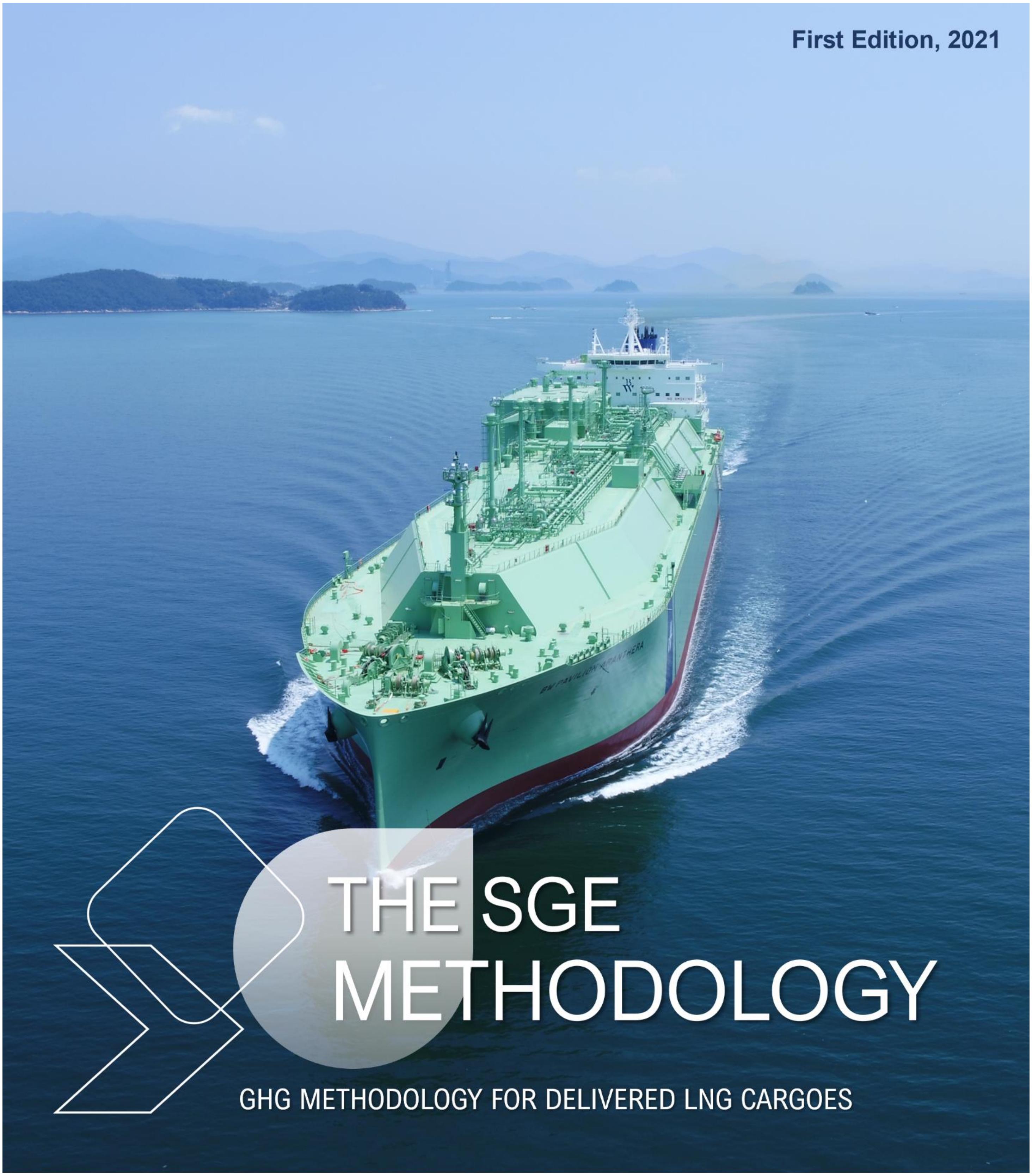
First Edition, 2021



THE SGE METHODOLOGY

GHG METHODOLOGY FOR DELIVERED LNG CARGOES

the human energy company™ Chevron

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PAVILION ENERGY

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GHG Methodology for Delivered LNG Cargoes

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PREFACE

This methodology supports a consistent approach to greenhouse gas (GHG) emissions calculations throughout the liquefied natural gas (LNG) value chain, and through independent verification, it enables GHG transparency and credibility of reporting. Such a consistent reporting approach on measurement, reporting and verification is necessary for the industry to become more cognisant of GHG emissions, which should lead to improvements in the management of such emissions.

Although generic product life cycle accounting standards are well established, this initiative reflected the lack of a specific approach to LNG that would govern consistency and verifiability of the SGE (Statement of Greenhouse Gas Emissions) on a cargo-by-cargo basis.

The SGE Methodology is designed with reference to currently available product life cycle accounting standards, principally the GHG Protocol Product Life Cycle Accounting and Reporting Standard and ISO14064:2018. It assumes the use of established industry approaches for the calculation of GHG emissions associated with combustion, flaring, venting, fugitive emissions and imported energy. It does not seek to mandate a particular standard or quantification approach. The boundary of reporting includes emissions attributable to the LNG cargo from wellhead to discharge flange at the discharge point.

The SGE Methodology has been developed by a team of technical specialists representing Chevron, QatarEnergy and Pavilion Energy, supported by global sustainability consultancy Environmental Resources Management Ltd. (ERM).

We are very grateful to the many individuals who have offered insights through conversations with our team since this initiative began in March 2020.

We are particularly grateful for the detailed feedback provided by these five independent reviewers of the draft methodology, who represent industry participants, third-party verifiers and an independent viewpoint: Professor Jonathan Stern of The Oxford Institute of Energy Studies, JERA, Lloyd’s Register, Maran Gas Maritime Inc, and Flex LNG.

EXECUTIVE SUMMARY

The Statement of Greenhouse Gas Emissions (SGE) Methodology is one of the first published methodologies specifically developed to quantify the greenhouse gas (GHG) emissions associated with a delivered liquefied natural gas (LNG) cargo. It provides a measurement, reporting and verification methodology which compliments common GHG reporting processes to deliver a consistent, verified SGE for each delivered LNG cargo.

The SGE Methodology is intended for industrywide adoption and is applicable across the LNG value chain - from wellhead to delivery point. It can be used by integrated producers and operators of individual segments that contribute to the value chain GHG footprint, as shown in Exhibit E.1 below.

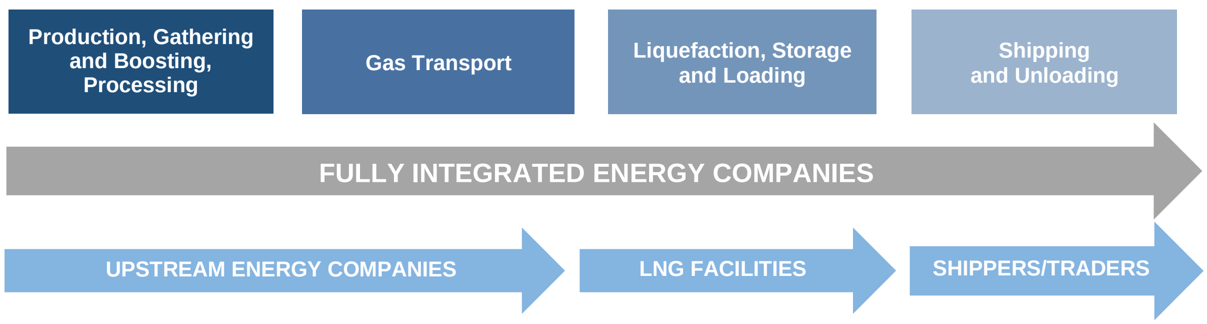

Exhibit E.1. Life cycle stages in the LNG value chain

The methodology has been developed by a technical team representing Chevron, QatarEnergy and Pavilion Energy, supported by Environmental Resources Management Ltd. (ERM), an independent sustainability consultancy, and has been independently reviewed by: Professor Jonathan Stern of the Oxford Institute of Energy Studies, JERA, Lloyd's Register, Maran Gas Maritime Inc., and Flex LNG.

Carbon Footprint Quantification

The SGE Methodology is based on the principles of coherence, relevance, completeness, consistency, transparency, and accuracy.

Coherence: The SGE Methodology provides a measurement, reporting and verification methodology based on industry standards[1] and enables LNG sellers to develop and adapt their internal GHG reporting processes to deliver a SGE for each cargo.

Relevance and completeness: The SGE Methodology covers operational emissions associated with all life cycle stages from production wellhead to delivery point, including an incoming ballast voyage and in-port emissions for shipping. Emissions associated with operation of the discharge terminal through to end user are not addressed but could be added as a separate component to fulfil a "cradle-to-grave" life cycle assessment.

[1] The SGE Methodology is designed with reference to currently available product life cycle accounting standards, principally the GHG Protocol Product Life Cycle Accounting and Reporting Standard and ISO14067:2018.

***Consistency**:* The SGE is quantified and reported per cargo both as total GHG emissions, expressed as carbon dioxide equivalent (CO_2e), emissions intensity per energy content delivered, expressed as tCO_2e/mmBtu, and methane intensity per energy content delivered, expressed as tCH_4/mmBtu. At a minimum, emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) must be included. All emissions are expected to be allocated appropriately to LNG and all other co-products.

Transparency and accuracy: Each SGE is subject to independent third-party verification. The SGE Methodology includes the development and maintenance of a Methodology Monitoring Plan (MMP). The MMP is a documented procedure that sets out how the reporter intends to meet the criteria established in the SGE Methodology, and it clearly identifies emission sources, calculation approaches, and internal controls. Exhibit E.2 outlines the key steps in developing a MMP and using this to calculate and report a SGE for a delivered LNG cargo.

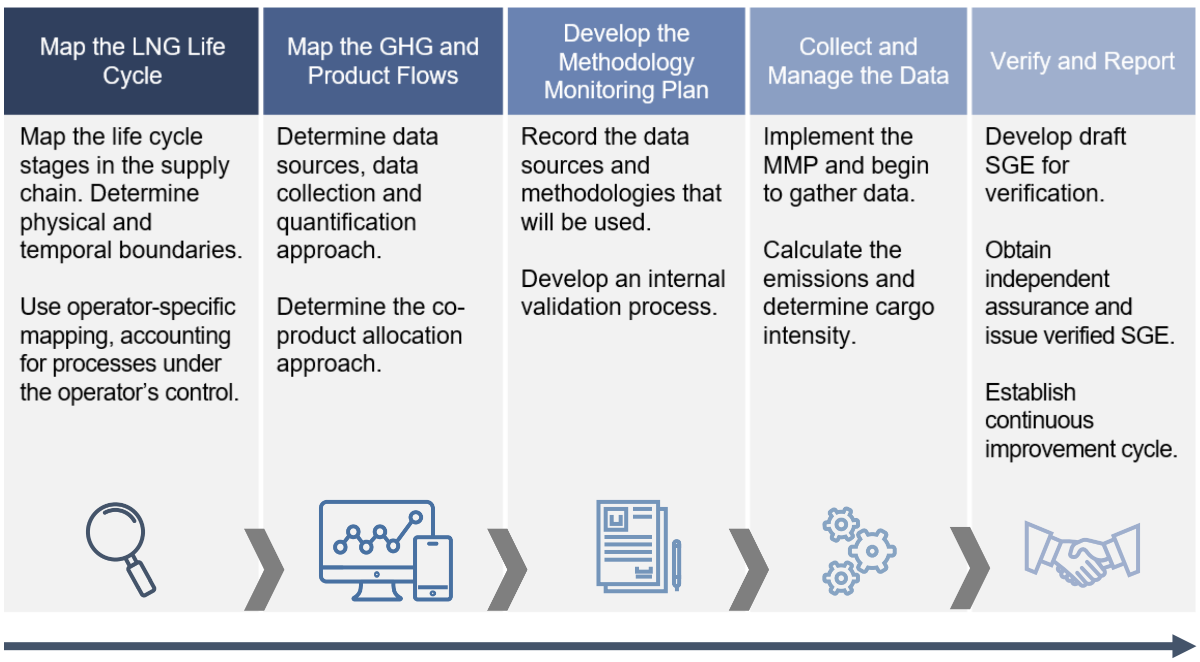

Exhibit E.2. Key steps to developing a Methodology Monitoring Plan and reporting an SGE

Source Data

The SGE Methodology requires reporters to use the highest-quality data available. For operated assets, the best available data is expected to be primary data, where data is sourced from operations and is specific to the value chain of the delivered LNG.

For third-party sourced inputs or products, the SGE Methodology provides a tiered approach using secondary (non-specific) data where primary data is not available. Use of primary data is expected to increase over time and, in all cases, the data used will be transparently presented for assurance to a third-party verifier. Exhibit E.3 shows this tiered approach to primary and secondary data.

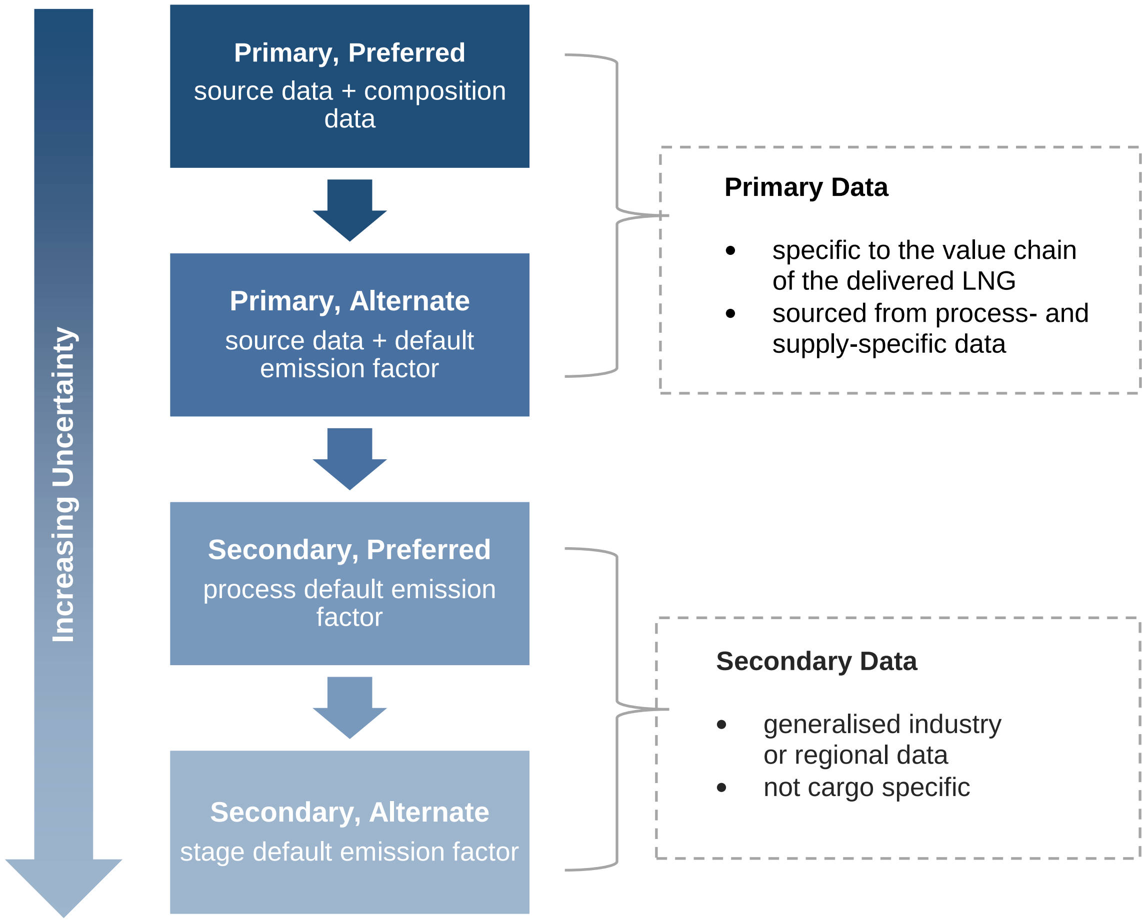

Exhibit E.3 Hierarchy of data sources and effect on uncertainty

Assurance

Consistent with the principles of transparency and accuracy, the SGE Methodology sets out the ambition that SGEs will achieve a reasonable level of assurance by a third-party verifier. The verifier will assure that the SGE has been calculated per the SGE Methodology and that there are no material errors or omissions in the reported SGE.

Continuous Improvement

Over time, both the SGE Methodology and its application are expected to evolve as more detailed and granular source data become available and as industry regulations and GHG reporting standards advance. Industry should strive to improve the data quality and the transparency of their value chains over time and to demonstrate continuous improvement in reducing the uncertainty level of the SGE.

Table E-1 below summarises the key approaches taken by the SGE Methodology.

In conclusion, the developers of the SGE Methodology welcome working with the LNG industry to promote further advancement of product carbon footprinting.

Table E-1. Summary of SGE Methodology

Methodology Scope	Measurement, reporting, and verification of the product carbon footprint of LNG cargos
Applicability	LNG value chain
Use of Primary Data	Yes, preferred
Use of Secondary Data	Yes, if primary data not available
Gases Included	CO_2, CH_4, and N_2O, at a minimum
Methane Considerations	Source-specific calculations. Quantification based on leak detection where available
Global Warming Potentials	AR5 (CO_2 =1, CH_4 = 28, and N_2O=265)
Physical Boundary	
Wellhead	Included
Processing	Included
Pipeline	Included
Liquefaction	Included
Shipping, Laden Voyage	Included
Shipping, Ballast Voyage	Included (repositioning)
Regasification	Excluded
Distribution Pipeline	Excluded
End Use	Excluded
Temporal Boundary	Best available for LNG production (no longer than a 12-month average), cargo-specific for shipping
Allocation Basis	Energy, HHV
Treatment of non-energy products (e.g., helium)	First allocate emissions between energy and non-energy products based on mass, then within the energy products category allocate their share based on energy content
Reported Units	tCO_2e/mmBtu, tCH_4/mmBtu, and tCO_2e
Reporting Frequency	Per cargo
Third-Party Verification	Required. Reasonable assurance expected where possible

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GUIDE TO USING THIS METHODOLOGY

This document sets out an approach to determining the greenhouse gas (GHG) emissions and intensity (CO_2e/mmBtu) associated with the production and delivery of the Statement of Greenhouse Gas Emissions (SGE) for a cargo of liquefied natural gas (LNG). The approach is based on product life cycle accounting methods and, at a minimum, includes emissions of CO_2, CH_4 and N_2O associated with all processes attributable to the LNG, from production at the wellhead to delivery at the discharge manifold.

It is expected that the user of this methodology will also reference relevant standards for GHG accounting and the quantification of GHG emissions relevant to each stage of the delivered LNG value chain, from the production wellhead to the point of discharge from the LNG tanker – that is, on a “cradle to gate” basis.

The methodology addresses:

- Reporting principles
- Boundaries
- Quantification and allocation methods
- Reporting
- Assurance

Prior to calculating the SGE for a cargo of LNG, a methodology monitoring plan (MMP) must be developed for the cargo’s LNG value chain. Table 1 outlines the key steps in developing an MMP. Once an MMP has been developed, an SGE for a delivered cargo can be calculated and reported. Table 2 outlines the key steps to calculating and reporting an SGE for a delivered cargo using the MMP. Details and examples are provided throughout this document.

Table 1. Key Steps to Develop an MMP

Step	Action	SGE Methodology Section Reference	Notes
Map life cycle stages in the applicable LNG value chain.	Trace the value chain of an LNG cargo and identify all life cycle stages included in the SGE boundary.	2.3	The SGE Methodology has adopted a cradle-to-gate physical boundary, or, more specifically, from upstream production at the wellhead to point of LNG delivery.
Map the processes within each identified stage.	Identify the processes within each stage that are attributable to the product, that is, LNG cargo. Document those determined to be non-attributable (e.g., oil export pumps).	ANNEX D	The identification of attributable or non-attributable processes supports later allocation of emissions to specific products/co-products.
Determine quantification methods and data sources.	From data source to calculation, define the emissions quantification approach that will be taken, the data that will be required and the sources of those data. Define the sources of default factors. Define the temporal boundary of reporting.	3	Primary data and source-specific calculation methods should be used wherever possible. The temporal boundary must be 12 months or less.
Determine the allocation approach for co-products.	Where processes generate more than one product, co-product allocation may be necessary. Identify co-products from each attributable process and determine the approach to allocate GHG emissions to LNG and other co-products.	2.6 and ANNEX B	Energy basis is the preferred allocation approach. When this is not possible, allocation can be based on a mass approach or other applicable approach.
Develop an MMP.	Document the specific calculation and co-product allocation methodology approaches, calculation factors, and supporting information that describes the procedures employed to calculate the relevant emissions intensity and to ensure that the data used are appropriate and of good quality. Include an approach to quality assurance over the data and calculations.	5.2.1 and ANNEX D	This includes emissions calculation methodologies, allocation methodologies and the approach to apportioning abnormal events across the temporal boundary.

Table 2. Application of MMP to Calculate and Report the SGE for a Delivered LNG Cargo

Step	Action	SGE Methodology Section Reference	Notes
Calculate emissions.	In line with the MMP: • collect data and assess data quality/uncertainty; • calculate per-stage emissions for allocation to co-products; and • allocate emissions to co-products	3 and 2.5	
Determine emissions intensity.	Calculate the emissions intensity of the delivered LNG cargo. All emissions attributable to the delivered cargo must be included in the SGE, and the final emissions intensity must account for product "shrinkage" across the LNG value chain.	2.6	This methodology recommends the use of the carry-forward method and includes an example calculation. Shrinkage factors can also be used. Intensity values will be applicable throughout the defined temporal boundary.
Provide SGE reporting.	On delivery of the LNG cargo, provide an SGE that is compliant with the SGE Methodology, including intensity and total emissions at the point of delivery.	4	
Obtain assurance.	Commission third-party verification of the SGE and restate the SGE if applicable, based on either the verification conclusions or operational adjustments.	5	
Conduct reviews to ensure continuous improvement.	On a regular basis, and in response to verification conclusions, review the opportunities to improve the data quality and reduce uncertainty.	6	This may include moving from secondary to primary data approaches or reducing uncertainty in existing approaches.

1 INTRODUCTION

This methodology sets out the approach to quantify the Statement of Greenhouse Gas Emissions for each cargo of delivered LNG, expressed on an energy basis – for example, tonnes CO_2e per mmBtu of LNG (the SGE Methodology) – as well as in total tonnes CO_2e per cargo. The SGE Methodology provides a calculation and reporting framework, based on industry standards, against which LNG sellers can develop and adapt their internal GHG reporting processes to deliver a verifiable SGE for each delivered cargo.

The SGE Methodology describes the agreed approach to calculate CO_2e emissions from wellhead to delivery point (defined as the discharge manifold) associated with production, gathering, processing, gas transport, liquefaction, storage and loading, shipping, and unloading of the natural gas included within each cargo of LNG delivered, including an incoming ballast leg as well as in-port emissions of the ship (during loading and discharge operations) for the shipping stage. Emissions associated with operation of the discharge terminal (storage, regasification) and downstream (transmission, distribution, end use) are excluded. The SGE Methodology is therefore not intended to represent a full life cycle assessment of emissions associated with LNG.

The SGE Methodology does not define calculation methodologies or sources of emission factors in detail. To meet the objectives of transparency and verifiability, SGE Reporters (Reporters) shall maintain a documented SGE Methodology Monitoring Plan that clearly identifies emission sources and calculation approaches in line with accepted standards for GHG product accounting and industry practices for GHG reporting. Where primary data and source-specific emission factors are not available, the MMP should clearly reference appropriate secondary factors that may be applied.

Reference sources commonly used for GHG reporting across the LNG value chain, such as the API Compendium for the LNG production stages and the and, recently, Sea Cargo Charter for shipping, are considered to be compatible with best practise. It may also be the case that other overriding factors, including national and regional legislation, define the choice of default factors (such as in the case of companies reporting under regional programmes like NGERs [Australia], CARB [California] and EU ETS [EU]).

Although it is recognised that Reporters and other participants in the LNG production cycle may wish to offset all or part of their direct emissions, this should not be used to reduce the apparent intensity of the SGE. The SGE must be based on the operational emissions associated with each stage of the life cycle.[2] If offsets have been applied, then these may be reported separately from the SGE. Carbon capture and storage within the production process is not considered offsetting.

[2] The intent of the SGE methodology is to capture attributable emissions associated with each stage of the life cycle, without including the effect of any offsets occurring outside of the production process. The use of secondary data in this context is acceptable, though not preferred, as it is indirectly based on relevant operations from the LNG production chain.

1.1 Reporting Principles

The SGE Methodology is based on the established greenhouse gas accounting principles of *relevance, completeness, consistency, transparency, accuracy* and *coherence*. This core set of principles applies to all GHG inventories or product footprints regardless of company, industry or jurisdiction.

The GHG Protocol Product Life Cycle Accounting and Reporting Standard sets out the following definitions:

Coherence Choose methodologies, standards and guidance documents that are already recognised internationally in order to enhance comparability between carbon footprints. An additional principle of coherence is included in ISO14067:2018.

Relevance Ensure that the product GHG inventory accounting methodologies and report serve the decision-making needs of the intended user. Present information in the report in a way that is readily understandable by the intended users.

Completeness Ensure that the inventory report covers all product life cycle GHG emissions and removals within the specified boundaries; disclose and justify any significant GHG emissions and removals that have been excluded.

Consistency Choose methodologies, data and assumptions that allow for meaningful comparisons of a GHG inventory over time.

Transparency Address and document all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the methodologies and data sources used in the inventory report. Clearly explain any estimates and avoid bias so that the report faithfully represents what it purports to represent.

Accuracy Ensure that reported GHG emissions and removals are not systematically greater than or less than actual emissions and removals and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable intended users to make decisions with reasonable assurance as to the reliability of the reported information.

2 ACCOUNTING APPROACH

The SGE Methodology is not designed to replace established standards and methodologies for GHG accounting and calculation. It provides an approach that adopts the core principles of GHG accounting and reporting and reflects established standards for GHG quantification applied within the sector.

2.1 Reference Standards

The delivered LNG cargo represents a product, and the quantification of emissions associated with each LNG cargo is informed by established reference standards for product accounting. Product standards in common use include the following:

- **GHG Protocol Product Life Cycle Accounting and Reporting Standard**
- **ISO14067:2018 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification**
- **PAS2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services**

Under a product-based accounting approach, the emissions from each relevant stage of the value chain are apportioned to the delivered product.

At an entity level, the accounting for the emissions typically follow standards for corporate GHG accounting, such as the GHG Protocol Corporate Standard[3] and ISO14064-1:2018,[4] with calculation methodologies informed by sector-specific approaches such as the API Compendium or protocols established under national or regional regulatory standards. The interrelationships between these standards and calculation approaches as applied in this methodology are illustrated below in Figure 2.1.1.

3 https://ghgprotocol.org/corporate-standard
4 https://www.iso.org/standard/66453.html

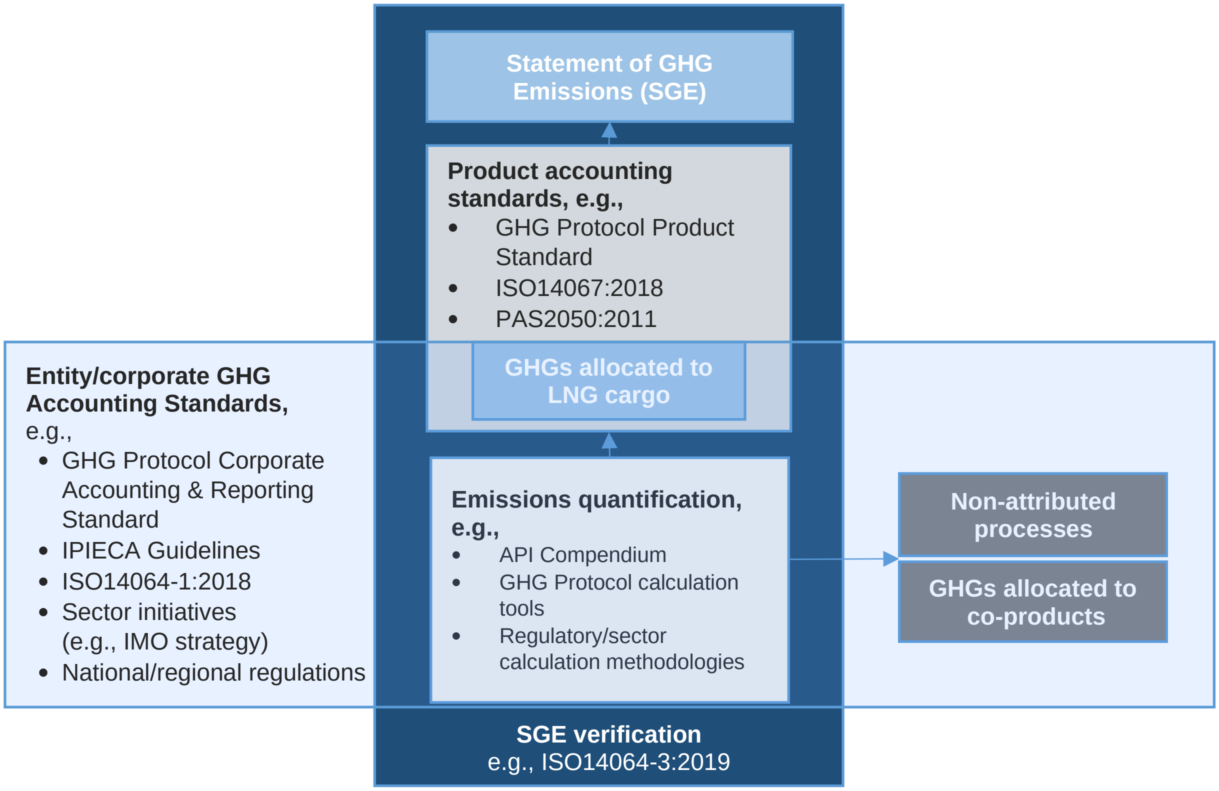

Figure 2.1.1. Interrelationships between standards and calculation methodologies for product GHG accounting

The SGE relates specifically to the footprint of a delivered LNG cargo, and a product life cycle accounting standard is most appropriate for calculating and reporting the GHG footprint of the LNG from well to discharge terminal. The entity/corporate accounting standards applied by the Reporter (or individual entity within its value chain) will be key references for quantification at each stage of the LNG value chain. The SGE Methodology sets out key boundary conditions that are relevant to each stage of the LNG production, liquefaction and delivery life cycle.

The SGE Methodology is aligned to the principles of the GHG Protocol Product Standard and ISO14067:2018 and also recognises the ongoing emergence of LNG-specific standards.

Verification of the SGE (see section 5) shall be governed by established standards for GHG verification, of which ISO14064-3:2019 is widely used for verification associated with regulatory GHG reporting, certification of “carbon credits” and corporate GHG inventories.

2.2 Accounting Scope

The scope establishes what must be included or excluded from the calculated GHG emissions total for the delivered cargo. The key elements to be determined, in line with the selected accounting standard classifications, are described below.

2.2.1 Units of Reporting

The SGE shall be reported as:

- **Mass (metric tonnes) CO_2e per cargo** and
- **Intensity of CO_2e per energy content**, expressed as a ratio of mass of CO_2e to energy content of LNG. For LNG cargoes, recommended units are metric tonnes CO_2e per mmBtu of delivered LNG product

In accordance with the product life cycle accounting approach, a consistent unit of analysis for the GHG assessment should be selected to compare emissions across Reporters and across different life cycle stages of LNG. The energy content of the product is a common basis for assessing the life cycle of oil and gas products. Using mmBtu of LNG product for each LNG cargo allows comparison of all shipments on a common basis. The unit of mmBtu of LNG product is commonly used across multiple LNG life cycle studies.

In line with industry practise, the energy content (mmBtu) shall be reported on the basis of gross calorific value, also known as higher heating value (HHV). The methodology for reporting HHV should be aligned with product quality requirements to prevent the need for repeat analysis to different standards.

Reporting on the basis of both absolute CO_2e emissions per cargo and GHG intensity per cargo provides the opportunity for comparative assessment over time and between suppliers. A transparent and consistent intensity factor can therefore play a role in incentivising decarbonisation across the life cycle stages for the LNG.

Approach to Determining Energy Content
LNG energy content and density may be determined by a number of methods. ISO6976 2018 is one common method, on the basis of a dry ideal gas at combustion and metering reference conditions of sixty (60) degrees Fahrenheit and a pressure of fourteen decimal six nine six (14.696) pounds per square inch absolute. Other methods include GPA2145. There are also various methods for determining LNG density, such as those based upon the revised Klosek-McKinley formula from ISO6578, or methods such as NBS 77-867, NBS 80-1030 and ISO6578. For the purposes of SGE quantification, a specific method is not prescribed; however, it is noted that Reporters should utilise a consistent approach across all stages of their SGE Methodology Monitoring Plan. Analysis should be based on standard conditions and specified in the MMP.

Consideration of Options and Selection for the SGE Methodology

By using emissions intensity, described as emissions produced (kg or tCO_2e of emissions) per product based on a unit of energy as the denominator, the method allows for comparison across different volumes and forms of LNG products and co-production of products through the value chain, notably the following:

- Common basis allows for comparison of different shipments of LNG originating from various locations, with different qualities of gas.
- LNG as a product takes different forms along the value chain (raw gas, processed natural gas, LNG in storage and LNG in transit). Using units of energy is the most appropriate way to compare these products using a common metric.
- Product-focused, intensity-based emission calculations on an energy basis are common across the oil and gas industry, so many suppliers may be able to directly integrate this methodology into existing reporting frameworks.

Key Specification	Options Considered	Selection
Unit of reporting intensity	Energy basis (MJ or mmBtu of LNG product; based on lower or higher heating value (LHV or HHV) Mass basis (tonne or kg of LNG)	Energy basis (mmBtu) Higher heating value (HHV/GHV/GCV) basis

Note: The terms *HHV*, *GHV* (gross heating value) and *GCV* (gross calorific value) are interchangeable, as are the terms *LHV* (lower heating value) and *NCV* (net calorific value).

2.2.2 Included Gases

For the GHG footprint of production, transport and delivery of a delivered cargo of LNG, the most significant and commonly reported GHG emissions are CO_2, CH_4 and N_2O (with N_2O being a minor constituent). These three gases shall be included in the SGE calculations as a minimum.

The emissions from each GHG constituent are multiplied by the associated GWP and added together to produce a total tCO_2e across all GHGs.

$$tonnes[gas] * GWP = tonnes\ CO_2e[gas]$$
$$tonnes\ CO_2e[total] = \sum tonnes\ CO_2e[gas]$$

Each of these greenhouse gas quantities should be accounted for separately to allow verification and ensure use of appropriate GWPs within the SGE Methodology.

Consideration of Options and Selection for the SGE Methodology

GHG accounting standards consider seven GHGs – CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3. Within the LNG value chain, key emission sources relate to combustion, flaring, venting and fugitive emissions, which primarily are associated with emissions of CO_2, CH_4 and N_2O. HFCs may be used as refrigerants and SF_6 in transformers, both of which are used in tightly controlled closed-loop systems from which releases are unlikely to be significant.

The methodology therefore sets CO_2, CH_4 and N_2O as a minimum for inclusion in GHG accounting.

Key Specification	Options Considered	Selection
Included gases	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	At a minimum CO_2, CH_4, and N_2O

Approach to Reporting of Methane

The SGE Methodology recognises the importance of methane emissions in the transition to a lower-carbon economy and is fully aligned with complete and transparent reporting of methane emissions.

Although the SGE Methodology is not prescriptive, it is recognised that there are a growing number of methodologies and approaches to measuring or estimating methane emissions in the oil and gas value chain, such as Canary, MiQ and OGMP 2.0.

It is expected that participants in the SGE Methodology are aware of these approaches and implement the most appropriate high-quality approach for their operations based on these or similar methodologies, aligned with the principles of continuous improvement as laid out in the SGE Methodology.

Similar to industry best practices and these emerging methodologies, the SGE Methodology strongly recommends the use of primary preferred data, which requires source-specific emissions calculations and includes LDAR (Leak Detection and Repair) as a primary preferred approach to fugitive emissions. Additional information on methane calculation approaches is provided in Section 3.4 and 3.5.

The methodology also recognises that the GWP of methane continues to be reviewed. Users of this methodology must incorporate any changes to GWPs during the annual MMP review process.

2.2.3 Global Warming Potential (GWP)

The GWP allows comparisons of the global warming impacts of different gases. It is a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of one tonne of CO_2.

The GWPs applied shall be the most up-to-date values based on the consensus of scientific research set out in the latest Intergovernmental Panel on Climate Change (IPCC) Assessment Report. At the time of first issuance of this SGE Methodology, the IPCC Fifth Assessment Report (AR5) is chosen as the basis for the GWPs to be updated as appropriate, as when a new IPCC Assessment Report is issued. It is expected that GWPs will be reviewed through the annual review process, as relevant, to be aligned with the latest IPCC Assessment Report.

Updates to the GWPs shall be adopted from the reporting period following the issuance of a new IPCC Assessment Report, and it is not necessary to adjust calculations within a reporting period.

The following values represent the 100-year GWPs included in AR5:

- CO_2 = 1
- CH_4 = 28
- N_2O = 265

The GHG Protocol Initiative has established a 100-year basis as a standard. This is in line with entity reporting that will be undertaken by operating companies across each relevant life cycle stage. This also aligns with the methodologies applied to calculate the CO_2e emissions avoidance or removal from certified GHG offset programmes.

Each GHG (CO_2, CH_4 etc.) is typically accounted for separately in GHG reporting. If an emission source along the value chain has aggregated CO_2e quantities that had been compiled with GWPs that are not AR5 100-year values, the total CO_2e can then be recalculated using the individual greenhouse gases.

Consideration of Options and Selection for the SGE Methodology

The SGE Methodology uses the 100-year GWP values published in the latest IPCC Assessment Report (currently, AR5). The 100-year values have been selected to align with the GHG Protocol and other standards applied for corporate-, product- and project-level GHG accounting.

Use of a 20-year GWP, which may be more closely aligned with the decay period for methane in the atmosphere, was considered. However, consistency of reporting with corporate inventories and offset accounting was considered to be important; therefore, a 100-year period has been chosen.

Key Specification	Options Considered	Selection
GWP	• SAR, AR4, AR5,	• Latest IPCC Assessment Report (currently, AR5)
	• 20-year, 100-year, 500-year	• 100-year

2.3 Physical Boundaries

The physical boundary defines the operations, facilities and sources of emissions that will be included in the SGE. The boundary considerations for the methodology and recommended approaches are described below.

2.3.1 Life Cycle Stages

The SGE shall include, at minimum, the sources of GHG emissions associated with production, transport, liquefaction and shipping. Although exploration and drilling are relevant life cycle stages, the significance of associated emissions to the overall cargo footprint is considered low and potentially of high uncertainty, given the need to amortise emissions over the lifetime of the well.

> The SGE Methodology is a cradle-to-gate approach. The physical boundary will not include regasification and will stop at the point of delivery (discharge manifold) at the port.

Life Cycle Stage	**Production, Gathering and Boosting, Processing**	**Gas Transport**	**Liquefaction, Storage and Loading**	**Shipping and Unloading**
Boundaries	• Inlet – production well • Outlet – custody transfer meter to transmission pipeline	• Inlet – custody transfer meter between production and transmission pipeline • Outlet – liquefaction inlet boundary meter	• Inlet – plant inlet boundary meter • Outlet – loading manifold non-return valve	• Inlet – loading manifold non-return valve • Outlet – discharge manifold non-return valve • Ballast journey*
Predominant Emission Sources	• Combustion – mobile and stationary • Venting and flaring • Fugitives • Scope 2 imported energy	• Combustion – mobile and stationary • Venting and flaring • Fugitives • Scope 2 imported energy	• Combustion – mobile and stationary • Venting and flaring • Fugitives • Scope 2 imported energy	• Combustion – mobile • Venting and flaring • Fugitives • Scope 2 imported energy while in port
Preferred GHG Quantification Approach	• Common methodology considerations • API Compendium or equivalent national legislation • Based on fuel consumed, flared, vented and so on • Calculation factors based on known compositions • Including CO_2, CH_4, and N_2O			• Shipping-specific approach • Based on fuel consumed, gas vented and so on • Calculation factors based on known composition or commercial fuels • Including CO_2, CH_4, & N_2O

* Please refer to ANNEX A for a more detail description of ballast journey boundaries

Figure 2.3.1. Stages of the LNG value chain and associated GHG emission sources

In mapping the sources of emission to be included in the footprint, the stages can be divided into sub-boundaries, which identify the relevant emission-producing activities covered in each stage, to ensure full capture of emissions and to prevent double counting.

- **Emissions from the production and processing stage** include all combustion, venting, flaring and fugitive sources, as well as emissions from imported electricity and heat, due to activities related to production and processing. The physical boundaries shall be the natural gas wellhead to the transmission pipeline transfer meter. For the purposes of the SGE Methodology, the interface between the reservoir and the production asset is taken as the wellhead and marks the point at which the well fluids can be considered to be produced.

- **Emissions from gas transportation** include gas compression or venting sources from the pipeline transfer meter to the liquefaction plant inlet boundary meter. In some cases, a gas plant may be co-located with a liquefaction plant, in which transport emissions may be minimal or non-existent. Emissions from the liquefaction facility include all activities related to gas conditioning, cooling, storage and loading, up to the loading manifold of the LNG shipping vessel.

- **Emissions from liquefaction** include all combustion, venting, flaring and fugitive sources, as well as emissions from imported electricity and heat, due to activities related to treatment, liquefaction, storage and loading of the LNG.

- **Emissions related to LNG shipping** include emissions from the laden voyage, both in port and at sea, as well as discharge at the receiving manifold. Shipping stage emissions shall also include the inward ballast voyage and inbound port activities. The laden voyage will be based on opening the Custody Transfer Management System (CTMS) at the loading port and then closing the CTMS post-discharge. For the incoming ballast leg, the base principle is that the Reporter will be responsible for the proportion of the incoming ballast leg that is under the control of the Reporter. This is further defined in ANNEX A.

Consideration of Options and Selection for the SGE Methodology

Although there will be GHG emissions associated with exploration and drilling, including combustion and potentially venting/flaring, it is considered that these emissions are non-material over the lifespan of an installation. There is also likely to be considerable complexity in accurately allocating emissions from a one-off event across the life span of the asset and to a single LNG cargo. Similarly, ongoing well interventions and development or infill drilling can be considered non-material over the lifespan of the asset and per cargo.

It is recognised that aggregated, secondary data approaches include exploration and drilling data that are difficult to disaggregate. These should not have a material effect on the quality of that data in addition to the aggregated approach itself.

The life cycle stages of the SGE Methodology therefore include all emissions from the operational phase of the LNG value chain, from gas wellhead to shipping discharge terminal, including extraction, processing, storage and transportation within this boundary. Note that although emissions from all of these parts of the value chain should be included, it is not necessary to report each element individually when integrated facilities may manage reporting in an aggregated approach.

Key Specification	Options Considered	Selection
Life cycle stages	• Exploration • Drilling • Extraction / production • Gathering and boosting • Processing • Transmission • Liquefaction • Storage and loading • Shipping • Unloading • Regasification • End use	• Extraction / production • Gathering and boosting • Processing • Transmission • Liquefaction • Storage and loading • Shipping (including inward ballast) • Unloading

The relative contributions of the various life cycle stages have been addressed in several life cycle assessments, including that by PACE Global, depicted below in Figure 2.1.2, which shows the proportion of GHG emissions by stage of the LNG production chain – “cradle-to-grave’, based on final usage of the LNG in power generation. This has been re-normalised in Figure 2.1.3 for a cradle-to-gate approach as per the SGE Core Methodology and has been used to inform the selection of stages included. It is noted that combustion may not be the only end use for LNG; however, the study by PACE Global (2015) is based on this outcome.

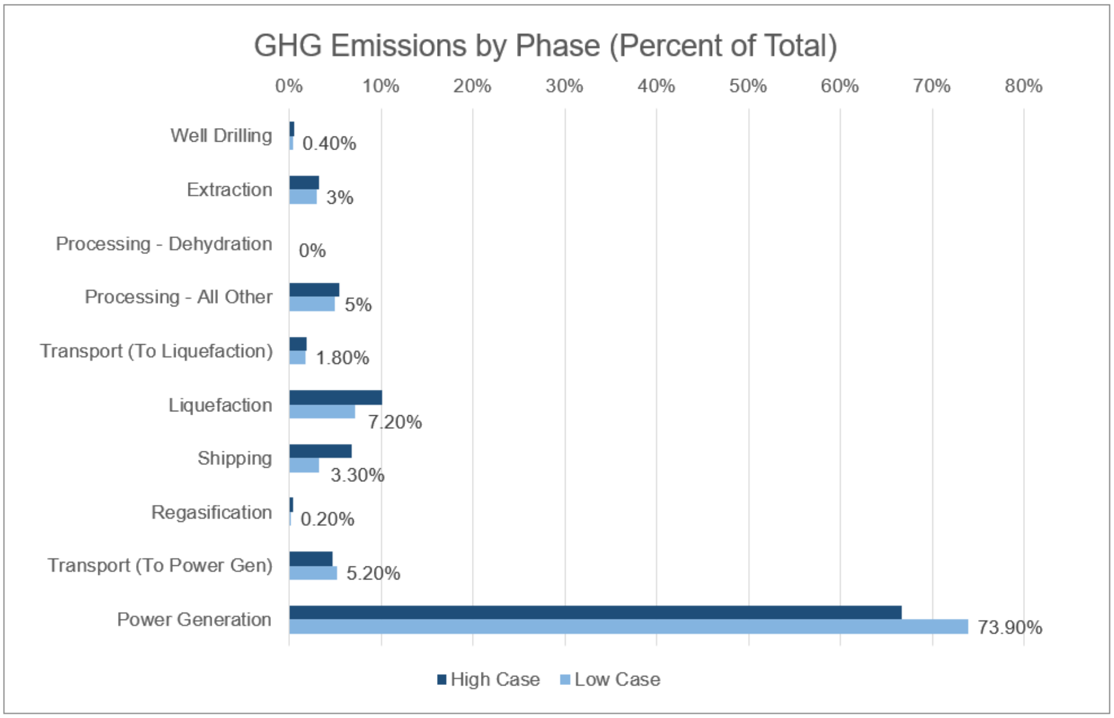

Figure 2.3.2. Proportion of GHG emissions by stage of the LNG production chain – cradle to grave (Source: PACE Global, 2015)

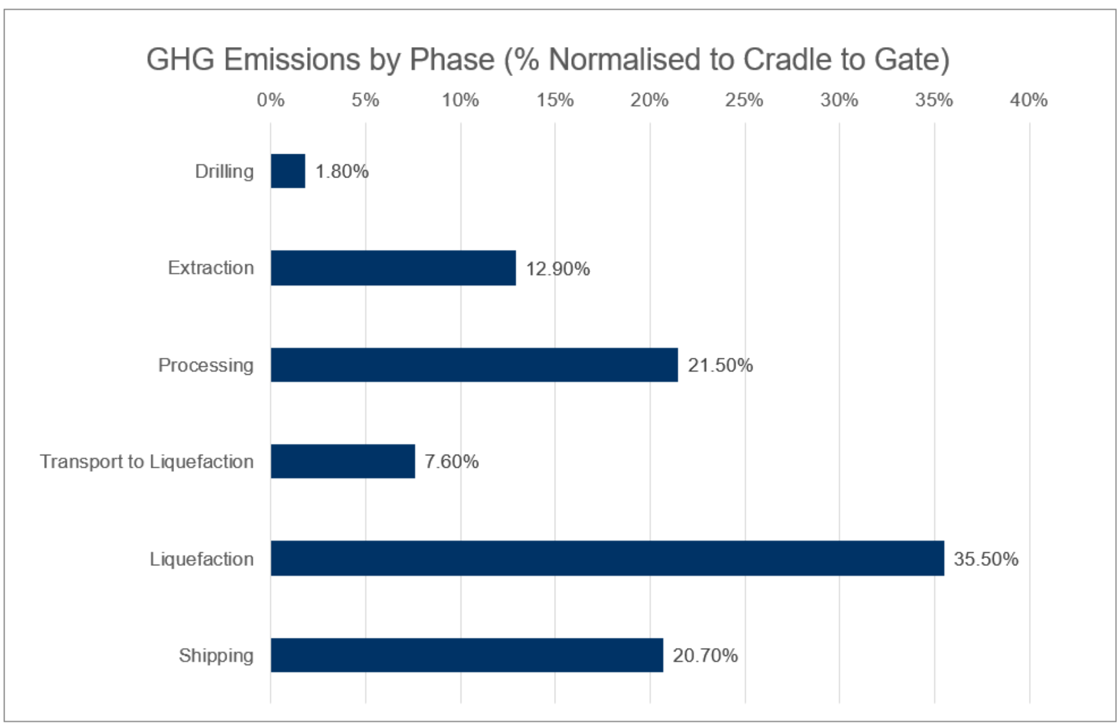

Figure 2.3.3. Proportion of GHG emissions by stage of the LNG production chain – normalised to cradle to gate (adapted from PACE Global, 2015 full life cycle assessment)

2.3.2 Source Exclusions

In line with the boundaries described above, the following sources are excluded from the SGE. These are not considered to be material according to available life cycle assessment studies and are not directly relevant to the quantification of GHG emissions associated with a given cargo.

Construction emissions

Emissions associated with the fuel use, transportation and contractor activities for building natural gas extraction or processing facilities, pipelines, liquefaction plants and/or LNG transport ships. These are expected to be non-material.

Steel, concrete or other materials of construction

LCA emissions associated with the raw material extraction processing, transportation and fabrication, which is used to construct the infrastructure across the LNG value chain. These are expected to be similar across cargoes.

Raw material inputs besides oil and gas produced

Examples include diethanolamine for acid gas recovery (AGR), glycol used in dehydration, production chemicals, mole-sieve media and so on.

Consideration of Options and Selection for the SGE Methodology

Construction emissions, steel or other materials of construction, and raw materials besides oil and gas produced are considered to be non-material according to LCA studies available and are not directly relevant to the quantification of GHG emissions from a given cargo. They are therefore excluded from the scope of this methodology.

Key Specification	Options Considered	Selection
Source exclusions	• All ancillary materials	• Construction emissions • Steel or other materials of construction • Raw materials besides oil and gas produced (e.g., diethanolamine for AGR)

2.4 Temporal Boundaries

ISO14067:2018 Section 6.3.6 requires that a time boundary be established for which the product carbon footprint (the GHG intensity of the delivered cargo) is representative, considering both interannual and intra-annual variability and covering any specific periods required. Reporters shall define an appropriate temporal boundary in their methodology documentation. The temporal boundary shall cover no more than 12 calendar months, maximising the potential to use primary data. This may include, for example, a prior calendar year or a rolling 12-month (or shorter) average. It is expected that Reporters work toward reducing the length of time between the time period covered by the SGE temporal boundary and the actual time period of production with the objective of aligning the SGE as closely as possible to the emissions associated with the delivered cargo. The shipping stage shall use cargo-specific reporting. Further details of shipping-specific approaches are included in ANNEX A.

Temporal issues may be addressed by using an intensity metric (tCO_2e/mmBtu) based on annualised or other representative period, which would correct for small data anomalies. The verification approach shall include any need to make retrospective adjustments to issued SGEs, taking into account the temporal boundary chosen.

Consideration of Options and Selection for the SGE Methodology

It is intended to achieve a cargo footprint that as closely as possible represents the emissions associated with the delivered LNG. For shipping, cargo-specific fuel and emission data can be derived, and therefore no averaging over time was considered necessary. Other stages, however, present considerable complexities associated with assigning emissions to a particular cargo. Entity-level reporting generally is consolidated over months, quarters or an annual basis.

To accommodate variations within entities and stages and also to ensure that irregular activities such as shutdowns are apportioned appropriately, a definitive temporal boundary for stages from production to liquefaction is not specifically defined. Reporters are encouraged to develop a temporal boundary aligned with their reporting that represents a reasonable calculation of emissions associated with the delivered LNG.

Key Specifications	Options Considered	Selection
Temporal boundary	• Rolling 12-month average • Most recent reporting year • Cargo specific	• Cargo specific for shipping • “Best available” for LNG production, maximum 12 months

Approach to Shipping Temporal Boundaries

The shipping element of the SGE shall consist of both an incoming ballast leg and a laden leg. Detail of the respective boundaries is given in ANNEX A and is based on control of the vessel by the Reporter. The ballast leg will be defined by the commercial in-charter agreement.

In general terms, this means the following:

- Open CTMS at loading port to close CTMS at discharge port for the laden leg
- Point of control by the Reporter for the incoming ballast leg, which may differ depending on circumstances immediately prior to the ballast leg

It is also noted that the Reporter may use alternative points based on ANNEX A, subject to verification that these do not result in material differences to the SGE.

2.5 Co-product Allocation Approach

When a process in the life cycle has multiple products, it is necessary to allocate the emissions associated with that process to each product.

Different co-products will be produced or co-managed along the value chain of LNG (e.g., co-production of natural gas and oil or processing of natural gas and natural gas liquids during the extraction and processing stage of LNG). Most co-products in the LNG value chain may be measured according to their energy content, and emissions shall be allocated on the basis of the energy content of the different products. A limited number of co-products, such as helium or CO_2 used for enhanced oil recovery (EOR), do not have energy content, and engineering approaches based on mass value may need to be undertaken where no energy basis can be applied. Only those emissions allocated to the LNG value chain shall be reported in the SGE.

An energy allocation approach is aligned with common practise for transportation and fuel LCA studies and is also consistent with the overall unit of analysis (i.e., mmBtu of LNG product). By using units of energy assigned to each co-product, the appropriate emissions can be excluded or allocated to the LNG value chain. Use of an energy basis removes the potential variability of allocation by economic value.

In general, the hierarchy of preference for allocation, based on the product accounting standards, is Energy > Mass > Economic Value.

Consideration of Options and Selection for the SGE Methodology

Different co-products are produced or co-managed along the value chain of LNG. Emissions are therefore allocated to each co-product so that the SGE represents only the emissions associated with the LNG.

All co-products in the LNG value chain are typically measured according to their energy content, making energy allocation a logical co-product allocation approach aligned with best practise and the overall unit of analysis. Energy is also the primary source of the GHG emissions associated with production and transport of LNG and its co-products.
Allocation based on mass represents an alternative physical allocation approach. This may be appropriate in some production scenarios, particularly for co-products that have no energy value.
The alternative approach, economic allocation, was not considered representative or practical.

Key Specification	Options Considered	Selection
Co-product allocation approach	• Physical allocation — Energy — Mass • Economic allocation	• Energy allocation • Mass allocation where products have no energy value, e.g., sulphur and helium*

* Note that where sulphur is produced as a product in the LNG plant, a mass allocation might be used, whereas export of hydrogen sulfide as a product to a third party might use an energy-based allocation. This will need to be established on a case-by-case basis.

2.5.1 Implementation of the Co-Product Allocation Approach

The SGE Methodology results in the implementation of a systematic approach to co-product allocation, based on the general process flow diagram set out in Figure 2.5.1 below. ANNEX B contains further detailed guidance per life cycle stages.

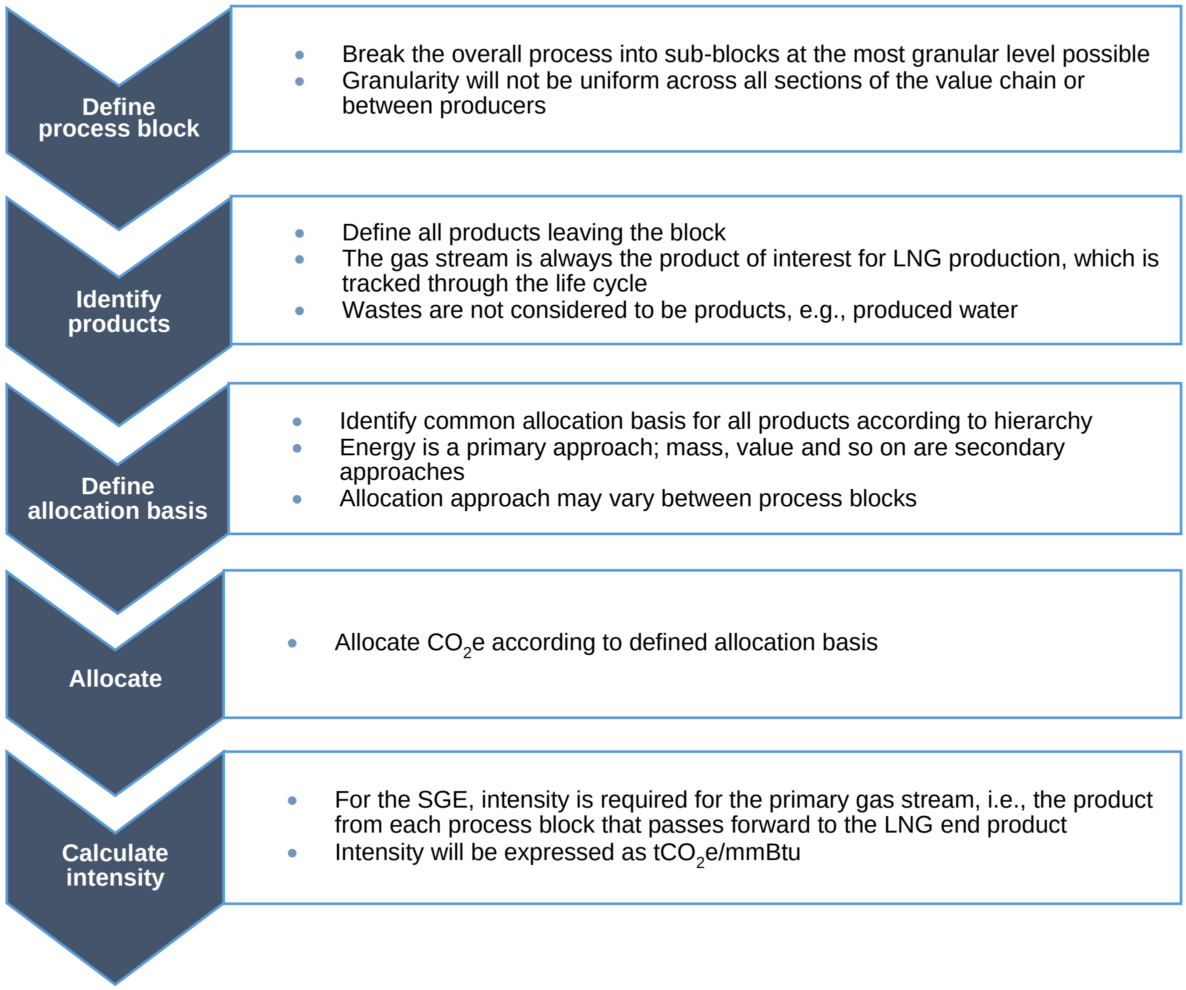

Figure 2.5.1. Systematic approach to co-product allocation

GHG allocation to co-products shall be based on proportional allocation of embodied emissions up to the point at which a product leaves the process. For example, in the case of NGL extraction, accumulated GHGs to that point in the process will be proportionally allocated, but no GHGs will be allocated backwards from subsequent steps. This will ensure that the GHG allocation to the final LNG product is neither systematically over-allocated nor systematically under-allocated.

If a facility produces more than one product, facility-level emissions should not simply be distributed to the various products produced by a facility. Instead, to the extent possible (in alignment with ISO14067:2018 and the GHG Protocol Product Life Cycle Guidance), the facility should be divided into sub-blocks. The sub-blocks should be at the most granular level achievable to minimise the need for allocation to co-products. This will allow emissions to be appropriately allocated based on the different processing requirements of each product.

Having completed the co-product allocation, the total GHGs allocated to products should be reconciled against the total facility GHGs for the reference period.

Tolling Arrangements

In the case of a tolling arrangement (e.g., at a liquefaction facility), the emissions from both upstream production and the facility emissions must be completely accounted for in accordance with the agreed hydrocarbon accounting methodologies for the facility and tolling arrangement.

Hydrocarbon accounting methodologies, otherwise referred to as production allocation methodologies, refer to the management process by which ownership of extracted hydrocarbons (and other associated substances) is determined and tracked between the point of sale and the point of extraction. In a tolling arrangement, hydrocarbon accounting methodologies are typically governed by joint operating agreements or similar contractual agreements. If a tolling arrangement does not provide hydrocarbon accounting methodologies, a hydrocarbon accounting methodology should be developed for the purpose of the SGE and included in the MMP. This methodology should be consistent with the expectation that all upstream and facility emissions are allocated to products.

Product GHG intensities from the same facility may therefore differ between two upstream producers using the same tolling facility based on the nature of the tolling agreement and differences in upstream gas sources.

As an example, an LNG plant receives gas from two upstream facilities with differing intensities.
Gas stream A – Upstream Production Intensity = 3.75 tCO_2e/mmBtu
Gas stream B – Upstream Production Intensity = 4.25 tCO_2e/mmBtu

The LNG facility's hydrocarbon allocation methodology allocates emissions evenly based on energy content to both gas streams with the exception of emissions from the acid gas recovery unit, which are allocated to streams based on their respective CO_2 content. In this example, gas stream A produces 10% of the total CO2 vented quantity from sweetening and gas stream B produces 90% of the total CO_2 vented quantity from sweetening. Accordingly, 90% of the total CO_2e associated with the Gas Sweetening process would be allocated to gas stream B. All other facility emissions would be allocated to the gas streams based on energy content. This approach yields different LNG facility intensities for both gas streams, as shown below.

LNG facility intensity for gas stream A = 12.0 tCO_2e/mmBtu
LNG facility intensity for gas stream B = 12.5 tCO_2e/mmBtu

The LNG plant has a shrinkage factor common to both streams (See Appendix 2) = 1.5

Accordingly, the emissions intensity of each gas stream at the point of discharge from the LNG plant would be:

Liquefied gas stream A – Intensity of LNG produced = 3.75 x 1.5 + 12.0 = 17.625 tCO_2e/mmBtu
Liquefied gas stream B – intensity of LNG produced = 4.25 x 1.5 + 12.5 = 18.875 tCO_2e/mmBtu

Within the SGE methodology approach, the intensities for gas stream A and gas stream B would be subject to independent verification (see section 5).

2.6 Calculation of the Final SGE Emissions Intensity

After calculating the emissions from each stage and allocating emissions to any co-products, the final step in the calculation methodology is to calculate the SGE emissions intensity of the delivered cargo. This SGE Methodology document recommends use of the carry-forward method described below, but other calculation approaches may also be used as long as all value chain emissions are allocated to products.

In the carry-forward method, cumulative emissions associated with the LNG value chain are tracked and carried forward into subsequent stages. For each stage or allocation block, all carried-forward, or embodied, emissions in the incoming energy stream are allocated to the total energy products leaving an allocation block, along with any emissions that occur during the stage or block.

The final emissions intensity of the delivered LNG cargo is the total carried-forward emissions at the SGE boundary divided by the total quantity of LNG delivered.

$$\textbf{Emissions intensity of delivered LNG cargo (SGE)} = \frac{\text{total carried-forward emissions from LNG value chain, as } CO_2e}{\text{quantity of delivered LNG, expressed as an energy content}}$$

Any calculation of the SGE emissions intensity must account for shrinkage of energy content across the value chain, as some gas may be utilised as fuel or lost to flaring or other processes in various stages. If the Reporter uses the carry-forward method described in this section, product shrinkage is implicitly accounted for by the methodology.

Although other calculation methods are acceptable, it should be noted that simply adding emissions intensities across an LNG value chain will likely not account for all value chain emissions due to product shrinkage and co-product allocation.

Example Calculation of the SGE Emissions Intensity

The worked example below provides a sample carry-forward calculation for a simplified LNG value chain consisting of four stages. Co-product allocation occurs during both the production and the liquefaction stages. Note that in stage 1, the co-product (oil) receives stage emissions but there are no embodied emissions to allocate. In stage 3, the co-product (NGLs) receives stage emissions as well as their proportion on an energy basis of the embodied emissions from stages 1 and 2.

Section 9.4 in ANNEX B works through this same LNG value chain scenario with an alternate methodology that uses shrinkage factors instead of the carry-forward calculation. As section 9.4 demonstrates, the SGE emissions intensity is the same for both the carry-forward and shrinkage factor approaches.

Table A. Example of Emissions Tracking Across a Simplified LNG Value Chain

		Product Tracing							Emissions Tracing and Allocation					
		Total Quantity of Product in LNG value chain at Start of Stage[1]	Quantity of Product Used or Lost During Stage[2]	Quantity of All Products at End of Stage[3]	Quantity of Product Diverted from LNG value chain during stage[4]	Type of Product Diverted from LNG value chain (co-products)	Quantity of Product in LNG value chain at end of stage[5]	Type of Product in LNG value chain	Total Stage GHG Emissions[6]	Stage GHG Emissions associated with Product Diverted from LNG Value chain[7]	Embodied Emissions associated with Product Diverted from LNG value chain[8]	Total Emissions associated with Diverted Product[9]	Stage GHG Emissions associated with Product in LNG value chain[10]	Carry-forward Emissions associated with Product in LNG Value chain[11]
		mmBtu	mmBtu	mmBtu	mmBtu		mmBtu		$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$
	Stage	A	B	C	D	E	F	G	H	I	J	K	L	M
Production, Gathering, and Boosting	1	6.0	-	6.0	3.0	Oil	3.0	Mixed gas	12.0	6.00		6.00	6	6
Gas Transport	2	3.0	0.20	2.8	-	None	2.8	Mixed gas	2.0				2	8
Liquefaction Plant	3	2.8	0.30	2.5	0.3	NGLs	2.2	LNG	12.5	1.50	0.96	2.46	11	18.04
LNG Transport	4	2.2	0.20	2.0	-	None	2.0	LNG	2.0				2	20.04

Result			Table Reference
SGE emissions intensity of delivered cargo[12]	10.02	$kgCO_2e/mmBtu$	M4/F4

Example Calculation of the SGE Emissions Intensity

[1] Total quantity of product in the LNG value chain decreases (shrinks) across the value chain. Causes of shrinkage across the value chain include use of product for power generation, flaring, boil off, venting or production diversion from the value chain (e.g., co-product allocation). Although it is acceptable that total product decreases across the value chain, total product should not increase. After the first stage, total quantity in the LNG value chain at the start of stage (column A) is the same as the quantity of product in the LNG value chain at the end of the previous stage (column F). For example, A2 = F1.

[2] Examples of product used or lost during the stage includes gas used for power generation or lost to flaring, among other examples. Product that is still monetisable (and not used or lost) is tracked separately as diverted product. No stage emissions will be allocated to product that is used or lost, and embodied (carried-forward) emissions associated with product used or lost will be allocated to the remaining products at the end of the stage.

[3] Total quantity of product at the end of the stage does not include product used or lost during the stage, C = A – B. Also, C = D + F.

[4] Quantity of product diverted from LNG value chain includes co-products such as oil and natural gas liquids. Both stage and embodied (carried-forward) emissions are allocated to co-products. Note that D + F = C.

[5] Quantity of product that continues in the LNG value chain decreases as the initial production stream is separated into other co-products and the gas stream is liquefied. Both stage and embodied (carried-forward) emissions are allocated to the products in the LNG value chain. Note that D + F = C.

[6] The total stage GHG emissions are the GHG emissions that occurred during the corresponding stage. These emissions are allocated to both co-products and products. Note that H = L + I.

[7] The stage GHG emissions associated with product diverted in the LNG value chain is the fraction of total stage emissions from H that are allocated to the co-products that leave the value chain. For example, in stage 1, the stage GHG emissions associated with product diverted from the LNG value chain are the share of the production facility's emissions that are allocated to oil. Emissions are allocated based on energy. I = H*D/C. Note that H = L + I.

[8] Co-products that leave the LNG value chain carry with them their share of the embodied emissions from previous processing (emissions that were carried forward). For example, the NGLs diverted from the LNG value chain in stage 3 carry with them their share of the emissions carried forward from the previous stages. The diverted upstream emissions for the NGL co-product example in the table is calculated as I3 = D3/C3*M2.

[9] The total emissions associated with the diverted product include both the allocated stage emissions and the diverted product's share of the embodied (or carried-forward) emissions. In the table, this is calculated as K = I + J. Note that all other embodied emissions stay with the LNG product.

[10] The stage emissions associated with product in the LNG value chain is the fraction of total stage emissions from H that are allocated to the product in the LNG value chain. For example, in stage 1, the stage GHG emissions associated with product in the LNG value chain are the share of the production facility's emissions that are allocated to mixed gas. Emissions are allocated based on energy. L = H*F/C. Note that H = L + I.

[11] Emissions are carried forward through the LNG value chain. Carried-forward emissions at the end of the stage include both stage emissions allocated to products in the LNG value chain and emissions associated with product in the LNG value chain that are carried forward from previous stages. Emissions are only removed if they are allocated to co-products that are diverted from the LNG value chain. For example, M2 = M1 + L2 – J2 and M3 = M2 + L3 – J3.

[12] The emissions intensity of the delivered LNG cargo is the total carried-forward emissions associated with product in the LNG value chain divided by the quantity of product delivered at the end of the LNG value chain. In the table, the emissions intensity of the delivered LNG cargo = M4/F4.

Example Calculation of the SGE Emissions Intensity

After development of an SGE calculation methodology, a check should be performed to confirm that all value chain emissions have been allocated to products. Table B provides an example calculation of this confirmation step.

Table B. Example Calculation of the SGE Emissions Intensity

Result			**Table Reference**
Emissions allocated to LNG:	20.04	$kgCO_2e$	M4
Emissions allocated to other products	8.46	$kgCO_2e$	sum(L)
Emissions allocated to all products	28.50	$kgCO_2e$	M4 + sum(L)
Total emissions from all stages	28.50	$kgCO_2e$	sum(H)

Total emissions from all stages are allocated to all products (28.5 $kgCO_2e$= 28.5 $kgCO_2e$), check complete

As discussed in section 10, simple addition of the emissions intensities across a value chain is often an inappropriate approach, as addition of emissions intensities does not account for product shrinkage or co-product allocation of embodied emissions. This point is demonstrated in the calculation below.

SGE emissions intensity

if intensities were added $= \frac{6\ kgCO_2e/mmBtu}{3\ mmBtu} + \frac{2\ kgCO_2e/mmBtu}{2.8\ mmBtu} + \frac{11\ kgCO_2e/mmBtu}{2.2\ mmBtu} + \frac{2\ kgCO_2e/mmBtu}{2\ mmBtu}$

$= 8.71\ kgCO_2e/mmBtu$

This result of 8.71 $kgCO_2e$/mmBtu is significantly less than the 10.02 $kgCO_2e$/mmBtu result from the carry-through method because it does not properly account for shrinkage or co-product allocation. Completion of a check-step for this approach would indicate that total emissions allocated to LNG under this method is only 8.71 kg/mmBtu*2mmBtu = 17.42 $kgCO_2e$, well short of the 20.04 $kgCO_2e$ that were produced during the LNG value chain.

ANNEX B contains additional worked examples demonstrating the calculation of an SGE emissions intensity using the carry-forward method in sections 10.2 and 10.3 as well as an example calculation using an alternate methodology that tracks shrinkage in 10.4.

3 CALCULATION METHODOLOGY

3.1 Introduction

The calculation of the SGE shall be based on intensity (tCO_2e/mmBtu) of the delivered cargo. Depending on the configuration of the Reporter's operations and the operational/temporal boundaries applied, the cargo intensity value is likely to take account of a series of production and processing steps, for each of which there is an appropriate allocation of emissions between the gas and/or LNG and co-products.

A sample LNG value chain with emissions allocation to both LNG and co-products is provided in Figure 3.1.

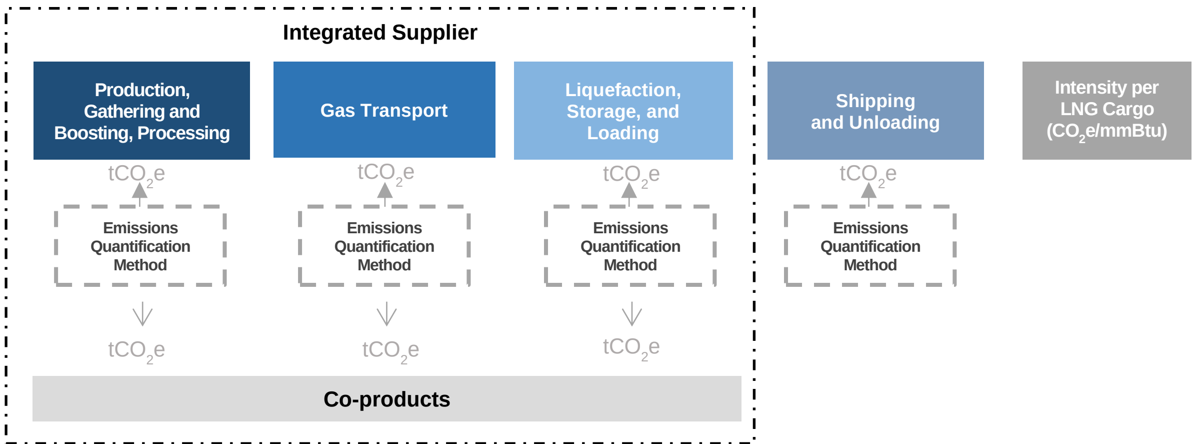

Figure 3.1. Representation of LNG value chain with co-product allocation

In developing a methodological approach, it is recognised that the potentially fragmented LNG value chain may impact an individual Reporter's access to the highest-quality data sources.

Potential sellers of LNG range from fully integrated energy companies that are in control of all relevant life cycle stages, from natural gas production to final delivery of the LNG cargo, and that have well-developed GHG accounting methodologies at the organisational level, through to energy commodity traders and marketers who may have limited access to source-based emissions data. There may be other market players in between who will have detailed GHG information about only specific stages within the value chain (e.g., liquefaction or shipping).

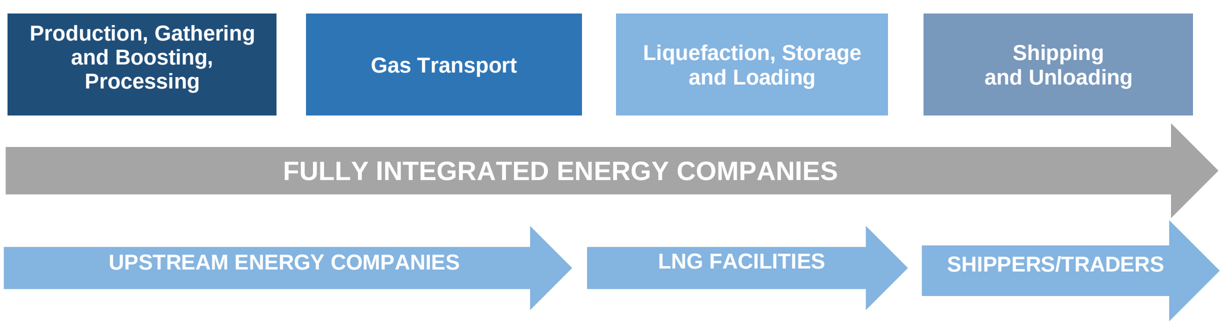

Figure 3.2. Potential scenarios of data availability by suppliers across the LNG value chain stages

To accommodate this diversity of potential sellers, the SGE Methodology has chosen a tiered approach to facilitate adoption. It is expected that the use of primary data will increase over time and that the approaches taken will be transparently presented for assurance by a third-party verifier (see section 5).

The intention is that the SGE be verifiable to a level of reasonable assurance, although it is acknowledged that only limited assurance may be possible (section 5) initially. By offering multiple approaches to calculating GHG emissions, the methodology provides options for smaller or disaggregated sellers and traders with data access limitations while they seek to improve data quality.

Under this approach, it would be possible for non-integrated participants in the production chain to supply data to the next stage, based on verified intensities at each stage and the principle of carrying forward emissions into the next stage (see section 10 for detail of the co-product allocation approach and carry forward method on a stage-by-stage basis).

This section outlines the hierarchical approach, in order of preference, to methodologies for the SGE quantification that may be applied to generate GHG intensity metrics across the relevant boundary for each life cycle stage.

3.2 High-Level GHG Calculation Equation

In GHG accounting, the overarching equation for calculating GHG emissions from both combustion and non-combustion sources is:

GHG emissions (CO_2e) = activity data x emission factor x calculation factor(s) x GWP

In the context of the oil and gas sector, the inputs to this equation are:

GHG emissions	**:**	Calculated GHG emissions, metric tonnes CO_2 equivalent (tCO_2e).
Activity data	**:**	Transactional data that represents the quantity for a given period (e.g., standard cubic feet [scf]/cubic metres [m^3] of fuel gas burned, number of low-bleed pneumatic controllers etc.). Activity data are ideally measured but may be estimated based on engineering assumptions.
Emission factor	**:**	GHG emissions per unit of activity data (e.g., tonnes CO_2/scf fuel gas, kg CH_4/low-bleed pneumatic controller etc.). The emission factor can be based on measured data (e.g., gas compositional analyses) or a default for a given fuel or equipment type.
Calculation factor(s)	**:**	Additional factors used in GHG calculations, such as unit conversions, adjustment of default emissions factors or compositions, calorific value on the same basis as the chosen emission factor (GCV or NCV, also known as HHV or LHV, respectively; see section 7, Definitions and Abbreviations). Any calculation factors used in emissions estimation need to be

appropriate to the method in question and consistent with the basis of any other factors used. This is different from the SGE intensity reporting, which will always be based on HHV/GCV.

GWP **:** Global warming potential of the individual GHG constituent (see section 7, Definitions and Abbreviations).

For CO_2 from combustion, an ***oxidation factor*** may also be applied that defines the percent conversion of hydrocarbon molecules into CO_2 during the combustion process, if applicable. The oxidation factor is typically a default factor for combustion sources and flares and is not used when calculating non-combustion emissions. For combustion sources other than flaring, the oxidation factor is typically assumed to be 1. The oxidation factor may be incorporated within the emission factor.

The activity data and the emission factor must always be in the same units of measure (e.g., if activity data are in units of mmBtu, HHV/yr, then either the emission factor denominator must also be in units of mmBtu, HHV, or unit-of-measure conversions must be made to ensure that the calculation of GHG emissions is correct).

Because this common structure of the GHG estimation equation applies to most sources, the differences in method typically relate to the quality of the data that are available for either the activity data or the emission factor. As an example, activity data for a given combustion source can be measured or estimated, depending on whether a meter is installed. Another example is that the emission factor for a given combustion source can be calculated based on fuel composition, a site-specific proxy, through to a default factor based on the fuel type.

Although this high-level equation applies to the majority of GHG emission sources, there are certain sources that rely on other approaches for estimation. These methods are not excluded from the SGE Methodology and may include:

- direct measurement of emissions from a source (e.g., continuous emissions monitoring system data for combustion sources, leak measurement data for fugitive emissions etc.);
- a mass balance approach (e.g., CO_2 from acid gas removal units); and/or
- process simulation modelling (e.g., CH_4 from glycol dehydrators).

3.3 General Method Option Ranking

The GHG Protocol Product Life Cycle Accounting and Reporting Standard refers to two options for data sources that can be used to derive the GHG intensity for a given stage of the life cycle: primary data and secondary data. The SGE Methodology adopts this approach:

Primary data are collected from specific processes in the product's life cycle. These are typically process activity data (physical measures), direct emissions data or data that are averaged across all sites that contain the specific process. These data are directly attributable on a per-cargo basis within the scope, boundaries and temporal constraints.

Secondary data are not specific to a particular product's life cycle and would represent data derived from other generalised LCA and industry studies. Although often derived directly from the industry, these data are based on aggregated data generally collected by researchers and may not represent the operations of the specific LNG value chain directly, with potential differences in scope and boundaries.

This hierarchy of primary and secondary data forms the basis for calculating LNG GHG emissions intensity, and it is assumed that primary data will be used where possible due to the greater accuracy and precision of the resulting emission intensity calculations. It is expected that at each stage of the value chain, the relevant operator will collect primary data. However, this may not be fully available in cases where the Reporter does not have control over the full value chain (see section 5.2.1).

In addition, there will be varying levels of uncertainty associated with the methods within these two options, depending on the data available to the operator of the relevant stage. Therefore, calculation methods are grouped within the categories of primary and secondary data to reflect preferred approaches based on more accurate data. Alternate methods are used when the data for the preferred approach are not available.

This approach of categorising methods by primary versus secondary data, and within those categories by preferred and alternate methods, is shown below in Figure 3.3 and in Table 3-1. This hierarchy applies equally to data sources used to quantify GHG emissions and to data sources used to quantify production data used in calculating the SGE intensity metric.

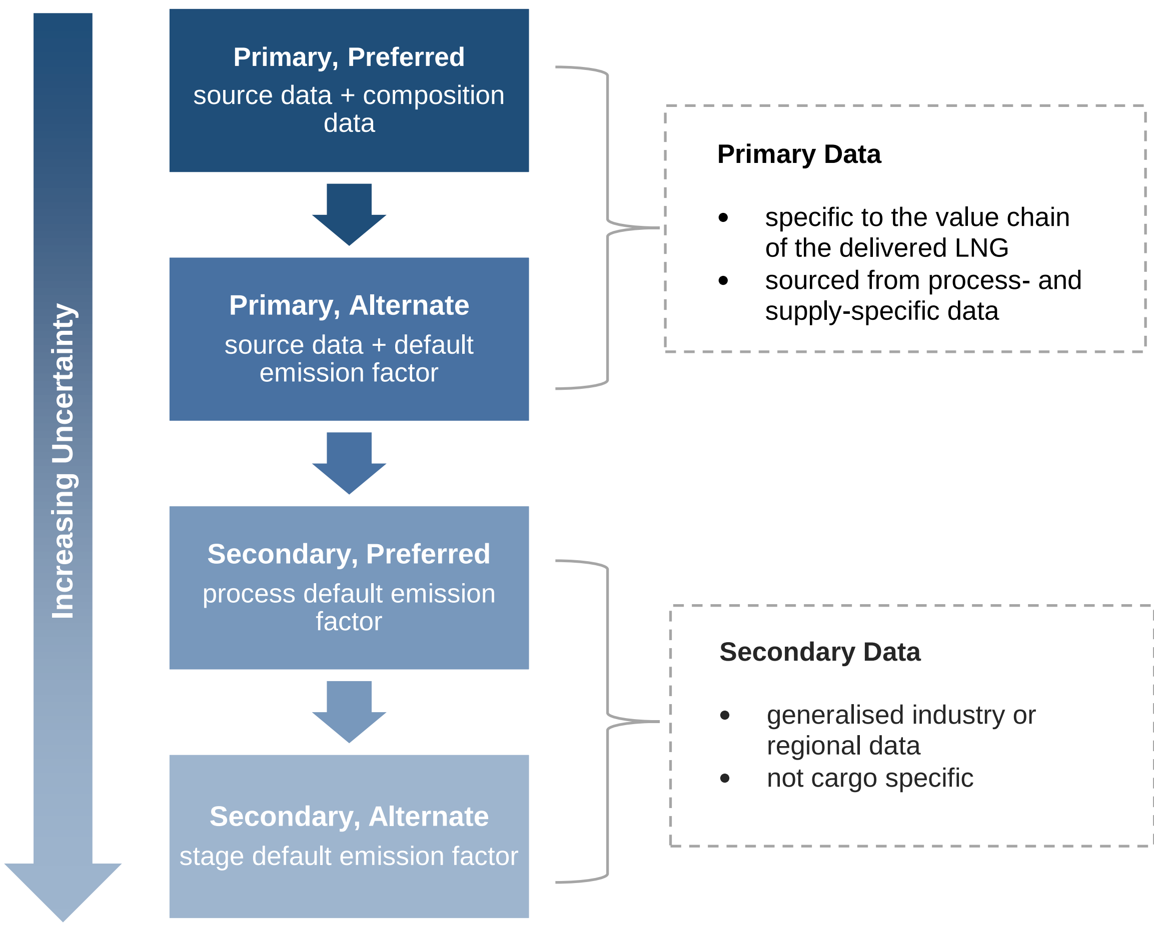

Figure 3.2. Methodology options related to level of uncertainty

Table 3-1 Categorising Primary and Secondary Data

Data Source	Description	Examples	Comment on Data Quality
Primary, preferred	Process-level data and composition	• Metered fuel gas, flare gas, diesel fuel consumption, venting • Based on direct metering or engineering calculation, for example, acid gas recovery mass balance • Emission factor based on specific gas composition through sampling • Liquid commercial fuels using standard industry factors	• Accuracy of metered data depends on complete coverage of sources under a structured maintenance and calibration programme • Gas sampling needs to be frequent enough to ensure that it is representative • Requires highest level of effort in data collection and quality assurance / quality check processes
Primary, alternate	Process-level data and default emission factor	• Engine run-hours and manufacturers or default machine-type consumption rate • Default emission factors for fuel gas in production • Mass balance data	• Manufacturers and default factors may not reflect actual operational parameters • Default fuel gas emissions may not be aligned with field gas composition • Represents a trade-off between data accuracy and ease of collection
Secondary, preferred	Process unit default emission factor	• Regionally specific data, for example, average emissions from acid gas recovery units (AGRU) modelled based on regional average gas CO_2 content • Process emissions modelled based on specific technology, for example, on waste heat recovery in a liquefaction plant	• May not have information about the specific processes or attributes of gas production, processing and transport to LNG liquefaction plant
Secondary, alternate	Stage or life cycle default emission factor	• Generic upstream GHG emissions per mmBtu gas (e.g., DEFRA factors)	• May not reflect equivalent boundaries • Will not reflect actual operational and source parameters, that is, type of production field, CO_2 content of gas, distance to liquefaction plant, liquefaction technology and operational mode

3.3.1 Selection of Primary Versus Secondary Data Sources

To reduce uncertainty, the selected methodology should preferentially be based on a primary data calculation approach for the applicable sources within each stage of the value chain: For the operator of the stage, this would translate into Scope 1 emissions (direct emissions) and Scope 2 emissions (emissions associated with energy, including electricity, steam, heating, cooling etc.) from source-specific emissions data for those sources attributable to the LNG cargo.

However, understanding that not all Reporters applying the SGE Methodology will be fully integrated and therefore may not have access to primary emissions data for each stage, hybrid approaches are also acceptable based on a mixture of assumptions, calculations and LCA-modelled approaches using published aggregated data.

The primary goal of the SGE Methodology is to use the most relevant and accurate data and methods available, particularly for material sources with the greatest contribution to the GHG emissions intensity for each life cycle stage.

Example Use and Acceptance of Secondary Calculation Factors			
Description	Commercial standard fuel emission factors	Equipment leakage rates for fugitive estimation	Fuel consumption based on engine power
Compatibility with SGE Methodology	Good	Good, with adjustment for methane composition	Poor
Rationale	Commercial standard fuels are subject to stringent quality standards, which define compositions and hence expected emission factors. Sampling of these fuels would not be considered a reasonable cost, though Reporters should ensure that the factors used are specific to the fuel used, that is, diesel versus MGO versus HFO.	Using “standardised” component-based leakage rates in preference to facility-level estimations is an accepted practise whilst moving to measurement-based approaches over time. The leakage rates may be based on an assumed percentage of methane, which can be adjusted to a facility-specific gas composition.	Although acceptable in some GHG inventory approaches, the non-specificity of the approach is a poor fit for the SGE Methodology. Under the data hierarchy, Reporters would be expected to move toward measured fuel consumption where possible.

3.3.2 Treatment of Non-material Sources

The primary goal is to use the most accurate data and method available, at least for material sources.

For the purposes of this SGE Methodology, non-material sources are considered to be those that collectively contribute less than 5 percent to an individual stage GHG intensity or less than 2 percent to the consolidated GHG intensity for the delivered LNG. For sources that are attributable to the delivered LNG, but that are not material, the effort involved in collecting more accurate data to use a primary preferred approach may not be justified due to the small contribution to the total; therefore, estimations or simplified approaches are accepted.

3.3.3 Selection of Preferred Versus Alternate Methods

The SGE Methodology is based on the principle of using the best-quality data available. This principle has been used to establish the following hierarchical considerations, which are represented in Figure 3.3.

Where primary preferred data are not available, the following hierarchy of preference applies: Primary Preferred > Primary Alternate > Secondary Preferred > Secondary Alternate. The selection of calculation method and whether the most accurate data sources have been applied will be assessed during verification (see section 5). It is expected that the Reporter will be able to demonstrate that:

- primary preferred data have been applied for material sources where such data are practically and economically feasible; and
- the use of primary alternate, secondary preferred or secondary alternate data are justified.

Example
In the production, gathering and boosting section of the SGE, a Reporter is able to access metered fuel gas activity data (primary preferred). The Reporter also (a) has composition data from facility design (primary alternate) and (b) takes monthly gas sample data that are representative of fuel gas (primary preferred). The expectation is that the monthly sample data should be used instead of the design data to develop an emission factor for the reporting period, as this approach is better aligned to the temporal boundary.
In the case of secondary approaches using LCA models, the modelling approach should be taken at the most granular level possible. An example is an LNG plant model that allows the user to specify individual unit processes, such as NGL recovery, AGR, power generation, liquefaction technology including compression and refrigeration, and waste heat recovery configuration, and to specify relevant gas characteristics, such as CO_2 percent and NGL percent.

It is the responsibility of the Reporter to demonstrate either that they have used the best available methods without incurring unreasonable costs in improving accuracy and reducing uncertainty or that improvement is not technically feasible. This principle applies at all levels of the data hierarchy. Whichever approach is adopted by any Reporter, the data and methodology must be transparent and verifiable.

It will be the responsibility of the third-party verifier to accept or reject the Reporter’s assertions related to selection of methodology within these principles.

3.3.4 Monitoring Methodology Plan

The Reporter shall develop a documented MMP that sets out the approach to calculating the SGE. A proposed outline for an MMP is set out in ANNEX D.

3.3.5 Data Flow Map

As part of the MMP, the Reporter shall develop a data flow map, including indication of all data sources, calculations applied and reference to the position in the methodological hierarchy. Further detail is included in ANNEX B.

3.3.6 Improvement Plan

Where the Reporter does not meet the primary preferred approach, it is expected that there will be a plan to do so or that there will be a demonstration that to do so would not make a significant difference in the GHG intensity of the delivered LNG and/or is not possible without incurring unreasonable cost.

The approach chosen and decisions made may take account of the significance of each source contribution and of the potential impact on the accuracy and uncertainty of the SGE. It is a principle of the SGE Methodology that the SGE can be verified to a level of reasonable assurance. Where the use of secondary data prevents this, the Reporter will prepare an improvement plan intended to achieve verification to a reasonable level of assurance.

3.3.7 Methodological Equivalence and Completeness

The SGE Methodology has not defined specific calculation references or approaches. It is recognised that specific selected reporting approaches may differ in boundary and scope because of legislation, corporate policies and so on. It is the role of the Reporter to demonstrate that the selected approach meets the requirements of the SGE Methodology and the life cycle approach and is using the best available data.

Reporters and operators of the value chain assets may therefore be following individual reporting standards or methods based on regional regulations, voluntary disclosure programmes or corporate methodologies that are not fully aligned with the primary preferred approach. Where a Reporter has data that are based on a regulatory or corporate approach (including data with external verification or assurance), those data and that approach, if following the methodological principles set out in the SGE Methodology, are considered valid.

Where such approaches are incomplete with respect to boundaries (for example, covering only major sources or only CO_2), the Reporter shall provide the relevant additional data to calculate GHG intensities that are in line with the minimum boundary requirements of the SGE Methodology (see section 2.3, Physical Boundaries). If methodological adjustments / additions are required, the methodologies should follow the data hierarchy set out in Table 3-1 above.

3.4 Primary Data Calculation Methodology

The primary data methodology, whether based on primary preferred or primary alternate, will be a calculation methodology based on established commonly used and understood calculations. The selection of the preferred or alternate data must be based on a combination of availability and impact on quality of reporting.

Although the exact data sources will be specific to the life cycle stage and actual operational configuration, a typical options selection approach is set out in the API Compendium for combustion and used to illustrate examples of primary preferred and primary alternate approaches (see Figure 3.5 below).

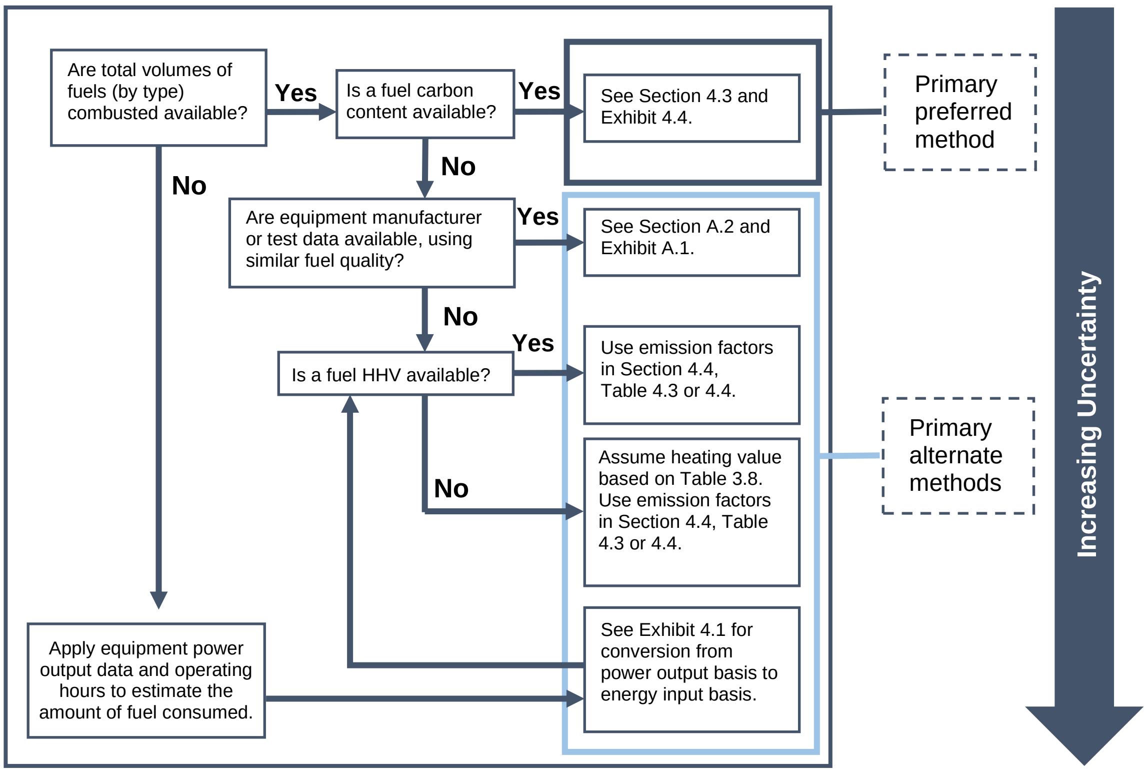

Figure 3.5. Example of GHG "decision tree" for combustion sources (based on API 2009)

3.4.1 Emission Sources

Emission sources at each relevant stage of the value chain will include:

- stationary combustion sources (e.g., fuel combustion [power generation, turbines, steam generation, heaters, pumps etc.], thermal oxidisers, incinerators and flares, etc.);
- mobile combustion sources (mobile equipment, vehicles, marine fuels., gas combustion units);
- indirect sources (electricity, steam generated by third parties);
- venting (process vents [dehydration, gas sweetening, pressure release valves etc.], mast venting during shipping activities); and

- fugitive emissions (equipment/pipeline leaks, refrigerant leaks).

Detailed calculation approaches for GHG emission sources within each life cycle stage of the value chain may be referenced from industry guidance such as section 2 of the API Compendium and regulatory methodologies ensuring that all relevant emissions such as methane slip from combustion are included. For details of the approach to emissions from shipping, please see ANNEX A, Specific Methodological Considerations for Shipping.

De minimus exclusions (and their basis for determination) should be identified in the MMP and transparent to the verifier.

3.4.2 Combustion Emissions (Mobile and Stationary Combustion, Flaring)

With reference to the generalised equation for GHG calculations introduced in section 3.2:

emissions (CO_2e) = activity data x emission factor x oxidation factor x GWP

Table 3-2 below provides details of the data used in the equation for combustion and flaring sources that differentiate between primary preferred and primary alternate data methods.

Table 3-2 Primary Preferred and Primary Alternate Data for Combustion and Flaring

Parameter	Primary, Preferred Data	Primary, Alternate Data
Activity data	• Metered fuel use for gaseous fuels or flaring • Stock accounting and delivery for liquid fuels (e.g., tank level measurements) • CTMS or fuel metering for shipping	• Estimated fuel use (e.g., gas mass balance based on other metered data, the use of a gas-to-oil ratio to calculate gas production, engine run-hours and specific fuel consumption for smaller engines such as fire pumps and emergency generators) • Modelled or calculated approaches to flaring, such as use of valve position indication, facility mass balance (where sensitivity allows)
Emission factor, CO_2	• Gaseous fuels: analysed fuel composition to derive emission factor • Liquid fuels: default fuel-specific emission factor, for example, for diesel, MGO, and so on • Boil-off gas (BOG) used in shipping, based on cargo analysis • Where available, including in shipping, composition could be measured by gas chromatograph (GC) or through periodic sampling	• Gaseous fuels: modelled or default fuel-specific emission factor • Liquid fuels: n/a
Emission factors, CH_4, N_2O	• CH_4 and N_2O from stationary and mobile combustion based on applicable default factors, including empirical studies and manufacturer's information, as relevant; also includes methane slip from shipping engines, gas combustion units (GCU) and so on • CH_4 for flaring calculated based on flaring oxidation factor discussed in the section below	

Parameter	Primary, Preferred Data	Primary, Alternate Data
	• Default fuel-specific emission factor	
Oxidation factor	• Combustion other than flaring: default assumption of 1.0 for estimation of CO_2 • In case of flaring, participants may use a measured or design flare oxidation factor subject to verification • Flaring: default assumption of 98% for estimation of CO_2 with 2% of the methane content in the flare gas remaining uncombusted	

3.4.3 Venting

Venting of methane in all stages of the value chain and CO_2 from AGRUs in gas processing and liquefaction stage are included within the SGE Methodology boundaries.

The generalised calculation equation for venting emissions is as follows:

emissions (CO_2e) = activity data x emission factor x GWP

Table 3-2 below provides details of the data used in the equation for venting sources that differentiate between primary preferred and primary alternate data methods.

Table 3-3 Primary Preferred and Primary Alternate Data for Venting

Vent Source	Parameter	Primary, Preferred Data	Primary, Alternate Data
"Cold" venting, equipment blowdowns (including associated gas venting)	Activity data	• Measured gas volume	• Estimated gas volume
	Emission factor	• Measured methane composition of vent gas	• Default methane composition
Gas-operated pneumatic controllers and pumps	Activity data	• Actual counts of natural gas–operated pneumatic controllers and pumps by type	• Default counts by sector
	Emission factor	• Device-specific default emission factor • Measured methane composition to adjust factor	• Device-specific default emission factor
Glycol dehydrator, crude tank flashing	Activity data	• Inputs into simulation model	• Dehydrator counts • Crude tank throughput • Default gas volume
	Emission factor	• Simulated vent gas volume (e.g., tank flash simulation, GlyCalc regenerator vent simulation) • Simulated vent gas methane composition	• Default emission factor
AGRU	Activity data	• Metered gas throughputs	• Estimated gas processing rate
	Emission factor	• Measured CO_2 inlet / outlet compositions • Direct measurement of CO_2 from regenerator vent • Measurement of CH_4Direct from regenerator vent	• Assume 100% CO_2 removal in the AGRU, which would be a conservative approach

Vent Source	Parameter	Primary, Preferred Data	Primary, Alternate Data
			• Methane emissions based on throughput value
Well maintenance and intervention activities (workovers, casing venting, liquids unloading, well completions)	Activity data	• Measured (or estimated) gas volume • Measured volume of nitrogen to be subtracted from total volume (e.g., energised well completion)	• Number of venting events (e.g., number of liquids unloading events) • Number of wells or throughput (casing gas venting)
	Emission factor	• Measured methane composition of vent gas	• Default emission factor, specific to type of venting event
EOR (enhanced oil recovery) injection pump blowdown	Activity data	• Number of blowdown events • Physical volume of EOR injection pump chambers • Density of EOR injection gas	• Extrapolation from historic events or similar operations
	Emission factor	• Measured or estimated CO_2 composition of injection gas	• Extrapolation from historic events or similar operations
Miscellaneous process vents (e.g., compressor or power turbine starts, rotating equipment seal vents)	Activity data	• Measured (or estimated) gas volume	• Number of venting events (e.g., number of compressor starts) • Amount of equipment vented (e.g., number of pressure relief valves)
	Emission factor	• Measured methane composition of vent gas	• Default emission factor, specific to type of venting event
Mast venting (shipping)	Activity data	• Based on metered venting where available	• Calculated vent volumes where metering is not available
	Emission factor	• Methane emission factors based on cargo gas analysis • Assumed no CO_2 or N_2O emissions from venting	• n/a

Example
Use of mass balance data is acceptable as a primary preferred approach for the estimation of CO_2 emissions from the AGRU. For example, in the case of an AGRU being used to remove CO_2 and H_2S from the gas, the activity data for the rejected sour gas may not be measured directly. However, if both composition and flow rates are measured upstream and downstream, a mass balance calculation of the CO_2 removed is a legitimate primary preferred approach. A primary alternate approach where downstream mass and composition are not known would be to conservatively assume 100 percent CO_2 removal in the AGRU and release to the atmosphere. The AGRU may also be a source of methane emissions, which should also be estimated for this methodology.

3.4.4 Fugitives

Fugitive emissions are defined as unintentional releases directly to the atmosphere, and although unlikely to represent a material contribution to the ultimate GHG intensity, they are an important contributor of methane losses and a focus for emission reduction across all life cycle stages of LNG. A hierarchy of approaches exists to estimate fugitive emissions. Table 3-4 below provides an overview of options using primary data, categorised into preferred and alternate data approaches. Further discussion on methane as a GHG of interest is found in section 2.2.2, Included Gases.

Table 3-4 Primary Preferred and Primary Alternate Data for Fugitives

Parameter	Primary, Preferred Data	Primary, Alternate Data
Activity data, equipment leaks	• Installation-specific LDAR approaches with quantified leakage rates • Number of leaking components from leak screening • Component counts by type of device and type of service (e.g., number of valves in gas service)	• Component counts by type of device (e.g., number of valves) • Counts of major equipment and default population factors (e.g., number of wells and default valves/well) • Gas throughput (e.g., mmscf/yr gas throughput)
Emission factor, equipment leaks	• Default leaking component emission factor in units of scf/component-hr • Default component – service type emission factor in units of scf/component-hr • Methane composition of gas stream or analysed cargo for shipping	• Default component emission factor in units of scf/component-hr • Default emission factor in units of scf/component-hr • Default emission factor in units of tCH_4/mmscf
Activity data, pipeline leaks	• Pipeline km	
Emission factor, pipeline leaks	• Measured emission factor per km of pipeline and components	• Default emission factor per km of pipeline
Fluorinated gases	• Based on purchased / used quantities (to be included if material)	

This SGE Methodology does not prescribe specific LDAR approaches. Examples of LDAR include the application of US EPA Method 21, optical gas imaging, toxic vapor analysers (TVA), and others.

3.4.5 Emissions Associated With Indirect Energy

Emissions associated with indirect energy usage are those arising from the generation of energy for electricity, heating or cooling that is imported from a third party. This includes energy supplied by nonoperated joint ventures such as cogeneration (cogen) plants. Based on a product life cycle approach, all imported energy, regardless of ownership or operatorship of the supply, should be included. These emissions are reported as Scope 2 in an organisation's corporate inventory.

As a primary data approach, the generalised equation is:

emissions (CO_2e) = energy imported x emissions factor

For electricity, a location-based emission factor or market-based emission factor may be applied in line with the GHG Protocol guidance.

> **A location-based method** utilises grid average emission factors for the defined geographic location, including local, subnational or national boundaries.
>
> **A market-based method** reflects emissions from energy that has been contractually purchased by the operator for which there is a source-specific emission factor and that is bundled with appropriate Energy Attribute Certificates in line with the GHG Protocol Scope 2 Guidance.

For energy other than electricity (e.g., purchased steam), a location-based method is not relevant. The approach must be either specific to the source of energy production (primary preferred) or based on default factors (secondary).

Table 3-5 below provides an overview of options using primary data, categorised into preferred and alternate data approaches.

Table 3-5 Primary Preferred and Primary Alternate Data for Emissions Associated with Indirect Energy

Parameter	Primary, Preferred Data	Primary, Alternate Data
Activity data	• Metered energy consumed from steam and electricity from direct transfer of energy from a third party (e.g., third-party cogen) • Energy consumed from energy suppliers through contractual instrument (e.g., renewable energy provider) • Residual energy consumed from electric grid that is not through a contractual instrument • Total electricity consumed from grid based on supplier invoice	• Engineering estimates of energy consumption based on equipment design/throughput
Emission factor	• Market-based approach • Fuel-combustion-derived emission factors from a third party (e.g., electricity and steam from third-party cogen) with emissions allocated appropriately to each energy stream, i.e., $kgCO_2e/MJ_{Steam}$, $kgCO_2e/MJ_{electricity}$ • Emission factor from contractual instruments with an energy provider, plus default emissions factor from residual mix for the grid	• Location-based approach • Default national/regional average grid emission factor

The energy used is expected to be based on metered energy used as the basis for invoicing. If a market-based approach is used, evidence of cancellation of associated Energy Attribute Certificates will need to be made available to the verifier in line with GHG Protocol guidance.

3.5 Secondary Data Methodologies

Methodologies that apply secondary data (not sourced directly from operations within the LNG cargo value chain) will have a higher degree of uncertainty than primary data methodologies.

3.5.1 Secondary Preferred Methodology

The secondary preferred approach entails LCA modelling of the GHG intensity for each stage of the life cycle based on specifying the relevant process units that should be included. For example, use of an LCA model such as OPGEE or CA-GREET allows for user inputs for specific processes or relies on default assumptions if the process unit–level input is not available.

A number of applicable models may be available, and a selection of example references is included in ANNEX B.

All process units and other activities for inclusion should be identified for each life cycle stage. Examples of potential process units at each stage are given in Table 3-6 below:

Table 3-6 Examples of process units by stage

Stage	Example Relevant Process Unit
Upstream production, gathering, boosting and processing	• Power generation • Compression • Gas dehydration • AGR for CO_2 • Flaring • Venting • NGL recovery
Gas transport	• Compression • Venting (e.g., blowdowns) • Pipeline leakage (based on km)
Liquefaction and storage	• NGL recovery • Power generation • Liquefaction technology, including compression and refrigeration • Waste heat recovery configuration
Shipping	• Size and type of vessel / fuel • Power generation / engine operations

In the case of a shipping ballast leg, where primary data may not be available, potential sources of secondary data include:

- simulated emissions and consumptions, using automatic identification system (AIS) data to determine speeds and distance for the voyage; combined with a speed-consumption model of the ship that is preferably calibrated or verified against known data;

- extrapolation from similar known ballast legs either for a specific ship or based on similar class of ships; and
- the use of distance tables or a voyage calculator based on the ballast speed and consumption.

3.5.2 Secondary Alternate Methodology

The secondary alternate methodology shall be an LCA-based study or model that provides a default level GHG intensity for each stage, or combination of stages, without any process-unit-specific adjustments to the modelled emission factor. Secondary default approaches should be avoided as far as practicable, as they offer no direct indication of the actual GHG intensity of the emission sources and may not support verification to the level of reasonable assurance.

The approach is a calculation approach based on this generalised equation:

emissions (CO_2e) = stage emissions factor x activity data (throughput)

where:

- ***Stage emission factor*** = the default emission factor by entire stage of the process, for example, tCO_2e/mmBtu for the production stage

- ***Activity data*** = the mmBtu of LNG delivered as the unit of analysis

3.6 Method Selection by Life Cycle Stage

It is acknowledged that for some LNG suppliers, primary data may not be available across the stages of the LNG cargo value chain and may therefore have to rely on secondary data options. Figure 3.7 below indicates which options may be appropriate for each stage.

	Production, Gathering and Boosting, Processing	Gas Transport	Liquefaction, Storage Loading	Shipping and Unloading
Primary, Preferred Source data + composition data	Least uncertain, but may be boundary issues in assigning GHG to a specific cargo		Liquefaction plant GHG emissions likely already calculated with this approach	Most significant source data, such as fuel consumption, should be available
Primary, Alternate Source data + default emission data	May be acceptable for individual sources that do not significantly contribute to the total stage GHG emissions			
Secondary, Preferred Process default emission factor	May be necessary if primary data is not available		Not recommended for these stages, as primary data should be available	
Secondary, Alternate Stage default emission factor	Not recommended, as this approach would not reflect significant cargo-to-cargo variations			

Figure 3.7. Illustration of appropriateness of methods by life cycle stage

For the upstream production and processing stage, as well as the gas transport stage, primary data should be used when available and the preferred method utilised for the most significant emission sources. The use of primary, alternate data may be acceptable for sources that are not significant contributors to the overall intensity of the stage.

Secondary data, if required, should be based on the secondary, preferred methodology using an LCA model that considers process-unit-specific parameters and should not rely on stage-level default emission factors from LCA studies (i.e., the secondary, alternate method is not recommended).

For the liquefaction stage, it is expected that the Reporter will have the ability to obtain GHG intensity data from the LNG liquefaction plant used for each cargo. It is not expected that liquefaction will need to rely on secondary data sources. Therefore, the use of primary data methods is recommended.

Other than for the ballast leg, it is not expected that shipping will need to rely on secondary data sources. It is expected that vessel fuel consumption and vented/fugitive emissions will be provided at the point of discharge.

3.7 Key Factors that Will Influence the Variability Between Cargoes

An understanding of the more significant features that differentiate one cargo intensity from another will help inform decision making for both buyers and sellers of LNG. Table 3.7, below, offers a selection of parameters that are likely to have a significant influence on the overall GHG intensity.

Table 3-7 Parameters that are likely to be significant by stage

Stage	Significant Parameters
Production, gathering and boosting, processing	• Field type (offshore, associated, tight gas, shale gas etc.) • Gas-gathering configuration and distance • CO_2 content of gas • NGL content
Gas transport	• Transport distance from well to liquefaction plant
Liquefaction and storage	• Use of waste heat recovery • Refrigeration technology • CO_2 content of gas • NGL content
Loading, shipping and unloading	• Shipping distance • Vessel size, type, and Energy Efficiency Operational Indicator (EEOI) – Propulsion system – Fuel type – Boil-off rate • Vessel speed

Stage	Significant Parameters
	• External influences, including weather, current conditions, ice passages, delays, anchoring and other port requirements, etc. • Length of ballast voyage

3.8 Uncertainty Assessment

Data with a high level of uncertainty can negatively impact the overall quality of the SGE and its verifiability. ISO14067 defines uncertainty as *"a parameter associated with the result of quantification that characterises the dispersion of the values that could be reasonably attributed to the quantified amount."* It is typically based on quantitative estimates of the value of uncertainty and a qualitative discussion of the causes of uncertainty. Uncertainty may relate to quantification factors (such as an emission factor applied or a measurement from a meter), scenarios used to define a calculation approach or the inherent uncertainty within models used where activity data are not available.

> ISO14067:2018 (6.3.5) states:
>
> *A CFP study should use data that reduce bias and uncertainty as far as practical by using the best quality data available. Data quality shall be characterised by both quantitative and qualitative aspects.*

The SGE Methodology adopts, at minimum, a requirement that the Reporter shall provide a qualitative discussion of sources of uncertainty, with the intent that uncertainty will be demonstrably reduced over time to improve the overall quality of the SGE. This will provide a basis for improvement of accuracy over time and provide a high-level indication of the granularity of data that has been achieved. The Reporter should also quantify the major contributing factors to uncertainty when possible.

The qualitative uncertainty assessment shall include both inventory uncertainty and methodological choices, including:

- application of the co-product allocation approach;
- sources of emission factors and GWP values used (relevant to both primary and secondary data methods);
- uncertainties associated with measurement methods and source variability; and
- calculation models (if applicable).

The GHG Protocol Product Standard sets out the iterative process of tracking and evaluating uncertainty, as shown in Figure 3.3.

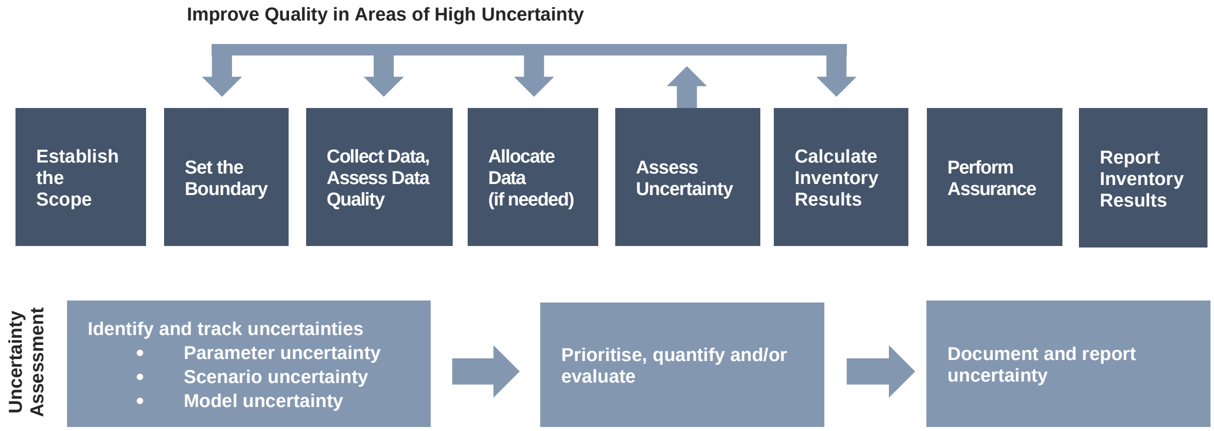

Figure 3.3. Uncertainty in GHG accounting (GHG Protocol Product Standard)

The uncertainty assessment report will form part of the Reporter's MMP and should address the key components set out in Table 3-8 below. The Reporter shall develop an uncertainty reduction plan that includes reviewing and updating the uncertainty assessment and reduction plan on an annual basis.

This requirement for a qualitative assessment of uncertainty does not preclude a Reporter from carrying out a quantitative assessment of uncertainty.

Whereas uncertainty is an inherent property of the measurement approaches taken in developing the SGE and can be reduced, errors are correctable, and it is the expectation that errors identified through verification or internal assurance by the Reporter will be corrected where possible, that is, where an error can be quantified.

Table 3-8 – Key Sources of Uncertainty, derived from section 6.3.5 ISO14067

Source of Uncertainty	Example Issues
Temporal coverage	• Impact of chosen temporal boundary(ies)
Allocation methods	• Allocation between co-products at each stage of the value chain
Measurement	• Uncertainty associated with measuring instruments and engineering assumptions
Data precision	• Potential uncertainty induced through rounding of values at inappropriate points in the calculation and through multiple manipulations of data
Data completeness	• Impact of deliberate exclusions of small sources • Potential differences in boundary when applying secondary factors
Data consistency	• Consistency over time (e.g., variations in production characteristics) • Impact of methodological changes (e.g., updated emission factors/GWPs), switch between primary and secondary data
Model uncertainty	• Where secondary data are based on models, these should be described. Identify their published source and areas where they may deviate from real-world conditions for the LNG supply source (e.g., secondary data sources may have been developed against different objectives or for different geographies)

3.9 Accounting for Offsets and Captured Emissions

Although it is recognised that Reporters and other participants in the LNG production cycle may wish to offset all or part of their direct emissions, this should not be used to reduce the apparent intensity of the SGE. The SGE must be based on the operational emissions associated with each stage of the life cycle.[5] If offsets have been applied, then these may be reported separately from the SGE.

Similarly, parties may wish to utilise offsets in LNG transactions. Offsets are outside the scope of this SGE Methodology and reporting of offsets shall be separate from the SGE.

If carbon credits have been created and sold from within a reporting stage (e.g., in relation to projects such as flare reduction and carbon capture, utilisation and storage (CCUS)), these credits shall be added to the SGE intensity value to prevent double counting of reduced emissions. If carbon credits have been created, the accounting treatment for purposes of the SGE shall be included in the MMP.

Carbon capture and storage (CCS) within the production process is not considered offsetting. SGE accounting for CCS or CCUS technologies must be based on net CO_2 emissions. Net CO_2 emissions should account for CO_2 captured and stored.

[5] The intent of the SGE Methodology is to capture attributable emissions associated with each stage of the life cycle, without including the effect of any offsets occurring outside of the production process. The use of secondary data in this context is acceptable, though not preferred, as it is indirectly based on relevant operations from the LNG production chain.

4 SGE REPORTING

Each delivered cargo of LNG shall be accompanied by an SGE that sets out the GHG emissions associated with the cargo, calculated on the basis of the SGE Methodology. The minimum content of the SGE shall include the following:

- Date of delivery
- Reporter identification
- Quantity (m^3, tonnes) and total energy content (mmBtu) of LNG delivered
- Specific energy content of LNG delivered – HHV/GHV/GCV
- GHG intensity and methane intensity – tCO_2e/mmBtu and tCH_4/mmBtu
- Total GHG emissions, optionally including breakdown by gas – CO_2, CH_4, N_2O
- Proportion of SGE emissions intensity that is based on secondary data sources (<25%, 25%-50%, 50%-75%, >75%)
- Confirmation that the SGE is calculated in accordance with the criteria set out in the SGE Methodology

The Reporter shall provide a draft SGE at the point of delivery, including relevant evidence that is immediately available, such as a bill of lading.

The final SGE shall be provided post-verification and will be accompanied by a verifier report and opinion statement, which will include the level of assurance reached. This report may also include information from additional verification reports as required, where the LNG cargo has not originated from an integrated value chain.

The shipping element of the SGE may be immediately verifiable by the same independent verifier of the cargo transfer process.

5 ASSURANCE

5.1 Assurance Approach

The SGE provided by the Reporter is an assertion that states the calculated GHG emissions associated with the delivered cargo of LNG. As a potential basis for allocation of offsets, the SGE Methodology and the data reported for each cargo will need to be subject to an assurance process.

The purpose of assurance is to provide confidence that the SGE is a complete, accurate, consistent, transparent representation of GHG emissions associated with the delivered cargo and that it is based on the approach set out in the SGE Methodology and relevant reference standards (e.g., GHG Protocol Product Standard or ISO14067:2018).

Assurance providers need to be independent of the process and have a range of competencies in the methodological approach, the industry sector and the assurance process.

In line with the product LCA standards, assurance is achieved through two methods: critical review of the methodology and verification of the SGE.

Critical review assesses whether the approach for calculating the LNG GHG intensity has been developed in conformance with the SGE Methodology and supporting standards and whether the methodological choices made are reasonable.

The critical review will be conducted prior to the first verification and repeated if there are significant changes to the sources of emission or methodological approach.

Verification is an independent assurance over the tCO_2e per cargo stated in the SGE assessment, with focus on the reliability of the calculations and checks of the choice and validity of data sources.

The verification will be conducted at least once in a 12-month period and may cover one or more SGEs issued within this period.

A critical review of the alignment of the SGE Calculation and Reporting Methodology with the GHG Protocol Product Standard was completed as a component of the methodology development and may be repeated when the methodology is updated. Both the methodology review and the SGE verification may be undertaken by the same verifier.

Verification should be conducted in alignment with the requirements set out in ISO14064-3:2019 (or subsequent edition, if appropriate) or ISAE3410 (or the equivalent) and should include the following:

- A general process review, evaluating if the Reporter has developed, documented and implemented a process through an MMP to collect data in line with the methodology that has been critically reviewed. This would be applied to all cargoes delivered by that supplier and completed by the Reporter's assurance provider prior to SGE reporting.

- Verification of an SGE's data (based on suitable sampling of data throughout the stages of the value chain included in the SGE) to confirm that the intensity value(s) applied are reliable and have been calculated in accordance with the SGE Methodology and associated MMP. Verification of the individual SGEs will include verification of any adjustments needed under the allocation approach (see ANNEX B allocation) in order to meet the requirements of temporal boundaries and adjust for events such as a plant shutdown.

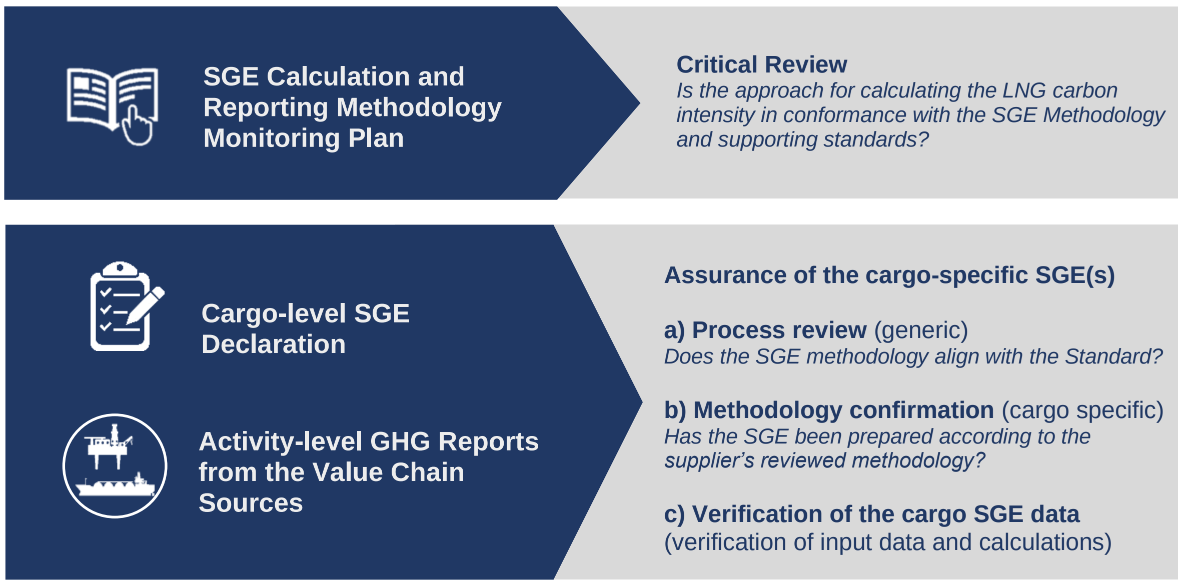

Figure 5.1. Illustration of assurance steps

5.1.1 Qualifications of the Entity Conducting the Assurance

Assurance and critical reviews shall be undertaken by a qualified individual / entity that is independent of the methodology or inventory development. For third-party verification, it is expected that the verification team should meet the qualification criteria set out in ISO14065:2020 or equivalent.

5.2 Assurance Considerations

5.2.1 Content and Implementation of the MMP

Reporters shall develop a fully documented Monitoring Methodology Plan, including the content detailed in ANNEX D as a minimum. The intent of the MMP is to prevent misstatements in the SGE and ensure conformance to the MMP and SGE Methodology.

5.2.2 Internal Quality Assurance / Quality Check

Reporters shall develop internal assurance processes in line with good industry practise and considering the following:

- Full and clear documentation of procedural controls and methodologies
- Definition of a clear chain of data management
- Separation and independence of function, that is, the data generator should not be providing internal data assurance
- Management of data changes and corrections, including traceability and approval
- Periodic internal audit of the MMP versus the requirements of the SGE Methodology and the effectiveness of implementation

5.2.3 SGE Cargo Verification

Reporters shall develop and present calculation of the data and supporting information associated with each SGE.

5.3 Level of Assurance

The ultimate decision on the level of assurance at which a verification statement is issued will lie with the lead verifier and the verification body. This will take account of the materiality of errors, omissions, the use of secondary data and any other factors the verifier deems material in relation to the likely decisions taken by the user of the information supplied. This approach is consistent with the requirements of ISO14064-3.

Consistent with the principle to achieve a fully transparent and complete SGE, reasonable assurance is the preference for the SGE. A Reporter that secures limited assurance should have a plan to move to reasonable assurance over time. The level of assurance is agreed with the verifier in advance and will inform the planning of verification activities.

Defined Levels of Assurance

Under ISO14064-3:2019, the definitions of limited and reasonable assurance are as follows:

Reasonable Assurance	• Where the nature and extent of the verification activities have been designed to provide a high, but not absolute level of assurance on historical data and information

A reasonable assurance opinion is typically expressed in positive language (e.g., “we conclude that the SGE issued on [date] is a true and fair representation of the GHG footprint”).

Limited Assurance	• Where the nature and extent of the verification activities have been designed to provide a reduced level of assurance on historical data and information

A limited assurance opinion is typically expressed in negative language (e.g., “we conclude that nothing came to our attention that the SGE issued on [date] is not a true and fair representation of the GHG footprint”).

As stated above, the ambition of the SGE Methodology is that SGEs will achieve a reasonable level of assurance. However, it is recognised that at least at early stages of adoption, this may not be feasible or cost effective. The level of assurance conducted will be identified on the verification report.

The verification opinion provided upon conclusion of the verification may be unmodified (the SGE has been prepared in alignment with the SGE Methodology) or modified (the SGE has been prepared in alignment with the methodology except for non-material instances of non-alignment or the SGE has not been prepared in alignment with the methodology). The verifier may also decide that there is not sufficient evidence to support verification, and the conclusion will be “unverified.”

In line with ISO14064-3, the verifier shall plan and perform the verification with an attitude of professional scepticism and using a risk-based approach and shall assess whether the SGE is complete, accurate and in conformance with the SGE Methodology requirements and the Reporter’s MMP.

An overview of the two levels of assurance described above is provided in Table 5-1.

Table 5-1 Overview of Reasonable and Limited Assurance

Level of Assurance	Description	Advantages	Disadvantages
Reasonable (recommended)	Highest level of assurance. Leads to a positive assurance statement (e.g., "in our opinion, the reported cargo footprint of x CO_2e in the SGE is fairly stated in conformance with the SGE calculation and reporting methodology").	Good confidence that the cargo footprint is reliable based on extensive testing of source data.	May be high cost and may require regular visits to assets within the reporting chain. More time intensive.
Limited	Controls based on limited sampling, leading to a negative assurance statement (e.g., "based on our review, we are not aware of any material modification that should be made to the assertion in the SGE that the reported cargo footprint is x tCO_2e").	Provides confirmation that the approach is being followed and data rolled up according to the methodology.	Will have a lower coverage of tested source data from individual assets/companies included in the data set.

5.3.1 Reliance on Other Assurance / Verification Activities

For the verification of the cargo SGE, an approach would need to be developed between the assurance provider and the Reporter, which will depend on:

- whether the Reporter has operational control throughout the life cycle stages of the value chain or needs to secure data from other operators;
- whether reporting assets are under a verified regulatory regime with compatible GHG reporting requirements; and
- whether the Reporter and / or operators of upstream life cycle stages have a corporate GHG assurance programme that delivers a defined level of assurance.

For non-integrated Reporters, if other verification / assurance activities are undertaken within the value chain, then these activities may potentially be relied upon (subject to agreement from the assurance provider). If the output data, sources or boundaries are different from the data required for the SGE calculation, then additional assurance activities will be needed to close the gap. The applicability and acceptability of these would need to be reviewed on a case-by-case basis according to the specific value chain used by the Reporter.

5.3.2 Timing of Assurance

Apart from emissions associated with the shipping voyage, it will not be possible to provide reasonable assurance back to source for each cargo of LNG at the point of delivery without undue verification effort / cost. It will therefore be necessary for the assurance provider to build a framework of assurance activities that will grow over time to provide the required level of confidence in the reported SGE.

Under the SGE Methodology, there will be a reconciliation period, not exceeding 12 months, to take account of adjustments to the SGE based on events, such as shutdowns, plant stability issues and so on, that may be reasonably attributed across a year so as not to over- or under-allocate emissions in a shorter time frame. A Reporter may choose a shorter period over which to carry out assurance or may adopt varying reference periods, such as a rolling year, provided they conform to the minimum requirements of the SGE Methodology.

5.3.3 Content of the Verification Statement and Verification Documentation

A verification opinion statement shall be issued for each SGE report, that is, related to a specific cargo of LNG. Where a verifier verifies more than one SGE report at the same time, a single verifier opinion statement may be issued by the verification body provided it clearly identifies the relevant cargoes and any differences in opinion for each cargo.

The verifier opinion shall include as a minimum the following information:

- Individual verifier's name and, if relevant, the verifier's organisation (verification body)
- Identification of all verification team members
- Verifier's contact details, including address and telephone number
- Name of independent technical reviewer / person authorising issuance of the opinion on behalf of the verification body
- Details of the organisation making the claim, that is, the Reporter issuing the SGE
- A means of identifying each SGE included in the opinion
- Quantity of LNG delivered, emissions intensity and total SGE emissions verified
- Date of the opinion and standard of assurance achieved
- Dates of site visits undertaken, if applicable
- Summary of the verification activities undertaken and of any reliance on verification by others
- Verification findings and continuous improvement recommendations
- Identification of any material or non-material misstatements or non-conformities that have not been corrected prior to issuance of the verification opinion
- Identification of data gaps and methodologies used to fill them
- A clear verification conclusion based on the level of assurance achieved or a statement that a specific SGE is not verified

The verification body shall retain suitable internal verification documentation in order to demonstrate the verification activities undertaken and evidence in support of any findings. This shall include:

- details of the verifier team used and their specific roles;
- strategic assessment and verification plan;
- details of documents and evidence reviewed during the verification;
- verification risk assessment, including assessment of inherent risk and control risks and details of tests implemented;
- verification criteria and data testing carried out;
- issues identified during verification and their resolution; and
- dates of the monitoring methodologies applied and any changes made to the MMP during the verification process.

5.3.4 Verifier Competence and Selection

It is the responsibility of the verification body to ensure that personnel are competent for the roles they undertake, based on a combination of knowledge, experience and training, and to retain suitable evidence to demonstrate both initial and continuing competence and development.

The verification team, including verifiers, lead verifiers, technical experts and independent technical reviewers, must collectively demonstrate:

- familiarity with the requirements of the SGE Methodology;
- familiarity with relevant GHG accounting and product-based GHG footprinting standards, such as GHG Protocol Product Standard and ISO14067:2018;
- suitable process/industry knowledge, including knowledge of GHG calculation approaches relating to sources of GHG emissions across all stages of the LNG value chain;
- familiarity with verification standards and approaches such as ISO14064-3:2019, EU Accreditation and Verification Regulations, and so on; and ongoing CPD.

At this point of initial development of the SGE Methodology, it is not yet envisaged that full accreditation rules will apply in this circumstance.

5.3.5 Verification of Shipping Leg

It is expected that verification of the shipping leg may be undertaken on a per-voyage basis. Data gathering by vessel and other means of reporting at the end of each voyage would be forwarded for further assessment via the custodian operator of the process or directly to the third-party verifier, depending on the channels of communication and software tools available / used.

Example Verification of Shipping Leg
After closing the CTMS, data can be migrated via data-gathering software to the GHG application or similar enterprise resource planning system (ERP) shipping software and then to the verifier. The verifier will assess data measured by metering equipment on the vessel. In case of metering equipment failure, tank accounting will be performed to provide fall-back data. Further supporting data to be used by the verifier include cargo documents, port documents, automatic identification system (AIS) data, surveyor reports and so on. For further data assurance, the cargo surveyor may be appointed to witness: • the custody transfer process, the fuel remaining on board (ROB) at load port, and the fuel ROB at discharge port; • the opening of the CTMS at the loading port and the closing of the CTMS at the discharge port; and • the relevant start / end point of the incoming ballast leg.

6 CONTINUOUS IMPROVEMENT AND USE OF HIGHER-TIER METHODOLOGIES

The tiered methodology (primary and secondary data approaches) allows reporting flexibility to companies regardless of where they lie on the value chain and the GHG information available to them while still meeting the elements of the SGE Methodology.

Underlying the SGE Methodology is the principle that over time, the methodology and its application are expected to develop and become more refined as more information becomes available to both integrated and portfolio suppliers, allowing more detailed and granular calculation of GHG emissions data. The methodology may also continuously be adapted in line with more robust industry regulations and international GHG emissions reporting standards. The following general principles of continuous improvement apply:

- It is the responsibility of the Reporter to collect detailed emissions data and to improve data quality and transparency of their value chain over time.
- It is the responsibility of the Reporter to demonstrate continuous improvement in reducing the uncertainty level of the SGE.
- Reporters shall develop and implement an improvement plan, including responses to verification outcomes and self-identified opportunities to improve data quality and transparency.
- Continual improvement is not an absolute expectation – it must be balanced by consideration of cost-effectiveness and practicability of implementation. It is the Reporter's responsibility to demonstrate that these criteria are applied. It is expected, however, that any identified non-conformances with the SGE Methodology will be corrected.

Specific data quality indicators may be identified and defined based on the GHG Protocol Product Standard (see Table 6-1 below) and assigned qualitative scoring criteria. Where the Reporter is claiming improvement in data quality, this shall be reflected in the MMP and suitable evidence demonstrated to the verifier.

Table 6-1 Data quality indicators (Source: GHG Protocol Product Standard)

Indicator	Description	Relation to Data Quality
Technological representativeness	The degree to which the data reflect the actual technology(ies) used	Companies should select data that are technologically specific.
Temporal representativeness	The degree to which the data reflect the actual time (e.g., country or site)	Companies should select data that are temporally specific.
Geographical representativeness	The degree to which the data reflect the actual geographic location of the activity (e.g., country or site)	Companies should select data that are geographically specific.
Completeness	The degree to which the data are statistically representative of the relevant activity Completeness includes the percentage of locations for which data are available and used out of the total number that relate to a specific activity. Completeness also addresses seasonal and other normal fluctuations in data.	Companies should select data that are complete.
Reliability	The degree to which the sources, data collection methods and verification procedures used to obtain the data are dependable	Companies should select data that are reliable.

Example approaches to scoring of data quality indicators are included in ANNEX C. These are intended as illustrative only. It is recognised that individual suppliers may already have established methodologies in place.

It is the responsibility of the Reporter to demonstrate to the satisfaction of the third-party verifier that the best available data have been used in calculation of the SGE and that where secondary data are being used, there are no available primary data of equivalent or better quality.

Table 6-2 Sample scoring criteria for performing a qualitative data quality assessment (Source: GHG Protocol Product Standard)

Score	Representativeness to the Process in Terms of:				
	Technology	**Time**	**Geography**	**Completeness**	**Reliability**
Very Good	Data generated using the same technology	Data with less than 3 years of difference	Data from the same area	Data from all relevant process sites over an adequate time period to even out normal fluctuations	Verified data based on measurements
Good	Data generated using a similar, but different technology	Data with less than 6 years of difference	Data from a similar area	Data from more than 50% of sites for an adequate time period to even out normal fluctuations	Verified data partly based on assumptions or non-verified data based on measurements
Fair	Data generated using a different technology	Data with less than 10 years of difference	Data from a different area	Data from less than 50% of sites for an adequate time period to even out normal fluctuations or from more than 50% of sites, but for a shorter time period	Non-verified data partly based on assumptions or a qualified estimate (e.g., by sector expert)
Poor	Data where technology is unknown	Data with more than 10 years of difference or age unknown	Data from an area that is unknown	Data from less than 50% of sites for a shorter time period or unknown representativeness	Non-qualified estimate

7 DEFINITIONS AND ABBREVIATIONS

7.1 Definitions

Activity data	Transactional data that represents the quantity for a given period – standard cubic feet (scf)/cubic metres (m^3) of fuel gas burned, number of low-bleed pneumatic controllers and so on. Activity data are ideally measured, but may be estimated based on engineering assumptions.
Calculation factors	Additional factors used in GHG calculations, such as unit conversions, adjustment of default emission factors or compositions, and energy contents (NCV/LHV or GCV/HHV), to be used as appropriate to the method in question.
Carbon dioxide equivalent (CO_2 equivalent, CO_2e)	Unit for comparing the radiative forcing of a GHG to that of carbon dioxide – ISO14067:2018.
Carbon footprint of a product (CFP)	Sum of GHG emissions and GHG removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change – ISO14067:2018.
Data-flow activities	Activities related to the acquisition, processing and handling of data that are needed to draft an emissions report from primary source data.
Emission factor	GHG emissions per unit of activity data (e.g., tonnes CO_2/scf fuel gas, kg CH4/low-bleed pneumatic controller, tCO_2e/MMBTU, tCO2e/tonne etc.). The emission factor can be based on measured data (e.g., gas compositional analyses) or a default for a given fuel or equipment type.
Emissions	Calculated GHG emissions, metric tonnes CO_2 equivalent (tCO_2e).
Energy Attribute Certificates	Category of contractual instruments used in the energy sector to convey information about energy generation to other entities involved in the sale, distribution, consumption or regulation of electricity. This category includes instruments that may go by several different names, including certificates, tags, credits and so on – GHG Protocol Scope 2 Guidance.
Global warming potential (GWP)	Index based on radiative properties of GHGs that measures 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 CO_2 – ISO14067:2018.
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 Earth's surface, the atmosphere and clouds – ISO14067:2018.

Greenhouse gas emission (GHG emission)	Release of a GHG into the atmosphere – ISO14067:2018.
Location-based approach	Method to quantify Scope 2 GHG emissions based on average energy generation emission factors for defined geographic locations, including local, subnational and national boundaries – GHG Protocol Scope 2 Guidance.
Market-based approach	Method to quantify the Scope 2 GHG emissions of a Reporter based on GHG emissions emitted by the generators from which the Reporter contractually purchases electricity bundled with contractual instruments or contractual instruments on their own – GHG Protocol Scope 2 Guidance.
Non-material sources	Those that collectively contribute less than 5 percent to an individual stage GHG intensity or less than 2 percent to the consolidated GHG intensity for the delivered LNG.
Oxidation factor	Percent of conversion of hydrocarbon molecules into CO_2 during the combustion process, if applicable. The oxidation factor is typically a default factor for combustion sources and flares and is not used when calculating non-combustion emissions.
Partial carbon footprint of a product (partial CFP)	Sum of GHG emissions and GHG removals of one or more selected process(es) in a product system, expressed as CO_2 equivalents and based on the selected stages or processes within the life cycle – ISO14067:2018.
Primary data	Quantified value of a process or an activity obtained from a direct measurement or a calculation based on direct measurements – ISO14067:2018.
Process	Series of steps and activities for producing a product or generating a result.
Reasonable assurance	High level of assurance allowing for no more than a remote likelihood that material misstatements exist.
Reporter	Entity which applies the SGE Methodology and delivers the Statement of Greenhouse Gas Emissions (SGE).
Secondary data	Data that do not fulfill the requirements for primary data – ISO14067:2018.
SGE Methodology	Document and principles laid out that describe the overall approach to the SGE scope, boundaries and process for generating a per-cargo SGE.
SGE Methodology Monitoring Plan (MMP)	Collection of documented approaches used by a Reporter to define the process they use to collect data, calculate and allocate emissions, and derive an SGE for reporting, including their internal assurance processes and approach to continuous improvement.
Stage	Any major section of the process for producing LNG, such as production and gathering or liquefaction.

Statement of Greenhouse Gas Emissions (SGE)	Assertion that states the GHG emissions associated with a given quantity / cargo of the delivered product.
System boundary	Boundary based on a set of criteria representing which unit processes are a part of the system under study – ISO14067:2018.
Uncertainty	Parameter associated with the result of quantification that characterises the dispersion of the values that could be reasonably attributed to the quantified amount – ISO14067:2018.
Unit process	Smallest element considered in the life cycle inventory analysis for which input and output data are quantified – ISO14067:2018.
Verification	Independent assessment of the reliability (considering completeness and accuracy) of a GHG inventory.

7.2 Abbreviations

API – American Petroleum Institute

AR5 – Assessment Report 5, the fifth Assessment Report of the IPCC

CARB – California Air Resources Board

CPD – continuing professional development

CTMS – Custody Transfer Measurement System (for delivery of a ship's cargo)

DEFRA – UK Department for Environment, Food & Rural Affairs

EU ETS – EU Emissions Trading System

GCV – gross calorific value

GWP – global warming potential, a unitless ratio to define the relative impact of a greenhouse gas versus carbon dioxide; is measured over a specified time horizon

HFO – heavy fuel oil

HHV – higher heating value, also known as GCV

IMO – International Maritime Organisation

IPCC – Intergovernmental Panel on Climate Change

ISO – International Organisation for Standardisation

LCA – life cycle assessment

LHV – lower heating value, also known as NCV

LNG – liquefied natural gas

MGO – marine gas oil

MiQ – Methane Intelligence Quotient

mmBtu – metric million British thermal unit

MMP – methodology monitoring plan

NCV – net calorific value

NGER – National Greenhouse and Energy Reporting scheme (Australia)

NGL – natural gas liquid

OGPM – Oil & Gas Methane Partnership

ROB – remaining on board (e.g., fuel ROB)

t – metric tonne, 1000kg; the unit used for reporting of GHG emissions as tCO_2e

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9 ANNEX A: SPECIFIC METHODOLOGICAL CONSIDERATIONS FOR SHIPPING

The total GHG emissions for each cargo will equal the sum of the production GHG emissions and the shipping GHG emissions, both calculated in accordance with the SGE Methodology. For shipping, as with the other components of the SGE, the calculation will include CO_2, CH_4 and N_2O as a minimum, in alignment with the general provisions of section 2 of the SGE Methodology. Refrigerants and SF_6 shall not be excluded if material.

Total shipping GHG emissions, as per the scope and boundaries identified in section 2 of the SGE Methodology, will use the same general approach as for other emissions, as per section 3 of the SGE Methodology, and are the sum of GHG emissions from:

1. **Fuel combustion** (all fuel including LNG/BOG, combustion in a GCU, or liquids);
2. **Venting**;
3. **Methane slip** associated with incomplete fuel combustion; and
4. **Fugitive emissions** associated with flange and equipment leaks.

9.1 Shipping-Specific Voyage and Reporting Boundaries

Laden Leg

Calculation of laden leg emissions under the SGE will begin at an open CTMS at the load port and will conclude following the closing of the CTMS at the discharge port. Alternative boundaries for the laden leg can be considered and agreed upon by the parties and the verifier, where shown to have no material influence on emissions estimates (e.g., flange connection / disconnection, pilot on-board at the load port to pilot off-board post-discharge).

Exclusions from the shipping component of the SGE can include emissions from search and rescue operations, based on verification.

Ballast Leg

The SGE will include an incoming ballast leg in line with emerging shipping industry expectations, such as the Global Logistics Emissions Council (GLEC) Framework, the Sea Cargo Charter (SCC) and others. The calculation of ballast leg emissions under the SGE will have different beginning and ending boundaries, depending on the specific circumstances of each voyage or the laden leg boundaries used. The base principle is that the Reporter will be responsible for the proportion of the incoming ballast leg that is under the control of the Reporter, which is that portion considered attributable to a specific cargo. This differs from the SCC approach in that the SCC is an operator-based reporting scheme to establish a total GHG inventory, whereas the SGE methodology seeks to allocate only that portion of total emissions attributable to a specific cargo.

The ballast leg will be defined by the commercial in-charter agreement.

Examples of different beginning ballast boundaries include:

- the conclusion of the laden voyage at the previous delivery port where the Reporter is in control of the vessel's previous voyage; and

- pilot off-board and associated fuel ROB quantities or CTMS where the vessel ballasts from an anchorage or shipyard (including refit, drydock or construction), or closing CTMS at the discharge terminal where the vessel is under multivoyage control by the Reporter, or a snap-shot CTMS at the point where the vessel comes under the control of the Reporter during a stub / positioning ballast passage provided the Reporter is in control of the vessel from that point.

The boundaries described above are also considered to apply for cargo swaps and third-party cargo purchases.

9.2 Shipping Data

The shipping element of any SGE is expected to be based on primary data in most cases, with emissions data to be compiled on a per-voyage basis and later consolidated into verified SGEs (see section 5.0, Assurance).

There may be cases where cargo swaps, in-charters and monitoring equipment failure would require the use of secondary data. In these cases, the Reporter shall satisfy the verifier that the best available data was used.

Although efforts shall be made to continually improve methane quantification techniques and approaches to quantification of N_2O, both methane and N_2O emissions may initially be based on the use of standard factors available from empirical studies, manufacturers and industry bodies (e.g., *The International Council on Clean Transportation Working Paper 2020-02*, the API Compendium, AP-42, as relevant to each emission source).

Emission sources relevant to shipping are detailed in section 3.

10 ANNEX B: GUIDANCE NOTES ON ALLOCATION OF EMISSIONS TO LNG AND OTHER CO-PRODUCTS

10.1 Principles of Allocation

General Approach

As per section 2.5.1 above, GHG allocation to co-products shall be based on proportional allocation of embodied emissions up to the point at which a product leaves the process.

For example, in the case of NGL extraction, accumulated GHGs to that point in the process will be proportionally allocated to the co-products leaving that stage based on energy content where possible (which may differ from the energy content entering the stage), but no GHGs will be allocated backwards from subsequent steps to these co-products. This will ensure that the GHG allocation to the final LNG product is neither systematically over-allocated nor systematically under-allocated.

If a facility produces more than one product, facility-level emissions should not simply be distributed to the various products produced by a facility. Instead, to the extent possible (in alignment with ISO14067:2018 and the GHG Protocol Product Life Cycle Guidance), the facility should be divided into sub-blocks. The sub-blocks should be at the most granular level achievable to minimise the need for allocation to co-products. This will allow emissions to be appropriately allocated based on the different processing requirements of each product.

In carrying out the allocation, emissions associated with non-attributable processes or operations should not be included in the GHG allocation where these can be sufficiently segregated. Using upstream three-phase separation as an example, with gas as the oil co-product, flaring from the separation may be allocated proportionally to the energy content of the oil and gas streams. Any subsequent treatment, pumping and so on of the oil stream is no longer associated with the gas stream and any emissions that can be clearly identified as relating to these processes can be excluded from subsequent allocation steps.

Having completed the co-product allocation, the total GHGs allocated to products should be reconciled against the total facility GHGs for the reference period.

The following section outlines the general approach that may be taken at each stage of the LNG production process; note that stages may occur in differing order.

Production, gathering and boosting

Figure 10.1, below, represents a typical overall block diagram for the steps from gas production to gas transmission. This may require further subdivision depending on the outputs, as below.

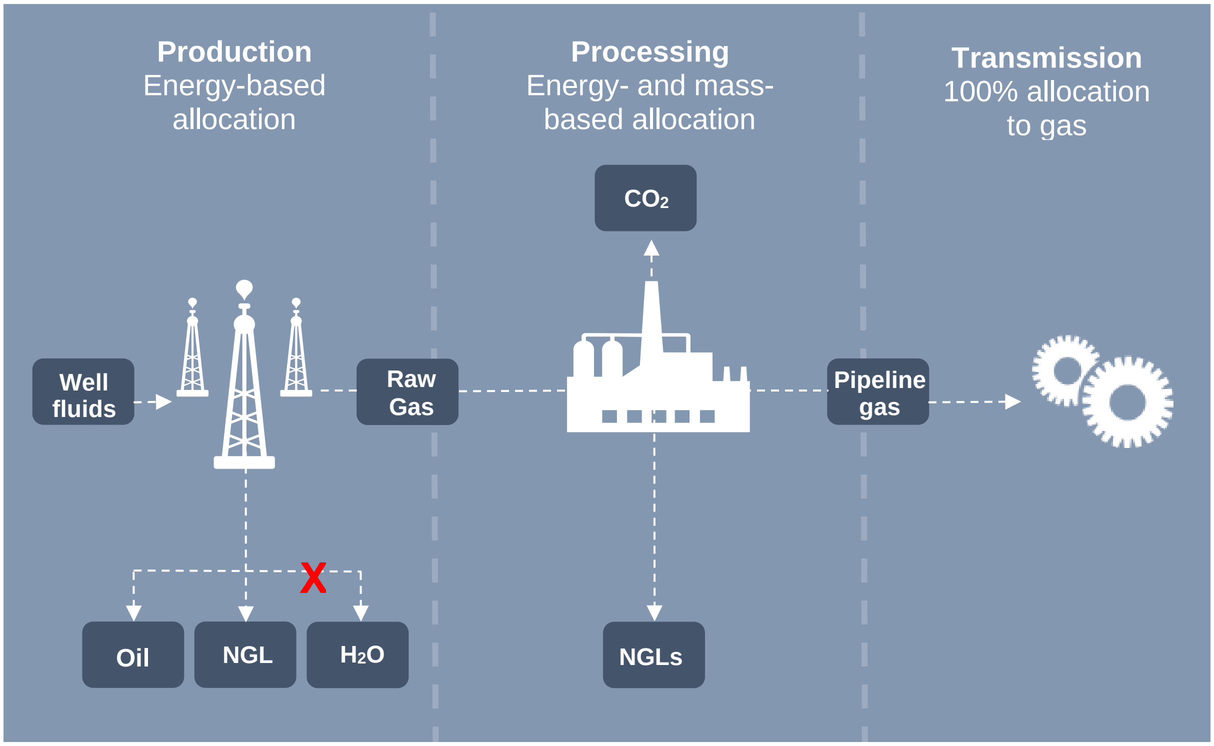


Figure 10.1. Block diagram for typical gas production, processing, and transmission

Co-products at this stage may include oil, NGLs/condensates, liquefied petroleum gas (LPG) and domestic gas.

Emissions are likely to come from combustion, venting, flaring and fugitives. Where relevant and to the extent that metered consumption and other data flows allow, improved allocation accuracy will be achieved through identification of processes and emissions that can be attributable to the co-products, and in particular the gas stream. If operations are not attributable to the gas stream, such as oil storage and transport, the emissions from these non-attributable processes should not be included.

Gas treatment operations may take place at various points in the value chain, either at the LNG plant, in the production operations or as a stand-alone midstream operation and may occur on either side of booster compression and transportation. The allocation approach remains the same in any case.

Where CO_2 is recovered from acid gas in the production operations, the recovered CO_2 can be treated as a co-product if utilised in EOR, otherwise it would be expected to be considered a waste and any emissions associated with AGR would be allocated across other product streams.

Allocation should be based on energy content of products with the exception of the AGRU as above. Appropriate allocation will require the production process to be broken into smaller sub-blocks to the extent possible. As an example, booster compression emissions are attributable to gas but not to oil. If sufficient data are available, a specific emissions calculation or estimate should be made.

Where CO_2 is considered as a product, the GHG allocation to the CO_2 product may be based on a mass ratio of tonnes CO_2 product to tonnes of total monetisable product (hydrocarbons and CO_2) upon leaving the sub-block. Thereafter, the balance of GHG may be allocated to LNG based on the energy ratio of the gas produced to total energy of remaining monetisable products.

The AGR process should be treated as a sub-block for allocation if possible.
Produced water (even if reinjected into the reservoir) is not considered a co-product.

Gas transmission

Gas transmission is not expected to require an allocation approach as there are no identified co-products, that is, the gas entering the transmission system is the same as the gas entering the LNG plant.

There may however be shrinkage, in which a part of the gas stream is utiliised as fuel for compression engines, in which case the carried-through emissions in the incoming gas are added to the emissions from compression. The resulting output intensity is then based on the energy content of the gas leaving the compression stage. This is further illustrated in section 10.2.

LNG production

In any LNG production facility, it is expected that the bulk of the energy utilised (and therefore GHG emitted) is in the LNG liquefaction section. For LNG plants that produce significant by-products, such as condensates, LPG, sulphur and/or helium, simply dividing the total GHG emitted by the overall production mmBtu ratio of LNG to total monetisable products will not yield a logical co-allocation of GHG to LNG. Where relevant and to the extent that metered consumption and other data flows allow, improved allocation accuracy will be achieved through identification of processes and emissions that can be attributable to the co-products, and in particular the gas stream. Therefore, to the extent possible, a granular approach should be used, that is, the plant should be split into sub-blocks or unit operations.

If the gas in the pipeline has already been sweetened/dehydrated and the heavy hydrocarbons have been removed in upstream facilities so that the pipeline gas composition is suitable for direct feed to an LNG liquefaction block, then the GHG emissions from the transmission operations should be carried forward into the LNG plant and be allocated between LNG and other products, such as domestic gas supply, and following energy-based allocation principles.

However, if the gas still requires conditioning to make it suitable for feed into an LNG liquefaction plant, the GHG emissions have to be allocated to all products or co-products produced by the LNG production plant taking into account emissions carried forward into the LNG plant from previous stages and allocated between the LNG product and co-products.

An example of a possible approach to identifying process blocks for an LNG production plant receiving sour gas feed is shown in the illustrative example below (Figure 10.2), with potential approaches to each.

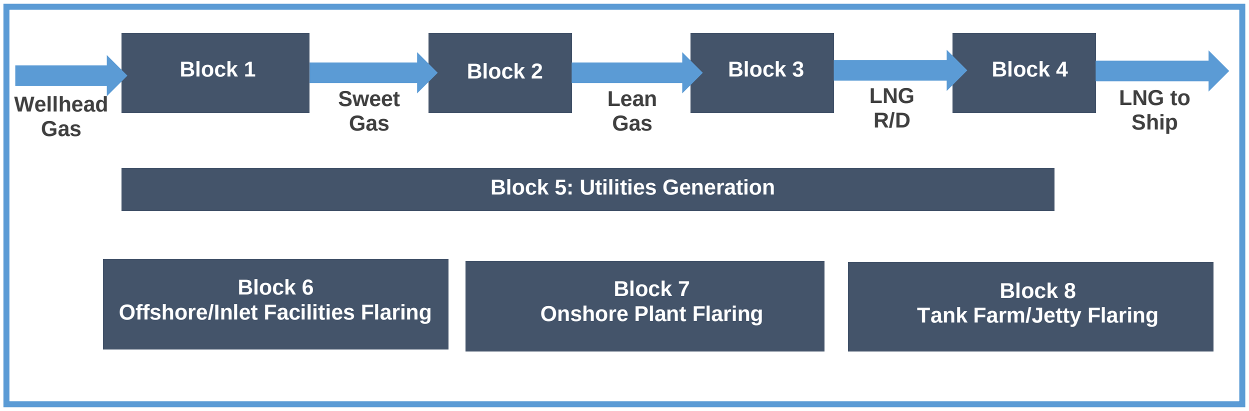


Figure 10.2. Example process block breakdown for an LNG plant

Notes: If the LNG production facility receives gas feed via pipeline and the gas has been treated upstream to sweeten/dehydrate and remove heavy hydrocarbons, then the facility may have a much simpler configuration, with fewer number of process blocks.

1. Utilities Systems

The utilities systems in an LNG plant are highly integrated, and they vary depending on plant design configuration and age, such as the use of electric-drive versus direct-drive versus steam-driven compression turbines. The allocation approach needs to be tailored to the granularity of information available through sub-metering of fuel gas or other energy use.

The highest point on the hierarchy would be to allocate total CO_2e from the utilities section proportionally on the basis of measured usage of the energy produced in steam and electricity.

Where this is not technically feasible, it is acceptable to allocate the GHG emissions from fuel combusted to produce the LNG plant steam / electricity to LNG using approaches including engineering estimates of proportional consumption within the identified sub-blocks (e.g.,10% used in gas dehydration), through to the least accurate approach, which would use the mmBtu ratio of LNG to total monetisable product for the overall plant.

2. Flare Systems

The plant's flare system may be split into "flare blocks" for the purpose of more accurate flaring GHG allocation. Where it is possible to allocate flaring to specific sub-blocks through specific metering, process information or other estimation, it is expected that this will be done.

GHG emissions during plant turnarounds and other significant unplanned outages, during which time production is nil or significantly reduced, will need to be identified and allocated over the full annual production or other reference period (as per the verification reference period) to ensure there are no anomalies in the GHG allocation.

This proportion of flaring may or may not be included in the draft SGE, but must be included in the final verified SGE.

Remaining flaring (i.e., associated with production operations) in flaring systems that are serving multiple sources may have its associated GHG co-allocated based on the overall mmBtu ratio of LNG to total monetisable product, for example, a common flare system for LPG production and the liquefaction section.

Flaring systems that have a more localised function may have their co-allocation done to more accurately reflect their GHG weightage, for example, GHG emissions from the flare system in the LNG tank farm and loading operations would be allocated 100 percent to LNG.

3. Liquefaction Process

The GHG allocation to LNG in each process block is calculated by taking the GHG emitted in that process block and multiplying by the mmBtu-based ratio of LNG to total monetisable products leaving that block. For example, as LNG is the only monetisable product in the LNG liquefaction block, 100 percent of GHG generated in this block will be allocated to LNG. (This granular approach also ensures that the GHG co-allocation in each block is attributed only up to the point that the product is produced and not thereafter, e.g., once the feed gas has been sweetened, no allocation of sulphur is made for all process blocks downstream of the sulphur removal.)

4. Additional Co-Products and CCUS

GHG reduction due to CCUS is accounted for in the process block where the CCUS application is implemented. The GHG co-allocated to LNG is then based on the net balance GHG emissions (i.e., GHG produced due to combustion/energy use less GHG recovered through CCUS).

Where gas sweetening is part of the LNG plant and results in the removal of H_2S, the allocation approach as defined in the MMP will need to consider the most appropriate allocation approach for that H_2S. Where recovery of sulphur as a monetisable product occurs, a mass-based approach may be applicable, whereas sale of H_2S to a third party may make an energy-based allocation more appropriate, using the HHV of the recovered H_2S to allocate GHG to that stream.

As helium *(de minimis)* does not have an energy value, the GHG allocation to helium may be estimated with a similar cluster approach but based on co-products' mass ratios. Where the energy/GHG emissions associated with the helium extraction process can be identified, this should be allocated on the basis of the mass ratio of the LNG to the helium product. If it is not possible to ascribe detailed energy consumption to the helium extraction process, the GHG allocated to helium may be subtracted from the overall site production GHG on a mass basis before the balance GHG is then co-allocated based on the products' mmBtu ratios as discussed above.

5. Reconciliation

Add up the GHG co-allocated to LNG in each of the blocks to yield the total plant GHG co-allocated to LNG. All GHG generated in the reference period for calculating the SGE must be fully allocated to all products produced in that reference period so that there is no unaccounted GHG accrual and carry-forwards into the following period. It is also recommended that total LNG plant GHG is reconciled against LNG production, energy co-products and other co-products such as sulphur, helium, CO_2 and so on.

LNG storage and LNG shipping

No co-product allocation is expected from either of these operations, as LNG is the only product.

10.2 Illustrative Examples of Allocation

The following illustrative examples take a basic LNG production chain from wellhead to LNG production, using simplified data to illustrate the principle of the allocation approach to be followed.

These examples demonstrate allocation and intensity determination using the recommended carry-forward option. This approach tracks energy content from production to final liquefaction and does not require the calculation of intensities of individual stages or tracking of shrinkage in energy content due to flaring or fuel gas usage. Consideration of these factors is built into the calculations of the approach, which carries forward emissions associated with the LNG value chain from one stage to the next. The first example is presented in both tabular and graphical formats.

Although shrinkage does not need to be explicitly calculated, it does affect the ultimate intensity of the LNG. This is illustrated in example 3, which focusses on two process blocks and demonstrates the impact of shrinkage of the energy content. Allocation and intensity determination option B, illustrated toward the end of section 10.3, Detailed Worked Example, does require explicit calculation of the intensities of individual stages and tracking of shrinkage in energy content due to flaring or fuel gas usage.

Material flows considered for these examples are:

A – LNG;
B – NGLs produced in the liquefaction plant;
C – oil and NGLs at production stage;
D – CO_2 emitted in sweetening – unutilised, therefore treated as a waste.

Example 1. Carry-forward method with co-product allocation

The partial value chain depicted in

Figure 10.3 evaluates an LNG value chain from production through several processing stages to LNG creation. Note that this example ends at the liquefaction plant, but a final SGE under this SGE Methodology would need to include any additional stages up to the point of product delivery at the receiving port.

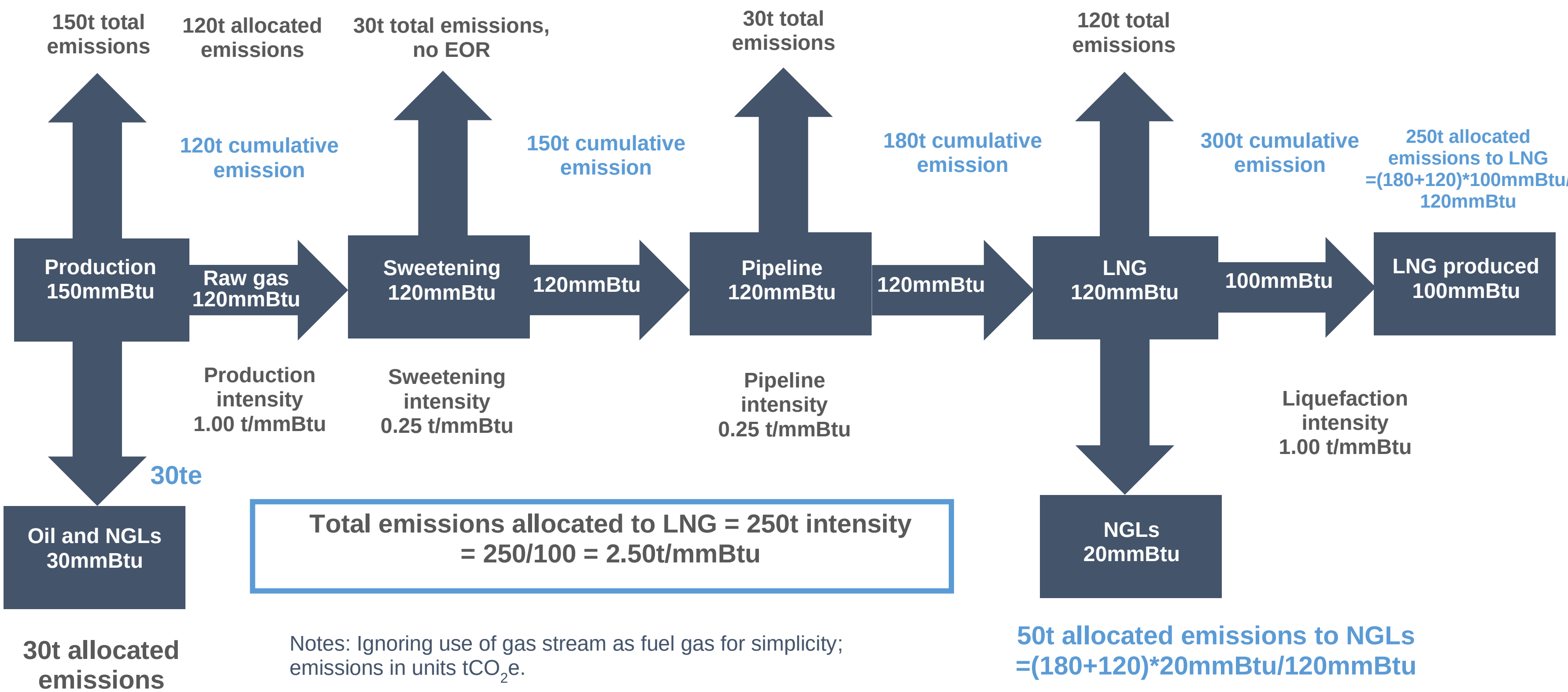


Figure 10.3. Graphical depiction of value chain and emissions and product tracing

The values in

Figure 10.3 can be traced and calculated as shown in Table 10-1 below. Table 10-1 also details the emissions allocation approach for each stage.

Table 10-1. Detailed product tracing and emissions allocation

	Material flows and energy content (mmBtu)			**Emissions allocation (tCO_2e)**				**Allocation approach**
	Flows in	Flows out	Materials leaving the chain (shrinkage)	Total	Flows out	Materials leaving the chain	Cumulative allocation to process flow	
Production and gathering	A + B + C + D = 150	A + B + D = 120	C = 30	150	A + B + D = 120	C = 30	120	Energy basis on total monetisable products
Gas treatment	A + B + D = 120	A + B = 120	D = 0 energy content	30	A + B + D = 30	D = 0, not a co-product	120 + 30 = 150	100% to LNG
Gas transmission	A + B = 120	A + B = 120	None	30	A + B = 30	None	150 + 30 = 180	100% to LNG
Liquefaction	A + B = 120	A = 100	B = 20	120	A = 100	B = 20	180 + 120 = 300 LNG = 300 x (100/120) = 250 NGLs = 300 x (20/120) = 50	Energy basis, cumulative emissions split by monetisable products

Lastly, this same example can be worked using the same table as shown in section 2.6, as shown in Table 10-2 below.

Table 10-2. Emissions tracking, allocation and calculation of the SGE emissions intensity

		Product Tracing							Emissions Tracing and Allocation					
		Total Quantity of Product in LNG value chain at Start of Stage[1]	**Quantity of Product Used or Lost During Stage[2]**	**Quantity of All Products at End of Stage[3]**	**Quantity of Product Diverted from LNG value chain during stage[4]**	**Type of Product Diverted from LNG value chain (co-products)**	**Quantity of Product in LNG value chain at end of stage[5]**	**Type of Product in LNG value chain**	**Total Stage GHG Emissions[6]**	**Stage GHG Emissions associated with Product Diverted from LNG value chain[7]**	**Embodied Emissions associated with Product Diverted from LNG value chain[8]**	**Total Emissions associated with Diverted Product[9]**	**Stage GHG Emissions associated with Product in LNG value chain[10]**	**Carry-forward Emissions associated with Product in LNG value chain[11]**
		mmBtu	mmBtu	mmBtu	mmBtu		mmBtu		tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
Stage		A	B	C	D	E	F	G	H	I	J	K	L	M
Production	1	150	-	150	30	Raw gas	120	Oil + NGLs	150	30		30	120	120
Gas Treatment	2	120	-	120		Gas	120	None	30				30	150
Gas Transmission	3	120	-	120		Gas	120	None	30				30	180
Liquefaction	4	120	-	120	20	LNG	100	NGLs	120	20	30	50	100	250

Result			**Table Reference**
Emissions intensity after liquefaction[12]	2.50	tCO_2e/mmBtu	K4/B4

[1] Note that total products in each stage decrease (shrink) across the value chain. Causes of shrinkage across the value chain include use of product for power generation, flaring, boil-off, venting or production diversion from the value chain (e.g., co-product allocation). Although it is acceptable that total product decreases across the value chain, total product should not increase. After the first stage, total quantity in the LNG value chain at the start of stage (column A) is the same as the quantity of product in the LNG value chain at the end of the previous stage (column F). For example, A2 = F1.

[2] Examples of product used or lost during the stage include gas used for power generation and gas lost to flaring, among other examples. Product that is still monetisable (and not used or lost) is tracked separately as diverted product. No stage emissions will be allocated to product that is used or lost, and embodied (carried-forward) emissions associated with product used or lost will be allocated to the remaining products at the end of the stage.

[3] Total quantity of product at the end of the stage does not include product used or lost during the stage, C = A – B. Also, D + F = C.

[4] Quantity of product diverted from LNG value chain includes co-products such as oil and natural gas liquids. Both stage and embodied (carried-forward) emissions are allocated to co-products. Note D + F = C.

[5] Quantity of product that continues in the LNG value chain decreases as the initial production stream is separated into other co-products and the gas stream is liquefied. Both stage and embodied (carried-forward) emissions are allocated to the products in the LNG value chain. Note D + F = C.

[6] The total stage GHG emissions are the GHG emissions that occurred during the corresponding stage. These emissions are allocated to both co-products and products. Note H = L + I.

[7] The stage GHG emissions associated with product diverted in the LNG value chain is the fraction of total stage emissions from H that are allocated to the co-products that leave the value chain. For example, in stage 1, the stage GHG emissions associated with product diverted from the LNG value chain are the share of the production facility's emissions that are allocated to oil. Emissions are allocated based on energy. I = H*D/C. Note that H = L + I.

[8] Co-products that leave the LNG value chain carry with them their share of the embodied emissions from previous processing (emissions that were carried-forward). For example, the NGLs diverted from the LNG value chain in stage 4 carry with them their share of the emissions carried forward from the previous stages. The diverted upstream emissions for the NGL co-product example in the table is calculated as J4 = D4/C4*M3.

[9] The total emissions associated with the diverted product include both the allocated stage emissions and the diverted product's share of the embodied (or carried-forward) emissions. In the table, this is calculated as K = I + J. Note that all other embodied emissions stay with the LNG product.

[10] The stage emissions associated with product in the LNG value chain is the fraction of total stage emissions from H that are allocated to the product in the LNG value chain. For example, in stage 1, the stage GHG emissions associated with product in the LNG value chain are the share of the production facility's emissions that are allocated to mixed gas. Emissions are allocated based on energy. L = H*F/C. Note that H = L + I.

[11] Emissions are carried-forward through the LNG value chain. Carried-forward emissions at the end of the stage include both stage emissions allocated to products in the LNG value chain and emissions associated with product in the LNG value chain that are carried forward from previous stages. Emissions are only removed if they are allocated to co-products that are diverted from the LNG value chain. For example, M2 = M1 + H2 – J2, and M3 = M2 + H3 – J3.

[12] The emissions intensity of the delivered LNG cargo is the total embodied (carried-forward) emissions associated with product in the LNG value chain divided by the quantity of product delivered at the end of the LNG value chain. In the table, the emissions intensity of the delivered LNG cargo = M4/F4.

After completing the emissions intensity calculations, a confirmation step is recommended to check that all emissions from the value chain have been allocated to products.

Table 10-3. Confirmation all emissions from value chain have been allocated to products

Result			**Table Reference**
Emissions allocated to LNG	250	tCO_2e	K4
Emissions allocated to other products	80	tCO_2e	sum(J)
Emissions allocated to all products	330	tCO_2e	K4 + sum(J)
Total emissions from all stages	330	tCO_2e	sum(F)

Total emissions from all stages are allocated to all products (330 tCO_2e = 330 tCO_2e); check complete.

Example 2. Carry-forward method with co-product allocation with multiple sub-blocks

This provides another example of the carry-forward method with co-product allocation for the portion of the LNG value chain from production to export. Note that this example ends at export compression, but a final SGE under this SGE Methodology would need to include any additional stages up to the point of product delivery at the receiving port.

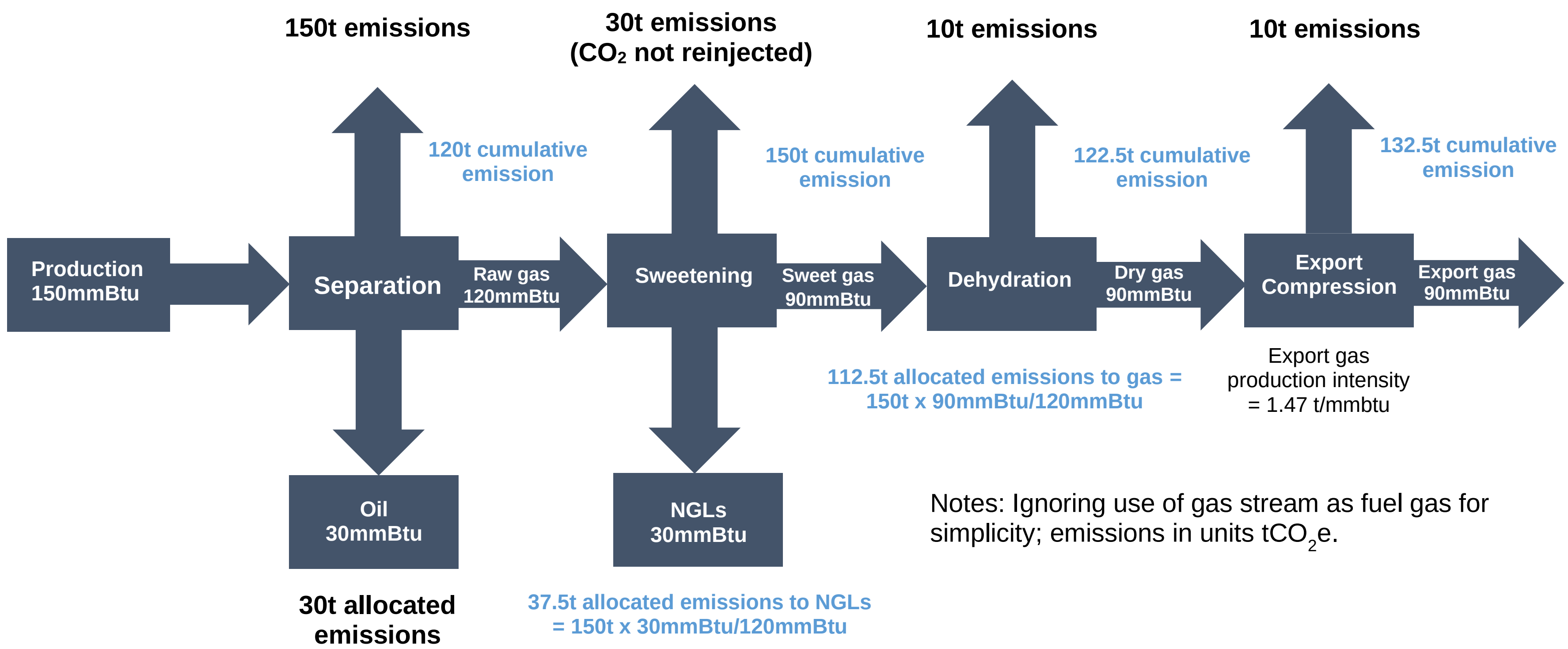


Figure 10.4. Graphical depiction of value chain and emissions and product tracing

Table 10-4. Emissions tracking, allocation and calculation of the SGE emissions intensity

		Product Tracing							Emissions Tracing and Allocation					
		Total Quantity of Product in LNG value chain at Start of Stage[1]	Quantity of Product Used or Lost During Stage[2]	Quantity of All Products at End of Stage[3]	Quantity of Product Diverted from LNG value chain during stage[4]	Type of Product Diverted from LNG value chain (co-products)	Quantity of Product in LNG value chain at end of stage[5]	Type of Product in LNG value chain	Total Stage GHG Emissions[6]	Stage GHG Emissions associated with Product Diverted from LNG value chain[7]	Embodied Emissions associated with Product Diverted from LNG value chain[8]	Total Emissions associated with Diverted Product[9]	Stage GHG Emissions associated with Product in LNG value chain[10]	Carry-forward Emissions associated with Product in LNG value chain[11]
		mmBtu	mmBtu	mmBtu	mmBtu		mmBtu		tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
Stage		A	B	C	D	E	F	G	H	I	J	K	L	M
Separation	1	150	-	150	30	Oil	120.0	Raw gas	150	30.0	-	30	120	120
Sweetening	2	120	-	120	30	NGLs	90.0	Sweet gas	30	7.5	30	37.5	22.5	112.5
Dehydration	3	90	-	90	-	None	90.0	Dry gas	10	-	-	-	10	122.5
Export Compression	4	90	-	90	-	None	90.0	Export gas	10	-	-	-	10	132.5

Result			Table Reference
Emissions intensity after export compression[12]	1.47	tCO_2e/mmBtu	K4/B4

[1] Note that total products in each stage decrease (shrink) across the value chain. Causes of shrinkage across the value chain include use of product for power generation, flaring, boil-off, venting or production diversion from the value chain (e.g., co-product allocation). Although it is acceptable that total product decreases across the value chain, total product should not increase. After the first stage, total quantity in the LNG value chain at the start of stage (column A) is the same as the quantity of product in the LNG value chain at the end of the previous stage (column F). For example, A2 = F1.

[2] Examples of product used or lost during the stage includes gas used for power generation or lost to flaring, among other examples. Product that is still monetisable (and not used or lost) is tracked separately as diverted product. No stage emissions will be allocated to product that is used or lost, and embodied (carried-forward) emissions associated with product used or lost will be allocated to the remaining products at the end of the stage.

[3] Total quantity of product at the end of the stage does not include product used or lost during the stage, C = A – B. Also, D + F = C.

[4] Quantity of product diverted from LNG value chain includes co-products such as oil and natural gas liquids. Both stage and embodied (carried-forward) emissions are allocated to co-products. Note D + F = C.

[5] Quantity of product that continues in the LNG value chain decreases as the initial production stream is separated into other co-products and the gas stream is liquefied. Both stage and embodied (carried-forward) emissions are allocated to the products in the LNG value chain. Note D + F = C.

[6] The total stage GHG emissions are the GHG emissions that occurred during the corresponding stage. These emissions are allocated to both co-products and products. Note H = L + I.

[7] The stage GHG emissions associated with product diverted in the LNG value chain is the fraction of total stage emissions from H that are allocated to the co-products that leave the value chain. For example, in stage 1, the stage GHG emissions associated with product diverted from the LNG value chain are the share of the production facility's emissions that are allocated to oil. Emissions are allocated based on energy. I=H*D/C. Note that H = L + I.

[8] Co-products that leave the LNG value chain carry with them their share of the embodied (carried-forward) emissions from previous processing. For example, the NGLs diverted from the LNG value chain in stage 2 carry with them their share of the emissions carried forward from the previous stages. The diverted upstream emissions for the NGL co-product example in the table is calculated as J2 = D2/C2*M1.

[9] The total emissions associated with the diverted product include both the allocated stage emissions and the diverted product's share of the embodied (carried-forward) emissions. In the table, this is calculated as K = I + J. Note that all other embodied emissions stay with the LNG product.

[10] The stage emissions associated with product in the LNG value chain is the fraction of total stage emissions from H that are allocated to the product in the LNG value chain. For example, in stage 1, the stage GHG emissions associated with product in the LNG value chain are the share of the production facility's emissions that are allocated to raw gas. Emissions are allocated based on energy. L = H*F/C. Note that H = L + I.

[11] Emissions are carried forward through the LNG value chain. Carried-forward emissions at the end of the stage include both stage emissions allocated to products in the LNG value chain and emissions associated with product in the LNG value chain that are carried forward from previous stages. Emissions are removed only if they are allocated to co-products that are diverted from the LNG value chain. For example, M2 = M1 + L2 – J2 and M3 = M2 + L3 – J3.

[12] The emissions intensity of the delivered LNG cargo is the total carried-forward emissions associated with product in the LNG value chain divided by the quantity of product delivered at the end of the LNG value chain. In the table, the emissions intensity of the LNG value chain after export compression = M4/F4.

After completing the emissions intensity calculations, a confirmation step is recommended to check that all emissions from the value chain have been allocated to products.

Table 10-5. Confirmation all emissions from value chain have been allocated to products

Result			Table Reference
Emissions allocated to LNG value chain	132.5	tCO_2e	K4
Emissions allocated to other products	67.5	tCO_2e	sum(J)
Emissions allocated to all products	200	tCO_2e	K4 + sum(J)
Total emissions from all stages	200	tCO_2e	sum(F)

Total emissions from all stages are allocated to all products (200 tCO_2e= 200 tCO_2e); check complete.

Example 3. Carry-forward method with co-product allocation and shrinkage factors

Figure 10.5 below shows three stages of the LNG value chain. In stage 2, emissions are co-allocated to two products. In stage 3, product shrinkage as part of the raw gas in the LNG value chain is used for fuel. Table 10.6 calculates the carried-forward emissions and emissions intensity at the end of this part of the value chain. In addition to use of the carry-forward method, Figure 10.5 also demonstrates how a shrinkage factor can be used to account for emissions associated with product used in the value chain.

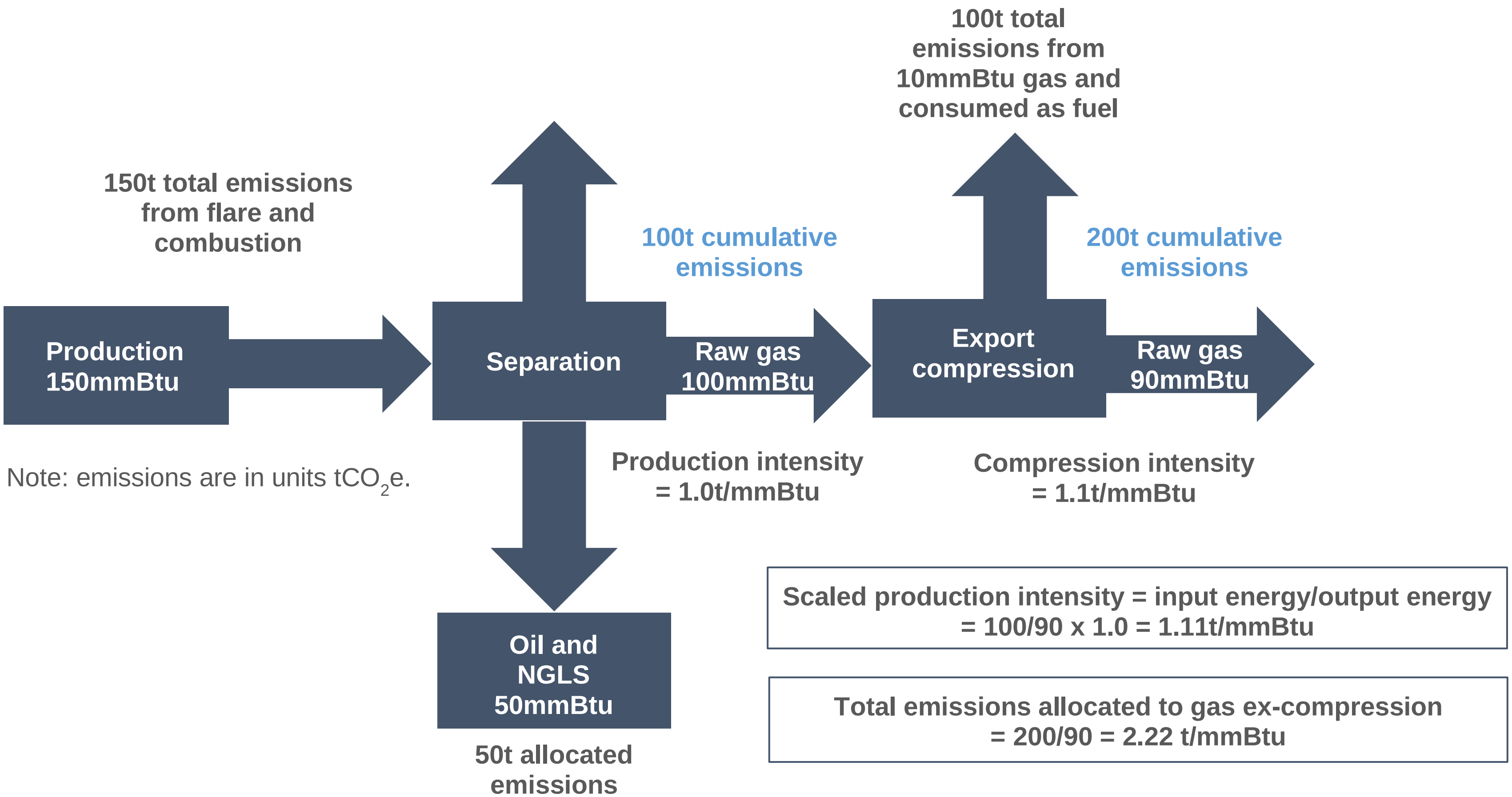


Figure 10.5. Graphical depiction of value chain and emissions and product tracing

Table 10-6. Emissions tracking, allocation, and calculation of the SGE emissions intensity using the carry-through approach

Stage		Product Tracing							Emissions Tracing and Allocation					
		Total Quantity of Product in LNG value chain at Start of Stage[1]	Quantity of Product Used or Lost During Stage[2]	Quantity of All Products at End of Stage[3]	Quantity of Product Diverted from LNG value chain during stage[4]	Type of Product Diverted from LNG value chain (co-products)	Quantity of Product in LNG value chain at end of stage[5]	Type of Product in LNG value chain	Total Stage GHG Emissions[6]	Stage GHG Emissions associated with Product Diverted from LNG value chain[7]	Embodied Emissions associated with Product Diverted from LNG value chain[8]	Total Emissions associated with Diverted Product[9]	Stage GHG Emissions associated with Product in LNG value chain[10]	Carry-forward Emissions associated with Product in LNG value chain[11]
		mmBtu	mmBtu	mmBtu	mmBtu		mmBtu		tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
		A	B	C	D	E	F	G	H	I	J	K	L	M
Production	1	150	-	150	-	None	150	Raw gas	150	-	-	-	150	150
Separation	2	150	-	150	50	NGLs	100	Raw gas	-	-	50	50	-	100
Export Compression	3	100	10	90	-	None	90	Dry gas	100	-	-	-	100	200

Result	Table Reference
Emissions intensity after export compression[12]: 2.22 tCO_2e/mmBtu	M3/F3

[1] Note that total products in each stage decrease (shrink) across the value chain. Causes of shrinkage across the value chain include use of product for power generation, flaring, boil-off, venting or production diversion from the value chain (e.g., co-product allocation). Although it is acceptable that total product decreases across the value chain, total product should not increase. After the first stage, total quantity in the LNG value chain at the start of stage (column A) is the same as the quantity of product in the LNG value chain at the end of the previous stage (column F). For example, A2 = F1.

[2] Examples of product used or lost during the stage includes gas used for power generation or lost to flaring, among other examples. Product that is still monetisable (and not used or lost) is tracked separately as diverted product. No stage emissions will be allocated to product that is used or lost, and embodied (carried-forward) emissions associated with product used or lost will be allocated to the remaining products at the end of the stage.

[3] Total quantity of product at the end of the stage does not include product used or lost during the stage, C = A – B. Also, D + F = C.

[4] Quantity of product diverted from LNG value chain includes co-products such as oil and natural gas liquids. Both stage and embodied (carried-forward) emissions are allocated to co-products. Note D + F = C.

[5] Quantity of product that continues in the LNG value chain decreases as the initial production stream is separated into other co-products and the gas stream is liquefied. Both stage and embodied (carried-forward) emissions are allocated to the products in the LNG value chain. Note D + F = C.

[6] The total stage GHG emissions are the GHG emissions that occurred during the corresponding stage. These emissions are allocated to both co-products and products. Note H = L + I.

[7] The stage GHG emissions associated with product diverted in the LNG value chain is the fraction of total stage emissions from H that are allocated to the co-products that leave the value chain. For example, in stage 2, the stage GHG emissions associated with product diverted from the LNG value chain are the share of the production facility's emissions that are allocated to NGLs. Emissions are allocated based on energy. I = H*D/C. Note that H = L + I.

[8] Co-products that leave the LNG value chain carry with them their share of the embodied emissions from previous processing (emissions that were carried-forward). For example, the NGLs diverted from the LNG value chain in stage 2 carry with them their share of the emissions carried forward from the previous stages. The diverted upstream emissions for the NGL co-product example in the table is calculated as I2 = D2/C2*M1.

[9] The total emissions associated with the diverted product include both the allocated stage emissions and the diverted product's share of the embodied (carried-forward) emissions. In the table, this is calculated as K = I + J. Note that all other embodied emissions stay with the LNG product.

[10] The stage emissions associated with product in the LNG value chain is the fraction of total stage emissions from H that are allocated to the product in the LNG value chain. For example, in stage 1, the stage GHG emissions associated with product in the LNG value chain are the share of the production facility's emissions that are allocated to mixed gas. Emissions are allocated based on energy. L = H*F/C. Note that H = L + I.

[11] Emissions are carried forward through the LNG value chain. Carried-forward emissions at the end of the stage include both stage emissions allocated to products in the LNG value chain and emissions associated with product in the LNG value chain that are carried forward from previous stages. Emissions are only removed if they are allocated to co-products that are diverted from the LNG value chain. For example, M2 = M1 + L2 – J2 and M3 = M2 + L3 – J3.

[12] The emissions intensity of the delivered LNG cargo is the total carried-forward emissions associated with product in the LNG value chain divided by the quantity of product delivered at the end of the LNG value chain. In the table, the emissions intensity of the LNG value chain after export compression = M3/F3.

After completing the emissions intensity calculations, a confirmation step is recommended to checkhat all emissions from the value chain have been allocated to products.

Table 10-7. Confirmation that all emissions from value chain have been allocated to products

Result			Table Reference
Emissions allocated to LNG value chain	200	tCO_2e	M3
Emissions allocated to other products	50	tCO_2e	sum(L)
Emissions allocated to all products	250	tCO_2e	M3 + sum(L)
Total emissions from all stages	250	tCO_2e	sum(H)

Total emissions from all stages are allocated to all products (250 tCO_2e = 250 tCO_2e); check complete.

10.3 Detailed Worked Example

The following section illustrates a worked example of the allocation approach for LNG production from the upstream production stage through to the point of LNG produced for storage and shipping.

Although the values for both energy content and emissions are not intended to represent operational reality, they have been used to demonstrate the detailed allocation approach that can be taken, including a need to select the appropriate basis for that allocation. The scenario depicted is split into three life cycle stages and includes sub-allocation as appropriate. The three life cycle stages included for this example are:

- Stage 1 – Production
- Stage 2 – Midstream
- Stage 3 – LNG production plant

Nomenclature used in the example to denote specific items is as follows:

- E – Emission point, that is, E1.1 = emission point 1 in stage 1
- A – Interim allocation point, that is, A3.2 = allocation point 2 in stage 2
- P – Product leaving the life cycle; a material flow only designated as a product if it is not being further processed in the LNG life cycle, that is, P2.1 = product 1 from stage 2
- Consistently labelled sub-stages, that is, 1.4 PowerGen = sub-stage 4 of stage 1, the production stage

Energy content is in units of mmBtu, and emissions are in units of tCO_2e.

Detailed Worked Example, Using Carry-Through Approach

10.3.1 Stage 1 – Production

The production stage includes:

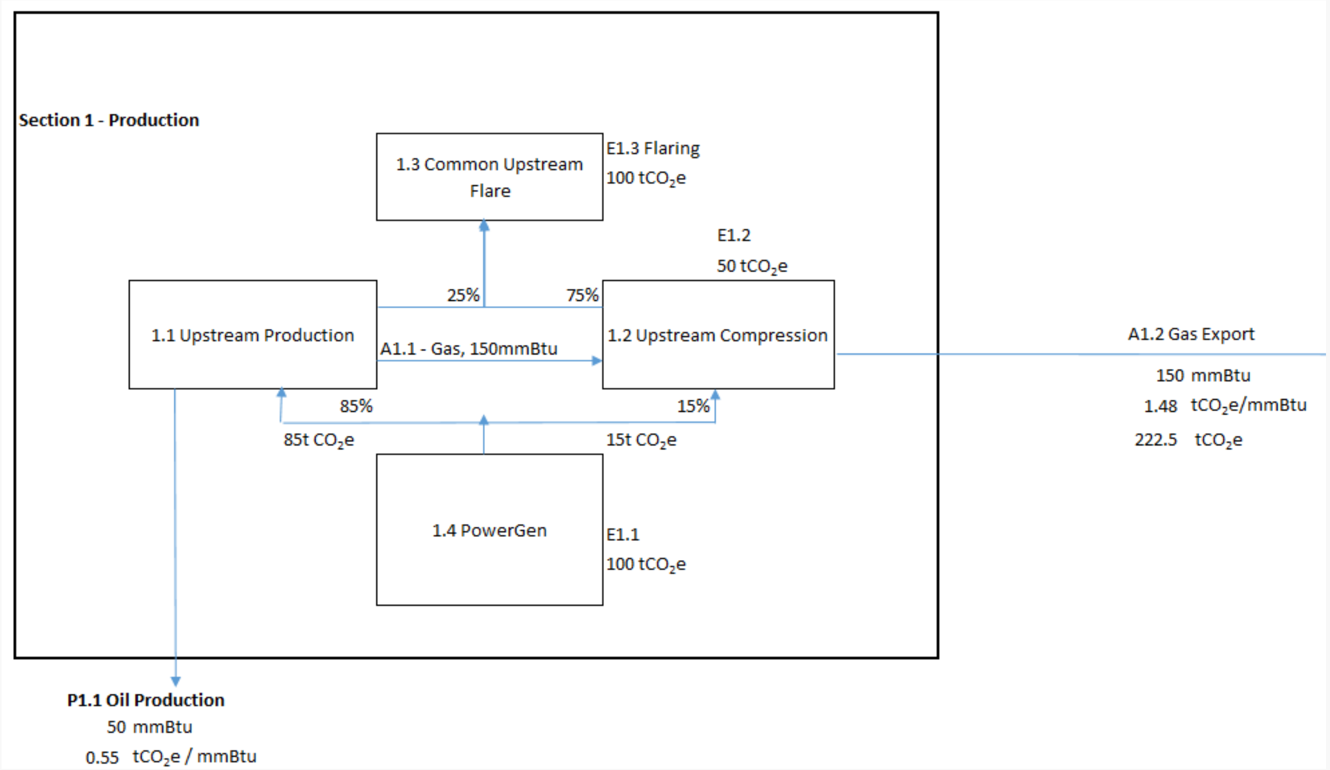
- 1.1 Upstream production – producing P1.1 crude oil and A1.1 raw gas;
- 1.2 Upstream compression – producing A1.2 exported gas;
- 1.3 Common flare system, with no products, but consuming waste gas from stages 1.1 and 1.2; and
- 1.4 Power generation, producing no products, but producing emissions from gas combustion.

Emissions are allocated in the following manner:

- E1.1 Power generation emissions – estimated 85 percent of energy consumed in 1.1, upstream production and 15 percent in 1.2, upstream compression
- E1.2 Direct drive compression turbines – 100 percent of energy consumed in 1.2, upstream compression
- E1.3 flaring, single flare meter – allocated between 1.1 and 1.2 based on energy content, estimated at 25 percent from 1.1 and 75 percent from 1.2

Emissions are further sub-allocated by energy content within each sub-stage.

There is no requirement to account for shrinkage at this stage, as this is the source of the gas that will become LNG.



Stage 1 – Calculation Basis

Emissions (CO_2e)	
E1.1 – Power generation	100
E1.2 – Gas Export compression	50
E1.3 – Flaring	100

Material Flows	Energy Content (mmBtu)
P1.1 – Oil production	50
A1.1 – Raw gas	150
A1.2 – Gas export	150

Emissions allocation by sub-stage %			
Stage	E1.1	E1.2	E1.3
1.1 – Upstream production	85%		25%
1.2 – Upstream compression	15%	100%	75%

Emissions allocation CO_2e							
Material Flows	Energy Content (mmBtu)	E1.1	E1.2	E1.3	Total (CO_2e)	Intensity (CO_2e/mmBtu)	Leave/ carry forward
P1.1 – Oil production	50	21.3		6.3	27.5	0.55	L
A1.2 – Gas export	150	78.8	50.0	93.8	222.5	1.48	CF

Detail

- Allocation of E1.1 to P1.2 = 85% x 100te x 50/200 mmBtu = 21.25 tCO_2e
- Allocation of E1.2 to P1.2 = 0
- Allocation of E1.3 to P1.2 = 25% x 100te x 50/200 mmBtu = 6.25 tCO_2e
- Allocation of E1.1 to A1.2 = 15% x 100te x 150/200 mmBtu = 78.75 tCO_2e
- Allocation of E1.2 to A1.2 = 100% x 100te = 100 tCO2e
- Allocation of E1.3 to A1.2 = 75% x 100te x 150 / 200 mmBtu = 93.75 tCO_2e

Total allocated to P1.1 = 27.5te giving an intensity of 27.5/50 = 0.55 tCO_2e/mmBtu

Total allocated to A1.2 = 222.5te giving an intensity of 222.5/150 = 1.48 tCO_2e/mmBtu

Note that a sub-allocation could be made around block 1.1; however, this has been incorporated into the detail above.

10.3.2 Stage 2 – Midstream Gas Processing

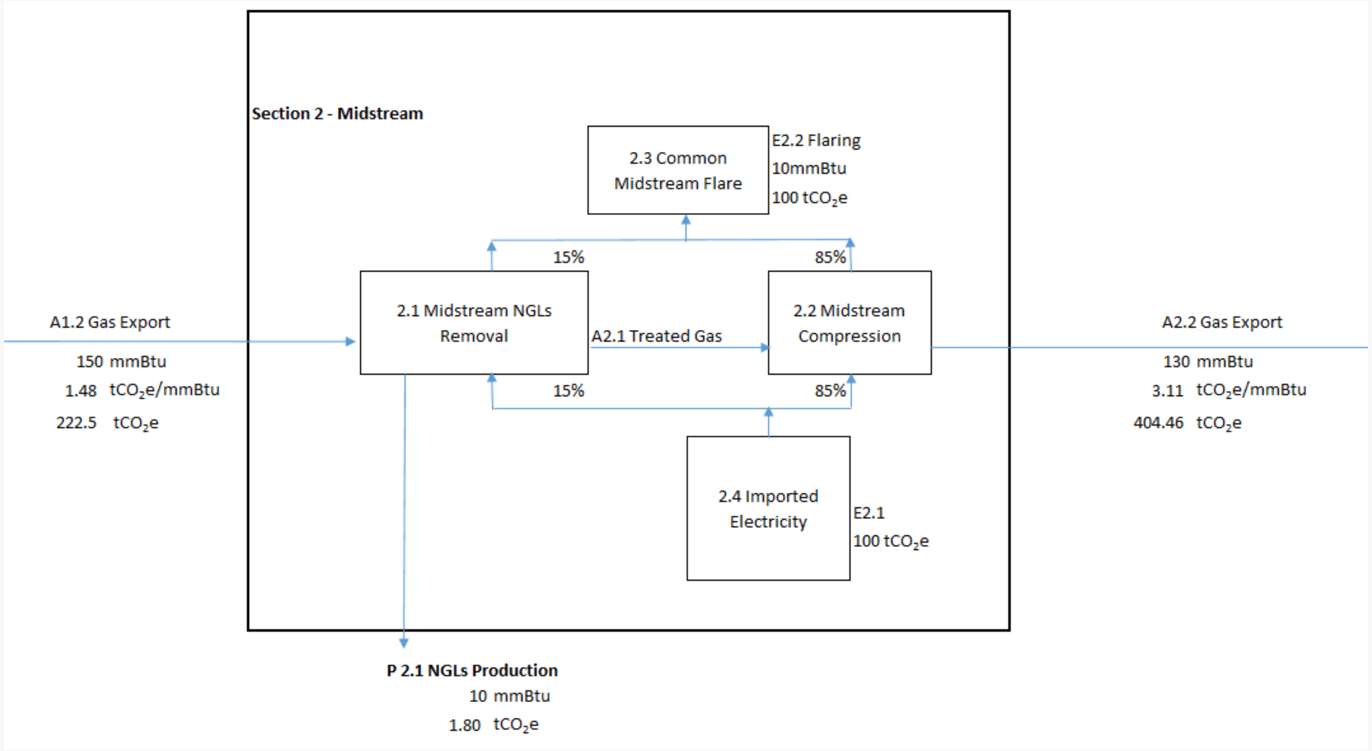
The midstream stage includes:

- 2.1 NGL removal – producing P2.1 NGLs and A2.1 treated gas;
- 2.2 Midstream compression – producing A2.2 exported gas;
- 2.3 Common flare system, with no products, but consuming waste gas from stages 2.1 and 2.2; and
- 2.4 Imported electricity requiring allocation of emissions based on a grid-factor.

Emissions are allocated in the following manner:

- E2.1 Emissions due to imported electricity – Estimated 15 percent in 2.1, NGL removal, and 85 percent of energy consumed in 2.2, midstream compression
- E2.2 Flaring, single flare meter – Allocated between 2.1 and 2.2 based on energy content, estimated at 55 percent from 2.1 and 85 percent from 2.2.

Emissions are further sub-allocated by energy content within each sub-stage.



Stage 2 Calculation basis

Emissions (CO_2e)	
E2.1 – Imported electricity	100
E2.2 – Flaring	100

Material Flows	**Energy Content (mmBtu)**
Inlet – A1.1	150
P2.1 – NGLs	10
A2.1 – Gas export	130
E2.2 – Flaring	10

Note that in this case, a shrinkage ratio must be calculated based on the losses of energy content in the gas flared.

Shrinkage ratio = total energy in / total energy out = 150 / (150-10) = 1.07

Emissions Allocation by Sub-stage %		
Stage	E2.1	E2.2
Inlet – A1.2		
P2.1 – NGLs	15%	15%
A2.1 – Gas export	85%	85%

Material Flows	Energy content (mmBtu)	Brought forward (CO_2e)	E2.1	E2.2	Total (CO_2e)	Intensity (CO_2e/ mmBtu)	Leave/carry forward
P2.1 – NGLs	10	15.89	1.1	1.1	18	1.80	L
A2.1 – Gas export	130	206.61	98.9	98.9	404	3.11	CF

Detail

- Emissions brought forward associated with P2.1 = 1.48 x 10 x 1.07 (shrinkage factor) = 15.89 tCO_2e
- Allocation of E2.1 to P2.1 = 15% x 100t x 10/140 mmBtu = 1.1 tCO_2e
- Allocation of E2.2 to P2.1 = 15% x 100e x 10/140 mmBtu = 1.1 tCO_2e

Total allocated to P2.1 = 15.89t carried forward + 2.2t allocated in this stage giving an intensity of 18/10 = 1.80 tCO_2e/mmBtu

Emissions brought forward associated with A2.2 = 1.48 x 130 x 1.07 = 206.61 tCO_2e

Allocation of E2.1 to A2.2 = 85% x 100te x 130/140 mmBtu = 98.9 tCO_2e

Allocation of E2.2 to A2.2 = 85% x 100te x 130/140 mmBtu = 98.9 tCO_2e

Total allocated to A2.2 = 206.6t carried forward + 197.8t allocated in this stage giving an intensity of 404.5/130 = 3.11 tCO_2e/mmBtu

Total emissions allocated at this stage = 422.5 tCO_2e

A cross-check shows that total emissions = imported emissions + allocated emissions = 222.5 + 200 = 422.5 tCO_2e.

Note that a sub-allocation could be made around block 2.1; however, this has been incorporated into the detail above through use of the percentage of allocation to energy flows.

10.3.3 Stage 3 – LNG Production

The midstream stage includes:

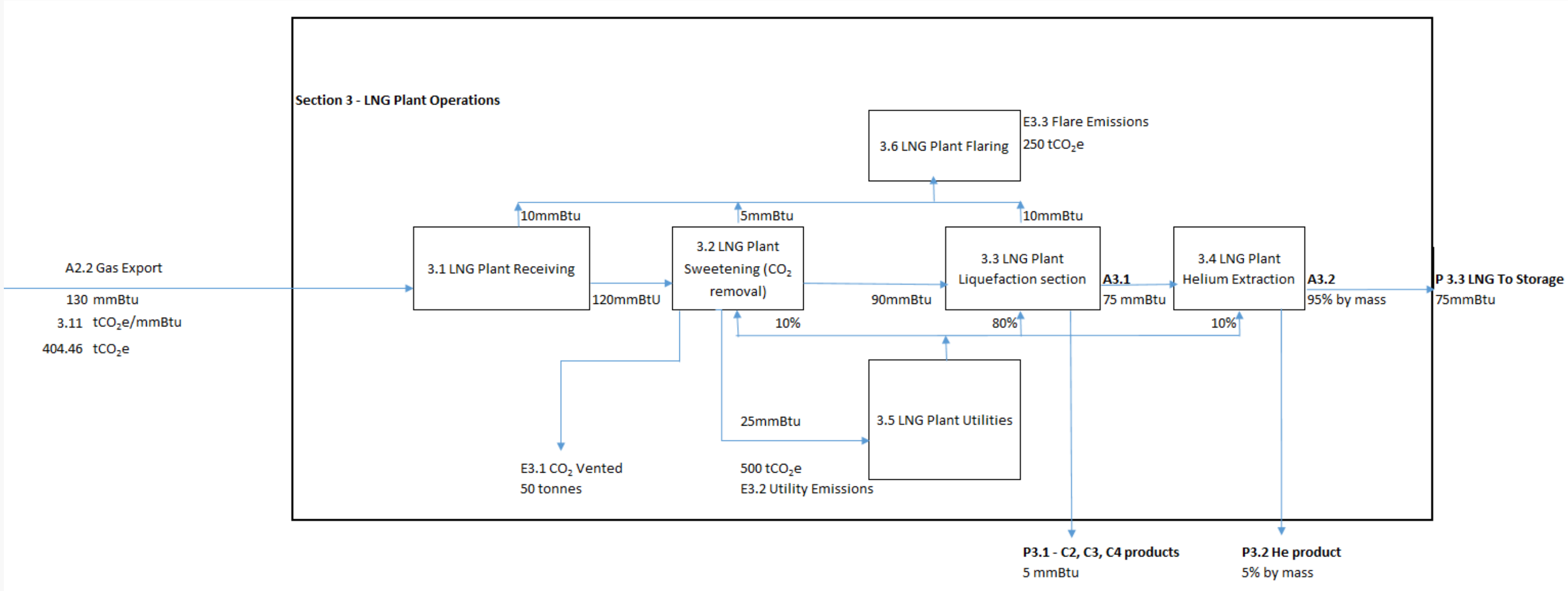
- 3.1 Receiving;
- 3.2 Gas sweetening;
- 3.3 LNG liquefaction;
- 3.4 Helium extraction from LNG;
- 3.5 Common utilities; and
- 3.6 Common flare systems.

Emissions are allocated in the following manner:

- E3.1 Emissions from gas sweetening – Allocated 100 percent to material leaving the LNG liquefaction plant based on energy content
- E3.2 Emissions from utilities plants – Allocated 10 percent to sweetening plant, 80 percent to LNG liquefaction and 10 percent to helium extraction
- E3.3 Flaring, single flare meter – Allocated among receiving, gas sweetening and LNG liquefaction based on energy content of the gas flared and estimated contribution from each section

Interim allocation point A3.1 (see flow chart below) is used to allocate emissions to P3.1 – C2-C4 products extracted in the LNG plant, on the basis of energy content.

The carried-forward GHG footprint at this point is then allocated by mass to P3.2 helium and P3.3 LNG to storage, at point A3.2.



Stage 3 Calculation basis

Emissions (CO_2e)	
E3.1 – CO_2 removed in sweetening	50
E3.2 – Utilities	500
E3.2 – Flaring	250
Total	800

Material Flows	**Energy Content (mmBtu)**
Inlet – A2.2	130
Products	
P3.1 – C2-C4 product	5
P3.2 - Helium	5% by mass
P.3 - LNG to Storage	95% by mass Energy content 75

Losses	
E3.2 – Utilities	25
E3.3 – Flaring (total)	25

Shrinkage ratio = total energy in/total energy out = 130 / 80 = 1.625

Interim allocation at point A 3.1 – after liquefaction, where P3.1 leaves the system

Emissions Allocation by Sub-stage %			
Stage	E3.1	E3.2	E3.3
3.3. LNG liquefaction	100	90	100

This allocation is then further split on the basis of energy content in P3.1 (5/80) and A3.1 (75/80):

Material Flows	Energy content (mmBtu)	Brought forward (CO_2e)	E3.1	E3.2	E3.3	Total (CO_2e)	Intensity (CO_2e/ mmBtu)	Leave/carry forward
A3.1 – LNG to Helium Extraction	75	379.19	47	422	234.375	1,082	14.43	CF
P3.1 – C2-C4 products	5	25.28	3	28	15.625	72	14.43	Leave

Detail

- Emissions brought forward associated with P3.1 = 3.11 x 5 x 1.625 (shrinkage factor) = 25.28 tCO_2e
- Allocation of E3.1 to P3.1 = 100% x 50te x 5/80 mmBtu = 3.1 tCO_2e
- Allocation of E3.2 to P3.1 = 90% x 500te x 5/80 mmBtu = 28.13 tCO_2e
- Allocation of E3.3 to P3.1 = 100% x 250te x 5/80 mmBtu = 15.63 tCO_2e

Total allocated to P3.1 – C2-C4 = 25.28t carried forward + 46.88t allocated in this stage giving an intensity of 72.15/5 = 14.43 tCO_2e/mmBtu

- Emission brought forward associated with A3.1 = 1.48 x 75 x 1.625 = 379.2 tCO_2e
- Allocation of E3.1 to A3.1 = 100% x 50te x 75/80 mmBtu = 46.88 tCO_2e
- Allocation of E3.2 to A3.1 = 90% x 500te x 75/80 mmBtu = 421.88 tCO_2e
- Allocation of E3.3 to A3.1 = 100% x 250te x 75/80 mmBtu = 234.38 tCO_2e

Total allocated to A3.1, LNG to helium extraction = 379.2 tCO_2e carried forward + 703.1 tCO_2e allocated14. in this stage giving an intensity of 1082.3/75 = 14.43 tCO_2e/mmBtu

Total emissions allocated at this stage = 1154.5 tCO_2e

A cross-check shows total emissions = imported emissions + allocated emissions = 404.5 + 750 = 1154.5 tCO2e.

Allocation at point A3.2 between helium product and LNG to storage.

Because helium is not an energy product, the allocation is by mass in this case.

Total embedded emissions brought forward at A3.1 = 1082.3 tCO_2e
Allocated emissions in this process = 10% of E3.3 = 50 tCO_2e

Total allocation to P3.2 = 1132.3 x 5% = 56.6 tCO_2e
Total allocation P3.3 = 1132.3 x 95% = 1075.69 tCO_2e

Intensity of final LNG product = 1075.69/75 = 14.34 tCO_2e/mmBtu

10.4 SGE Calculation Using Shrinkage Factors

The worked example provided in section 2.6 using the carry-forward method is reworked here using shrinkage factors to calculate the final SGE.

When using an energy-based allocation approach, the shrinkage factor for each stage is calculated as the ratio of total energy products entering the stage divided by the total energy product exiting the stage, whether remaining in the LNG value chain or leaving as a co-product.

When using a mass-based allocation such as for helium, the shrinkage factor is calculated using the mass percent of the product remaining in the LNG value chain. As an example, if the helium stage results in 5 percent by mass helium production, the shrinkage factor used for calculation of the LNG production intensity would be 1-0.05 = 0.95.

It is not possible to combine mass and energy-based shrinkage factors in a single stage; the stage must be split to allow two shrinkage factors to be defined.

Once the shrinkage factors have been calculated, these are applied to the intensity from the preceding stages. This allows the scaled intensities to be added to provide the overall intensity having accounted for losses and product diversion. In a simple two-stage process, for example, the scaled stage 1 intensity = stage 1 intensity x scaling factor (stage 1 to stage 2), and the total intensity is given as scaled stage 1 intensity + stage 2 intensity. All production assumptions, stages and co-product allocation assumptions are consistent with the treatment in section 2.6. As the table demonstrates, the SGE emissions intensity is the same for both the carry-forward and shrinkage factor approaches.

The principles of the approach are illustrated in the following examples:

Detailed Worked Example Using Shrinkage Factors

For the detailed worked example above, it is also possible to allocate based on the intensity calculated per stage, combined with the stage to stage shrinkage factors. In this case, each stage intensity must be multiplied by the shrinkage factors of each of the following stages, and the resulting modified intensities can then be summed.

Stage 1 scaled intensity would therefore be:

Stage 1 unscaled intensity x stage 2 shrinkage factor x stage 3 shrinkage factor … stage *N* shrinkage factor

In this case, because stage 3 uses both mass and energy-based allocation to deal with the helium production, two factors must be used.

Stage 1 intensity for A1.1 = 222.5 tCO_2e / 150 mmBtu = 1.48 tCO_2e/mmBtu

Stage 2 intensity for A2.1 = 197.9 tCO_2e / 130 mmBtu = 1.52 tCO_2e/mmBtu

Stage 3a intensity for A3.1 = 703.1 tCO_2e/ 75mmBtu = 9.38 tCO_2e/mmBtu

Shrinkage stage 1 => stage 2 = 150/140 = 1.07

Shrinkage stage 2 => stage 3a = 130/75 = 1.63

Shrinkage stage 3a => stage 3b = 0.95

Stage 1 intensity including shrinkage	= 1.48 x 1.07 x 1.63 x 0.95	= 2.45 tCO_2e/mmBtu
Stage 2 intensity including shrinkage	= 1.52 x 1.63 x 0.95	= 2.35 tCO_2e/mmBtu
Stage 3a intensity including shrinkage	= 9.38 x 0.95	= 8.91 tCO_2e/mmBtu
Stage 3b intensity (no shrinkage)	= 47.5 tCO2e / 75 mmBtu	= 0.63 tCO_2e/mmBtu
Total intensity	= sum of modified intensities	= 14.34 tCO_2e/mmBtu

Example of Emissions Tracking Across a Simplified LNG Value Chain																	
		Product Tracing							Emissions Tracing and Allocation						Shrinkage Factor Approach		
		Total Quantity of Product in LNG value chain at Start of Stage[1]	**Quantity of Product Used or Lost During Stage**[2]	**Quantity of All Products at End of Stage**[3]	**Quantity of Product Diverted from LNG value chain during stage**[4]	**Type of Product Diverted from LNG value chain (co-products)**	**Quantity of Product in LNG value chain at end of stage**[5]	**Type of Product in LNG value chain**	**Total Stage GHG Emissions**[6]	**Stage GHG Emissions associated with Product Diverted from LNG Value chain**[7]	**Embodied Emissions associated with Product Diverted from LNG value chain**[8]	**Total Emissions associated with Diverted Product**[9]	**Stage GHG Emissions associated with Product in LNG value chain**[10]	**Carry-forward Emissions associated with Product in LNG Value chain**[11]	**Emissions Intensity**[12]	**Shrinkage Factor**[13]	**Emissions intensity per stage with shrinkage factor applied**[14]
		mmBtu	mmBtu	mmBtu	mmBtu		mmBtu		$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$	$kgCO_2e$/ mmBtu		$kgCO_2e$/ mmBtu
Stage		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Production, Gathering and Boosting	1	6.00	-	6.00	3.00	Oil	3.00	Mixed gas	12.00	6.00		6.00	6.00	6.00	2.00	1.00	2.64
Gas Transport	2	3.00	0.20	2.80	-	None	2.80	Mixed gas	2.00				2.00	8.00	0.71	1.07	0.88
Liquefaction Plant	3	2.80	0.30	2.50	0.30	NGLs	2.20	LNG	12.50	1.50	0.96	2.46	11.00	18.04	5.00	1.12	5.50
LNG Transport	4	2.20	0.20	2.00	-	None	2.00	LNG	2.00				2.00	20.04	1.00	1.10	1.00
												SGE from carry-forward method in kgCO2e/ mmBtu:		**10.02**	SGE from shrinkage factor approach in kgCO2e/ mmBtu:		**10.02**

[1] Note that total products in each stage decrease (shrink) across the value chain. Causes of shrinkage across the value chain include use of product for power generation, flaring, boil-off, venting or production diversion from the value chain (e.g., co-product allocation). Although it is acceptable that total product decreases across the value chain, total product should not increase. After the first stage, total quantity in the LNG value chain at the start of stage (column A) is the same as the quantity of product in the LNG value chain at the end of the previous stage (column F). For example, A2 = F1.

[2] Examples of product used or lost during the stage includes gas used for power generation or lost to flaring, among other examples. Product that is still monetisable (and not used or lost) is tracked separately as diverted product. No stage emissions will be allocated to product that is used or lost, and embodied (carried-forward) emissions associated with product used or lost will be allocated to the remaining products at the end of the stage.

[3] Total quantity of product at the end of the stage does not include product used or lost during the stage, C = A – B. Also, D + F = C.

[4] Quantity of product diverted from LNG value chain includes co-products such as oil and natural gas liquids. Both stage and embodied (carried-forward) emissions are allocated to co-products. Note D + F = C.

[5] Quantity of product that continues in the LNG value chain decreases as the initial production stream is separated into other co-products and the gas stream is liquefied. Both stage and embodied (carried-forward) emissions are allocated to the products in the LNG value chain. Note D + F = C.

[6] The total stage GHG emissions are the GHG emissions that occurred during the corresponding stage. These emissions are allocated to both co-products and products. Note H = L + I.

[7] The stage GHG emissions associated with product diverted in the LNG value chain is the fraction of total stage emissions from H that are allocated to the co-products that leave the value chain. For example, in stage 1, the stage GHG emissions associated with product diverted from the LNG value chain are the share of the production facility's emissions that are allocated to oil. Emissions are allocated based on energy. I = H*D/C. Note that H = L + I.

[8] Co-products that leave the LNG value chain carry with them their share of the embodied emissions from previous processing (emissions that were carried forward). For example, the NGLs diverted from the LNG value chain in stage 3 carry with them their share of the emissions carried forward from the previous stages. The diverted upstream emissions for the NGL co-product example in the table is calculated as J3 = D3/C3*M2.

[9] The total emissions associated with the diverted product include both the allocated stage emissions and the diverted product's share of the embodied (carried-forward) emissions. In the table, this is calculated as K = I + J. Note that all other embodied emissions stay with the LNG product.

[10] The stage emissions associated with product in the LNG value chain is the fraction of total stage emissions from H that are allocated to the product in the LNG value chain. For example, in stage 1, the stage GHG emissions associated with product in the LNG value chain are the share of the production facility's emissions that are allocated to mixed gas. Emissions are allocated based on energy. L = H*F/C. Note that H = L + I.

[11] Emissions are carried-forward through the LNG value chain. Carried-forward emissions at the end of the stage include both stage emissions allocated to products in the LNG value chain and emissions associated with product in the LNG value chain that are carried forward from previous stages. Emissions are only removed if they are allocated to co-products that are diverted from the LNG value chain. For example, M2 = M1 + L2 – J2 and M3 = M2 + L3 – J3. The emissions intensity of the delivered LNG cargo is the total carried-forward emissions associated with product in the LNG value chain divided by the quantity of product delivered at the end of the LNG value chain. The emissions intensity of the delivered LNG cargo = M4/F4.

[12] Under the shrinkage approach, emissions intensity is calculated for each stage, N = L/F.

[13] Under the shrinkage approach, the shrinkage factor for the first stage is 1. After the first stage, the shrinkage factor is calculated as the quantity of all products at the end of the stage divided by the quantity of product that was in the LNG value chain at the beginning of the stage, O = A/C.

[14] Under the shrinkage approach, the emissions intensity for each stage is adjusted for shrinkage. The shrinkage-adjusted emissions intensity per stage is the stage emissions intensity multiplied by all shrinkage factors from stages after that stage. For example, P1 = N1*O2*O3*O4 and P2 = N2*O3*O4 and P3 = N3*O4. P4 = N4. Finally, to calculate the total emissions intensity, the shrinkage-adjusted emissions intensity is added for all stages (=N1+N2+N3+N4).

11 ANNEX C: EXAMPLE UNCERTAINTY DATA QUALITY INDICATOR MATRIX

Source of Uncertainty	Alignment to GHG Protocol Section 8	Score	Attributes and Score				
			1 (low)	2	3	4	5 (high)
Temporal Coverage	**Temporal Representativeness**	**Qualitative Attributes**	SGE is based on average production emissions taken over a period exceeding 12 months. Shipping emissions may not be voyage specific.	SGE is based on annual average production emissions of the year in which the relevant cargo has been delivered and the total number of cargoes delivered in that year. Shipping emissions may not be voyage specific.	SGE is based on average production emissions taken over the quarter within which the relevant cargo has been delivered. Shipping emissions would be expected to be voyage specific.	SGE is based on average production emissions taken over the month in which cargo is delivered. Shipping emissions would be expected to be voyage specific.	Production GHG is cargo specific, that is, near real time. Shipping emissions would be expected to be voyage specific.
		Justification for score selected					
Allocation Methods **(i.e., using data specific to the sites producing the LNG and following the defined approach)**	**Geographical Representativeness** **Technological Representativeness**	**Qualitative Attributes**	Allocation is based on average industry data and may not include differentiation by stage. Shipping GHG emissions may be based on the relevant voyage, but using average performance data for the type of ship used to carry the cargo or on average performance data for all LNG carriers.	Allocation is based on averaged data for basin, region or technology, using a stage-based approach. Shipping GHG emissions may be based on the relevant voyage, but using average performance data for the type of ship used to carry the cargo.	Allocation is site specific, but does not consider an energy-based approach at any stage. Shipping GHG emissions are based on specific, relevant voyage using data from the ship used to carry the cargo.	Allocation is site specific and energy based, per stage, but does not follow the carry-forward approach as outlined in SGE Methodology; that is, all emissions may be allocated at the stage in which they occur. Shipping GHG emissions are based on specific, relevant voyage using data from the ship used to carry the cargo.	Allocation of emissions is site specific and energy based. The method follows a granular approach so that no GHG is allocated to a product downstream of its rundown in the process. Shipping GHG emissions are based on a specific, relevant voyage using data from the ship used to carry the cargo.
		Justification for score selected					
Data Sources and Measurement Accuracy **(i.e., primary versus secondary approaches and data management)**	**Technological Representativeness** **Completeness**	**Qualitative Attributes**	Data is based on secondary approaches in all respects.	Secondary data is used for part or all of production intensity, that is, specific intensity for LNG plant and average data for pipeline gas supply. Shipping may be voyage specific.	All data are based on primary sources and use site-specific approaches. Activity data may be metered or estimated. Measurement systems may not have defined calibration or maintenance approaches or may have installation and design factors that affect accuracy. Some activity data may be from primary alternate methodologies, such as mass balance, valve positioning and engineering estimates. Estimates have no routine update. Emission factors for major sources may be based on sampling an analysis or may use modelled / design / proxy values on a limited	All data are based on primary sources and use site-specific approaches. Activity data are metered, using high-quality measurement systems with defined calibration and maintenance approaches. Some activity data may be from primary alternate methodologies, such as mass balance, valve positioning and engineering estimates. Emission factors for major sources may be based on sampling an analysis or use modelled / design / proxy values on a limited basis such as for flaring, fugitives and so on. Modelled compositions are regularly	All data are based on primary sources and use site-specific approaches. Activity data are metered, using high-quality measurement systems with defined calibration and maintenance approaches. Emission factors for major sources are site specific based on a defined sampling plan or use of online GC analysis. Laboratories used for analysis follow a quality management system certified to or consistent with ISO17025. Fugitives estimations are based on site-specific data/measurements

Source of Uncertainty	Alignment to GHG Protocol Section 8	Score	Attributes and Score				
			1 (low)	2	3	4	5 (high)
					basis such as for flaring, fugitives and so on. Modelled compositions are not routinely updated. Laboratories used for analysis follow a quality management system certified to or consistent with ISO17025. Default factors may be used for standard commercial fuels.	updated based on process changes. Laboratories used for analysis follow a quality management system certified to or consistent with ISO17025. Default factors may be used for standard commercial fuels. Data is taken from a single controlled source with limited manipulation.	(such as those meeting tier 5 of OGMP 2.0). Default factors may be used for standard commercial fuels. Data taken from a single controlled source with limited manipulation.
		Justification for score selected					
Data Completeness	**Completeness**	**Qualitative Attributes**	SGE Methodology does not address completeness. This could include the use of secondary data for all aspects of reporting.		Methods used include all material sources. May also include sources not specifically required for the SGE, such as drilling.	All relevant sources included as per SGE. Non-material sources and some material sources may be estimated and may exceed to 5% per stage, 2% total. Data sources match temporal boundary.	All relevant sources included as per SGE. Non-material sources may be estimated up to 5% per stage, 2% total. Data sources match temporal boundary.
		Justification for score selected					
Data Consistency	**Reliability**	**Qualitative Attributes**	Data quality or transparency prevents verification to source, or verifier unable to issue an opinion or limited assurance with significant findings. Internal control processes are limited and ineffective, with no separation between data origination and internal assurance.		All data are verifiable, though may include use of substantial secondary data. This results in a limited assurance opinion with no major findings, though there may be improvement recommendations.	All data are verifiable (assume SGE verification process will take place). There may be minor conformance issues and improvement recommendations at SGE verification, allowing reasonable assurance statement with comments. There is no significant verification finding related to internal control processes.	All data are verifiable (assume SGE verification process will take place). There will be no significant findings at SGE verification, allowing a reasonable assurance statement with no comments. There is no verification finding related to internal control processes.
		Justification for score selected					

12 ANNEX D: CONTENT OF THE SGE METHODOLOGY MONITORING PLAN (MMP)

It is expected that the majority of Reporters using the SGE Methodology will already have well-established GHG accounting processes and practices at the installation and corporate levels, based around regulatory or corporate GHG inventory reporting needs. It is not the intent of the SGE Methodology to require development of a new approach to GHG accounting, but rather to utilise existing data sources and calculation methodologies and adapt these to meet the criteria and methodological approaches set out in the SGE Methodology and the appropriate reference standards.

ANNEX D sets out the minimum content of a Methodology Monitoring Plan for the SGE Methodology. It may be interpreted in the context of existing systems and processes, which may be appropriately cross-referenced with the SGE Methodology and focused on the relevant elements for determining the SGE.

The monitoring plan for a participant shall contain at least the following information:

1. General information on the installations and activities included in each stage

(a) A description of the installation(s) and activities carried out by the installations that are relevant to each stage included within the reporting boundary, including a list of energy flows, emissions sources, and fuel or emission streams to be monitored, the GHGs included. The description should meet the following criteria:

- It must sufficiently put forth how to demonstrate that neither data gaps nor double counting of emissions and energy content occur.
- It must include a simple diagram of the emission sources, source streams, sampling points and metering equipment in order to support and simplify describing the installation or referencing emission sources, source streams, measuring instruments and any other parts of the installation relevant for the MMP, including data flow activities and control activities.

(b) A description of the procedure for managing the assignment of responsibilities for monitoring and reporting within the installation and for managing the competences of responsible personnel.

(c) A description of the procedure for regular evaluation of the monitoring plan's appropriateness, covering at least the following:

- Checking the list of emissions sources and source streams, ensuring completeness of the emission sources and source streams and that all relevant changes in the nature and functioning of the installation will be included in the MMP.
- Assessing potential measures for improvement of the MMP applied, specifically improving access to primary data sources, improving accuracy of data used and reducing uncertainty of the SGE.

(d) A description of the written procedures of the data flow activities, including a diagram where appropriate for clarification.

(e) A description of the written procedures for the control activities established.

(f) The version number of the MMP and the date from which that version of the monitoring plan is applicable.

2. A detailed description of the calculation-based methodologies where applied, consisting of the following elements:

(a) a detailed description of the calculation-based methodology applied, including a list of input data and calculation formulae used, a list of all relevant calculation factors and the approach to co-product allocation;

(b) where the operator intends to make use of simplified approaches, a listing of those sources to which the simplified approaches will apply and an estimation of the percentage of the SGE covered;

(c) a description of the measurement systems used, their measurement range and the exact location of the measuring instruments to be used for each of the source streams and energy flows to be monitored (see number 4 below);

(d) where applicable, for each of the source streams, the default values used for calculation factors indicating the source of the factor or the relevant source from which the default factor will be retrieved periodically;

(e) where applicable, a list of the analysis methods to be used for the determination of all relevant calculation factors for each of the source streams and a description of the written procedures for those analyses;

(f) where applicable, a description of the procedure underpinning the sampling plan for the sampling of fuel and materials to be analysed and the procedure used to revise the appropriateness of the sampling plan; and

(g) where applicable, a list of laboratories engaged in carrying out relevant analytical procedures and details of any laboratory accreditations or, where the laboratory is not accredited, a description of the quality management system approach in use.

3. Where a secondary data methodology is applied to all or part of the SGE Methodology, a detailed description of the monitoring methodology applied for those stages or emission sources and justification of the appropriateness of the secondary data used

4. A detailed description of the measurement-based methodologies, where applied, including the following:

(a) a description of the measurement method, including descriptions of all written procedures relevant for the measurement and the following:

- Any calculation formulae used for data aggregation and used to determine the annual emissions of each emission source
- The method for determining whether valid hours or shorter reference periods for each parameter can be calculated and for substitution of missing data

(b) a list of all relevant emission points during typical operation phases and during restrictive and transition phases, including breakdown periods or commissioning phases, supplemented by a process diagram where requested by the competent authority;

(c) where flue gas flow is derived by calculation, a description of the written procedure for that calculation for each emission source monitored using a measurement-based methodology;

(d) a list of all relevant equipment, indicating measurement frequency, operating range and uncertainty;

(e) a list of applied standards and of any deviations from those standards;

(f) a description of the written procedure for carrying out the corroborating calculations where applicable;

(g) a description of the method of how CO_2 stemming from biomass is to be determined and subtracted from the measured CO_2 emissions and of the written procedure used for that purpose, where applicable; and

(h) where applicable and where the operator intends to make use of simplification for minor emission sources, a categorisation of the emission sources into major and minor emission sources.

5. A detailed description of the monitoring methodology where inherent CO_2 is captured and transferred for storage or use in EOR in the form of a description of the written procedures applied for monitoring any leakage from the transport and storage networks, including the following elements:

(a) where applicable, the location of equipment for temperature and pressure measurement in transport networks;

(b) where applicable, procedures for preventing, detecting and quantifying leakage events from transport networks;

(c) in the case of transport networks, procedures effectively ensuring that CO_2 is transferred only to installations where any emitted CO_2 is effectively monitored and accounted for;

(d) where applicable, a description of continuous measurement systems used at the points of transfer of CO_2 between installations transferring CO_2 or the determination method used; and

(e) where applicable, quantification methodologies for emissions of CO_2 released to the water column from potential leakages as well as the applied and possibly adapted quantification methodologies for actual emissions or CO_2 released to the water column from leakages or otherwise lost from the storage facility.

6. A detailed description of the methodology used to allocate GHG emissions at all stages of the LNG production process, including the following elements:

(a) the approach to segregation of the processes into suitable blocks and determination of energy content, inputs, outputs and emission sources per block; and

(b)

(c) the allocation principle adopted in line with section 2.5, and where an energy-based approach has not been taken, a description of why this is not considered practicable.

7. A detailed description of the approach to data correction in general and to the annual evaluation of and, if necessary, implementation of any required corrections to SGEs issued in the previous year, based on an annual verification process.

8. A detailed description of any projects within the boundary of each stage that have been registered for the issuance of carbon credits and the associated accounting treatment to avoid double counting between the emissions included in the SGE and the emissions from any third party that may utilise the carbon credits as an offset.

13 ANNEX E: EXAMPLE SOURCES OF SECONDARY DATA

Secondary Data Resource	Description	Boundaries	LNG Life Cycle Stages	Products	Type of Data	Comments	Reference Documents	Links
The Oil Production Greenhouse Gas Emissions Estimator (OPGEE)	Open source engineering-based LCA tool specifically for oil production that estimates GHG emissions from production, processing and transport of crude	Exploration to refinery gate	· Exploration · Production · Transport	· Crude · Produced gas	· Secondary preferred (process unit-level emission factors) · Secondary alternate (stage-level emission factors)	Includes embodied emissions from construction materials (e.g., concrete, steel) and raw materials (e.g., DEA, TEG)	OPGEE_documentation_v2.0.pdf	http://pangea.stanford.edu/departments/ere/dropbox/EAO/OPGEE/OPGEE_documentation_v2.0.pdf
GABI	General licensed LCA modelling software and content databases, now owned by Sphera	Extraction to end of life for numerous raw materials and processes; not specific to oil and gas	· Well drilling · Natural gas production and processing · Transportation via pipeline · Liquefaction	· Economywide products · LNG	· Secondary alternate data	Data set includes well drilling, natural gas production and processing, transportation via pipeline and LNG tanker, and liquefaction; main technologies such as conventional (primary, secondary, tertiary) and unconventional production (shale gas, tight gas, coal bed methane), both including parameters like energy consumption and transport distances; gas processing technologies individually considered for each production country; all LNG delivering countries contribute by their corresponding shares (taken from national statistics) to the LNG mix; inventory mainly based on secondary data	GaBi_Life_Cycle_Engineering_ Suite_15.pdf	http://gabi-documentation-2021.gabi-software.com/xml-data/processes/2bd997cf-bc56-4963-a194-10514d00cd30.xml https://gabi.sphera.com/america/databases/gabi-data-search/ https://gabi.sphera.com/uploads/media/GaBi_Life_Cycle_Engineering_Suite_15.pdf
SimaPro model and Ecoinvent database	General licensed LCA modelling software and Ecoinvent content databases	Extraction to end of life for numerous raw materials and processes; not specific to oil and gas		· Economywide products · LNG	· Secondary alternate data			
Wood MacKenzie LNG Carbon Emissions Tool	LNG life cycle tool developed by Wood MacKenzie and offered as a licensed software tool	According to website, tool includes CO_2 and CH_4 emissions from 18 emission sources along the LNG value chain	· Upstream Ppipeline · Liquefaction · Shipping · Regasification · End market	· LNG	· Secondary preferred data · Secondary alternate data	Includes emissions estimations for all operational and under-construction LNG projects, as well as those expected to take FID in the next 18 months; estimate the CO_2 and CH_4 emissions from 18 distinct emissions sources along the LNG value chain, from upstream production to gas combustion; allows the selection of vessel size, speed and propulsion technology in calculating the shipping emissions		https://www.woodmac.com/consulting/multi-client-studies/LNG-Carbon-Emissions-Tool/
US National Energy Technology Laboratory (NETL) LCA Tool	Open source LCA tool for LNG sourced from the US	· Cradle to gate · Cradle to grave	· Extraction · Processing · Transport · Energy conversion facility · Product transport · End use	· US domestic natural gas (7 sources, from conventional to shale basins) · LNG	· Secondary preferred data · Secondary alternate data	NETL LCA model contains 127 unit processes that account for emissions from projection through transmission	NETL, *Life Cycle Greenhouse Gas Perspective on Exporting Liquefied Natural Gas From the United States: 2019 Update* NETL, *Life Cycle Analysis of Natural Gas Extraction and Power Generation*, May 29, 2014	https://globallnghub.com/wp-content/uploads/2019/10/2019-NETL-LCA-GHG-Report.pdf https://www.netl.doe.gov/projects/files/NaturalGasandPowerLCAModelDocumentationNG%20Report_052914.pdf

14 ANNEX F: EXEMPLAR SGE AND VERIFICATION REPORT FORMATS

Although the following report formats include all of the information required by the SGE Methodology, these are to be considered as exemplar formats only, and it is recognised that both Reporters and verifiers may have pre-existing requirements for document formatting.

Example Statement of Greenhouse Gas Emission (SGE) Report

1. Cargo Details

Reporter		
Load Port		
Date Cargo Loaded		
Discharge Port		
Date Cargo Delivered		dd/mm/yyyy
Vessel Used (name/IMO number)		

Cargo Type	LNG	
Quantity		tLNG
Energy Content		mmBtu total
LNG HHV		mmBtu / tLNG

Alternative units may be used, but must be specified

2. GHG Data

2.1. GHG included

	CO_2	CH_4	N_2O
Yes/No			
GWP Applied	1	28	265

2.2 Per Cargo GHG Intensity

	CH_4 $tCH_4/tLNG$	CH_4 $tCH_4/mmBtu$	% Secondary Data Used (drop-down options)
Methane Cargo Intensity			**51-75%**

	GHG $tCO_2e/mmBtu$	% Secondary Data Used (drop-down options)
Total Cargo Intensity		**51-75%**

Total Cargo SGE (tCO_2e)	
Total Cargo Delivered (mmBtu)	

2.3 Emissions Breakdown

	GHG Emissions Allocated to the LNG Product Stream	**Stage intensity**	**Stage Shrinkage Factor**	**Methods**
Lifecycle Stage (may be combined)	**GHG tCO_2e**	**tCO_2e/ mmBtu**	**ratio**	**% Secondary Data Used (drop down options)**
Production and Gathering				**<25%**
				25-50%
Transmission				**51-75%**
				>75%
Liquefaction, Storage and Loading				**<25%**
				<25%
Shipping and Unloading				**<25%**
				<25%
				<25%

Example SGE Verification Report

1. Verifier Details

Name of Verification Body		
Verification Body Address		
Verification Body Contact Phone Number		
Verification Standard Applied		
Accreditation Body (ISO 14065) and Reference		If not accredited state "None."

Lead Verifier	
Verifier 1	
Verifier 2	
Technical Expert 1	
Technical Expert 2	

Independent Technical Reviewer	
Authorisation to Issue	

2. SGE Details

Reporter		
Load Port		
Discharge Port		
Date Cargo Delivered		dd/mm/yyyy
Vessel Used		

Cargo Type	LNG	
Quantity Delivered		tonnes
Energy Content		mmBtu total
LNG HHV		mmBtu / tonne

	tCO2e/mmBtu	% Secondary Data Used
Total Cargo Intensity	1.25	**51-75%**

Total Cargo SGE (t CO2e)	

3. Verification details

3.1 Opinion

Date of Opinion		dd/mm/yyyy
Opinion	Verified With Comments	
Level of Assurance	Reasonable Assurance	
Date of Site Visits		dd/mm/yyyy
Personnel Carrying Out Site Visits		

3.2 Reliance on verification by others

Stages Verified by Others		**Y/N (drop down)**
Production and Gathering	Extraction	No
	Gathering and Boosting	No
Transmission	Mid-stream Processing	No
	Pipeline Transmission	No
Liquefaction, Storage and Loading	Liquefaction	No
	Storage and Loading	No
Shipping and Unloading	Shipping - Ballast Leg	Yes
	Shipping - Laden Leg	Yes
	Unloading	Yes

3.3 Verification Detail

Summary of Verification Activities Undertaken	
Verification Findings	
Recommendations for Improvement	
Mis-statements or Non-conformities Identified and Not Corrected Prior to Issuance	
Are any mis-statements or non-conformities material?	No