MiQ Supply Chain Protocol

Background

MiQ strives to provide buyers and end-users with complete emissions intensity data for the natural gas supply chain so they may make informed decisions on what gas they chose to source. In the last few years, carbon intensity and methane intensity of natural gas, has become of critical importance to importing countries, utilities and industrial consumers that buy gas or import LNG, as well as hydrogen and ammonia producers who readily source natural gas as feedstock.

MiQ has developed a robust, measurement-informed, third-party assured program, known as MIQ Certification, for evaluating emissions performance at the asset level, in order to provide the market with the highest quality emissions data available today.

However, at this early stage the voluntary market is facing two critical issues:

(1) A lack of certified measurement-informed, high-quality data from each segment of the supply chain
(2) A growing list of heterogenous MMRV methodologies, voluntary initiatives[1], and regional studies each attempting to assess the amount of methane loss from various regions, countries, or a company's operational footprint.

There is an urgent, unmet need to credibly map the full gas supply chain emissions for buyers and importers. How else will these parties base their gas purchase decisions upon credible emissions profiles, and drive down overall emissions? For reference, a full gas supply chain can involve several different segments from well to gate, each with different emissions data sources and quality.

Considering the above, MIQ has built an open protocol based on accepted LCA principles to qualify the heterogenous data sources required to build the full gas supply chain. This Protocol allows a wide variety of data sources – certified and uncertified - and rank or map the quality of each data methodology. It shall also evolve to incorporate new methodologies and methane science.

Build upon existing LCA methodologies

MiQ believes that alignment around workable life-cycle assessment (LCA) methodologies with meaningful and fit-for-purpose data quality indicators can support end users and the energy market with informed decisions. LCA methodologies - where designed to meet the needs of the user - can identify the materiality of emissions from a supply chain, combine heterogenous data sources, fill in the gaps with best available information, all while defining standards for what passes as the highest fidelity of information.

Below we describe the **MiQ Supply Chain Protocol for Natural Gas,** a framework of data quality indicators to support the development of full supply chain emission intensities. We encourage adoption of this open-source, LCA framework by regulators, certifiers, importers, and gas end-users.

MiQ's aim is to continue to certify only the highest-quality, measurement-informed, third-party assured, asset-level emissions data ,while simultaneously supporting best-available information to the marketplace for use in such supply-chain analyses.

[1] https://highwoodemissions.com/reports/voluntary-emissions-reduction-initiatives-in-2023/

Supply-chain analyses

As stated above, MiQ's goal is to provide buyers the complete and robust emissions data from the full natural gas supply chain to natural gas end-users for the purposes of supporting informed market decisions based on methane and greenhouse gas emissions. To accomplish this, MiQ draws on the guidance for developing life cycle inventories (LCI) as established by ISO14050[2] and 14044[3]. A number of key principles must be honoured under this guidance:

- **The boundaries must be defined**: for MiQ's Protocol, the boundaries include "well-to-gate" emissions. The well must include all extraction and production activities. The gas is defined as the offtake point of a major natural gas buyer such as a utility or industrial user. For LNG shipments, the gate may be in a different country as the well.
- **The environmental factors assessed, and process unit must be defined**: MiQ's Protocol evaluates GHG emissions, as limited to CO_2, N_2O and CH_4 emissions. MiQ will provide raw emissions data only and does not prescribe a specific global warming potential in the calculation of a CO_2e. At minimum, an LCI must include CH_4 emissions or "methane loss", to support an informed natural gas marketplace. For consistency, the process unit must be defined and applied consistently throughout the LCI. In this protocol, the process unit as 1 MMBtu of pipeline-quality natural gas, with a heating value of 1.04 MMBtu/Mscf and 95% methane molar content. Emissions are evaluated on an annual or rolling 12-month basis to avoid omission of stochastic or fat-tail emissions which may represent a significant portion of the LCI.
- **Unit processes** (or the smallest element considered in the LCI for which input and output data are quantified) **must be defined**: MiQ's Protocol defines a process unit as the inclusive emissions under a single asset in a single region managed by a single operator. For some operators, this includes only one stage of the natural gas supply chain, from Production, Boosting and Gathering, Processing, Transmission, Storage, Liquefaction, Shipping, Regasification. For integrated operators, the unit process may include a combination of these stages. Further division is not permitted as to avoid omission of emissions from older, neglected, lower-producing or higher risk equipment within an asset which may significantly impact the LCI. Emissions associated with shrinkage (i.e. fuel gas usage) or non-energy intensives streams, must be included at the output of each unit process.
- **A materiality of emission sources must be evaluated**: for MiQ's Protocol, all segments of the natural gas supply chain must be estimated from well to gate. Natural gas moved across large international regions must also include the emissions from international transportation. For seaborne: LNG liquefaction, shipping and/or regasification must be included. Piped: Transmission must be included.
- **Data quality should be evaluated** for each LCI: The MiQ Protocol utilizes data quality indicators based on guidance from ISO 14044 to evaluate the level of confidence for emissions data from each unit process, assessing Time-related representativeness, Geographical Representativeness, Technological Representativeness, Completeness, and Reproducibility. A full treatment of these data quality indicators is found below and in Appendix A.

[2] ISO 14040: Environmental Management - Life Cycle Assessment - Principles and Framework ; Author, International Standard Organization ; Published, 1997, Amended 2020.

[3] ISO 14044: Environmental Management—Life Cycle Assessment—Requirements and Guidelines," International Organization for Standardization (ISO), Geneve, 2006, Amended 2020

Data quality requirements

A full Life Cycle Inventory of a natural gas supply chain can be developed based on the boundaries and definitions outlined above. MiQ seeks to provide a minimum level of data quality for each LCI to ensure sufficient marketplace confidence for decision making. These minimum data quality thresholds are expected to evolve over time as improved data quality across the sectors become available and markets impose stricter requirements on data quality and lower uncertainty.

In order to assess data quality, MiQ refers to ISO14044 which outlines the following critical topics areas:

a) time-related coverage: age of data and the minimum length of time over which data should be collected;
b) geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the study;
c) technology coverage: specific technology or technology mix;
d) precision: measure of the variability of the data values for each data expressed (e.g. variance);
e) completeness: percentage of flow that is measured or estimated;
f) representativeness: qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage);
g) consistency: qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis;
h) reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study;
i) sources of the data;
j) uncertainty of the information (e.g. data, models and assumptions)

Table 1. Matrix of Data Quality indicators for evaluation of quantified emissions (CO2e, or CH4) in a natural gas life cycle inventory per unit process

DQIs	**<-- Highest Score**		**Lowest Score -->**
Time-related representativeness	1. <3 yrs	2. <6 yrs	3. <10 yrs
Geographical representativeness	1. Asset-level, asset that is being evaluated	2. Sub-asset level or regional, same geographical region	3. Country-level estimate, if multiple regions are possible
Technological representativeness	1. Quantification methods include measurement-based, facility-specific emission factors, process models or calculations which address all "technologies" within a unit process and a temporally complete range of operating conditions or emission distributions	2. Quantification methods include generic emission factors addressing all "technologies" or emission sources within unit process	3. Quantification methods apply emission category level factors, or are estimated by comparing similar unit processes where more data is available
Completeness	1. A materiality of unit process flow as well as emissions flow is captured by quantification methods (i.e. through temporally complete and/or spatial top-down and bottom-up quantification methods)	2. A materiality of unit process flow and emissions flow is captured through either top-down, or bottom-up quantification methods, or comparable representation through a moderate sampling set	3. A small sampling size of unit process and emissions flow is used to represent larger asset
Reproducibility[4] *See EPA DQIs: Process Review*	1. Third party audit with reasonable assurance[5] or peer-reviewed studies	2. Third party audit with limited assurance[6] or non-peer reviewed publication (i.e. white paper)	3. Self-reporting or First party audit

[4] Reproducibility category references the process review from EPA DQIs: EPA/600/R-16/096, June 2016, retrieved from: www.epa.gov/research. Protocols must be available to third party auditors.
[5] Reasonable Assurance, consistent with EPA requirements for DQI's (footnote 4), must include a subject matter expert (SME) for emissions in question as well as an LCA Expert. Reasonable Assurance means sufficient evidence is gathered as part of a systematic review which identifies key risks and involves tests of controls, data verification, and evaluation of underlying assumptions and methods. Includes site visits to test data management processes and equipment.
[6] Limited Assurance means sufficient evidence is gathered, though it's deliberately limited, focused on the GHG inventory and underlying data, with testing procedures more limited in scope and no site visits to verify emissions sources and data.

Table 1 above illustrates how the above ISO 14044's guidance is used to evaluate the data quality from various sources on natural gas emissions. These topic areas were aggregated and combined under 5 unique categories, entitled: **time-related representativeness, geographical representativeness, technological representativeness, completeness, and reproducibility**. "Precision" and "uncertainty" as related to measurement-informed inventories are subsumed under the requirements for "technological representativeness" and "completeness", however we offer suggestions for calibrating variance for unit process and supply chain emissions over time, below. "Consistency" is achieved through adherence to the requirements for process unit-level LCI definitions set forth above.

Currently available data sources range greatly from peer-reviewed academic publications of measurement campaigns to national inventories based on generic emission factors. Data scales also range from national to regional to asset level. Most sources of data are accepted using this approach, but are ranked as shown below against five DQI categories. Consistent with methods applied in many risk matrices, scores for each category are multiplied together to result in a single data quality indicator for each unit process. Examples of how DQI's may be calculated for select heterogenous data sources at the unit process level can be found in **Appendix A.**

DQIs are useful when applied at the full supply chain or system process[7] level, to compare or judge respective natural gas streams – particularly where the life cycles are complex and require various data sources. The following examples are offered to illustrate how DQI's could be functionally put into practice:

- Minimum requirements for data quality are imposed by governing bodies for enforcing emission intensity thresholds (i.e. a materiality of unit process emissions must have a DQI score of ≤x for the value to qualify for use), thereby assuring sufficient fidelity for importing thresholds or usage within an emissions trading scheme. Note, there is a risk and perverse incentive to requiring a materiality of total supply chain emissions to meet a minimum DQI, as oftentimes the least emitting operators also are pursuing the highest quality metrics and assurance for evaluating their emissions. Alternatively, this can be dealt with by requiring minimum DQIs for the highest impact segments where the risk of undercounting or uncertainty is the greatest.

Table 2. Minimum DQI's required for each unit process in the natural gas life cycle inventory.

Unit Process	Segment Impact	Minimum Data Quality Indicator (DQI)
Onshore + Offshore Production	High Impact	≤2
Boosting & Gathering	Med Impact	≤6
Processing	Low Impact	≤12
Transmission	Low Impact	≤12
Storage	Low Impact	≤12
Liquefaction	Low Impact	≤12
Shipping	Low Impact	≤12
Regasification	Low Impact	≤12

[7] Def: system process - the result of the compilation and quantification of inputs and outputs for a product throughout its life cycle (ISO 14040). A system process is a single, cradle-to-gate aggregation of all environmental flows caused by the provision of the reference product.

- Skew factors (i.e. +30% for DQIs ≤x, +50% for DQIs ≤y) are added to system process emissions and calibrated over time through global tracking programs. This method may be best applied where absolute emission intensities (as opposed to thresholds) are utilized.
- In instances where uncertainty is difficult to consistently evaluate, confidence bounds or uncertainties may be approximated using various DQIs (i.e. ±10% for DQIs ≤x, ±50% for DQIs ≤y)

The first option is illustrated for a potential import threshold where different minimum data quality indicators are required for each segment of the supply chain (**Table 2**). **High-impact segments** are defined as possessing the highest risk for unaccounted emissions or super-emitting methane events which may require higher quality data thresholds. Such sectors may also often represent a significant portion of emissions in a given LCI, if all segments were accounted for equally. **Low-impact segments** are defined as possessing the lowest relative risk for unaccounted for emissions or representing a significant portion of the LCI emissions. Under this scheme, high-impact segments would be required to have a data quality indicator of 2 or better. Medium impact segments would need a data quality indicator of 6 or better, while low impact segments would need 12 or better.

Calculating total supply-chain methane emissions

MiQ currently[8] defines emissions for each certified segment – or unit process – on a g/MMBtu basis of pipeline quality gas. This Supply Chain Protocol proposes to calculate supply chain emissions for the combined life cycle inventory on g/MMBtu basis of gas delivered to the gate. The total LCI can be calculated as the sum of the emissions from individual unit processes. As shrinkage and process gas must be accounted for in each unit process, it is not further calculated at this stage.

Under the MiQ Supply Chain Protocol, a supply chain LCI must contain at minimum CH4 emissions for each unit process. A complete GHG intensity, or CO2-equivalent, emissions are encouraged yet optional under the Protocol, yet must evaluate individual emission intensities for CO2, N2O and CH4 for each unit process. To calculate the CO2-equivalent, the relevant GWP can be multiplied for each greenhouse gas, however, the same GWP must be used for each unit process in order to calculate a combined supply chain CO2-e. MiQ recommends the use of the 20-year GWP, which is 82.5 times that of CO2 for methane under AR6[9].

In cases where no data is available at the threshold DQI required for the segment, we recommend an operator applies the best available data source (lowest DQI available) and then assigns and adds an uncertainty or correction factor to the available data, where supporting information is available. For example, the current US GHGI has been evaluated to underestimate national US methane emissions in the production sector by at least 1.5-2.0x according to Rutherford et al (2021)[10]. A producer wishing to apply

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[8] https://miq.org/document/miq-program-guide/

[9] Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, ... B. Zhou (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[10] Rutherford, Jeffrey S., Evan D. Sherwin, Arvind P. Ravikumar, Garvin A. Heath, Jacob Englander, Daniel Cooley, David Lyon, Mark Omara, Quinn Langfitt, and Adam R. Brandt. “Closing the methane gap in US oil and natural gas production emissions inventories.” Nature communications 12, no. 1 (2021): 4715

a data source from the GHGRP, circa 2022 reporting year under the previous Subpart W reporting methodologies, might add 60% correction factor to this value.

Note, while uncertainty may be evaluated as a +/- (plus or minus) estimate around a mean value, market instruments require a single value to build a portfolio. It is standard practices when marketing gas to evaluate the price with the conservative case; given this precedent

Worked Examples

To illustrate how the MiQ Supply Chain Protocol can be applied in practice, the following case-studies evaluating two potential natural gas supply chains located inside the US, as well as two importing gas supply pathways to the European Union, are found below in **Figure 1**.

For the domestic US supply cases, the total CH_4 intensity for the two system processes range by a factor of 2, from ~180 gCH4 / MMBtu to ~90 gCH4 / MMBtu. Data quality indicators for each unit process in this example range from 1 (best) to 12 (worst). For the EU import supply cases, the total CH_4 intensity for the two system processes range by more than a factor of 2, from ~120 gCH4/MMBtu to ~50 gCH4 / MMBtu. The extent of the supply chain illustrates the impact of transport on the final CH4 intensity. In theory, European buyers can assess the overall reliability of the two supply chain emission inventories as "high" given the adherence to the MiQ Protocol requirements, however may impose stricter DQI requirements over time as data becomes available. The US and EU utilities may also use the resulting emissions intensity to determine scope 3 impact on their company's carbon footprint or structure gas contracts and pricing with regards to the relative emissions.

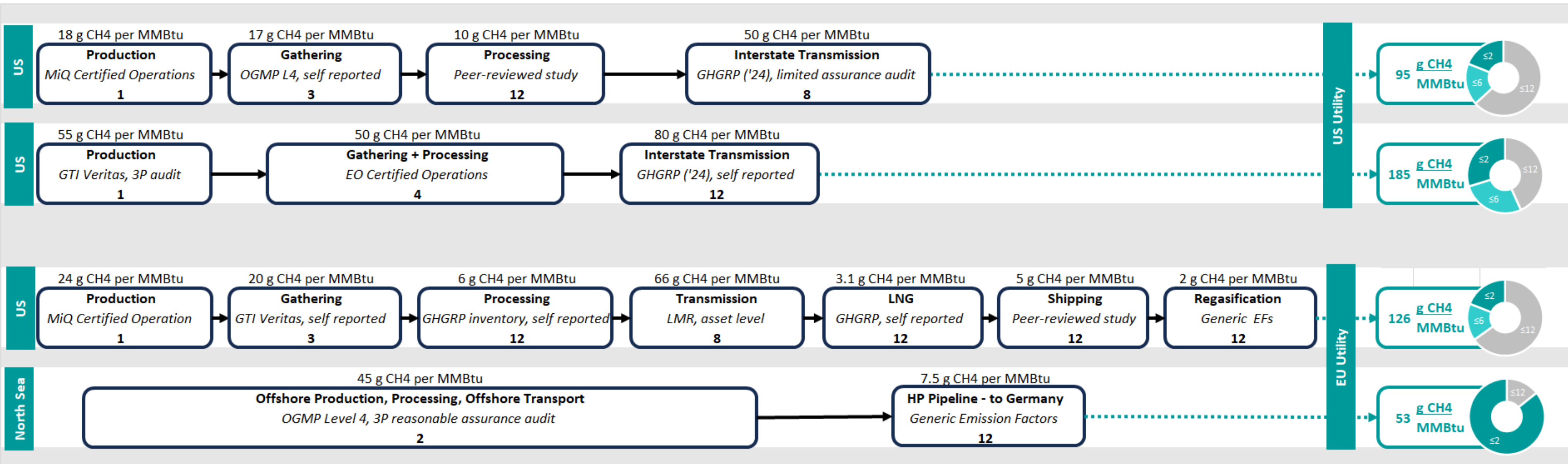

Figure 1. Calculated System Process methane emissions for two natural gas supply chains delivered to a theoretical US and EU utility

Conclusions

- Credible and transparent carbon footprints are necessary for all energy choices to meet current global energy demands while supporting the energy transmission. Demand-side levers and access to markets are an effective and growing mechanism to limit the generation and trade of high carbon intensive natural gas.
- Support and expansion of these mechanisms requires access to credible emissions data, available today, and cannot wait for a single, universally adopted MMRV or emissions accounting standard. Data types may vary, yet their quality is quantifiable.
- Life cycle assessments are an established and standardized tool for assessing carbon footprints across a product's supply chain, following the guidance of ISO14044, and readily manage heterogeneous data from multiple sources and of varying quality.
- Data quality indicators (DQIs) may be used to evaluate the confidence levels of available data by looking closely at the temporal, geographical and technological representativeness of the data, the completeness of inventory to include all emissions and flows, as well as the reproducibility of the results by third party assessors.
- The MiQ Supply Chain Protocol offers a straightforward example of how DQIs can be implemented today using the best available, yet heterogenous, data to realize emissions inventories well-to-gate for natural gas to support market drivers.

Appendix A – Data Quality Indicators

Examples for various data sources found below in Table A-2. Each data source must be evaluated against the five categories in Table 1 and assigned a score from highest (1) to lowest (3). The scores for each of the 5 categories are multiplied together, resulting in a combined, evenly weighted impact DQI for each data source.

Table A-1. Examples of possible data sources, at the process unit level, are evaluated to determine the final DQIs for each source.

Data Source	*Time-related Represent-ativness*	*Geographical Represent-ativeness*	*Technological Represent-ativeness*	*Complete-ness*	*Reproduc-ibility*	***DQI***
Currently Available Data Sources						
MiQ[11] , MiQ-EO[12]	1	1	1	1	1	**1**
EO	1	1	2	2	1	**4**
Sherwin et al (2024)[13], basin level	1	2	2	1	1	**4**
OGMP L4 single Asset, UN review	1	1	1	2	3	**6**
MiQ LNG Shipping Model[8]	1	1	3	3	1	**9**
OGMP L3 single Asset, UN review	1	1	2	2	3	**12**
NETL Model (2019)[14]	2	3	2	2	1	**24**
MiQ-HW Index (2023)[15]	2	3	2	1	2	**24**
Rutherford et al (2021)[10]	2	3	2	2	1	**24**
Alvarez et al (2018)[16]	2	3	2	2	1	**24**

[11] https://miq.org/documents/?cat=miq-standards-2
[12] https://www.equitableorigin.org/
[13] Sherwin, Evan, Jeffrey Rutherford, Zhan Zhang, Yuanlei Chen, Erin Wetherley, Petr Yakovlev, Elena Berman et al. “Quantifying oil and natural gas system emissions using one million aerial site measurements.” Nature 627, (2024): 328–334
[14] Littlefield, James, Augustine, Dan, Pegallapati, Ambica, Zaimes, George G., Rai, Srijana, Cooney, Gregory, and Timothy J. Skone, P.E.. Life Cycle Analysis of Natural Gas Extraction and Power Generation. United States: N. p., 2019. Web. doi:10.2172/1529553.
[15] https://miq.org/wp-content/uploads/2023/06/MiQ-Highwood-Index.pdf
[16] Alvarez, Ramón A., Daniel Zavala-Araiza, David R. Lyon, David T. Allen, Zachary R. Barkley, Adam R. Brandt, Kenneth J. Davis et al. “Assessment of methane emissions from the US oil and gas supply chain.” Science 361, no. 6398 (2018): 186-188

GREET, placeholder values[17]	2	3	2	2	2	**48**
OCI+ Model[18]	1	2	3	2	3	**36**
IEA GMT[19]	1	3	3	2	3	**54**
Examples of Potential Data Inputs						
OGMP[20] L4/5 Asset w 3P RA[21] Audit	1	1	1	1	1	**1**
GTI Veritas[22] Asset w 3P RA Audit	1	1	1	1	1	**1**
OGMP L4 Asset w 3P RA Audit	1	1	1	2	1	**2**
GTI Veritas Asset, self-reported	1	1	1	1	3	**3**
OGMP L4/5 Asset, UN review	1	1	1	1	3	**3**
GHGRP (2024)[23] Asset w 3P RA Audit	1	1	2	2	1	**4**
LMR[24] - full asset	1	1	2	2	2	**8**
GHGRP(2024) Asset, w 3P LA[25] Audit	1	1	2	2	2	**8**
GHGRP(2024) Asset, self-reported	1	1	2	2	3	**12**
OGMP L4/5 Company level[26], UN Review	1	N/A	1	1	3	**N/A**

[17] https://www.energy.gov/eere/greet
[18] https://ociplus.rmi.org/
[19] https://www.iea.org/reports/global-methane-tracker-2023
[20] https://ogmpartnership.com/guidance-documents-and-templates/
[21] RA = reasonable assurance audit
[22] https://veritas.gti.energy/protocols; includes all three protocol pathways.
[23] Pending final rule using 2024 proposed revisions for Subpart W; dependent on source-level measurement or modeling pathways
[24] https://go.projectcanary.com/l/971793/2023-04-28/3w3fm/971793/1688139239C1l0ZN2P/Low_Methane_Rating__LMR__Protocol_V1.2.pdf
[25] LA = limited assurance audit
[26] Company-wide emission totals or any corporate level reporting whose operational and geographical footprint extend beyond a single asset are not applicable at the unit process level and therefore not applicable to supply chain emissions accounting protocols.