The Payne Institute for Public Policy
AT COLORADO SCHOOL OF MINES

April 7, 2026

Tracking and Transacting Clean Natural Gas: Operationalizing Environmental Attribute Tokens

Commentary by Liam O’Byrne and Brad Handler

EXECUTIVE SUMMARY

There is an emerging need for companies to track and disclose the carbon intensity of the natural gas and other fossil fuel-based products they buy. This is due to a regulatory push, including in the European Union and California, as well as expectations that corporations will follow through on stated voluntary commitments to decarbonize[1]. For producers of these fuels, documenting carbon intensity, at least at scale, requires systems that standardize — and make very easily auditable — the inputs and processes involved in determining that intensity. Recent technological advances, including widely available blockchain-based systems and emerging autonomous AI agents, are facilitating how this information is

[1] Admittedly there is uncertainty as to the breadth, depth and implementation timing of government and corporate commitment. The EU has adopted methane rules, with key implementation details like maximum methane-intensity values and enforcement policy to phase in over time. Further, the EU has stipulated that a relatively more exacting documentation method, known as trace-and-claim, would be required. Yet it also made clear (in March 2026 with the backdrop of spiking energy prices with the Iran conflict) that its application of these rules will be sensitive to energy security and that member states can delay the application of any penalties if deemed necessary to avoid risks to energy supply. And on the commercial side, reference points for buyer demand for low methane natural gas or derivative products remain sparse.

captured and shared with buyers; they can also automate procurement, compliance and reporting. Further, with these systems in place, the financial services industry can leverage them to create new markets for and with this data, including to foster conditions for trading of low methane emissions products.

The prevalent tracking system that has evolved is a thermal certificate model, in which a digital token represents a defined energy quantity (MMBtu). The token can "carry" any number of attributes, including a carbon-intensity value, or a fugitive methane emissions intensity value, that is traceable to measured inputs of emissions and hydrocarbon production and documented assumptions. These tokens are machine-readable, independently verified data containers. They also carry full methodological provenance to allow for the verification that appropriate procedures were followed to derive that carbon footprint.

The purpose of this paper is to describe the carbon attribution and tokenization processes that are evolving around U.S. liquefied natural gas (LNG) production. It also offers some of the European regulatory context that is encouraging tokenization to follow specific protocols. In this vein the paper offers a detailed illustration of one such token that has a verification approach that is consistent with an International Standards Organization (ISO) framework, which is part of what the tokens must have to gain widespread acceptance, particularly in regulated jurisdictions such as the EU, and to foster practical application at scale.

Acknowledgements

The Payne Institute gratefully acknowledges the support and guidance of EarnDLT in the development of this report.

Table of Contents

GLOSSARY

Book-and-claim — Attribute accounting in which environmental attributes are decoupled from the specific physical molecules delivered; claims rely on purchase/transfer and retirement of attributes rather than continuous physical chain-of-custody.

Cargo Emissions Tag (CE Tag) — A per-cargo emissions disclosure artifact intended to travel with an LNG cargo, reporting lifecycle GHG metrics (absolute and/or intensity) and methane intensity using a stated methodology and evidence set.

Crypto-Asset Service Provider (CASP) — Under EU digital-asset rules, an entity providing services such as custody, exchange, or trading platforms for crypto-assets; relevant here because environmental attribute tokens may implicate CASP obligations depending on structure and use.

DID (Decentralized Identifier) — A standard digital identifier that gives a token, organization, or data source a unique machine-readable identity, making it easier for different systems to verify who issued it and trust the information attached to it.

Digital twin (of LNG) — The structured digital representation of a specific LNG quantity and its attribute profile (inputs, assumptions, calculations, evidence, and verification artifacts) that serves as the basis for token issuance.

Distributed ledger — A shared record-keeping system maintained across multiple participants (e.g., blockchain or DAG networks) that can provide durability, timestamping, and tamper-evident history for token registries.

Environmental Attribute Certificate (EAC) — A transferable certificate representing a fixed energy quantity with attached environmental attributes; in this paper, implemented as an environmental attribute token.

Environmental attribute token — A digital thermal certificate (typically 1.0 MMBtu per token) that carries standardized, auditable emissions attributes (e.g., CI, methane intensity) plus linked evidence and verification artifacts, and supports transfer and retirement to prevent double claiming.

Final CI (delivery-adjusted CI) — The carbon intensity that adds logistics/shipping emissions (parameterized by the buyer's destination or delivery endpoint) to the plant-side "base" CI.

Financial instrument (MiFID context) — A legally defined instrument subject to EU financial-market rules; relevant here because certain token structures can fall under MiFID II rather than (or in addition to) MiCA.

GREET — Argonne National Laboratory's lifecycle model/dataset used to estimate GHG emissions for energy pathways; referenced here for standardized transport-related emissions additions (e.g., per-mile, per-MMBtu factors).

Internet of Things (IoT) ingestion — Automated data capture and transfer from networked meters/sensors into processing systems to reduce manual error and strengthen evidentiary integrity.

ISO 14064-3 — The ISO standard for validating and verifying greenhouse gas statements, including requirements for scope, criteria, evidence evaluation, and the content of the verification or validation statement.

ISO 14067 — The ISO standard for quantifying and reporting the carbon footprint of products using a life-cycle-based methodology, with requirements for transparent boundaries, calculation methods, and results reporting.

Markets in Crypto-Assets (MiCA) — The EU regulation establishing disclosure and conduct obligations for crypto-asset issuers and service providers; relevant where environmental attribute tokens are treated as crypto-assets.

Markets in Financial Instruments Directive/Regulation (MiFID II/MiFIR) — EU financial-market rules that can apply if a token/structure meets the definition of a financial instrument.

Mass balance — An accounting method for situations where molecules mix, ensuring attributed outputs do not exceed attributed inputs over a defined system/time period; used to preserve chain-of-custody integrity when physical segregation is not feasible.

Measurement, Reporting, and Verification (MRV) — The end-to-end process of quantifying emissions (measurement), documenting methods/results (reporting), and obtaining independent assurance against stated criteria (verification).

MRV Equivalence — A determination that a non-EU measurement/reporting/verification regime is sufficiently comparable to EU requirements to satisfy import-facing obligations.

OGMP 2.0 — The Oil and Gas Methane Partnership 2.0 framework for methane emissions reporting and improvement; referenced as a recognized methodology that can complement ISO-aligned accounting.

Registry agnostic — A design principle in which token identifiers, evidence references, and audit history can be exported or mapped across registries without losing integrity or traceability.

Retirement (of tokens) — The irreversible marking of a token as used so its attributes cannot be claimed again, preventing double counting.

Smart contract — Programmable digital logic that automatically executes predefined rules for issuance, validation, transfer, and recordkeeping within a transaction or asset lifecycle.

Thermal certificate — A certificate representing a standardized quantity of energy (here typically 1.0 MMBtu) that can be paired with verified environmental attributes.

Trace-and-claim — Attribute accounting that maintains a defensible linkage to specific physical supply pathways (or mass-balance equivalents when mixing occurs), supporting provenance-anchored claims that are stronger than book-and-claim.

BACKGROUND: EUROPEAN REGULATIONS

LNG attribute tokens straddle two sets of regulations: those that apply to carbon emissions and those that apply to digital assets. Europe has been at the forefront of both, passing legislation related to both the tracking of emissions attributes of products, corporate disclosure of carbon emissions and the use of digital assets. Therefore, even with the current landscape threatening to soften corporate obligations on the continent, Europe remains a useful region to consider operationalizing the use of tokens for low methane intensity natural gas. The EU regulations related to this topic include:

- **The EU Methane Regulation (Reg. (EU) 2024/1787)** sets measurement, reporting and verification (MRV) obligations for EU operators and adds import-facing duties that phase in: MRV-equivalence by 1 Jan 2027, annual methane-intensity reporting starting 5 Aug 2028, and compliance with a maximum methane-intensity limit for new/renewed contracts starting 5 Aug 2030[2,3] (see Appendix for more detailed timeline).
  - As it relates to domestically produced gas, operators are subject to MRV/LDAR and venting/flaring limits under the Methane Regulation; for imports, the law is in force and importer obligations are phasing in.[4,8]
- **Renewable Energy Directive (RED II/III)'s Union Database (UDB)** records traceability and mass-balance for renewable fuels used in transport for uniqueness verification. In practice, the UDB is relevant as a working European example of how digital systems can be used to track sustainability

[2] https://eur-lex.europa.eu/eli/reg/2024/1787/oj/eng

[3] https://energy.ec.europa.eu/document/download/b5\45c5a6-03c9-4cfa-805a-0411de927ce6_en?filename=Methane%20regulation%20import%20requirements%20Q%26A.pdf

[4] https://energy.ec.europa.eu/document/download/b545c5a6-03c9-4cfa-805a-0411de927ce6_en?filename=Methane%20regulation%20import%20requirements%20Q%26A.pdf

attributes, prevent double counting, and support chain-of-custody claims across multiple market participants.[5,6]

- **Markets in Crypto Assets (MiCA) (Reg. (EU) 2023/1114)** mandates that issuers of emissions tokens face disclosure duties that now include sustainability indicators specified in ESMA's (European Securities & Markets Authority) July 2024 final report on MiCA technical standards. More broadly, MiCA is relevant because it establishes a disclosure and conduct framework for crypto-assets offered in the EU, helping clarify when token issuers, offers, and service providers may fall within a harmonized regulatory regime.
- **Markets in Financial Instruments Directive and Regulation (MiFID)** also pertains to tokens, establishing that if a token/structure meets the definition of a financial instrument, MiFID II applies instead/as well. This is especially important for environmental attribute tokens because certain structures, rights, or trading arrangements could move a token from a pure registry or compliance tool into a regulated investment product or instrument.[7,8]
- **European Sustainability Reporting Standards (ESRS)** sets the framework for corporate level reporting of emissions (Europe's Corporate Sustainability Reporting Directive [CSRD] mandates ESRS-based sustainability statements with limited assurance). Accurate MRV and methodological transparency are expected, requiring data-quality controls and reproducible calculations.[9,10] ESRS E1 covers Scopes 1/2/3 ESRS is already adopted in EU law via Delegated Regulation (EU) 2023/2772.[11,12]

---

5 https://wikis.ec.europa.eu/spaces/UDBBIS/pages/68190923/Union%2BDatabase%2Bfor%2BBiofuels%2B-%2BPublic%2Bwiki

6 https://eur-lex.europa.eu/eli/dir/2023/2413/oj/eng

7 https://eur-lex.europa.eu/eli/reg/2023/1114/oj/eng

8 https://www.esma.europa.eu/sites/default/files/2024-07/ESMA75-453128700-1229_Final_Report_MiCA_CP2.pdf

9 https://eur-lex.europa.eu/eli/reg/2024/1787/oj/eng

10 https://eur-lex.europa.eu/eli/reg_del/2023/2772/oj/eng

11 https://eur-lex.europa.eu/eli/dir/2022/2464/2025-04-17/eng

12 https://eur-lex.europa.eu/eli/reg_del/2023/2772/oj/eng

The above notwithstanding, it is thought that, particularly with respect to tokens/crypto assets, there is more bolstering of the regulatory landscape that is necessary. For example, as these markets develop, it is encouraged that procedures and regulations for what constitutes the "perimeter" and Crypto Asset Service Provider (CASP) obligations for trading environmental attribute tokens are developed.[13,14]

THE MAKING OF AN LNG ATTRIBUTE TOKEN

Current best practices for tokenizing LNG attributes include as much direct measurement of fugitive methane emissions as practicable, automation of the ingestion of data (both production and regarding other attributes), the administration of protocols that are transparent, the assignment of emissions to specific volumes (and the basis for such assignation such as trace-and-claim or book-and-claim), and transparency with respect to all of these elements in the tokens themselves.[15] These elements break down as follows:

1. **Determining Upstream Emissions: emphasis on direct measurement.** In the production of natural gas from the subsurface (referred to as upstream operations), tools and techniques have developed to allow for direct measurement of methane and other Greenhouse Gas (GHG) emissions. Those tools include continuous monitoring, flyovers, and satellites, supported by analytics.[16]

2. **Determining Midstream Emissions: measurement is emerging; emissions factors still prevalent.** Because produced natural gas moves through an enormous pipeline system in the U.S., tracking of fugitive emissions remains heavily reliant on estimation, i.e. the use of established emissions factors applied to the number of miles of pipeline movement. With

---

[13] https://eur-lex.europa.eu/eli/reg/2023/1114/oj/eng

[14] https://www.esma.europa.eu/sites/default/files/2024-07/ESMA75-453128700-1229_Final_Report_MiCA_CP2.pdf

[15] For more detail than what is provided in this section, please see "Tokenizing the Environmental Attributes of Liquefied Natural Gas" published by the Payne Institute in July 2025

[16] MiQ. Certified Gas: A Cost-Effective Path to Emission Reduction, https://miq.org/thought-leadership/certified-gas-a-cost-effective-path-to-emission-reduction/

that said, some pipeline operator efforts do yield measured results, allowing for relatively specific estimates per physical supply pathways.[17,18]

3. **Determining Downstream (Liquefaction + Shipping) Emissions: emissions factors.** Liquefication emissions are largely tied to the energy used to cool the gas and are commonly estimated with emissions factors; shipping emissions are also calculated using factors that depend on transport type, fuel, and related parameters.[19]
4. **Automated Data Handling.** Measurements and estimates need to be transmitted into data systems that can organize and process them. Best practices include automated ingestion systems (using smart meters and the Internet of Things (IoT)-based communication) to reduce errors and improve transparency compared with manual entry.[20]
5. **Producing a Coherent Emissions/Attribute Profile.** Algorithmic-based platforms pull together operational volumes and emissions/attribute information and assign/link attributes for a given produced volume of gas so that intensities can be calculated consistently.[21,22]
6. **Follow Recognized Standards.** Emissions calculations should be performed according to approved methodologies and standards such as OGMP 2.0 and/or ISO 14067/14064, which helps ensure the results are defensible for buyers and regulators. The evidence package is then preserved as the "source of truth" for that LNG cargo being shipped.[23]
7. **Mass Balance Calculations.** Although less consistently applied to date, some providers use mass balance to preserve chain-of-custody integrity even when molecules mix physically. It appears plausible that this approach, which

---

[17] U.S. Energy Information Administration (EIA). https://www.eia.gov/energyexplained/natural-gas/natural-gas-pipelines.php
[18] ACS Sustainable Chemistry & Engineering. S.A. Roman-White et. al. https://pubs.acs.org/doi/10.1021/acssuschemeng.4c07162
[19] American Petroleum Institute (API). https://www.api.org/~/media/files/ehs/climate-change/api-lng-ghg-emissions-guidelines-05-2015.pdf
[20] CleanConnect.ai. https://cleanconnect.ai/provezero/
[21] Context Labs. https://contextlabs.com/solutions/daas/
[22] Triangle Digital. https://www.triangle.digital/industries/energy-transition
[23] KPMG. https://kpmg.com/us/en/media/news/kpmg-alliance-credibility-rigor-reporting.html

allows for confident trace-and-claim systems to tie specific attribute by molecule of LNG, should become more important over time.[24,25]

8. **Verification Using Independent Bodies.** Good governance practice is that the underlying data and the calculations are verified by an independent party (or a robust verification mechanism). This verification becomes part of the token's digital record.

9. **Creation of a "Digital Twin" of the LNG.** After aggregation, calculation, and verification, the result is a digital record that represents the LNG volume and its attributes ("digital twin").

10. **Token Minting.** Tokens are then created based on the digital twin for fixed quantities of gas (often described as Environmental Attribute Certificates), typically by uploading encrypted data and sequencing/timestamping it through smart contract-based registry processes.[26,27]

11. **Token Tracking and Retirement.** Providers typically run registry (exchange) functions that track token status along the value chain, support transfers to counterparties, and retire tokens after they are used so they cannot be claimed twice. There are various valid exchange architectures: public blockchains, permissioned/private systems, hybrid approaches that allow selective visibility, and DAG-style networks (e.g., Hashgraph) that emphasize different performance characteristics. The main goal is to keep records durable and auditable while still meeting real commercial privacy needs.[28,29]

12. **Additional Steps for Financial Instruments.** Tokens can be made eligible to be treated as financial instruments if required compliance standards are

---

[24] Carbon Trust. https://www.carbontrust.com/news-and-insights/insights/meet-customer-calls-for-lower-carbon-products-through-a-mass-balance-approach
[25] International Sustainability & Carbon Certification (ISCC). https://www.iscc-system.org/wp-content/uploads/2025/04/ISCC-EU-Mass-Balance-Guidance-Document_Version-1.0.pdf
[26] EarnDLT. https://earndlt.com/
[27] Fiùtur. https://www.fiuturx.com/post/fiutur-and-digital-asset-announce-tokenization-of-energy-supply-chain-attributes
[28] Canton. https://www.digitalasset.com/hubfs/Canton/Canton%20Network%20-%20White%20Paper.pdf
[29] Hedera. https://hedera.com/wp-content/uploads/2025/12/hh_whitepaper.pdf

met. In the U.S., such standards are set by the Financial Industry Regulatory Authority (FINRA).[30]

LNG ATTRIBUTE TOKEN STRUCTURE

To better assess the impact of regulatory and best practice standards on attribute tokens, it is instructive to review some specific elements of a compliant LNG attribute token[31]. For this purpose, the following discusses details of EarnDLT's QET-LNG[32]

A QET-LNG token is a thermal certificate where a token equals 1.0 MMBtu and carries a carbon intensity value reported in kgCO2e/MMBtu. The carbon intensity is presented as a plant-side ("base") CI that covers emissions from gas production/processing through liquefaction, plus a delivery-adjusted ("final") CI that adds transportation emissions based on the buyer's actual delivery endpoint, so the reported impact is dependent on where the LNG is shipped.

To maximize robustness, the scheme is "measurement first"; it calls for primary operational data (volumes, composition, energy use, pipeline injections, measured fugitive losses, delivery distances, etc.) and the artifacts that prove them (meter calibrations, utility bills, injection tickets, third-party reports, producer attestations, etc.).

When delivery is arranged through a marketplace, the transport addition is calculated in real time using a validated GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation)[33] factor of ~0.004632567 kg per mile

[30] Triangle Digital. https://www.youtube.com/watch?v=pljiSIBrqGE&list=PL41paEfBj4fzSHjdK0dYDiokMvQF0o3QS&index=9

[31] There are resources available that detail aspects of compliant tokens. A useful tool in this respect is published by **The Energy Emissions Modeling and Data Lab (EEMDL)**, which establishes standards for data capture, and thus tokenization. Some of EEMDL's standards, including those for units, for calculating delivery carbon intensity and prescribing the use of JSON, are discussed herein.

[32] It should be noted that EarnDLT's QET is being reviewed for illustration and educational purposes only; this paper does not suggest that other tokens do not follow these protocols. Further, opining about different protocols is outside the scope of this paper.

[33] https://www.energy.gov/eere/bioenergy/articles/greet-greenhouse-gases-regulated-emissions-and-energy-use-transportation

per MMBtu, a GIS (Geographic Information System) distance with +-2% tolerance, and annual parameter re-verification.

The token's data model bakes in quality controls so weak submissions never mint, the registry runs pre-issuance validation and duplicate prevention checks to catch inconsistencies early.

ISO Standards

Earn's QET-LNG follows the International Standards Organization (ISO) across several elements of token creation. These include uncertainty tolerances, reporting, verification, document retention, data structure and machine auditability, calculation transparency and audit trails, data quality and integrity, and regulatory readiness and integration. The list of ISO protocols followed can be found in Table 1 and a more detailed comparison of ISO vs. non-ISO procedures can be found in Appendix II.

Table 1: ISO Standards Applicable in EarnDLT's QET-LNG Methodology

Designed to be consistent with ISO standards

- 14067:2018 Clauses
    - 6.1–6.3 (goal and scope definition, functional unit, and system boundaries)
    - 7.4–7.5 (data quality and uncertainty)
    - 8 (reporting of product carbon footprint results)
- ISO 14064-3:2019 Clauses
    - 4.1–4.3 (principles and GHG statement),
    - 5.2–5.3 (level of assurance and objectives)
    - 7.2 (verification plan),
    - 7.3–7.4 (assessment of GHG information, internal controls, and data sampling),
    - 7.6–7.7 (evaluation of misstatements and uncertainty versus materiality thresholds)
    - 7.9 (evaluation of the GHG statement),
    - 8.2–8.3 (quality management and record-keeping)
    - 9.1 (verification report)

ISO-aligned verification includes various other elements. As it pertains to verification, protocols include that it must be performed on explicit portions of the portfolio (Earn sets 5% at the batch level and 2% for portfolios). Unit verification requires the CI to be confirmed in kgCO2e/MMBtu with any conversions documented and cross-checked. And the verifier must compare reports to independent calculations to ensure reports are within allowed error limits, which provides a practical guardrail between what’s measured and what’s claimable.

Although ISO does not mandate a specific digital format, its requirements map cleanly onto a schema-driven structure. ISO 14064-3 requires verification criteria that shall be relevant, complete, reliable, and understandable, shall be available to the intended user, and shall be referenced in the verification opinion, and it requires verifiers to obtain “sufficient appropriate evidence.” ISO 14067:2018 similarly requires reporting to be transparent while leaving report format to be defined by the study.[34] A JSON schema supports these ISO goals at the structure level by enforcing a consistent, valid layout (required fields, explicit references, and versioning), which improves completeness, traceability, and clear linkage between the opinion and referenced criteria.

Records and chain-of-custody are retained for at least ten years with cryptographically secured documentation.

Registry and Measurement-Standard Agnostic

EarnDLT’s tokens are issued and managed on its hashgraph registry. However, they can be exported or mapped to external registries without losing the audit trail, which is useful when a buyer needs a different platform. This registry agnosticism extends to a parallel and equally important design principle: measurement-standard agnosticism. North American upstream producers report under a range of recognized frameworks — NGSI, OGCI, OneFuture, MiQ, ISO 14067, and OGMP 2.0, among others — each with its own reporting boundaries, emission source categorizations, and intensity calculation conventions. Midstream operators face a similar patchwork. Rather than requiring producers or pipeline operators to conform to a single methodology, the QET's schema accepts data generated under any of these frameworks, captures the specific methodology applied as part of the token's provenance metadata, and normalizes the output into a consistent, machine-readable structure. The practical effect is that an EU importer receiving QET-LNG certificates need not dictate which MRV standard its upstream suppliers follow; the token itself carries sufficient methodological

[34] https://www.ditan.com/static/upload/file/20240522/1716345585128585.pdf

transparency for the importer to demonstrate compliance with the EU Methane Regulation's MRV equivalence requirements.

The same can be said for other regulated environments. For example, for California LCFS compliance, the methodology adds a lightweight LCFS “extension” that keeps the same underlying thermal certificate while containing additional quarterly fuel transaction reporting fields CARB (California Air Resources Board) requires—organization FEIN, reporting period (year & quarter), fuel pathway code (FPC), fuel amount, transaction type, transaction date, business partner (if applicable), aggregated transaction indicator, fuel application, and production company ID/facility ID (if applicable)—so the token can map cleanly into LCFS reporting. As a result of this structure, a single CARB-accredited verifier can issue one consolidated opinion covering both QET-LNG and LCFS requirements, reducing duplicate audits while preserving EarnDLT’s original provenance chain.

The immutable registry history, cross-registry mapping, and attached verification opinion are structured so that they can also support ISO 14064-3:2019 Clause 9.1 (contents of the verification statement) and ISO 14067:2018 Clause 8 (reporting of product carbon footprint results) when QET-LNG certificates are used as evidence in EU-facing disclosure. This combination of measurement-standard agnosticism at the input layer and regulatory compliance at the output layer is what allows the QET to function as a universal bridge between heterogeneous North American MRV practices and the EU's harmonized reporting requirements.

Per ISO standards, “Validation should involve establishing mass balances, energy balances and/or comparative analyses of emission factors or other appropriate methods. As each unit process obeys the laws of conservation of mass and energy, mass and energy balances provide a useful check on the validity of the description of a unit process” (ISO-14067:2018 §6.4.3)[34]

LATEST DEVELOPMENTS

Over the last several months, there has been continued evolution in the regulatory-based landscape and tools and practices tied to measurement of CI and operability of tagging and tokenization.

In late 2025, regulatory and commercial signals continued to converge on digital, auditable methane and lifecycle-emissions evidence as a practical requirement for cross-border gas trade. EU import methane rules push digital traceability options. On December 11, 2025, European Commission circulated simplified compliance pathways under the EU's methane import rules, including a digital "trace-and-claim" approach for fuels whose molecules mix and are hard to track physically. The practical impact is that importers and suppliers are being nudged toward digital attribute accounting to demonstrate compliance and avoid disputes over provenance. This shows regulation is actively creating a market for auditable, standardized emissions/attribute records because traditional documentation and tracing are proving too brittle at scale.[35] Notably, however, in this announcement and subsequent clarifications the EU indicated that penalties for non-compliance cannot threaten the security of energy supply, which suggests potential weakening of enforcement mechanisms.

Separately, midstream operators are moving toward instrumented, certifiable telemetry that is enhancing their ability to measure emissions through their pipelines. For example, Tallgrass announced real-time emissions detection and monitoring across all Rockies Express (REX) compressor stations, enabling third-party certification. This kind of continuous monitoring is directly relevant to the "evidence pack" problem for importers: it produces higher-frequency, audit-ready data that can be carried into verification and reporting workflows.[36]

User interfaces are also evolving. To offer one example, EarnDLT and Greentruth[37] are tightening the bridge between verification and transactions. Greentruth positions itself as an interface where users can discover, acquire, retire, and report verified emissions data via its GasTrace workflow. This development can make QET-LNG more commercially useful: it shortens the path from measurement and verification to an asset a buyer can find, transact, and use in reporting, while

[35] https://www.reuters.com/sustainability/climate-energy/eu-offers-simpler-rules-comply-with-methane-law-after-us-pressure-2025-12-11/
[36] https://tallgrass.com/newsroom/press-releases/tallgrass-energy-enters-agreement-with-project-canary-to-create-the-nations-first-certified-interstate-natural-gas-transmission-system
[37] https://greentruth.com/

also reducing manual reconciliation and double-counting risk through a blockchain-backed audit trail.

Finally, large LNG exporters are productizing cargo-level emissions disclosure. Cheniere issues per-cargo Cargo Emissions Tags (CE Tags) that provide lifecycle GHG (CO2e, absolute and intensity) and methane-intensity metrics calculated using a peer-reviewed LCA model—another indicator that cargo-level emissions disclosure is becoming a standardized commercial artifact rather than a bespoke reporting exercise.[38]

CONCLUSION

Emissions tokens are poised to become the contract-level evidence layer for lower-emissions energy trade. i.e., an artifact that travels with cargos and supports compliance, assurance, and commercial due diligence. To enforce this and make it manageable, frameworks such as those established by the EU (Methane Regulation, CSRD/ESRS digital reporting, RED/UDB, and MiCA/MiFID perimeters) all converge on machine-readable proofs with strong transparency characteristics. Tokens such as those issued by Earn serve the purpose of translating regulatory requirements into a consistent, machine-readable evidence layer. Because the QET is agnostic to the upstream and midstream measurement standard employed—it can serve as a universal bridge for EU-bound importers regardless of which MRV framework their suppliers follow.

Importantly, as the broader economy moves toward agentic AI — where autonomous reasoning models and software agents consume data at scale to make procurement, compliance, and reporting decisions — the value of tokens that embed full methodological provenance in a machine-readable structure compliant with DID (decentralized identifier) standards will increase. Tokens lacking this architecture cannot be reliably consumed by systems and agents. Those that possess it, however, such as the QET, become native inputs to automated decision-making. In other words, tokenization and smart contracts embedded in them

[38] https://lngir.cheniere.com/news-events/press-releases/detail/214/cheniere-to-provide-cargo-emissions-data-to-lng-customers

compress time-to-assurance, reduce transaction frictions, and hence raise trust across producers, traders, importers, etc.

Although not the focus of this paper, the scaling power of attribute tokens is also to provide the basis for market forces to act. They enable the financial services industry to assign value to those attributes, which can foster their use as collateral, for example.

Thus the convergence of environmental tokenization with agentic AI may prove transformative. A recent Financial Times analysis observed that the emerging "token economy" in AI risks commoditization when tokens are undifferentiated units of compute[39]. Environmental attribute tokens face no such risk when they are differentiated by design, encoding verified, methodology-specific emissions data — source, quantity, measurement protocol, chain of custody — in a machine-readable, DID-compliant structure that an AI agent can consume, reason over, and act on without human intermediation. One can envision a near future in which autonomous agents representing buyers, traders, and regulators continuously discover, evaluate, and transact verified environmental attributes in real time — compressing weeks of manual due diligence into seconds and enabling dynamic markets for low-emissions energy. In this world, the token is not merely a compliance artifact; it is the lingua franca through which machines negotiate the energy transition.

[39] https://www.ft.com/content/b7f681a5-fef8-4156-bbfa-88f9c93e08b4?syn-25a6b1a6=1

APPENDIX I: EU IMPLEMENTATION TIMELINE FOR IMPORTED FOSSIL FUELS

The next four years, (if the laws aren't watered down, which is a possibility given current political pressure/landscape), will bring significant ramping up of those efforts. Specific to imported products:

- 2027: "From 1 January 2027, importers shall demonstrate, and report in accordance with Article 27(1), to the competent authorities of the Member State in which they are established that the contracts concluded or renewed on or after 4 August 2024 for the supply of crude oil, natural gas or coal produced outside the Union cover only crude oil, natural gas or coal that is subject to monitoring, reporting and verification measures applied at the level of the producer that are equivalent to those set out in this Regulation." [40] **i.e., Prove the supplier uses EU-equivalent MRV methods.**
- 2028: "By 5 August 2028 and every year thereafter, for the supply contracts concluded or renewed on or after 4 August 2024, Union producers and, pursuant to Article 27(1), importers shall report to the competent authorities of the Member State in which they are established the methane intensity of the production of crude oil, natural gas and coal placed by them on the Union market calculated in accordance with the methodology set out pursuant to paragraph 4 of this Article."[40] **i.e., Required to submit actual methane intensity numbers using EU-equivalent MRV methods proven in 2027**
- 2030+: "By 5 August 2030 and every year thereafter, Union producers and importers placing crude oil, natural gas and coal on the Union market under supply contracts concluded or renewed after 5 August 2030 shall demonstrate to the competent authorities of the Member State in which they are established that the methane intensity … is below the maximum methane intensity values established in accordance with paragraph 6"[40] **i.e., Must not exceed maximum methane intensity values established using 2027 methodology, 2028 reporting standards.**

[40] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A32024R1787

APPENDIX II: COMPARISON OF ISO STANDARDS TO SAMPLE NON-ISO PRACTICES

Aspect	**ISO Compliant**	**Non-ISO Compliant**
Data Structure & Machine Auditability	Uses a structured, machine-readable JSON schema that encodes full provenance (source data, methodologies, algorithm parameters, quality control logs) for each token. This standardized format enables automated auditing and cross-platform data exchange, since every data point is traceable and formatted consistently.	Often relies on unstructured data or ad hoc formats with no standardized schema. Inconsistent or siloed data structures make automated verification difficult and hinder interoperability, leaving information scattered and not readily available across different platforms.
Calculation Transparency & Audit Trail	Every emissions calculation is algorithmically reproducible, with all inputs, parameters, and results logged on-chain in real time. The system maintains a complete audit trail (cryptographic timestamps, calculation metadata, and outcome logs), so anyone can verify how a token's carbon intensity was derived, and automated checks flag any anomalies.	Calculations may be opaque or performed offline, with no guarantee that independent parties can reproduce the results. There is typically no automatic on-chain log of computations, forcing auditors to rely on static reports or issuer claims, data can thus become "abstract, incomplete, and unverifiable" without a structured process. This lack of transparency undermines traceability and confidence in the token's numbers.
Verification & Assurance Rigor	Relies on third-party verification aligned with ISO 14064-3/14065 standards, using accredited independent verification bodies. Verifiers must have appropriate credentials (e.g. ISO 14065 accreditation, CARB LCFS approval) and technical expertise, providing high assurance that each token's GHG data and	Often lacks formal third-party oversight, some token systems rely on self-verification or minimal assurance with no accredited auditors involved. This weak assurance model leads to inconsistent quality and lower trust, as different issuers may apply varying methods and even equally skilled reviewers could reach

Aspect	ISO Compliant	Non-ISO Compliant
	calculations are validated to internationally recognized standards of quality and impartiality.	divergent conclusions without a common standard. In short, the data aren't guaranteed to be verified by an impartial, qualified party, eroding confidence.
Materiality & Uncertainty Controls	Employs explicit materiality thresholds and uncertainty quantification to ensure data accuracy. For instance, a single batch's carbon intensity variation over ~5% is flagged as material and requires attention, and each token's carbon intensity comes with a quantified uncertainty range (e.g. ±10% for an individual token) that is calculated and transparently reported. If thresholds are breached, the framework mandates corrective actions (such as increased measurement frequency or improved data precision) to maintain confidence in reported values.	Typically defines no clear materiality limit or uncertainty reporting. Significant variances in emissions data may go unflagged, and tokens seldom include a quantified confidence interval for their values. Without such standardized thresholds, large errors or data gaps might pass unnoticed, making it hard for stakeholders or regulators to judge the reliability of the token's claims or enforce consistency. In practice, the absence of formal uncertainty disclosures can mask the true variability in the data.
Data Quality & Integrity	Enforces strict data quality controls and documentation. Each token's JSON metadata includes a 'Quality Assurance' attribute capturing calibration standards (e.g. meter calibrations per ASTM/API), detection limits, required measurement audits, and measurement uncertainty documentation. Automated validation checks (such as cross verifying against utility records, mass-balance reconciliation, and	Often lacks embedded quality-control measures. Source data might be taken at face value from project operators without systematic calibration records, independent cross-checks, or rigorous validation. This raises the risk that errors or even double-counted emissions go unnoticed – indeed, traditional carbon credit approaches have been *"plagued by opaqueness…fueled by a lack of transparent and verifiable data,"*

Aspect	ISO Compliant	Non-ISO Compliant
	statistical outlier detection) are performed before token issuance. These built-in controls ensure no token is issued on dubious data; errors or double counting are caught early by quality control algorithms, and an immutable record of data integrity checks is maintained.	which contributes to integrity issues like greenwashing.[41] In a non-ISO token, there is generally no formal data quality hierarchy or audit trail to ensure the numbers are accurate and reliable.
Regulatory Readiness & Integration	Designed for compliance and easy integration with regulatory programs. The token's structure is modular to meet various jurisdictional requirements, for example, a QET-RNG-T token can be augmented with an LCFS-specific extension methodology to generate credits under California's Low Carbon Fuel Standard. Core data fields and calculation methods align with major regulations (e.g. CARB LCFS, U.S. EPA Renewable Fuel Standard, EU Methane Regulation), so the tokens can be readily used in official reporting or credit systems. This regulatory alignment means enterprises can trust that the token's data will satisfy compliance audits and integrate with government or exchange frameworks 'out of the box'.	Lacks alignment with established regulatory standards, meaning such tokens are usually not accepted directly in compliance markets. Ad-hoc tokens with non-standard data and unverifiable methods are confined to voluntary use unless they undergo substantial re-verification or retrofitting to meet regulators' criteria. In practice, the absence of common standards makes it difficult for regulators to even formulate oversight, so programs like EU ETS or LCFS generally do not recognize these tokens. This gap leaves non-ISO tokens less equipped for enterprise compliance integration, requiring extra steps to bridge to any formal regulatory system.

[41] https://prism.sustainability-directory.com/scenario/regulatory-frameworks-for-blockchain-carbon-offsetting

About the Authors

Liam O'Byrne, BS Computer Science, Colorado School of Mines
Liam O'Byrne is a student researcher at the Payne Institute. He is pursuing his B.S. in Computer Science at the Colorado School of Mines.

Brad Handler, Payne Institute Program Director, Energy Finance Lab, and Researcher
Brad Handler is a researcher and heads the Payne Institute's Energy Finance Lab. He is also the Principal and Founder of Energy Transition Research LLC. He has recently had articles published in the Financial Times, Washington Post, Nasdaq.com, Petroleum Economist, Transition Economist, WorldOil, POWER Magazine, The Conversation and The Hill. Brad is a former Wall Street Equity Research Analyst with 20 years' experience covering the Oilfield Services & Drilling (OFS) sector at firms including Jefferies and Credit Suisse. He has an M.B.A from the Kellogg School of Management at Northwestern University and a B.A. in Economics from Johns Hopkins University.

The Payne Institute for Public Policy
AT COLORADO SCHOOL OF MINES

About The Payne Institute

The mission of the Payne Institute at Colorado School of Mines is to provide world-class scientific insights, helping to inform and shape public policy on earth resources, energy, and environment. The Institute was established with an endowment from Jim and Arlene Payne and seeks to link the strong scientific and engineering research and expertise at Mines with issues related to public policy and national security.

The Payne Institute Commentary Series offers independent insights and research on a wide range of topics related to energy, natural resources, and environmental policy. The series accommodates three categories namely: Viewpoints, Essays, and Working Papers.

Visit us at www.payneinstitute.mines.edu

Follow Us

Disclaimer

The opinions, beliefs, and viewpoints expressed in this article are solely those of the author and do not reflect the opinions, beliefs, viewpoints, or official policies of the Payne Institute or