Xpansiv

Digital Monitoring, Reporting, and Verification for Digital Natural Gas

ASSET SPECIFICATION

2023-2024 | Version 3.0

Digital Monitoring, Reporting, and Verification for Digital Natural Gas

Asset Specification

Version 3.0* | July 2023

*Xpansiv authors Rob Bradshaw, Jeff Cohen, Tom Jones now part of Fiutur..

1.0 BACKGROUND AND APPLICABILITY

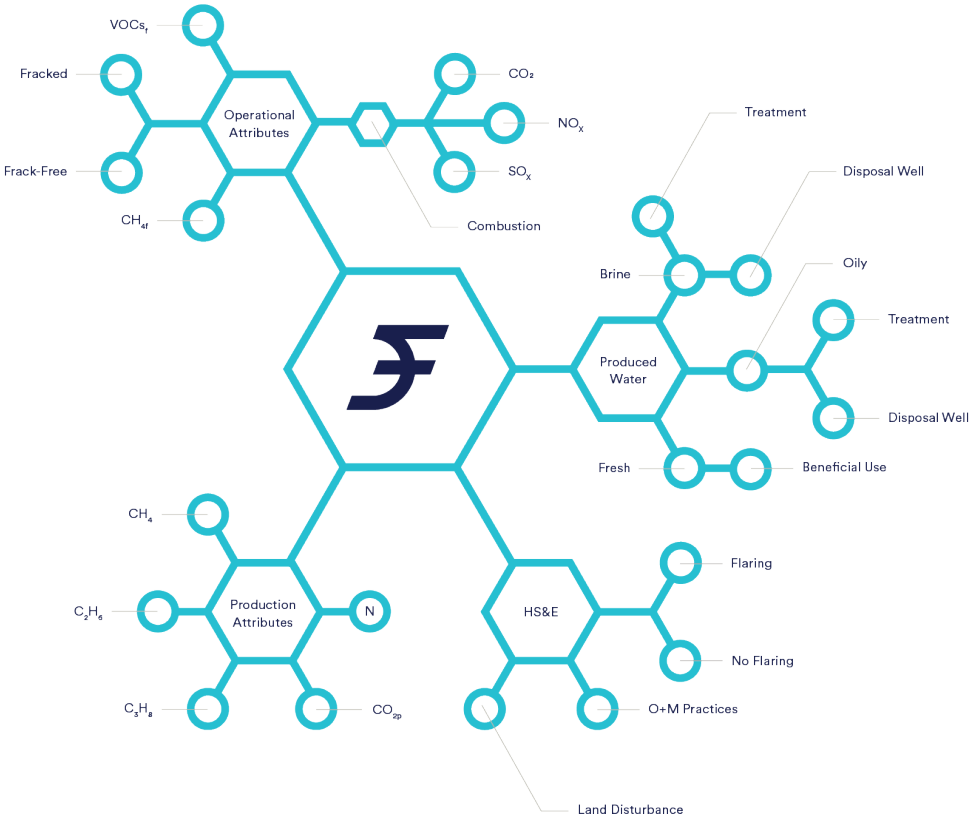
Xpansiv created the Digital Fuels Program™[2] to enable producers, operators, consumers, and other market participants to define, register and transact the environmental attributes of natural gas, crude oil, aviation fuel, hydrogen and other energy fuels. As part of the Digital Fuels Program, Xpansiv has developed standardized digital asset specifications to claim the environmental impacts and risks associated with energy production, movement, refining and use.

Each Digital Fuel Asset has a standardized structure, two parts, starting with the digital measurement, reporting and verification (MRV) requirements for that commodity group (i.e., natural gas, crude oil, aviation fuel, hydrogen and other energy fuels) along with a schedule of specifications for Products converted from Payload Datasets.

Digital Natural Gas™ (DNG)

"An immutable digital record representing the complete physical and energy profile of a specific production or operations unit of natural gas through an immutable provenance chain back to the source."

Digital Natural Gas Attributes



- Commodity
- Producer
- Lat/Long
- Production Type
- Marketed Gas
- Methane Emissions Intensity
- Water Intensity
- CO2 Content
- Butane Content
- Propane Content
- 3rd Party Facility Certification
- Land Use

[2]https://xpansiv.com/resources/

1.1 Use of this Document

This document supports the **Digital Fuels Program Governance Framework** by specifying the minimum Measurement, Reporting and Verification standards and required data for that base commodity asset and all convertible Products.

1. Collecting and verifying a standardized set of environmental attributes from each unit of commodity production, storage, transport, refining and use.
2. Rules for conversion of Payload Datasets into digital assets.

1.2 Periodic Reviews and Revisions

Pursuant to the guidance and input from market stakeholders under the Digital Fuels Program, Xpansiv as market operator will continue to update the standards and methodologies used to generate and register digital assets. Xpansiv is engaging with experts to exceed encouraging best practices. We welcome all participation in the Market Stakeholder Committee under the Digital Fuels Program to continuously improve and build the market.

2.0 DIGITAL MRV FOR DIGITAL NATURAL GAS

2.1 Monitoring and Onboarding of Operations

Digital Natural Gas assets are generated from assessments of the environmental attributes of specific units of natural gas production and/or operations, grounded in continuously metered operations data, combined with supplemental environmental data (e.g., ground-level infrared cameras, air sniffers, satellites), 3rd party certifications, and advanced analytics and modeling. High quality data can be captured from multiple technologies and monitoring systems[3] and verified to substantiate and authenticate property rights in environmental claims associated with physical natural gas.

2.1.1 Operations Data

- Operations data are captured from meters, scales, certified chemical analysis, sales records and other primary sources that are auditable/verifiable by a 3rd party, and from monitoring equipment calibrated to meet regulatory/technical specifications.
- Operations data should be measured using equipment calibrated to regulatory specifications, industry standards, and production accounting principles, along with any certified chemical analyses being regularly updated.
- Operations data that includes methane emission intensity calculations should align with industry best practices and international protocols for site level measurements such as Level 4 and Level 5 reporting under OGMP 2.0.

2.1.2 Supplemental Environmental Data

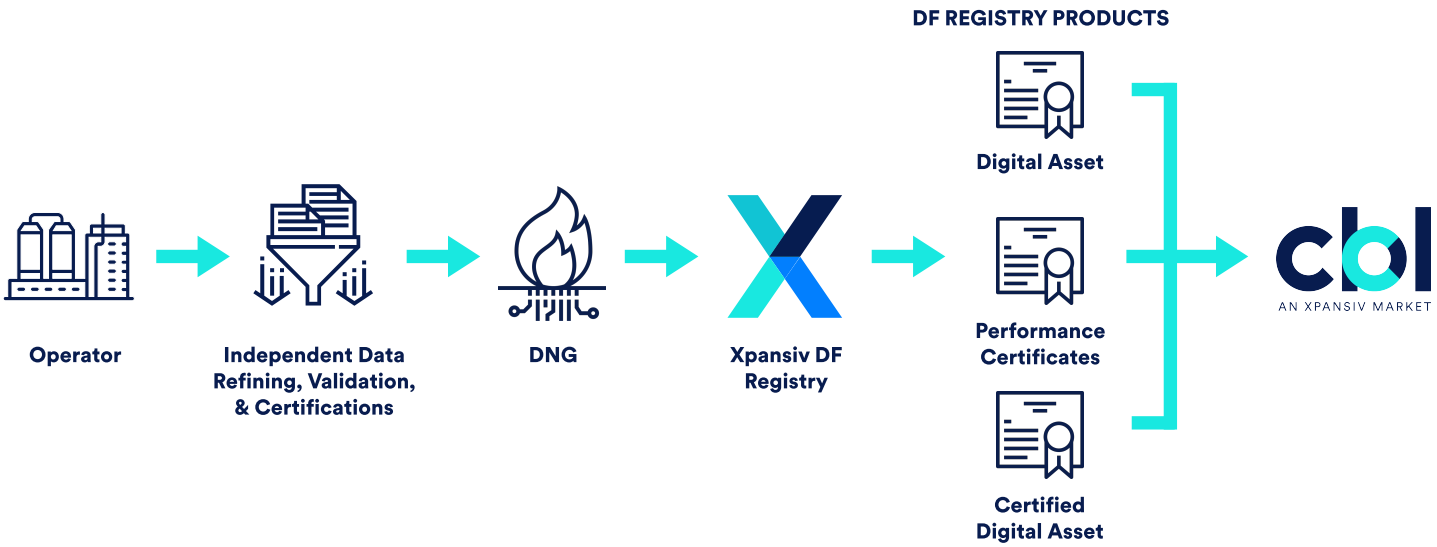
In addition to systems that capture and validate monitored primary data directly from meters and other instrumentation at facilities, primary production data can be supplemented by site-specific

[3]See for example, “Methane Quantification: Toward Differentiated Gas, An assessment of methane measurement and monitoring technologies. Coefficient, March 2022.

environmental monitoring, satellite measurements, modeling using established emission factors, independent third-party certifications, data-management systems, and other relevant sources.

Under the DF Governance Framework, all operations and supplemental environmental data are processed through an approved data refinery to identify and correct data fidelity errors and anomalies within reasonable variance limits.

XPANSIV DIGITAL FUELS REGISTRY



Required Base DNG Attributes

This section identifies and details the required base DNG attributes, broken out by physical basis products (upstream, midstream and downstream). From the base DNG digital asset, owners can transact as-is bi-laterally or convert that digital asset into scheduled Products assuming the Attributes and performance needed for that Product are met within the digital asset. The base DNG digital asset minimum data requirements do not include all optional attributes required to meet all Product specifications, as such care should be taken to target Attributes for specific Product needs (see Schedule of Available DNG Products).

Attributes defining base upstream DNG:

Attribute Name	Attribute Description	Reference Data: Reporting source, inputs, models, protocol
Operator Name	Legal name of operator entity	Retrieved from MSA
Facility Name	Common name of the operational facility	Defined by client and data integration team to reflect operational and accounting boundaries
Facility ID	Unique ID for operational facility	Determined by data integration team
Country	Country of origin	Operator provided or public source
State or Province	State or Province of origin	Operator provided or public source

Production Start	Start date/time for given data set	Operator provided
Production End	End date/time for given data set	Operator provided
Commodity Type	DNG	Defined in data integration
UOM	Energy, Unit or Volume measure of the commodity	Operator provided
Marketed volume	Quantity of commodity units (MMBtu) within the given data payload	Sales volume to match physical marketing
Assessment Boundary	Indication of the physical environmental boundary scope included in asset	Description of physical emissions assessment scope

Attribute Name	Attribute Description	Reference Data: Reporting source, inputs, models, protocol
Type	Well, Well Facility, Gathering Facility	Operator provided
ID	Well API number, Facility ID	Operator provided
Name	Permitted well/facility name	Operator provided
Lat/Long	Surface latitude and longitude of permitted well/facility	Operator provided
Volume	Well volume at point of allocation. (pre accounting)	Operator provided
Volume Unit	MCF, e3m3 at standard conditions	Operator provided

Optional DNG Attributes:

Distinct from the minimum required Attributes are the Attributes representing the environmental claim(s) associated to each unit of marketed volume, and the inherent value of the digital asset and converted Products. Given the array of environmental impacts across the energy chain, the DFP provides flexibility in the form of “additional extensible attributes” to create digital assets having Product optionality across an array of environmental claims. This includes, but is not limited to: carbon intensity, methane intensity, other GHG intensities, water use, land use, chemical use, and waste management.

Attribute Name	Attribute Description	Reference Data: Reporting source, inputs, models, protocol
Methane Emission Intensity	Amount of CH4 emission for a given dataset, calculated as (emission kgs / marketed gas kgs) expressed as a %.	Quantification body, protocol and if assessment and/or audit are independent parties
Methane Emission Inventory	Absolute value of CH4 emissions associated with the given data set. (Numerator in 'intensity' calculation)	Third party quantification and independent verification
CO2 Emission Inventory	Absolute value of CO2 emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
Equitable Origin EO100 Certification	Indication that the dataset represents production certified to the EO100 standard. presented as: True or False	URL or file attachment to EO100 certificate corresponding to Facility
Canary Trustwell Certification	Indication that the dataset represents production certified to the Trustwell standard. presented as standard score	Data provider integration
NOx Emission Inventory	Absolute value of NOx emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
SOx Emission Inventory	Absolute value of SOx emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
PM Emission Inventory	Absolute value of PM emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
PM2.5 Emission Inventory	Absolute value of PM2.5 emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
H2S Emission Inventory	Absolute value of H2S emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
Other air toxin Inventory	Absolute Value of other BTEX toxics (benzene, toluene, ethylbenzene and xylene) associated with the given data set, expressed in µg/m3	Third party quantification and independent verification

Produced Water Inventory	Absolute Value of produced water associated with the given data set, expressed in cubic meters	Third party quantification and independent verification
Other Hydrocarbon Inventory	Absolute Value of Other hydrocarbon production associated with the given data set, expressed in MMBtu	Third party quantification and independent verification
Other VOC Inventory	Absolute value of other VOC emissions associated with the given data set, expressed in kgs	Third party quantification and independent verification
ISO Certification	Indication that the Facility or wells within that Facility have an ISO Certification and type	URL or file attachment to ISO certificate corresponding to Facility and/or well(s)
Other Certification(s) not already mentioned	Extensible fields to indicate the dataset represents production certified by other standards, presented as: True or False; or grade and score	URL or file attachment to certificate corresponding to Facility and/or well(s)
Carbon Capture and Sequestration Inventory	Absolute value of CO2 that was captured and sequestered in association with the marketed volume	Third party quantification and independent verification
Associated Carbon Offsets	Absolute value (CO2eq) of retired carbon offsets associated with the marketed volume	Retirement certificate provided by client or integrated Offset registry
Transport Emission Factors	Absolute value of CO2eq associated with transportation to delivery point	Mileage or point based indication of delivery legs
Storage Emission Factors	Absolute value of CO2eq associated with storage over Production/Delivery period	Time based emissions factors corresponding to storage type and activity level
Reporting Level	Reporting level as aligned to Protocols such as: OGMP 2.0, GTI Veritas, QMRV and MiQ	Level 3 requires sample assessment quantification model + inventory list + EFs used + source. Level 4 adds site-specific EFs + activity factors. Level 5 adds site-level Monitoring Equipment Attribute as required
Monitoring Equipment	Equipment company, Type and Application	URL, data or file showing details of site-level monitoring scope

DNG JSON Payload Example (illustrative only, metadata and other fields not shown)


```
{
   "attributional_profile": [
    {
     "attribute_key": "facility_name",
      "attribute_value": "Operator Asset Sales Gas"
    },{
      "attribute_key": "facility_id",
      "attribute_value": "OPSFACI001XX"
    },{
      "attribute_key": "producer_name",
      "attribute_value": "Operator X Energy Incorporated"
    },{
      "attribute_key": "country",
      "attribute_value": "CA"
    },{
      "attribute_key": "production_type",
      "attribute_value": "Natural Gas"
    },{
      "attribute_key": "production_start",
      "attribute_value": "2022-MM-DD"
    },{
      "attribute_key": "production_end",
      "attribute_value": "2022-MM-DD"
    },{
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      "attribute_value": "0.02345678910"
    },{
      "attribute_key": "methane_emission_assessment_provider",
      "attribute_value": "Clearstone"
    },{
      "attribute_key": "eo100_certification",
      "attribute_value": true
    },{
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    },{
      "attribute_key": "produced_water_intensity",
      "attribute_value": "1.2345678"
    },{
      "attribute_key": "land_use_assessment_score",
      "attribute_value": "96.9"
    },
   ],
   "quantity": 9999999.8967420427,
   "quantity_unit": "MMBtu",
   "source_data_type": "dng"
   "assessment_boundary": "1A"}
```

For cases where multiple assessments apply against the same Attribute, we allow registration and presentation on the digital asset and converted Products. This includes supporting Reference Data contained in Proof-of-State (POS) workflow prior to registration event.

Example for Operator having multiple CO2eq assessments across same or overlapping assets:

Emissions MRV provider	Methane Emissions Intensity	Assessment Boundary	Model and/or protocol
Entity 1	0.15%	Production & processing	Model ABC v2.3
Entity 2	0.12%	Production	Bronze certification under program ABC
Entity N…	0.21%	Production to Mainline	Certification framework ABC valid 2022-2023

Midstream Attributes Within Base DNG

Referring to **Base upstream DNG definition**, the same minimum Attributes are required for Midstream applicability. In addition this Framework is extensible to the Transport and Storage sub-segments and the Attributes therin (building on available base upstream Attributes). There are standalone products representing the environmental impacts of storage and transport, apart from production DNG and converted Products.

Attribute Name	Attribute Description	Reporting Source
Storage Type	Common type of the storage location: depleted fields, aquifer storage, cavern or pipeline (used for Transmission pack, P&L and other mainline storage scenarios)	Operator provided
Injection and Withdrawal points	Location; can be one of: storage, mile markers or meter points	Operator provided

Reporting Source

Digital asset Attributes, Methane Emission Intensity for example, supporting reference data should conform to established protocols and standards such as:

- US EPA Greenhouse Gas Reporting Program (GHGRP)[4]
- Oil and Gas Methane Partnership (OGMP) 2.0 Framework[5]
- ONE Future Methane Intensity Protocol[6]
- Natural Gas Sustainability Initiative (NGSI) Methane Emissions Intensity Protocol[7]

[4] https://www.epa.gov/ghgreporting/subpart-w-rulemaking-resources;
[5] https://www.ogmpartnership.com/
[6]https://onefuture.us/wp-content/uploads/2021/12/ONE-Future-Protocol-2021.pdf
[7]https://www.aga.org/about/financial-outreach/natural-gas-sustainability-initiative-ngsi/

2.2 Data Management

See Digital Fuels Registry data onboarding guide for detailed information on data management in the context of the Xpansiv Proof of State (POS) subsystem outlined in Section 2.4.

- Operations data and secondary data must be managed, configured, processed, stored/secured, linked, and recorded to meet veracity/provenance requirements specified in relevant energy, environmental or climate MRV standards.
- Data management software must conform to an approved or certified data governance system or inter-operable data architecture with automatic and verifiable data reconciliation.
- Data is stored and where permitted, distributed, in an immutable format that ensures transparency and information security.
- The data file format should enable asset registration and property right claims on approved platforms that do not compromise confidentiality, trade secrets, or personal privacy.

2.3 Assessments & Verifications

Digital Natural Gas attributes may be quantified and independently verified provided that onboarding and processing of data includes the following[8]:

- Sources for each data item are identified including sources of cross-validation within the data set, or available from additional primary data, and confirmation of the timescale for all available data.
- Data gaps are analyzed and plugged based on receipts or conservative assumptions.
- Methods for receiving ongoing data are optimized based on a balance between timeliness and accuracy, e.g., automation, alerts on potential outliers.
- Operations data and digitized production infrastructure can be used in established Product specification to determine path-based[9] emissions intensities (e.g.,methane).
- Quantification models may conform to methane emission protocols such as *OGMP 2.0, Veritas; GTI Energy's Methane Emission Measurement and Verification Initiative*[10],
- foundational frameworks such as *ISO Quantification and reporting of greenhouse gas emissions and removals* (ISO 14064), *Greenhouse Life Cycle Assessment standards* (ISO 14040, 14044), The Greenhouse Gas Protocol[11], IFC Performance Standards on Environmental and Social Sustainability[12], and the World Bank Group Environmental, Health and Safety Guidelines[13].
- Measurements from stationary devices, drone-based sensors, aerial laser scanning, and satellite monitoring are used where available to verify emission intensity calculations.
- Where a reasonable level of assurance is required[14], the verification process should include the following:
    1. Examine the accuracy and reasonableness of the applied methodological approach for each source type, and perform calculation checks to either confirm correct application of the

[8]For example, the ISO 14064 Part 3 verification process requires that the principles of impartiality, evidence-based approach, fair presentation, documentation, and conservativeness be applied. The program under which the verification is to be performed needs to establish the required type of engagement, level of assurance, objectives, criteria, scope and materiality threshold.
[9]For example, specific volumes of produced natural gas, tracked from well pad to transaction point.
[10]https://veritas.gti.energy/protocols,
https://www.ccacoalition.org/en/resources/oil-and-gas-methane-partnership-ogmp-20-framework
[11]ghgprotocol.org
[12]www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards
[13]www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/ehs-guidelines
[14]In defining a reasonable level of assurance, independent verifiers should conform to ISO 14064-3, 3.6.6.

selected methodology or determine emissions based on a more appropriate (refined) methodology for comparison.
2. Identify and assess emission contributions for any unaccounted for sources.
3. Determine the materiality of the sum of the absolute values of all the identified discrepancies and unaccounted for emission contributions.

For each Attribute being assessed, operators should specify the entity that is providing quantification determinations and if an independent audit of that quantification has been performed.

Below are general reference data parameter examples required in verification of attribute values to achieve reasonable level of assurance. This list is for context only and is not exhaustive.

For data based Operational Attributes:

- Facility Network map
- Data Network map
- Equipment types and specifications
- Monthly receipts and dispositions
- Emissions, Source and Activity factors used in modeling
- Midstream balance reconciliation
- Fuel use volumes
- Vent and flare volumes
- Other hydrocarbon production volumes
- Other optional Reference Data points could include: factors used against network map, calculation assumptions made, uncertainty factors, etc.
- Scope of measurement fidelity
- Temporal references if not continuous monitoring and/or data aggregation methods used

In the absence of package-level information (meaning multiple gas forms flowing though the same path) where it is possible to divide and allocate total emissions inventory across multiple commodity types (i.e., NG, NGLs, Crude), as a conservative emissions intensity assessment assumption, all emissions should be attributed to the Marketed gas volume (i.e., NG) for each respective DNG payload and account for working interest allocation confirmed by the Operator to ensure DNG payload volume ownership rights.

In the absence of site-level measurement, a path source-based approach is expected to ensure minimum equipment information is required to account for possible emission sources. This includes, but is not limited to (for each commodity path): the type and number of processes and equipment packages at each facility along the path, and the following key attributes for each package (where applicable):

- Package-specific energy consumption (where metered), the process data needed to assess the amount of process work performed by the package, or the maximum rated power output.
- Type of energy input (i.e., electricity, fuel gas, process heat medium).
- Supply medium used for pneumatic devices associated with the package (i.e., natural gas or compressed air).
- Number and type of seals (i.e., packing case, wet seal, or dry-gas seal) associated with the package.
- Routing of emissions from pressure relief valves (i.e., vented to atmosphere or routed to a flare).

In addition to the verification processes described above, the technical documents[15] that specify data management processes and protocols and data quality standards associated with DNGs, undergo expert peer review, are published for "open source" use and feedback. The operational matrix underlying the Digital Fuels Program including the use of the digital assets and associated environmental attributes and claims, can be regularly assessed in independent audits.

2.4 Proof of State Auditability

Proof of State (POS) system (see Digital Fuels Registry data onboarding guide for details): a) establishes standard protocols for how data is collected, contextualized, and transferred; and b) records the full lifecycle of the digital assets (e.g., DNGs and environmental attributes) in an ecosystem-wide, immutable digital provenance chain, referenced on the retirement certificate, providing a forensic trail to how the ESG attributes and other assets are derived.

Each "data partner" (e.g., natural gas producer, operator, data refinery, monitoring system provider, buyer) operates according to a consistent set of APIs, enabling visibility for permissioned participants, including the registry operator or 3rd party auditors. Requirements for all data partners operating at each stage of the DNG asset lifecycle are available via the Xpansiv platform.

Registration of DNG Units enables the operator to request the reservation and verified conversion of the packaged attributes into issuance of standard Products (e.g., Responsibly Sourced Gas certified by EO100 or TrustWell, and/or Methane Performance Certificates). Given the flexibility in conversion of standard Products from digital assets, owners of resulting Products inherit data visibility rights to supporting reference data captured in the POS workflow.

2.6 DNG Conversions

- An eligible gas operator may request conversion by the independent market operator (1) an amount of DNG units to one or more Product(s) or (2) an amount of Products(s) back into DNG Units, in either case in accordance with the terms of the applicable Product Schedule[16], provided that in either case, such DNG Unit or Products has not been transferred, canceled, retired or otherwise used at the time of conversion on any interconnected Registry.
- Upon conversion and verified issuance of Products, all corresponding DNG Units substantiating such Products shall be reserved and locked in the eligible fuel operators' applicable Interconnected Registry Account and may not be transferred, canceled, retired or otherwise claimed or used by any entity except as part of the transfer, cancellation, retirement or other property right claim to the applicable Product.
- Each converted Product shall be given a unique digital identifier traceable to the underlying DNG Units and verified attributes.

[15]Including the Digital Fuels Governance Framework, the initial Asset Specification for DNGs and MPCs, and this document.

[16]Products may be derived and issued from certain DNG Units and authenticated by application of a standardized quantification methodology as further identified and described in the applicable Product Schedule. The Products of an amount of DNG Units is calculated based on the applicable Standard & Benchmarks for such Products as contained and described in the Eligible Fuel Digital Fuel Asset.

Schedule of Available Products from DNG Digital Assets

Every Product will have a detailed Quantification Method specifying additionality, deviation and/or extension required beyond base digital assets. This will include specifications for minimum MRV standards, Product data model, and required Reference Data. For example, Methane Performance Certificates are derived DNG products (See **Appendix A**).

APPENDIX A

Quantification Methodology for Methane Performance Certificates

Benchmarking Methane Performance for Upstream and Midstream Sub-segments

Version 3.0[17] | July 2023

[17]Jeff Cohen, Rob Bradshaw, Tom Jones from Xpansiv now part of Fiutur.

A.1 Introduction

Methane Performance Certificate™ (MPC)

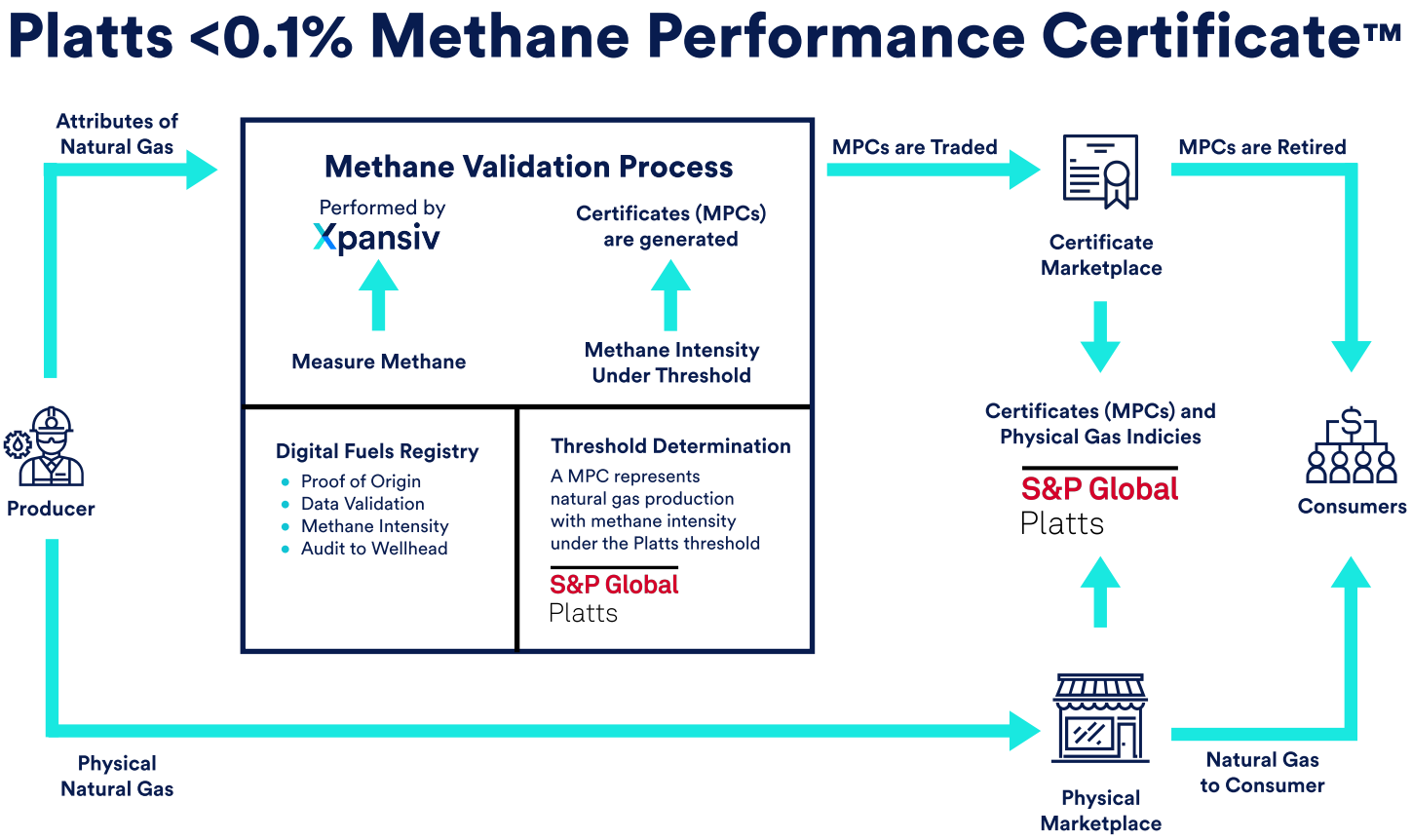
"A certification derived from Digital Natural Gas representing avoided methane emissions from a given segment of a specific unit of natural gas."

The 2023-2024 baseline methane emissions rate is estimated based on the most recent available data from the 2023 U.S. Greenhouse Gas Inventory, which includes methane emission estimates up through 2021. Subsequent applications of this Methodology will reflect the most current baseline data for the U.S. and where applicable, other countries or regions.

- The next U.S. GHGI is expected to be published in Q2 of 2024. At that time, Xpansiv would expect to calculate an updated baseline methane emission rate to be used for the subsequent 12-month period beginning on the 1st day of June 2024 extending to May 31, 2025.

Each MPC shall represent a synthetic quantity of an eligible natural gas with specific environmental attributes (e.g, methane) measured against the performance baseline applicable to U.S. and Canada Producers only, and thus only Producer assets from these countries are eligible.

Methodology to calculate MPCs representing the methane emission intensities for segments and sub-segments of the natural gas system, detailed in the following descriptions in Matrix A and illustrated in Diagram A.



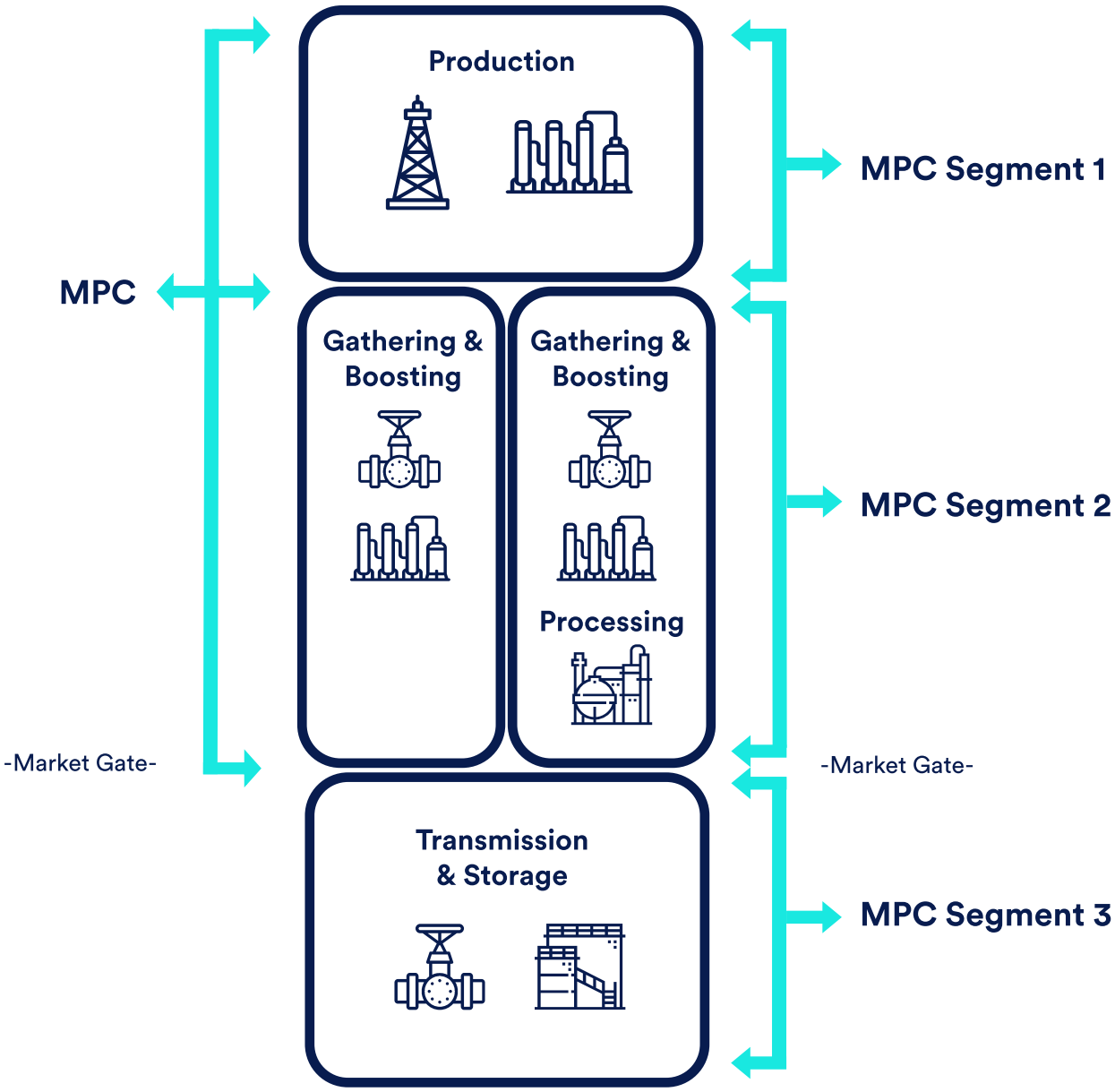
Matrix A. Categories of Methane Performance Certificates

MPC Category	Assessment Boundary
MPC[18]	Assessment begins at producing well and captures each fugitive methane source to Market Gate[19]; aligns with the original MPC assessment boundary in QF1.0 • Well pad • Gathering pipeline network • Boosting stations
MPC Segment 1	• Well pad • Well to first point of custody exchange or well pad allocation
MPC Segment 2	• Point of custody exchange or well pad allocation to transmission system • Gathering and boosting network • Processing prior to transmission system
MPC Segment 3	• Market gate to city gate or user point of delivery • Transmission network operations • Storage

The assessment boundaries do not include methane emissions from end-uses such as electricity generation or feedstock for chemical manufacturing.

[18]Current MPC Market products; MPC_0.1_2021, MPC_0.1_2022, MPC_0.1_2023
[19]'Market Gate' refers to the point/device/meter in the production system whose measurement data serves as the primary input to quantifying the contractual volume of 'Marketed Gas'.

MPC Categories and Assessment Boundaries



A.2 Estimated Baseline Intensity of Methane Emissions by Segment of Natural Gas Lifecycle

This Section provides an analysis used in deriving baseline intensities of methane emissions associated with different segments of the natural gas lifecycle that can be applied to the different categories of MPCs defined in Matrix A. This is only one of potentially multiple approaches that could be used to compute Methane Performance Certificates; other baselines or "benchmarks" for methane emission intensities could be determined to be more applicable for particular geographies, types of production, or other variables.

The following equations provide a "top-down" approach to estimate an average baseline methane emission intensity for the different MPC categories listed in Matrix A, utilizing the most recent available data on methane emissions and natural gas production in the U.S. The values for methane emissions from natural gas production used in the following equations are aggregated values as reported in the 2023 *U.S.*

Inventory of Greenhouse Gas Emissions and Sinks (GHGI). The U.S. GHGI is submitted on an annual basis by the United States to comply with existing commitments under the United Nations Framework Convention on Climate Change (UNFCCC).

A.2.1 MPC BASELINE EMISSION INTENSITY

Equation #1. Baseline Methane Emission Intensity for MPC Assessment Boundary

$$BEI = \frac{AME_{NG} \times ER_{NG}}{MK_{NG} \times 10^3 \times \rho_{CH4}}$$

WHERE		UNITS
BEI	Baseline intensity of upstream methane emissions in natural gas production	%
AME_{NG}	Aggregate U.S. upstream methane emissions from production of natural gas	kts
ER_{NG}	Energy ratio of produced natural gas relative to the energy content of total hydrocarbons produced with natural gas	%
ρ_{CH4}	Density of methane	MT/MCF
MK_{NG}	Marketed U.S. production of natural gas	MMCF

Values for the parameters used for Equation #1 are listed in Table A.1.

Table A.1. Parameter Values for Equation #1

PARAMETER	VALUE	SOURCE
2021 methane emissions from production of natural gas (AME_{NG}) including gathering and boosting	5107 kts	See Equation #2
Energy ratio (ER_{NG})	0.60	See Equation #3
2021 Marketed U.S. natural gas production (MK_{NG})	37328378 MMCF	EIA: 2021 *Natural Gas Gross Withdrawals and Production*[20], Marketed Production Data Series, Annual Million Cubic Feet
Density of Methane (ρ_{CH4})	0.0192 MT/MCF	US EPA GHGRP, 40 CFR 98.233 (u)(2)(v)

[20]https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm

Equation #2. Aggregate methane emissions from production of natural gas

$$AME_{NG} = ME_{NGS} + ME_{PS}$$

WHERE		UNITS
ME_{NGS}	Aggregate U.S. methane emissions from natural gas systems	kts
ME_{PS}	Aggregate U.S. methane emissions from petroleum systems	kts

Values for the parameters used for Equation #2 are listed in Table 2.

Table A.2. Parameter Values for Equation #2

PARAMETER	VALUE	SOURCE
2021 methane emissions from natural gas systems (ME_{NGS})	3,359 kts	Inventory of *U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-77*[21]. Natural gas production includes onshore and offshore production and gathering and boosting. Emissions from processing and exploration are not included.
2021 methane emissions from petroleum systems (ME_{PS})	1748 kts	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-77*[21]. Petroleum production includes: pneumatic controllers, offshore production, gas engines, equipment leaks, produced water, associated gas flaring, other sources.

Equations #3 and #4 provide derivations for the energy ratio of natural gas.

Equation #3. Energy Ratio

$$ER_{NG} = \frac{(\rho_{NG} \times 10^3 \times EC_{NG})}{TEC_{NGHC}}$$

WHERE		UNITS
P_{NG}	2021 U.S. natural gas production	MCF
EC_{NG}	Energy content of natural gas	MMBtu/MCF
TEC_{NGHC}	Total energy content of all US hydrocarbon production	MMBtu

[21]https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Values for the parameters used for Equation #3 are listed in Table A.3.

Table A.3. Parameter Values for Equation #3

PARAMETER	VALUE	SOURCE
Energy intensity of natural gas in the U.S. (EC_{NG})	1.146 MMBtu/MCF	Energy Information Administration, U.S. Department of Energy, *Monthly Energy Review, May 2023*, Table A4.[22]
Total Energy Content of all US hydrocarbon production (TEC_{NGHC})	79,552,189,878 MMBtu	See Equation #4

Equation #4. Total energy content of all US hydrocarbon production

$$TEC_{NGHC} = (P_{CO} \times 10^3 \times EC_{CO}) + (P_{NG} \times 10^3 \times EC_{NG}) + (P_{LC} \times 10^6 \times EC_{LC}) + (P_{NGL} \times 10^6 \times EC_{NGL})$$

WHERE		UNITS
P_{CO}	2021 U.S. crude oil production	MBBL
EC_{CO}	Energy content of crude oil	MMBtu/BBL
P_{NG}	2021 US natural gas production	MMCF
EC_{NG}	Energy content of natural gas	MMBtu/MCF
P_{LC}	2021 U.S. production of lease condensate	MMBBL
EC_{LC}	Energy content of lease condensate	MMBtu/BBL
PN_{GL}	2021 U.S. production of natural gas plant liquids	MMBBL
EC_{NGL}	Energy content of natural gas plant liquids	MMBtu/BBL

Values for the parameters used for Equation #4 are listed in Table A.4.

[22]https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

Table A.4. Parameter Values for Equation #4

PARAMETER	VALUE	SOURCE
2021 U.S. crude oil production (P_{CO})	4,107,585 MBBL	Energy Information Administration, U.S. Department of Energy[23]
Energy content of crude oil (EC_{CO})	5.69 MMBtu/BBL	Energy Information Administration, U.S. Department of Energy, *Monthly Energy Review, May 2023,* Table A2.[24]
2021 U.S. Natural Gas Production (P_{NG}) *Gross Withdrawals*	41,666,118 MMCF	Energy Information Administration, U.S. Department of Energy[25]
Energy Content of natural gas (EC_{NG})	1.146 MMBtu/MCF	Energy Information Administration, U.S. Department of Energy, *Monthly Energy Review, May 2023,* Table A4[26]
2021 U.S. production of lease condensate (P_{LC})	295 MMBBL	Energy Information Administration, U.S. Department of Energy[27]
Energy content of lease condensate (EC_{LC})	4.638 MMBtu/BBL	Energy Information Administration, U.S. Department of *Energy, Monthly Energy Review, May 2023,* Table A2, Natural Gasoline (Pentanes Plus)[28]
2021 U.S. production of natural gas plant liquids (P_{NGLs})	1970 MMBBL	Energy Information Administration, U.S. Department of Energy[29]
Energy content of natural gas plant liquids (EC_{NGls})	3.585 MMBtu/BBL	Energy Information Administration, U.S. Department of Energy, Monthly Energy Review, May 2023, Table A2[12]

Using Equation #1, a baseline methane emission rate (BEI) for the MPC Assessment Boundary yields:

$$BEI = 0.428\%$$

[23]https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm
[24]https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf
[25]https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm
[26]https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf
[27]https://www.eia.gov/dnav/ng/ng_prod_lc_s1_a.htm
[28]https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf
[29]https://www.eia.gov/dnav/ng/ng_prod_ngpl_s1_a.htm

2.2 MPC Segment 1 Baseline Emission Intensity

Equation #5. Baseline Methane Emission Intensity for MPC Assessment Boundary Segment 1

$$BEI_{S1} = \frac{AME_{S1} \times ER_{NG}}{MK_{NG} \times 10^3 \times \rho_{CH4}}$$

WHERE		UNITS
BEI_{S1}	Baseline methane emission intensity for production Segment 1	%
AME_{S1}	Aggregate U.S. methane emissions for Segment 1	kts
ER_{NG}	Energy ratio of produced natural gas relative to the energy content of total hydrocarbons produced with natural gas	%
ρ_{CH4}	Density of methane	MT/MCF
MK_{NG}	Marketed U.S. production of natural gas	MMCF

Values for the parameters used for Equation #5 are listed in Table A.5.

Table A.5. Parameter Values for Equation #5

PARAMETER	VALUE	SOURCE
2021 methane emissions from production Segment 1 (AME_{S1})	3559 kts	See Equation #6
Energy ratio (ER_{NG})	0.60	See Equation #3
2021 Marketed U.S. natural gas production (MK_{NG})	37,328,378 MMCF	EIA: 2021 *Natural Gas Gross Withdrawals and Production*[30], Marketed Production Data Series, Annual Million Cubic Feet
Density of Methane (ρ_{CH4})	0.0192 MT/MCF	US EPA GHGRP, 40 CFR 98.233 (u)(2)(v)

Equation #6. Aggregate Methane Emissions from MPC Assessment Boundary Segment 1

$$AME_{S1} = ME_{S1} + ME_{PS}$$

[30]https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm

WHERE		UNITS
$ME_{NG0.2}$	Aggregate U.S. methane emissions from natural gas systems production segment 1	kts
ME_{PS}	Aggregate U.S. methane emissions from petroleum systems	kts

Values for the parameters used for Equation #6 are listed in Table A.6.

Table A.6. Parameter Values for Equation #6

PARAMETER	VALUE	SOURCE
2021 methane emissions from natural gas systems production segment 1 (ME_{S1})	1811 kts	See Equation #7
2021 methane emissions from petroleum systems (ME_{PS})	1748 kts	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-77*[21]. Petroleum production includes: pneumatic controllers, offshore production, gas engines, equipment leaks, produced water, associated gas flaring, other sources.

Equation #7. Methane Emissions from Natural Gas Systems Production MPC Segment 1

$$ME_{S1} = ME_{ON} + ME_{OF}$$

WHERE		UNITS
ME_{ON}	U.S. methane emissions from Onshore production	kts
ME_{OF}	U.S. methane emissions from Offshore production	kts

Values for the parameters used for Equation #7 are listed in Table A.7.

Table 7. Parameter Values for Equation #7

PARAMETER	VALUE	SOURCE
2021 Methane Emissions from Onshore production (ME_{ON})	1787 kts	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-96*[21].
2021 Methane Emissions from Offshore Production (ME_{OF})	24 kts	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-96*[21].

Using Equation #5, a Baseline methane emission intensity (BEI_{S1}) associated with MPC Assessment Boundary Segment 1:

$$BEI_{S1} = 0.298\%$$

2.3 MPC Segment 2 Baseline Emission Intensity

Equation #8. Baseline Methane Emission Intensity for MPC Assessment Boundary Segment 2

$$BEI_{S2} = \frac{AME_{S2} \times 10^3}{MK_{NG} \times 10^3 \times \rho_{CH4}}$$

WHERE		UNITS
BEI_{S2}	Baseline methane emission intensity for 0.3 assessment boundary	%
AME_{S2}	Aggregate U.S. methane emissions for 0.3 assessment boundary	kt
ρ_{CH4}	Density of methane	MT/MCF
MK_{NG}	Marketed U.S. production of natural gas	MMCF

Values for the parameters used for Equation #5 are listed in Table A.8.

Table A.8. Parameter Values for Equation #8

PARAMETER	VALUE	SOURCE
2021 methane emissions from MPC segment 2 (AME_{S2})	2058 kts	See Equation #9
2021 Marketed U.S. natural gas production (MK_{NG})	37,328,378 MMCF	EIA: 2021 *Natural Gas Gross Withdrawals and Production*[31], Marketed Production Data Series, Annual Million Cubic Feet
Density of Methane (ρ_{CH4})	0.0192 MT/MCF	US EPA GHGRP, 40 CFR 98.233 (u)(2)(v)

Equation #9. Aggregate Methane Emissions for MPC Assessment Boundary Segment 2

$$AME_{S2} = ME_{GB} + ME_{PC}$$

WHERE		UNITS
ME_{GB}	2021 Methane Emission from Gathering and Boosting subsegment of Natural Gas Systems	kt
ME_{PC}	2021 Methane Emissions from Processing subsegment of Natural Gas Systems	kt

[31]https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm

Values for the parameters used for Equation #9 are listed in Table A.9.

Table A.9. Parameter Values for Equation #9

PARAMETER	VALUE	SOURCE
2021 Methane Emission from Gathering and Boosting subsegment of Natural Gas Systems (ME_{GB})	1548 kt	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-96*[21].
2021 Methane Emissions from Processing subsegment of Natural Gas Systems (ME_{PC})	510 kt	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-96*[21].

Using Equation #8, a Baseline methane emission intensity (BEIS2) associated with MPC Assessment Boundary Segment 2 yields:

$$BEI_{S2} = 0.287\%$$

2.4 MPC Segment 3 Baseline Emission Intensity

Equation #10. Baseline Methane Emission Intensity for MPC Assessment Boundary Segment 3

$$BEI_{S3} = \frac{AME_{S3} \times 10^3}{MK_{NG} \times \rho_{CH4}}$$

WHERE		UNITS
BEI_{S3}	Baseline methane emission intensity for MPC assessment boundary segment 3	%
AME_{S3}	Aggregate U.S. methane emissions for MPC assessment boundary segment	kt
ρ_{CH4}	Density of methane	MT/MCF
MK_{NG}	Marketed U.S. production of natural gas	MMCF

Values for the parameters used for Equation #10 are listed in Table A.10.

Table A.10. Parameter Values for Equation #10

PARAMETER	VALUE	SOURCE
2021 methane emissions from Transmission and Storage subsegment (AME_{S3})	1590 kt	*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2021, Table 3-96*[21].
2021 Marketed U.S. natural gas production (MK_{NG})	37,328,378 MMCF	EIA: 2021 *Natural Gas Gross Withdrawals and Production*[32], Marketed Production Data Series, Annual Million Cubic Feet
Density of Methane (ρ_{CH4})	0.0192 MT/MCF	US EPA GHGRP, 40 CFR 98.233 (u)(2)(v)

Using Equation #10, a baseline intensity of methane emissions (BERS3) associated with natural gas production in the U.S. yields:

$$BEI_{S3} = 0.222\%$$

As noted in the original DNG/MPC Asset Specification, these estimates comprise only one of potentially multiple approaches that could be used to compute benchmarks for methane emissions. Other baselines or "benchmarks" for methane emission intensities could be determined to be more applicable for particular geographies, types of production, or other variables. For any calculation based on existing reporting frameworks, data may under-represent the influence of the small number of "super-emitting" sources, or infrequent peak events (liquid unloading) that can account for a disproportionately large fraction of total methane emissions[33]. Additional data gathered through the Digital Fuels Program along with other information will continue to be assessed to ensure the most accurate and transparent estimates of benchmark emissions intensities.

[32]https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm
[33]Alvarez et al. (2018)

A.3 QUANTIFYING PRODUCER-SPECIFIC METHANE EMISSIONS

Digital Natural Gas includes a bottom up assessment of the methane emissions intensity of specific units of natural gas production at a given facility, grounded in continuously metered, primary production data combined with available secondary data (e.g., ground-level infrared cameras, satellites), and advanced analytics and modeling.

Two ESG reporting entities used in the Digital Fuels Registry were described in the QF v1.0. Since publication of the QF v1.0, the Digital Fuels Program ecosystem has expanded to include additional data sources, including for example on-site, continuous methane measurements that are used to register DNGs with methane emissions intensities for natural gas produced at facilities across North America.

Xpansiv continues to work with standards and certification bodies, data providers, data analytic companies, and others potential participants, provided that their inputs meet the specifications outlined in the Digital Fuels Program.5

A.4. DERIVING METHANE PERFORMANCE CERTIFICATIONS

As noted in the original Quantification Methodology (1.0), for a specific production volume of natural gas produced by a specific producer, MPCs correspond to comparative methane emissions intensity relative to the industry average[34] (i.e., the baselines derived in Section 2[35]).

Equation #11 illustrates how Methane Performance Certificates would be calculated for a given production source.

Equation #11: Methane Performance Certificates

$$MPC_{i,j,k} = [(BEI_k - CER_k) \div BEI_k] \times MK_j$$

WHERE		UNITS
$MPC_{i,j,k}$	Methane Performance Certificate(s) for natural gas production unit i at facility j for segment k	#
BEI_k	Benchmark methane emission intensity for natural gas segment k	%
CER_k	Calculated rate of methane emissions from natural gas segment k at facility j	%
MK_j	Quantity of marketed natural gas from facility j	MMBtu

[34]Because natural gas is transacted in terms of MMBtus, MPCs will be issued and registered based on the MMBtu volumes produced.
[35]As described in Section 1.6, under this Framework, Xpansiv plans to apply the most current baseline data to MPC calculations on a 12-month rolling schedule.

A.5 MPC ELIGIBILITY THRESHOLD

As part of launching the Digital Fuels Program in the fall of 2021, Xpansiv partnered with S&P Global Platts (now referred to as S&P Global) to establish an upstream methane emissions intensity of 0.1% as the threshold by which natural gas production would be considered eligible for generation of MPCs. Natural gas production determined to have a methane emission intensity above 0.1% would still be able to be registered for DNGs.

For 2023-2024, Xpansiv will maintain the 0.1% eligibility threshold for MPC and MPC S1 as defined in Section A.2.

At this stage of the Program's development, eligibility for MPC S2 and MPC S3 will not be tied to a specific methane emissions rate.

A.6 REQUIRED DNG ATTRIBUTES FOR MPC

In addition to the required base DNG attributes listed in the **Digital MRV** for DNG, Table A.11 lists the attributes of a natural gas production source that are required to be included to fulfill the MPC contract specifications in the Digital Fuels Program.

Table A.11. Required attributes for MPCs

Attribute Name	Attribute Description
Vintage Year	Year coinciding with Framework version
Methane Emission Benchmark Name	Benchmark name applied in applicable assessment boundary
Methane Emission Benchmark Rate	Benchmark emission rate of applicable assessment boundary
Quantification Methodology	Name and version of documentation
MPC Quantity	Count of eligible MPCs for a given data payload
MPC Eligible	Binary attribute indicating that emission values in the payload meet MPC criteria
Methane Emission Intensity	Emission intensity determined for the natural gas production source that is assigned to a given data payload
Methane Emission Assessment Provider	Name of Entity providing or certifying emissions assessment
Methane Emission Assessment Process	Process name used to assess emissions
Methane Emission Assessment Version	Version of entity assessment process
MPC Reduction Factor	Methane emission reduction measured against the baseline for a given data set
Industry Segment	Assigned assessment boundary for corresponding MPC category

A.7 QUANTIFICATION METHODOLOGY AUDITING

The Methane Emissions Intensity assessment methodology must be audited by an independent 3rd party and be subject to on-demand audit. This is to ensure consistency across digital assets and converted fungible MPC Products.

- The methodology audit is not intended for individual calculations, but rather should include proof that the assessment methodology provides accurate site-specific estimates, and that modeling assumptions, emission factors and other inputs are consistent with established regulatory requirements and best industry practices.
- The entity providing the Methane Emissions Intensity assessment must be separate from the auditing entity and include either a Professional Engineer, an analyst certified under ISO 9001 or ISO 14001 or comparable standard, or be a government regulatory agency with oversight responsibilities in the oil and gas sector.
- All potential methane emissions source types within the respective MPC Category Assessment Boundary must be accounted for.
- Emissions reported by detailed source type may use a combination of emission factors, including publicly available information (where data is credible and transparent for audit), direct measurement and predictive simulation modeling where appropriate such that assessment is site specific to that Facility.

Direct measurement technologies are acceptable, provided that they demonstrate accurate site-level measurement. This can include direct SCADA connection, satellite, aircraft, drone, and stationary monitoring.

APPENDIX B

Quantification Methodology for Placeholder Net-Zero Bundled Products

ANNEX I

DEFINITIONS & ACRONYMS

Please reference **Digital Fuels Program Governance Framework** for terms in this document not defined below.

API stands for American Petroleum Institute, and is one component of well identification normally consisting of three parts: operator name, well number and lease name.

EF (Emission Factors) refers to the GHG emissions constants used within a modeled calculation of overall GHG inventory.

Emissions intensity outlines the volume of emissions associated with a unit of energy or dataset, expressed as a percentage or absolute value.

Internet of Things (IoT) refers to the network of physical objects (“things”) that can be embedded with sensors, software and other technologies to connect and exchange data over the internet.