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Calculations of greenhouse gas (GHG) emissions throughout the liquefied natural gas (LNG) chain —

Part 1: General

Calcul des émissions de gaz à effet de serre (GES) dans la chaîne gaz naturel liquéfié (GNL) —

Partie 1: Généralités

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 9, *Production, transport and storage facilities for cryogenic liquefied gases.*

A list of all parts in the ISO 6338 series can be found on the ISO website.

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

Natural gas will play a key role in the energy transition (e.g. by replacing coal to produce electricity) and the use of liquefied natural gas (LNG) to transport natural gas is expected to increase. The process of liquefying natural gas is energy-intensive. Gas producers are increasingly accountable for their greenhouse gas (GHG) emissions and the ambition to reduce them. Furthermore, there is an emerging marketing demand for GHG data to enable commercial mechanisms such as offsetting to be utilized.

There is no standardized and auditable methodology to calculate the carbon footprint of the whole LNG chain (including but not limited to the well, upstream treatment, transportation, liquefaction, shipping, regasification and end user distribution). Various standards indicate possible approaches but are inconsistent in their results or not easily applicable.

The ISO 6338 series covers each part of the LNG chain, starting with liquefaction.

Attention should be paid to activities that can occur in different parts (e.g. gas treatment and distribution upstream of the liquefaction plant).

NOTE It is not possible to make like-for-like comparisons, or define a certification scheme, for one block only.

An example for e-methane is given in Annex C.

Calculations of greenhouse gas (GHG) emissions throughout the liquefied natural gas (LNG) chain —

Part 1:
General

1 Scope

This document:

— provides the general part of the method to calculate the greenhouse gas (GHG) emissions throughout the liquefied natural gas (LNG) chain, a means to determine their carbon footprint;

— defines preferred units of measurement and necessary conversions;

— recommends instrumentation and estimation methods to monitor and report GHG emissions. Some emissions are measured; and some are estimated.

This document covers all facilities in the LNG chain. The facilities are considered "under operation", including emissions associated with initial start-up, maintenance, turnaround and restarts after maintenance or upset. The construction, commissioning, extension and decommissioning phases are excluded from this document but can be assessed separately.

This document covers all GHG emissions. These emissions spread across scope 1, scope 2 and scope 3 of the responsible organization. Scope 1, 2 and 3 are defined in this document. All emissions sources are covered including flaring, combustion, cold vents, process vents, fugitive leaks and emissions associated with imported energy.

This document describes the allocation of GHG emissions to LNG and other hydrocarbon products where other products are produced (e.g. LPG, domestic gas, condensates, sulfur).

This document does not cover specific requirements on natural gas production and transport to LNG plant, liquefaction, shipping and regasification.

This document is applicable to the LNG industry.

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

ISO 14064-1, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

API *Consistent Methodology for Estimating Greenhouse Gas Emissions from Liquefied Natural Gas (LNG) Operations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14064-1 and the following 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
global warming potential
GWP
ratio of the time-integrated radiative forcing (warming effect) from the instantaneous release of 1 kg of the GHG relative to that from the release of 1 kg of CO_2

3.2
scope 1
direct greenhouse gas emissions
direct GHG emissions
emissions coming from sources that are owned or controlled by the facility

Note 1 to entry: This can be the emissions that are directly created by product fabrication or synthesis, for example, combustion fumes from a refinery.

3.3
scope 2
indirect greenhouse gas emissions from purchased and consumed energy
indirect GHG emissions from purchased and consumed energy
emissions from the generation of imported electricity, steam, and heating/cooling consumed by the facility

Note 1 to entry: These emissions physically occur at the facility where electricity, steam and cooling or heating are generated but as a user of the energy, the consuming party is still responsible for the greenhouse gas emissions that are being created.

3.4
scope 3
other indirect greenhouse gas emissions
other indirect GHG emissions
emissions from sources that are not owned and not directly controlled by the facility

Note 1 to entry: However, they are related to the company's activities. This is usually considered to be the supply chain of the company, so emissions caused by vendors within the supply chain, outsourced activities, and employee travel and commute. In many industries, these emissions account for the biggest amount of GHG emissions. This is due to the fact that in today's economy, many tasks are outsourced and few companies own the entire value chain of their products.

3.5
quality assurance
QA
planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process

3.6
quality control
QC
planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process

4 Principles

4.1 General

The application of the principles specified in 4.2 to 4.7 is fundamental to guaranteeing that GHG calculations are a true and fair account.

4.2 Relevance

Use data, methods, criteria, and assumptions that are appropriate for the intended use of reported information. The quantification and reporting of GHG emissions shall include only information that users – both internal and external to the plant – need for their decision-making. This information shall thus fit the intended purpose of the GHG project and meet the expectations or requirements of its users. Data, methods, criteria, and assumptions that are misleading or that do not conform to this document are not relevant and shall not be included.

4.3 Completeness

Consider all relevant information that can affect the accounting and quantification of GHG reductions, and complete all requirements. All relevant information shall be included in the quantification of GHG emissions. A GHG monitoring plan shall also specify how all data relevant to quantifying GHG reductions will be collected.

4.4 Consistency

Use data, methods, criteria, and assumptions that allow meaningful and valid comparisons. The credible quantification of GHG emissions requires that methods and procedures be always in the same manner, that the same criteria and assumptions be used to evaluate significance and relevance, and that any data collected and reported be compatible enough to allow meaningful comparisons over time.

4.5 Transparency

Provide clear and sufficient information for reviewers to assess the credibility and reliability of GHG emissions claims. Transparency is critical for quantifying and reporting GHG reductions, particularly given the flexibility and policy-relevance of many GHG accounting. GHG information shall be compiled, analysed, and documented clearly and coherently so that reviewers can evaluate its credibility. Information relating to the GHG assessment boundary and the estimation of baseline emissions should be sufficient to enable reviewers to understand how all conclusions were reached.

4.6 Accuracy

Uncertainties with respect to GHG measurements, estimates, or calculations should be reduced as much as is practical, and measurement and estimation methods shall avoid bias. Acceptable levels of uncertainty depend on the objectives for implementing a GHG project and the intended use of quantified GHG reductions. Where accuracy is sacrificed, data and estimates used to quantify GHG reductions shall be conservative.

4.7 Conservativeness

Where data and assumptions are uncertain and where the cost of measures to reduce uncertainty is not worth the increase in accuracy, best endeavours should be made to use the most probable data, with an analysis of the impact of likely uncertainty margins.

5 GHG inventory boundaries

Table 1 is a template for the reporting boundaries of the GHG report.

Table 1 — List of facilities

Relevant part of ISO 6338	In scope of the report	Out of scope of the report	Comment
Facility A	X		
Facility B		X	

The organization having financial and/or operational control over the facilities shall report all GHG emissions and removals within the reporting boundaries at least on an annual average basis.

6 Quantification of GHG emissions

6.1 Identification of GHG sources and quantification approach

6.1.1 General

The main emission sources to consider derive from fuel combustion, flaring, releases to atmosphere (including fugitive emissions) and emissions associated with imported energy or consumables. Tables 2 to 5 give an initial checklist of emission sources to consider, and an overview of typical quantification methods suitable for different emission sources.

The chosen method of quantification per emissions source differs from one facility to another. Different facilities have access to a varying number of flow meters, composition analysis equipment and level meters available.

Operators shall develop a GHG quantification plan to map out how all emission sources can best be identified in the facility, with a preference to obtain primary data for all major emission sources. The measurement plan shall also include an assessment of data accuracy and impact on the total GHG emissions calculation. This assessment allows the operator to assess if there is a need to further improve the amount or accuracy of instruments available for the total assessment. Guidance on this assessment is detailed in ISO 14064-1:2018, Annex C.

A list of activity data shall be defined based on reliability as primary and secondary data:

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

— secondary data: data obtained from sources other than primary data.

Primary data shall be used. Only in the absence of primary data, secondary data may be used, which can include estimated quantities and industry average emission factors.

Typically, primary data are recorded to enable GHG quantification contributing > 5 % of the site's total GHG emissions. For smaller individual sources a calculated approach is acceptable. CEN/TS 17874 defines material and non-material methane emissions.

6.1.2 to 6.1.5 describe sources to consider and typical quantification approach for the main emissions sources.

6.1.2 Emissions from fuel combustion

Table 2 is a template for describing the quantification approaches for emissions from fuel combustion.

Table 2 — Emissions from fuel combustion

Source	Examples	Quantification approach
Gas turbine drivers	Primary liquefaction drivers, power generation drivers, other refrigeration drivers (e.g. fractionation), CO_2 sequestration compressor drivers	Typically, primary data are recorded to enable GHG quantification. As a minimum, fuel gas consumption and composition are required. (Fuel composition at an LNG plant can vary widely depending on operating mode.)
Diesel drivers	Firewater pumps, power generation, boiler feed water pumps	Operator may report typical annual diesel consumption and include resulting annual emissions as a nominal allowance in the GHG calculation.
Boilers	Steam for turbine drivers, steam for process heating	Typically, primary data are recorded to enable GHG quantification for major fuel consumers (contributing >5 % of the total GHG emissions.) As a minimum, fuel gas consumption and composition shall be measured.
Fired heaters	Regeneration gas heater, heating medium heater, direct fired reboilers	If fuel measurements are available, operator should record total fuel gas consumption and composition. If direct fuel measurements are not available, a calculation based on operating duty and efficiency is acceptable.
Incinerators	Acid gas vent incinerator, thermal oxidizers, catalytic oxidizers, waste disposal	As above.
Unburned hydrocarbons shall be taken into account in all sections. If fuel measurements are available, operator should record total fuel gas consumption combined with combustion efficiency data for the fired equipment used. Ideally, combustion efficiency should be validated with measured emission data.		

6.1.3 Emissions from flaring and venting

Table 3 is a template for describing the quantification approaches for emissions from flaring and venting.

Table 3 — Emissions from flaring and venting

Source	Examples	Quantification approach
Atmospheric waste disposal from treating units	Acid gas vent, sulfur plant tail gas	Typically, primary data are recorded to enable GHG quantification from venting contributing >5 % of the site's total GHG emissions. For smaller individual sources a calculated approach based on heat and material balance data is acceptable. As a minimum, fuel gas consumption and composition are required.
Atmospheric venting of unburned hydrocarbon	Feed gas pipeline blowdown, storage tank venting and pressure protection, loading arm blowdown, compressor blowdown, flare operation with failed ignition	Typically, primary data are recorded for significant venting events, such as pipeline blowdown. A calculated approach is acceptable for venting events contributing <5 % of total annual emissions.
Flares	Process plant pressure protection, depressurising, storage tank pressure protection, boil-off gas management, refrigerant composition management, purge gas and pilots	Typically, primary data are recorded to enable GHG quantification from flaring contributing >5 % of the site's total GHG emissions. For smaller individual sources a calculated approach is acceptable.
Nitrogen vents from nitrogen rejection units (NRUs)	Nitrogen vents from NRUs can contain methane and are generally routed to atmosphere	If primary data are not available, a calculated allowance using licensor composition data may be used.
Unburned hydrocarbons shall be taken into account in all sections. Operator should record total flare gas, combined with combustion efficiency data for the flare tip used. Ideally, combustion efficiency should be validated with measured emission data.		

6.1.4 Fugitive emissions

Table 4 is a template for describing the quantification approaches for fugitive emissions.

Table 4 — Fugitive emissions

Source	Examples	Quantification approach
Permeation	Emissions through porous materials	Can be calculated with emissions factors for different materials.
Gas leaks	Leaks from pipes and fittings, rotating equipment seals, storage tank seals	Typically done via calculation using equipment count and standard leakage factors. Measured leakage data from atmospheric monitoring may be used to adjust the leakage factors applied.

6.1.5 Emissions associated with imported energy, utilities, and consumables

Emissions associated with imports require data from the exporter. Contractual relationship with the exporter should include a requirement to provide emissions data. In the absence of reliable GHG data for imports, the calculation shall account for the complete supply chain for the imported commodity. The cut-off criteria for reporting shall be defined in accordance with ISO 14044.

Table 5 is a template for quantification approaches for emissions associated with imported energy, utilities and consumables.

Table 5 — Emissions associated with imported energy, utilities, and consumables

Source	Examples	Quantification approach
Electric power	Power from third party fossil fuel combustion, power from grid	Primary data are recorded for total power consumed. GHG quantification requires intensity data from the supplier. In case of supply from a grid, the average intensity from all suppliers to the grid is required.
Heat or steam	Steam or heating medium from third party	Primary data are recorded for total imported heating utility. GHG quantification requires intensity data from the supplier. In case of heat generated from waste heat, emissions from primary fuel use may be excluded, but supplemental emissions such as pumping power, or back up fired heaters or boilers shall be included.
Other utilities	Cooling, air, nitrogen, water	Primary data are recorded for total imported utility. GHG quantification requires intensity data from the supplier. Secondary data are acceptable if primary data are not available.
Imported consumables	Refrigerant not produced on site	Primary data are recorded for quantities consumed. GHG quantification from consumables requires intensity data from the supplier. Secondary data are acceptable if primary data are not available.

6.2 Calculation of GHG emissions

6.2.1 Requirements and guidance

This subclause provides requirements and guidance regarding the evaluation of activity data and emission factors required to convert emission source data to GHG emissions. In some cases, emissions are measured directly (e.g. in case of venting), but most commonly a calculation is required to convert measured data to reported emissions (e.g. in case of fuel combustion).

Emission calculations shall be performed in accordance with API Consistent Methodology for Estimating Greenhouse Gas Emissions from Liquefied Natural Gas (LNG) Operations.

The key input data required to derive an emission factor are flowrate, composition, and combustion efficiency.

For flowrate, measured data should be used. However, in the absence or failure of measurement instrumentation, calculated approaches may be used, e.g. based on heat and material balances, or other data such as pressure drop which may be used to estimate a flowrate.

For composition, measured data should also be used. However, in the absence of measured data, calculated and estimated approaches may be used, e.g. based on periodic sampling or calculation from the heat and material balance. For sources with predictable composition (e.g. diesel fuel) standard emission factors may be used. See API GHG Compendium[14] for emissions standards and approach.

For combustion efficiency, measured data should be used. However, in the absence of directly measured data, the equipment vendor can supply efficiency data based on factory testing of their equipment or refer to API GHG Compendium[14] for typical values.

For methane emissions, CEN/TS 17874[7] defines that generic emission factors can only be used for non-material emissions

Each time a GHG emission evaluation is reported, the calculation approach shall also be stated, recognising that the quality of data available for this calculation impacts the accuracy of the results.

LNG plant GHG emissions are estimated using a combination of methodologies. Elements of the method consists of:

— direct measurements including mass balance approaches;

— emission factors including those provided by equipment manufacturers;

— engineering calculations that are based on process knowledge.

6.2.2 GHG inventory

6.2.2.1 General

A GHG emissions inventory is comprised of measured, calculated and estimated emissions from individual emission sources that are aggregated to produce the inventory, in accordance with the following steps.

— Define the purpose and content of the GHG inventory, GHG emissions sources and assessment boundary and the reference base year.

— Select activity data and emission factors: provide sector-specific good practice guidance and references for emission factors (see Clause 6).

— Select measuring technologies or calculation methods: describe different quantification methods depending on the availability of site-specific activity data and emission factors.

— Define the data recording and reporting criteria, and related documentation.

GHG Inventory methodology and process shall include the following elements:

— base year;

— GHG emission sources;

— activity data inputs;

— GHG emission factors;

— Global warming potentials.

The plant owner shall define requirements for the GHG inventory records, reports and documentation and archive it in a consistent manner.

6.2.2.2 Base year definition

A meaningful and consistent comparison of emissions over time requires that companies set a performance datum with which to compare current emissions. This performance datum is referred to as the base year emissions. It describes an activity or a set of activities that result in GHG emissions against which current activity emissions can be compared for the purpose of quantifying GHG reductions.

The selection of base year shall represent and be consistent to the following criteria:

— same boundary of activities;

— same technologies or practices;

— same plant configuration, deployment, implementation, operation;

— same type, quality, and similar quantity of product(s) or service(s) as the current year.

For consistent tracking of emissions overtime, the past base year emissions shall be recalculated, according to the new reporting boundary, when significant structural changes occur for any of the above criteria during the year of reporting.

6.2.2.3 GHG emission sources

The plant owner shall define a GHG assessment boundary through the following steps:

— identify the plant activities that comprise the GHG project;

— identifying the primary (major sources) and secondary (minor sources) effects associated with each plant activity listed in 6.1;

— thoroughly analysing the secondary effects to determine which are significant for the purpose of estimating and quantifying GHG reductions.

For complete, accurate and transparent quantification of GHG reductions, the GHG assessment boundary shall be clearly defined and reported. The GHG assessment boundary shall include the primary and significant secondary effects of all operational activities. Specific exclusions or inclusions shall be clearly identified and justified/explained; and exclusions shall not exceed 5 % of the aggregate GHG emissions in scope 1 and scope 2.

6.2.2.4 GHG emission factors

Different types of emission factors are used to convert activity data and upstream/downstream data into GHG emissions data.

a) Material emission factors

   1) Life cycle materials emission factors, which include emissions that occur at every stage of a material/product's life, from raw material acquisition or generation of natural resource to end of life.

   2) Cradle-to-gate ("upstream") emission factors, which include all emissions that occur in the life cycle of a material/product up to the point of sale by the producer.

b) Energy emission factors

   1) Life cycle fuel emission factors, which include not only the emissions that occur from combusting the fuel (Combustion emissions factors) but all other emissions that occur in the life cycle of the fuel such as emissions from extraction, processing, and transportation of fuels (Well-to-tank emission factors).

2) Combustion emission factors, which include only the emissions that occur from combusting the fuel.

c) Upstream and downstream transportation factors often included in specific international models such as the GHG protocol.

Company shall define emission factors used to convert activity data and upstream/downstream data into GHG emissions data, record and archive it in a consistent manner.

6.2.2.5 GHG global warming potentials

Each GHG has a unique atmospheric lifetime and heat-trapping potential. To express emissions based on their global warming potential, the mass of emissions of each GHG is multiplied by its corresponding GWP. The result is referred to as the CO_2-equivalent (CO_2-eq) emissions. Because the GWP of CO_2 is always 1, the mass emissions of CO_2 and the CO_2-eq emissions are identical. Global warming potentials are calculated over different time periods, typically ranging from 20 years to 500 years. The most common time period for expressing GWPs is 100 years.

The reporting entity shall define GWP reference used to convert GHG data into GHG equivalent and record and archive it in a consistent manner.

6.2.3 GHG quantification methods for fuel combustion

One of the features of LNG operations is that the carbon content of the fuel gas can vary throughout the operations chain and can also vary in different operating modes. During liquefaction, the fuel gas used typically has lower carbon content than the feed stream used for producing the LNG, since it consists mostly of lower molecular weight boil-off gas and most of the inlet gas stream's inert nitrogen.

6.2.4 GHG quantification methods for flaring and venting

6.2.4.1 General

GHG quantification shall follow the requirements and should follow the guidance in 6.2.1. Additional considerations are given in 6.2.4.2 to 6.2.4.3.

6.2.4.2 Flaring

The flare system at LNG facilities operates as an emergency facility. It is a critical part of the safety system and is designed to prevent escalation of accidents and dangerous situations. It is mainly used to eliminate any discharge from the pressure relief system. Any waste gas sent to the flare (i.e. gas from the process which is not recovered, such as dehydrator vents or compressor seal gas) is usually insignificant compared with other industrial processes such as petrochemical or refining.

In principal, operators should avoid operational flaring, however it is possible that small quantities of planned releases occur into the flare system, including fuel for pilots and purging, and exceptional operational releases such as for defrosting or refrigerant composition management. In these cases, the source gas entering the flare system should be known; and emissions factors may be derived.

In case of emergency flaring, an incident investigation should identify the source of a release; and this information may be used to derive an emission factor to apply to the event.

Measurement-based methane destruction efficiency, destruction efficiency determined through the application of correlations based on representative sampling, or in some cases process simulation and/or engineering calculations may be used for emissions quantification at the flare. These emissions quantifications shall be validated against relevant field data.

Measured combustion efficiency factors may also be used, recognizing they provide a conservative reported value compared to destruction efficiency. More information can be found in API Consistent Methodology for Estimating Greenhouse Gas Emissions from Liquefied Natural Gas (LNG) Operations, 2015.

6.2.4.3 Venting

Venting from the acid gas removal unit is often a significant contributor to total LNG plant emissions. The flowrate and composition of the vent gas are required to assess GHG emissions directly and may include co-absorbed methane. In some cases, this vent stream is fed an incinerator to destroy hazardous molecules such as benzene. In these cases an emission factor should be applied to account for the oxidation of hydrocarbons to CO_2, including the fuel used for incineration.

6.2.5 GHG quantification methods for fugitive emissions

Screening or direct measurement provides a more accurate overview of fugitive leaks and the effectiveness of mitigation measures. However, it may not be feasible in all the locations.

In the absence of directly measured data, a conservative allowance for fugitive emissions should be applied.

Alternatively, the operator may estimate fugitive emissions based on a component count with average emission factor, considering mitigation measures or technologies applied. Only equipment containing gases contributing to greenhouse gas potential (notably methane and CO_2) shall be counted, and credit may be taken for systems where the methane or CO_2 is diluted with other components that do not contribute to GHG potential. In the absence of composition data for a hydrocarbon gas stream, assume 100 % methane for this calculation.

Quantification of fugitive emissions can be carried out by applying component-level emission factors: see EPA AP-42 and EPA Method-21.

Infrared cameras can be used for direct measurement; see CEN/TS 17874[7].

Options for estimating fugitive GHG emissions (mainly methane emissions) include:

a) component counts and emission factors;

b) monitoring to detect leaking components;

c) engineering calculations using process model simulations.

Monitoring should in any case be repeated at least annually. In order from the least accurate to the most accurate method the following should be used.

— Quantifying by site population – based on the number of sites and the typical emission rate from that type of site. The emission rate source of information/data shall be appropriate and updated.

— Quantifying by equipment population – based on the number of a type of major equipment and the typical emission rate from that type of equipment. The emission rate for equipment type shall be appropriate and updated.

— Quantifying by component:

  — Quantifying by component count/populations – multiplying the number of components by the average emission rate per component. The average emission rate for component type shall be appropriate and updated.

  — Quantifying by screening – if screening to detect leaks has been carried out, components may be sorted into ‘leak’ and ‘no leak’ categories, and the number in those categories is multiplied by the appropriate emission factor.

  — Quantifying by direct measurement of leaks – all detected leaks on a site are measured for emission rate to produce the most accurate estimate for emissions from all fugitive leaks on the site.

6.2.6 Quantification methods for emissions from imported energy, utilities, and consumables

If imported energy is a significant contributor to the overall emissions footprint (e.g. for electric-driven LNG plant using imported power), it is preferable to quantify the scope 2 GHG emissions based on specific analysis related to the third-party supplier. The supply agreement may include provision for the third party to provide the data required for this analysis.

According to GHG Protocol Scope 2 Guidance[15], in case of indirect emissions from purchased energy, utilities, and consumables, in the absence of required data from third parties, a preferred approach for the estimation of GHG emissions is to use the emission factors derived from the IEA yearly report Emission factors[16].

6.2.7 Relevant period and frequency

Emission factors based on compositional analysis shall be reviewed at least once per year; each other emission factor shall be assessed through an initial dedicated study and reviewed if significative change to relevant assumptions occurs.

ISO 14064-1 should be used.

6.3 Preferred units

The primary unit for GHG intensity is grams of CO_2e per megajoule of LNG heating value (g/MJ) of exported product, with clarification of whether the data refers to higher or lower heating value - this may depend on the protocol in place for the LNG supply contract.

Alternately, GHG intensity may be reported in tonnes of CO_2e per tonne of LNG (t/t) provided the data is shared in conjunction with the LNG heating value (including clear statement of whether the higher or lower heating value has been used.)

A list of unit conversion factors is provided in Annex A.

6.4 Allocation

6.4.1 Principles

Allocation is used to apportion the total calculated GHG emissions to the intended commercial products. GHG is not allocated to waste streams. ISO 14044 prescribes the following allocation hierarchy.

a) Allocation should be avoided either by dividing the unit processes into sub-processes and collecting data specifically for each or by expanding the LCA system to include additional functions.

b) If avoidance is not possible, allocation should use the underlying physical relationship among co-products, such as mass or energy relationships or stoichiometric parameters.

c) If physical relationship is not possible, allocation should be done in a way that reflects another relationship such as economic value.

Whereas most of the outputs from an LNG facility are energy products such as gas, LPG and condensate, other potential outputs include sulfur and helium. The allocation procedure shall be in accordance with the hierarchy described in ISO 14044, refined to reflect the integrated nature of the LNG value chain and to enable an appropriate outcome for the respective outputs.

6.4.2 Methodology

For facilities that produce co-products, allocating the total GHG emitted in the same proportions as the heating value of each commercial product understates the allocation of GHG to LNG. It is therefore recommended to divide the overall process into smaller processing blocks, to analyse which products get the benefit of each emission source.

The following steps shall be applied for GHG allocation:

a) Divide the facility into smaller process blocks based on how product(s) are produced within the overall processing steps (refer to example in Figure C.1). Identify the mass flowrate of each stream in this diagram, including intermediate streams, but excluding any waste streams or consumed streams (e.g. fuel gas). The mass flow rates identified should add up to the total amount of commercial product, to ensure that all emissions are allocated to commercial products only.

b) From the complete listing of GHG sources identified in the calculation described in 7.2, the quantities of each emission source are assigned to one or more processing blocks. For example, an emission from a source which benefits just one processing block, such as a fired heater reboiler, is fully assigned to that block. However, an emission from a source that benefits multiple blocks shall be divided between the blocks in proportion to the benefit; for example, power generation emissions may be assigned in proportion to the power consumed. The outcome of this step is a total GHG quantity associated with each block.

c) For the first block, assign the total GHG in the block to the product streams from the block, in the same proportion as the mass flows of those product streams. These assigned GHG quantities are referred to as "embedded emissions" associated with the streams.

d) For each subsequent block, calculate the total GHG emissions in that block by adding the embedded emissions in the feed streams to that block to the GHG emissions generated in that block. Assign the total GHG in the block to the product streams from the block, in the same proportion as the mass flows of those product streams. In most cases, the breakdown of the LNG process will have one or more recycle streams (such as liquids from the fractionation unit recycled to the front-end condensate unit). In these cases, the calculation requires iterations to converge a consistent balance. (This is usually simple, e.g. using goal-seek function on a spreadsheet.)

e) Some sources of emissions such as flares and utilities systems in a plant are likely to be highly integrated. In cases where granular breakdown to allocate emissions to specific processing blocks is not feasible, the GHG emissions should be allocated to products in the same proportions as the result of the calculation described in steps a) to d) above.

There can be significant GHG emissions during plant turnarounds and other significant non-routine activities, with no actual production. These emissions should be identified separately, and applied to subsequent production, allocated to products in the same ratio as the result of calculation steps a) to e) above, and divided across the time to the next such activity. For example, for a 3-year turnaround cycle, 1/3 of the emissions associated with the turnaround activity are allocated to the products per year subsequently.

If the facility is operated for an extended time in an operating mode which is substantially different to normal operation (such as turndown operation with reduced use of the fractionation unit), this operating mode should be investigated to adjust the allocation ratios for this period, if required.

Per GHG protocol product standard, no emission shall be allocated to waste product, including co-products with no or low commercial value, such as produced water.

While this process is preferably followed using measured operating data, it is recognized that in many cases, the required data will not be available with sufficient granularity. In these cases, the same analysis may be completed using heat and material balance data to determine the ratios of GHG intensity for each product, and these ratios used to allocate the total GHG inventory based on actual product rates.

6.5 Carbon capture

6.5.1 Opportunities for carbon capture

Carbon capture, use and/or sequestration (CCUS) may be installed at facilities. The CCUS system can capture CO_2 from a variety of sources, including, in order of likelihood:

— concentrated CO_2 from acid gas removal unit vent;

— combustion emissions from gas turbine drivers;

— combustion emissions from fired equipment;

— pre-combustion carbon capture by conversion of hydrocarbon to hydrogen, with sequestration of the CO_2 that is formed in the process, and using hydrogen as fuel.

The CO_2 that is captured is used or sequestered, most likely in a geological structure such as an aquifer or depleted reservoir. In some circumstances the CO_2 may be put to beneficial use, e.g. for pressure maintenance of a hydrocarbon reservoir. Credit can only be taken for sequestration if there is certainty that the CO_2 cannot re-enter the atmosphere.

6.5.2 Quantification of carbon capture benefit

Carbon capture equipment has a high energy consumption.

— Significant heat input is used to extract and isolate CO_2 from either the natural gas feed stream or from the pre/post combustion streams, to regenerate the solvents used.

— Significant power input is required for compression to the disposal destination pressure.

The emissions associated with operating the CCUS system, resulting from fuel use to provide heat and power, shall be accounted in the overall facility emissions balance. The benefit of CCUS systems is a reduction of emissions. If net emissions cannot be measured directly, the calculation of emissions from a source fitted with CCUS systems, is:

$$X = Y \times (1 - e \times a) \quad (1)$$

where

X is the net CO_2 emitted;

Y is the total CO_2 at source;

e is the system efficiency as fraction of total CO_2 captured;

a is the CCUS systems availability as fraction of total liquefaction plant operating time that CCUS systems operate (with adjustment for periods operating at partial capacity).

7 GHG inventory quality management

7.1 General

The owner of the facilities shall track GHG emissions related to its own activity and boundary over time in response to a variety of business goals, including:

— public reporting;

— establishing GHG targets;

— managing risks and opportunities;

— addressing the needs of investors and other stakeholders.

To track consistently GHG emissions, the following shall be in place:

— GHG Inventory: provide reliable GHG data over time and within the boundary of the plant;

— internal reporting and documentation: define the internal documentation to support emissions calculations;

— quality control: ensure the consistency of the methodological approach.

7.2 GHG emission calculation approach

The GHG emission calculation is defined in 6.2.

GHG assessment outputs shall be made available as follows:

— the GHG assessment summary and key indicators on an annual basis; GHG assessment shall be revised in case of new design opportunities or changes in the life cycle assessment;

— the GHG quantification (tonnes of CO_2eq) as indicator air emission/carbon dioxide (CO_2), by location, on an annual period basis, to allow the continual tracking of LNG plant goals and targets monitoring.

The plant owner shall select the appropriate GHG quantification methods based on data availability and the intended use of the data and associated with level uncertainty. Methodology, level of uncertainty, activity data, GHG assessment calculations, analysis and outputs shall be documented and recorded and made available upon request for internal review and for external assurance.

7.3 Estimation of inventory uncertainties

Activity data uncertainties are based on the quantitative uncertainty assessments and methods for combining uncertainties as provided as a reference by the IPCC good practice guidance[17]. Uncertainty estimation methods are to be provided, and appropriate references should be provided for both data and assumptions.

7.4 Procedures for documentation and archiving

A GHG archive database shall be put in place to record, report, manage and maintain the facilities GHG inventory and the documentation of inventory information. The archive should be sufficiently complete to allow an informed analyst to obtain relevant data sources and spreadsheets, reproduce the inventory and review all decisions about assumptions and methodologies that have been made.

7.5 Quality control

It is performed by personnel compiling the inventory. The QC system is designed to:

— provide routine and consistent checks to ensure data integrity, correctness, and completeness;

— identify and address errors and omissions;

— document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardized procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters and methods.

For the scope of the GHG inventory, quality control (QC) activities shall be performed at several different stages during the preparation, implementation, recording and reporting of LNG plant GHG data as follow:

— regular checks shall be carried out to determine the consistency and completeness of data;

— checks are carried out to ensure that the data are compiled correctly to meet the overall reporting requirements;

— a number of checks are conducted with regard to data archiving and documentation.

Type of data checks to be implemented on an annual basis includes:

— checks in relation to consistency, primarily identify and document deviations of implied emission factors in the time series;

— checks on correctness of aggregating sub-categories;

— checks on completeness of information;

— checks to determine if gap filling is required in respect of estimates of emissions or removals;

— checks as to whether methodological and data changes resulting in recalculations;

— checks as to whether uncertainty estimates have been included;

— check against documentation of any further findings and procedures applied.

Any corrective action resulting from the initial checks is taken. If there are problems that cannot be resolved immediately, the QA/QC coordinator identifies and documents these issues and makes provisions for any follow-up action that may be needed.

All deviations, incorrect sums, gaps or other issues identified during the quality check, as well as corrective and preventive actions, are compiled and documented in the QA/QC annual report, and made available for external review.

7.6 Quality assurance

Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures.

Reviews verify that:

— measurable objectives were met;

— the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability;

— the inventory supports the effectiveness of the QC programme.

The owner of the facilities shall ensure QA procedures are in place and an objective review is regularly implemented to assess the quality of the inventory and to identify areas where improvements can be made.

Results of QA objective reviews are compiled and documented in the QA/QC annual report, and made available for external review.

8 GHG reporting

8.1 General

Reporting should conform with ISO 14064-1.

8.2 Additional information

A minimum of climate-related risks and opportunities key performance indicators (KPIs) should be reported on an annual basis, in alignment with “Key Performance Indicators for Environmental, Social & Governance Issues” from EFFAS, “United Nations Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development” and in accordance with plant owner strategy and risk management process.

Information on requirements from international initiatives on climate ambitions can be found in Annex B.

KPIs can include the following:

a) Absolute GHG emission and energy-related KPIs

  — total GHG (tonnes CO_2eq) emissions per year;

  — GHG by scope 1, 2, 3 if applicable per year;

— GHG by contributors: CO_2, methane, other GHGs;

— energy use.

b) Intensity GHG and energy - KPIs[15]

— GHG intensity;

— GHG per LNG product;

— low-carbon energy consumption or production (%).

Low-carbon power is electricity produced with substantially lower greenhouse gas emissions than conventional fossil fuel power generation

c) Absolute and intensity GHG targets;

— scope of targets;

— type of targets (absolute or intensity);

— targets already underway or planned;

— approach used to measure progress towards these targets;

— baseline period and timescale, along with progress towards meeting targets.

8.3 GHG emission reduction

To valorize the development and mitigation contribution over time and in accordance to the elected boundary, net (or "relative") GHG emissions against the baseline shall be assessed as follows:

— net GHG emissions contribution that the plant is expected to achieve on an annual basis and at normal operating capacity;

— net emissions for the plant baseline year;

— net GHG accounting should include all scope 1, scope 2, and - if declared - emissions, scope 3 where applicable.

NOTE Leakage in scope 3 can be included where this is identified as an issue.

8.4 Carbon offset and emission trading

Carbon offsets can be purchased by an organization to offset emissions from scope 1, scope 2, and scope 3.

Purchased offsets such as direct emission reductions and/or removals that occur outside the organizational boundary of the reporting organization, shall be quantified using an internationally recognized methodology such as PAS 2060 carbon neutrality.

9 Independent review

An independent review of the quantification of the GHG emissions can bring confidence to the off takers on the accuracy and reliability of the stated data for any of these products.

Annex A
(informative)

Conversion factors for reference

A.1 Unit conversion factors

Unit conversion factors are described in Table A.1.

Table A.1 — Unit conversion factors

Quantity		Equivalent to		Comments
1 000	MJ	0,947 8	mmBTU	(Million BTU)
1	MJ/kg	429,9	BTU/lb	
1	g/MJ	3,6	g/kWh	Gram of CO_2e
1	g/MJ	2,33	lb/mmBTU	Gram of CO_2e
1	tonne CO_2	537,269	Sm^3 CO_2	Standard conditions = 15 °C and 1,013 25 bar a (288,15 K and 101,325 kPa)

A.2 Approximate conversions

Approximate conversions are described in Table A.2.

Table A.2 — Approximate conversions (dependant on specific LNG product properties)

Quantity		Approximately equivalent to		Comments
1	m^3 LNG	0,456	tonnes LNG	Based on LNG density 456 kg/m^3
1	tonne LNG	2,193	m^3 LNG	Based on LNG density 456 kg/m^3
1	m^3 LNG	600	Sm^3 natural gas	Based on LNG density 456 kg/m^3, molecular weight 17,97 kg/kmol, molar volume 23,645 m^3/kmol
1	Mt/y LNG	141	Million std ft^3 per day (mmSCFD) natural gas	Based on LNG plant operating at 90 % availability (341 stream days per year)
1	g/MJ	0,055	t/tLNG	Based on LNG higher (gross) heating value 55 MJ/kg Gram or tonne of CO_2e

Annex B
(informative)

International initiatives on climate ambitions

The KPIs and related requirements to access to key international initiatives, agreements and reporting/accounting standards on climate ambitions and zero carbon emission strategies are given in Table B.1.

Table B.1 — KPIs and related requirements

International climate initiative, standard /framework	Type	Requirements	Timeframe	External verification	Comments
SBTs science based targets Initiative	Global GHG targets consistent with the level of decarbonization required to keep global temperature increase well below 2 °C compared to pre-industrial temperatures	The target shall cover company-wide scope 1 and scope 2 and all relevant GHGs as required in the GHG protocol corporate standard	The target shall cover a minimum of 5 years and a maximum of 15 years from the date of announcement of the target	Included	Companies should complete a scope 3 screening before setting their GHG emission reduction targets covering all relevant scope 3 categories as defined by the GHG protocol corporate value chain (scope 3) accounting and reporting standard
CDP carbon disclosure project	Global disclosure system for managing the environmental impacts of the private sector	CDP's general climate change questionnaire includes the following: Governance Risks and opportunities Business strategy Targets and performance Emissions methodology Emissions data Energy Additional metrics Verification Carbon pricing Engagement	The target shall cover a minimum of 3 years and a maximum of 15 years from the date of announcement of the target	Requested as key indicator	