consumption of each energy carrier, as well as any other quantified GHG activity data relevant to the transport operations of the TOC. In situations where the GHG activity data results from the use of different GHG sources (energy carriers), GHG activity data shall be quantified separately for each GHG source (energy carrier).

This step shall distinguish the following two situations:

— **No allocation needed**: when each vehicle operating in the TOC provides the same functionalities to all consignments carried, all GHG emissions within the TOC shall be added.

Conversion of GHG activity data into vehicle operation and energy provision GHG emissions shall be conducted using Formulae (9) and (10) for each type of GHG activity A_i:

$$G_{VO,TOC,A_i} = Q_{TOC,A_i} \times \varepsilon_{VO,A_i} \tag{9}$$

$$G_{VEP,TOC,A_i} = Q_{TOC,A_i} \times \varepsilon_{VEP,A_i} \tag{10}$$

where

G_{VO,TOC,A_i}	is the vehicle operation GHG emissions of the TOC for GHG activity type A_i;
Q_{TOC,A_i}	is the quantity of GHG activity type A_i for the TOC (e.g. A_i is combustion of diesel fuel and Q_{diesel} equals 12,000 kg of diesel or A_i is leakage of refrigerant R-134a and Q_{R-134a} equals 100 kg of the refrigerant R-134a);
ε_{VO,A_i}	is the vehicle operation GHG emission factor for GHG activity type Ai (e.g. $\varepsilon_{VO,diesel}$ = 3,22 kg CO_2e/kg or $\varepsilon_{VO,R-134a}$ = 1,430 kg CO_2e/kg);
G_{VEP,TOC,A_i}	is the vehicle energy provision GHG emissions of the TOC for GHG activity type A_i;
μ_{VEP,A_i}	is the vehicle energy provision GHG emission factor for GHG activity type A_i (e.g. $\varepsilon_{VEP,diesel}$ = 0,56 kg CO_2e/kg).

Values for GHG emission factors should be used as set out in ISO 14083:2023, Annex Q. Where national legislation mandates the use of specific GHG emission factors, or a government provides GHG emission factors for voluntary GHG emission reporting, the use of these sources of GHG emission factors shall be clearly documented.

Where there are multiple GHG activity types (e.g. the vehicles use different energy carriers or refrigerants), the GHG emissions for each GHG activity type shall be calculated separately and then

added together to provide the total GHG emissions of the TOC. Formulae (11), (12) and (13) shall be used:

$$G_{\text{VO,TOC}} = \sum_i G_{\text{VO,TOC,A}_i} \tag{11}$$

$$G_{\text{VEP,TOC}} = \sum_i G_{\text{VEP,TOC,A}_i} \tag{12}$$

$$G_{\text{VEP,TOC}} = \sum_i G_{\text{VEP,TOC,A}_i} \tag{13}$$

where

$G_{\text{VO,TOC}}$ is the vehicle operation GHG emissions of the TOC;

$G_{\text{VO,TOC,A}_i}$ is the vehicle operation GHG emissions of the TOC for each GHG activity type A_i;

$G_{\text{VEP,TOC}}$ is the vehicle energy provision GHG emissions of the TOC;

$G_{\text{VEP,TOC,A}_i}$ is the vehicle energy provision GHG emissions of the TOC for GHG activity type A_i;

G_{TOC} is the total GHG emissions of the TOC.

The GHG emission intensity of the TOC shall be calculated by dividing the total GHG emissions of the TOC by the total transport activity of the TOC using Formula (14):

$$g_{j_v,\text{TOC}} = \frac{G_{j_v,\text{TOC}}}{T_{\text{TOC}}} \tag{14}$$

where

j_v is either the vehicle operation or the vehicle energy provision;

$g_{j_v,\text{TOC}}$ is the total GHG emissions for activity type j_v for the TOC;

$G_{j_v,\text{TOC}}$ is the total GHG emissions for activity type j_v for the TOC;

T_{TOC} is the transport activity of the TOC.

The outcome shall be expressed as mass of CO_2e per transport activity.

— **Allocation needed**: when the vehicles of the TOC provide different functionalities (providing different functionalities to different groups of freight), the corresponding GHG emissions shall be calculated for each group.

The principles of the previous point shall be adapted, in order to quantify the following separately:

— $G_{\text{TOC,all}}$: GHG emissions of the TOC that result from GHG activity that benefits all freight equally;

— $G_{\text{TOC,sgi}}$: GHG emissions of the TOC that result from GHG activity that benefits a specific group or groups of freight sg_i differently to other freight within the TOC (i from 1 to n, n being the number of specific groups).

This allocation of GHG emissions shall ensure that no GHG emissions are lost or double-counted, and therefore that Formula (15) is verified:

$$G_{\text{TOC}} = G_{\text{TOC,all}} + \sum_i^{n\text{TOC}} G_{\text{TOC,sg}_i} \tag{15}$$

where

G_{TOC} is the vehicle operation GHG emissions of the TOC;

$G_{\text{TOC,all}}$ is the GHG emissions of the TOC resulting from GHG activity that is not related to any specific group of the TOC;

$G_{\text{TOC,sg}_i}$ is the GHG emissions of the TOC resulting from GHG activity calculated for the specific group sg_i of the TOC;

n_{TOC} is the number of specific groups of the TOC.

The chosen allocation principles shall remain consistent over time and shall be documented transparently, as appropriate.

Only one type of transport activity distance (SFD or GCD) shall be used for the calculation of transport activity of a TOC.

In this general case, calculation of the freight transport activity of a TOC shall be made using Formula (16):

$$T_{TOC,f} = \sum_{i}^{c} M_i \times s_{\text{ci}} \tag{16}$$

where

$T_{\text{TOC,f}}$ is the freight transport activity of the TOC;

M_i is the mass of an individual consignment i in the TOC;

s_{ci} is the transport activity distance of an individual consignment i in the TOC;

c is the number of consignments in the TOC.

In the case of a TOC with multi-temperature vehicles (τ different temperature conditions), a freight transport activity shall be calculated separately for each temperature condition t_k for freight, with k from 1 to τ, where t_1 is ambient, using Formula (17), which is similar to Formula (16):

$$T_{\text{TOC,k}} = \sum_{i}^{v_{c,\tau k}} M_{i,k} \times s_{\text{pi},\tau k} \tag{17}$$

where

$T_{\text{TOC,k}}$ is the freight transport activity of the consignments in temperature condition t_k of the TOC;

$M_{i,k}$ is the mass of the individual consignments i in temperature condition t_k of the TOC;

$s_{\text{pi},\tau k}$ is the transport activity distance of an individual consignment i in temperature condition t_k of the TOC;

$v_{c,\tau k}$ is the number of consignments of type t_k in the TOC;

Finally, the transport activity for the TOC should be calculated using Formula (18):

$$T_{\text{TOC,f}} = \sum_{i}^{\tau} T_{\text{TOC,k}} \tag{18}$$

where

$T_{\text{TOC,f}}$ is the freight transport activity of the TOC;

$T_{\text{TOC,k}}$ is the freight transport activity of the consignments in temperature condition t_k of the TOC;

τ is the number of temperature conditions.

In the case of a TOC of freight of multi-temperature vehicles with n_t different temperature conditions t_k (k from 1 to n_t, e.g. t_1 is ambient, t_2 is refrigerated), the calculation of GHG emissions intensities shall rely on:

— the calculation of GHG emissions in accordance with allocation of specific GHG activities;

— the calculation of transport activities of the TOC in accordance with the previous statements.

Then, the GHG emission intensities of the freight with each temperature condition within the TOC shall be calculated using Formula (19):

$$g_{j_v,\text{TOC,k}} = \frac{G_{j_v,\text{TOC,all}}}{T_{\text{TOC}}} + \frac{G_{j_v,\text{TOC,k}}}{T_{\text{TOC,k}}} \tag{19}$$

where

j_v is either the vehicle operation or the vehicle energy provision;

$g_{j_v,\text{TOC,k}}$ is the GHG emission intensity for activity type j_v for freight of temperature condition t_k in the TOC;

$G_{j_v,\text{TOC,all}}$ is the GHG emission for activity type j_v that is not related to control of temperature conditions (e.g. GHG emissions related to propulsion of the ship in maritime transport)

$G_{j_v,\text{TOC,k}}$ is the total GHG emissions for activity type j_v for freight of temperature condition t_k in the TOC;

T_{TOC} is the transport activity of the TOC;

$T_{\text{TOC,k}}$ is the freight transport activity of the consignments in temperature condition t_k of the TOC.

4.3.2.6.5.4   Quantification and calculation of GHG emissions at HOC level

GHG activity data shall encompass all GHG sources of the HOC, and therefore shall consist of the total consumption of each energy carrier used, as well as any other quantified GHG activity relevant to the hub operations. In situations where the GHG activity data results from the use of different GHG sources (energy carriers), GHG activity data shall be quantified separately for each GHG source (energy carrier).

In situations where a GHG source is related to a specific group of freight within the HOC, the corresponding GHG activity data shall be quantified separately for this group.

ISO 14083 gives examples of allocation principles of GHG activity data for the HOC.

The calculation of GHG emissions of a HOC shall distinguish the following two situations:

— **No allocation needed**: when each hub operator in the HOC provides the same functionalities to all consignments carried, all GHG emissions within the HOC shall be added.

Conversion of GHG activity data into hub equipment operation and energy provision GHG emissions shall be conducted using Formulae (20) and (21) for each type of GHG activity A_i:

$$G_{\text{HEO,HTOC},A_i} = Q_{\text{HOC},A_i} \times \varepsilon_{\text{HEO},A_i} \tag{20}$$

$$G_{\text{HEEP,HOC},A_i} = Q_{\text{HOC},A_i} \times \varepsilon_{\text{HEEP},A_i} \qquad (21)$$

where

$G_{\text{HEO,HOC},A_i}$ is the hub operation GHG emissions of the HOC for GHG activity type A_i;

Q_{HOC,A_i} is the total quantity of GHG activity type A_i for the HOC (e.g. A_i is combustion of diesel fuel and Q_{diesel} equals 12,000 kg of diesel or A_i is leakage of refrigerant R-134a and $Q_{\text{R-134a}}$ equals 100 kg of the refrigerant R-134a);

μ_{HEO,A_i} is the hub equipment operation GHG emission factor for GHG activity type A_i (e.g. $\varepsilon_{\text{HEO,diesel}}$ = 3,22 kg CO_2e/kg or $\varepsilon_{\text{HEO,R-134a}}$ = 1,430 kg CO_2e/kg);

$G_{\text{HEEP,HOC},A_i}$ is the total hub operation energy provision GHG emissions of the HOC for GHG activity type A_i;

$\varepsilon_{\text{HEEP},A_i}$ is the hub equipment energy provision GHG emission factor for GHG activity type A_i (e.g. $\varepsilon_{\text{HEEP,diesel}}$ = 0,56 kg CO_2e/kg).

Values for GHG emission factors should be used as set out in ISO 14083:2023, Annex J. Where national legislation mandates the use of specific GHG emission factors, or a government provides GHG emission factors for voluntary GHG emission reporting, the use of these sources of GHG emission factors shall be clearly documented.

Where there are multiple GHG activity types (e.g. the equipment and facilities use different energy carriers or refrigerants), the GHG emissions for each GHG activity type shall be calculated separately and then added together to provide the total GHG emissions of the HOC. Formulae (22), (23) and (24) shall be used:

$$G_{\text{HEO,HOC}} = \sum_i G_{\text{HEO,HOC},A_i} \qquad (22)$$

$$G_{\text{HEEP,HOC}} = \sum_i G_{\text{HEEP,HTOC},A_i} \qquad (23)$$

$$G_{\text{HOC}} = G_{\text{HEO,HOC}} + G_{\text{HEEP,HTOC}} \qquad (24)$$

where

$G_{\text{HEO,HTOC}}$ is the hub equipment operation GHG emissions of the HOC;

$G_{\text{HEO,HOC},A_i}$ is the hub equipment operation GHG emissions of the HOC for each GHG activity type A_i;

$G_{\text{HEEP,HTOC}}$ is the hub equipment energy provision GHG emissions of the HOC;

$G_{\text{HEEP,HTOC},A_i}$ is the hub equipment energy provision GHG emissions of the HOC for GHG activity type A_i;

G_{HOC} is the total GHG emissions of the HOC.

The GHG emission intensity of the HOC shall be calculated by dividing the total GHG emissions of the HOC by the total transport activity of the HOC using Formula (25):

$$g_{j_H,\text{HOC}} = \frac{G_{j_H,\text{HOC}}}{H_{\text{HOC}}} \qquad (25)$$

where

j_H is either the vehicle operation or the vehicle energy provision;

$g_{j_H,HOC}$ is the total GHG emissions for activity type j_H for the HOC;

$G_{j_H,HOC}$ is the total GHG emissions for activity type j_H for the HOC;

H_{HOC} is the transport activity of the HOC.

he outcome shall be expressed as mass of CO_2e per hub activity.

— **Allocation needed**: when the hub(s) of the HOC provides different functionalities (providing different functionalities due to different temperature conditions of freight), the corresponding GHG emissions shall be calculated for each group.

The principles of the previous point from "**No Allocation needed**" shall be adapted, in order to quantify the following separately:

— $G_{HOC,all}$: GHG emissions of the HOC that result from GHG activity that benefits all freight equally.

— G_{HOC,sg_i}: GHG emissions of the HOC that result from GHG activity that benefits a specific group or groups of freight sg_i differently to other freight within the HOC (i from 1 to n, n being the number of specific groups).

This allocation of GHG emissions shall ensure that no GHG emissions are lost or double-counted, and therefore that Formula (26) is verified:

$$G_{HOC} = G_{HOC,all} + \sum_{i}^{nHOC} G_{HOC,sg_i} \tag{26}$$

where

G_{HOC} is the GHG emissions of the HOC;

$G_{HOC,All}$ is the GHG emissions of the HOC resulting from GHG activity that is not related to any specific group of the HOC;

G_{HOC,sg_i} is the GHG emissions of the HOC resulting from GHG activity calculated for the specific group sg_i of the HOC;

n_{HOC} is the number of specific groups of the HOC.

The chosen allocation principles shall remain consistent over time and shall be documented transparently, as appropriate.

The hub activity shall be quantified by the quantity of freight (outbound) relevant for the HOC.

The user shall choose the most appropriate unit for the quantity of the hub activity. The choice shall remain consistent over time for each hub (and its HOCs) and shall be documented transparently, as appropriate.

In the case of a HOC of freight of multi-temperature vehicles with n_t different temperature conditions t_k (k from 1 to nt, e.g. t_1 is ambient, t_2 is refrigerated), the calculation of GHG emissions intensities shall rely on:

— the calculation of GHG emissions in accordance with allocation of specific GHG activities;

— the calculation of transport activities of the HOC in accordance with the previous statements.

Then, the GHG emission intensities of the freight with each temperature condition within the TOC shall be calculated using Formula (27):

$$g_{j_H,HOC,k} = \frac{G_{j_H,HOC,all}}{H_{HOC}} + \frac{G_{j_H,HOC,k}}{H_{HOC,k}} \tag{27}$$

where

j_H is either the vehicle operation or the hub equipment operation or the hub equipment energy provision;

$g_{j_H,HOC,k}$ is the GHG emission intensity for activity type j_H for freight of temperature condition t_k in the HOC;

$G_{j_H,HOC,all}$ is the GHG emission for activity type j_H that is not related to control of temperature conditions (e.g. GHG emissions related to the yard lighting) ;

$G_{j_H,HOC,k}$ is the total GHG emissions for activity type j_H for freight of temperature condition t_k in the HOC;

H_{HOC} is the hub activity of the HOC;

$H_{HOC,k}$ is the hub activity of the consignments in temperature condition t_k of the HOC.

4.3.2.6.5.5 Calculation of GHG emissions for a transport TCE

This subclause sets out the step of calculation of GHG emissions for one TCE of a transport chain, taking place within a TO. The GHG emission intensity for the TOC associated with the transport operation related to the TCE shall be selected. The GHG emissions of a TCE shall be calculated using Formulae (28) and (29):

$$G_{j_V,TCE} = g_{j_V,TOC} \times T_{TCE} \times \delta \tag{28}$$

where

j_V is either the vehicle operation or the vehicle energy provision;

$G_{j_V,TCE}$ is the total GHG emissions for activity type j_V for the TCE;

$g_{j_V,TOC}$ is the GHG emission intensity for activity type j_V for the TOC;

T_{TCE} is the transport activity for the TCE;

δ is the DAF between the transport distance type used for the transport activity of the TCE and the transport distance type used for the GHG emission intensity of the TOC.

Use of a DAF is only required in cases where the actual distance is used for calculation of the GHG emission intensity of the TOC. Otherwise, the DAF = 1 and Formula (45) is simplified.

$$G_{TCE} = G_{VO,TCE} \times G_{VEP,TCE} \tag{29}$$

where

G_{TCE} is the GHG emissions of the TCE;

$G_{VO,TCE}$ is the vehicle operation GHG emissions of the TCE;

$G_{VEP,TCE}$ is the vehicle energy provision GHG emissions of the TCE.