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

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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).

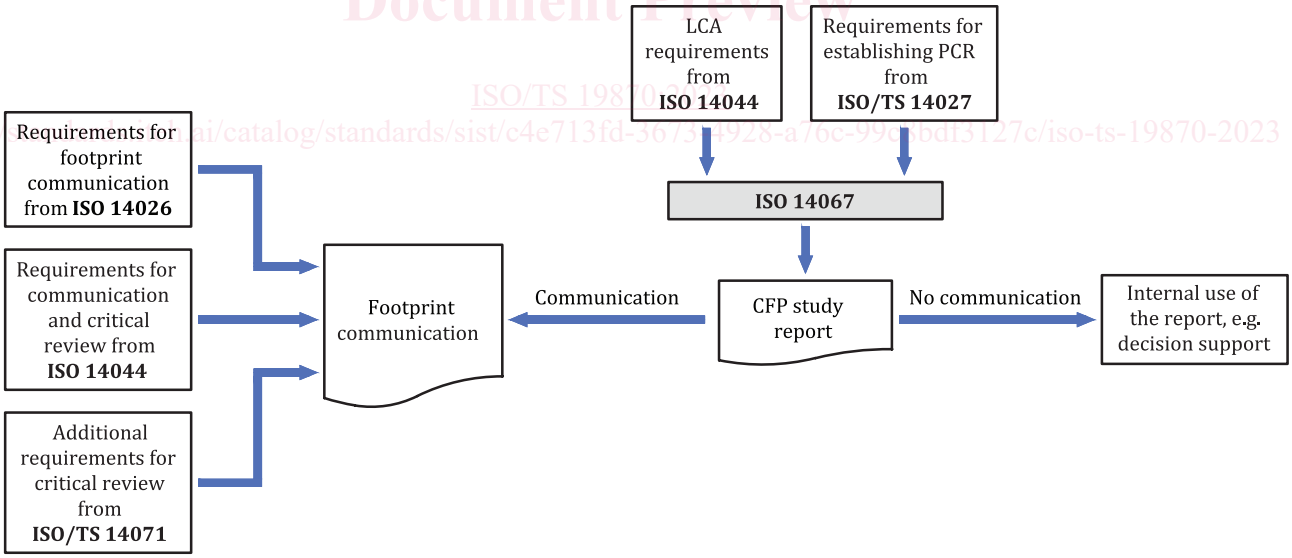
GHG initiatives on mitigation rely on the quantification, monitoring, reporting and verification of GHG emissions and/or removals. International Standards that support the transformation of scientific knowledge into tools can help in reaching the targets of the Paris Agreement to address climate change.

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.

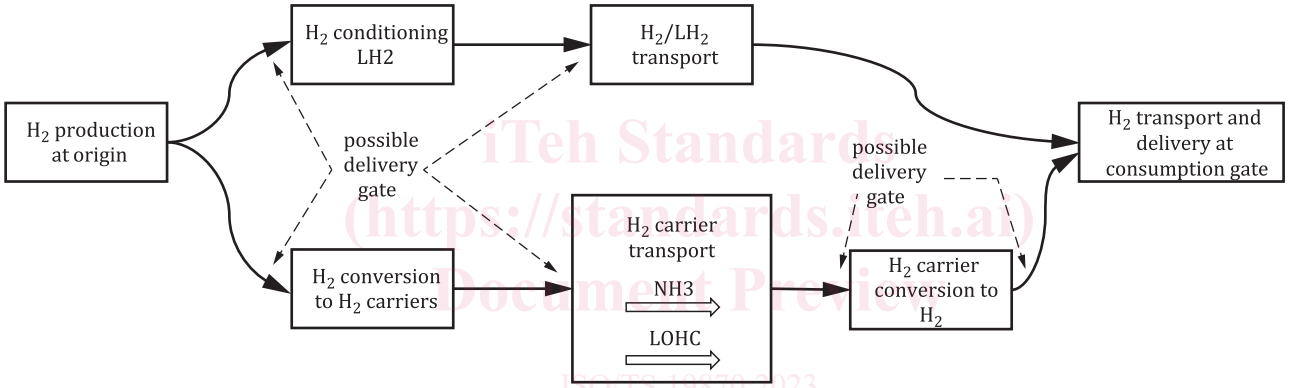


Figure 2 — Examples of hydrogen supply chain

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 *CO_2 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_2e
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]