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Differentiated Gas and the Chain of Custody:

A Comparative Analysis of "Trace and Claim" and "Book and Claim" for Natural Gas Emissions Intensity

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1 Preface

The widespread adoption of LNG transformed natural gas into a global commodity subject to commercial and regulatory pressures. These pressures have led to the transition to “differentiated gas” in the global natural gas markets, which a commodity valued for its environmental attributes, particularly its emissions intensity. This shift is driven by new, stringent regulations, such as Article 27 and Annex IX of the EU Methane Regulation, which mandates provenance and emissions data for imports.[1] This requirement necessitates a credible chain-of-custody (CoC) model to track attributes through the fungible, co-mingled gas supply chain. This paper compares two of the primary accounting-based CoC models: "Book and Claim" (B&C) and "Trace and Claim" (T&C).

This analysis finds that the B&C model, which decouples environmental attributes from the physical product[2], offers flexibility by creating two disjointed markets but is fundamentally incompatible with new provenance-based regulations[5] and carries significant speculatory and greenwashing risks. In contrast, the T&C model transactionally binds attributes to specific, nominated volumes of gas via Sale and Purchase Agreements (SPAs) and a "plausible physical pathway" requirement, thereby fully complying with both the letter and intent of the regulation.

We demonstrate that T&C is not only compliant with regulations, but also operationally feasible, supported by existing contractual frameworks like NAESB addenda and active commercial implementations using technology to enforce contractual obligations. The paper further outlines a major, but often unrecognized, value of the T&C model, which is its flexibility in its data requirements. Even though T&C has been criticized as being too difficult to implement, we show that it is a scalable framework that can be implemented immediately using readily available estimated data (low-fidelity) to meet initial reporting rules, but can evolve to incorporate high-fidelity, measurement-based, and tokenized data[6] as technology, markets, and regulations mature. This evolutionary potential, combined with its ability to directly incentivize producer-level abatement[5], makes the T&C model the ideal architecture for a high-integrity, differentiated natural gas market.

2 The Imperative for Emissions Traceability in Global Gas Markets

2.1 The Rise of "Differentiated Gas"

The global natural gas market is undergoing significant evolution. Historically, natural gas has been treated as a pure commodity, priced almost exclusively on its energy content (measured in British Thermal Units or MMBTU or 100,000 BTUs), location, and volume (MCF or 1,000 cubic feet). This paradigm is changing. A new market is emerging for "differentiated gas," a product that is valued not only for its energy but also for its environmental attributes, most notably its emissions intensity.[6]

This differentiation is being driven by both commerical and regulatory pressures. On the commercial front, a market for "responsibly sourced gas" (RSG) has gained significant traction, particularly in North America.[6] This designation, often certified by third-party standards, allows producers and transporters to market their gas as being produced with low fugitive emissions and managed by the best practices in environmental stewardship. Forward-thinking operators have adopted these practices to gain a competitive edge and, in some cases, to secure premium pricing from buyers with corporate sustainability goals – with the recent investments in data centers being a prime example[18]. This voluntary action has established the commercial precedent that not all gas is created equal, setting the stage for more formalized accounting and robust validation to ensure the highest attribute veracity.

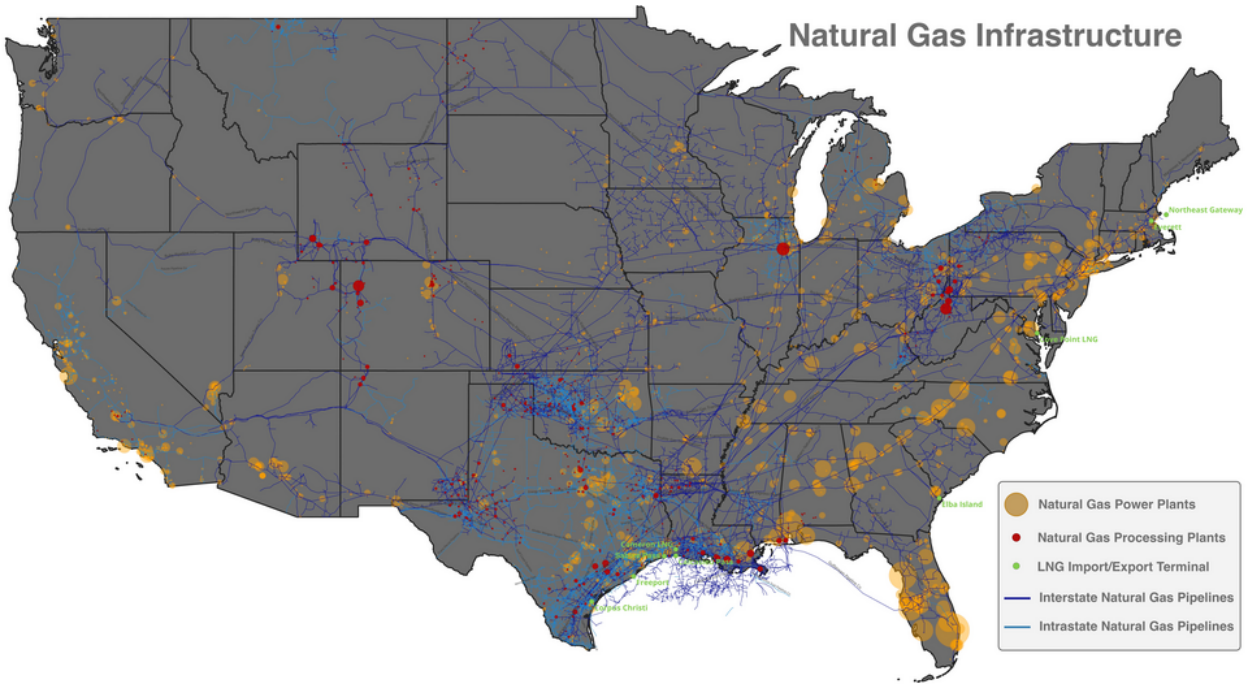
2.2 Regulatory Catalysts: The EU Methane Regulation as a Significant Development

While voluntary action opened the door, new, stringent regulations are accelerating the restructuring of the market. The most significant catalyst is the European Union's Methane Regulation, introduced in 2024.[1] This regulation is a significant development, moving methane intensity from a beneficial marketing attribute to a prerequisite for market access. The regulation mandates that importers of oil and gas into the EU must obtain "quality data on the origins and associated emissions of imports".[1] This is a legal requirement. By 2027, all imports must comply with the EU's domestic standards for monitoring, reporting, and verification (MRV).[6] Furthermore, the regulation will prescribe maximum levels of methane emissions associated with imported liquefied natural gas (LNG) and pipeline gas, effectively creating a performance standard.[6]

This regulatory development creates a requirement for a "credible and transparent chain of custody model".[1] Importers will be legally obligated to prove the emissions intensity of their specific gas purchases. This regulatory requirement is a significant market driver, more universal than the voluntary "carrot" of RSG branding. It is effectively bifurcating the global gas market into two tiers: a compliant, high-value market for verified, low emissions intensity gas that has access to the EU, and a non-compliant, lower-value market for unverified gas that will face penalties or be locked out entirely.

2.3 The Central Challenge: Accounting for a Fungible, Co-Mingled Commodity

The primary technical challenge in meeting these voluntary and regulatory demands lies in the fundamental nature of natural gas. As a commodity, it is fungible. Gas from thousands of different production assets, each with a unique emissions profile, is co-mingled in common carrier pipelines and transportation networks.[5]



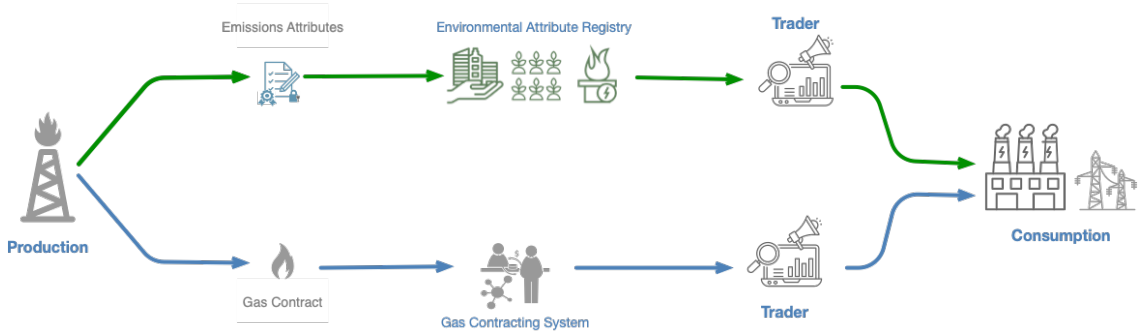
Natural Gas Pipelines - Wikipedia

Once in the pipeline as *pipeline quality gas*, the molecules from a "clean" (low-emission) well are physically indistinguishable and inseparable from the molecules of a "dirty" (high-emission) well. The gas may also be transported through a high-emission or a low-emission pipeline. This co-mingling and variable pathways make the most straightforward chain-of-custody model, "physical segregation," economically and logistically impractical. Physical segregation would require "separate shipping routes and storage"[1] or dedicated infrastructure from the source to the consumer, an approach that is "extremely cumbersome," cost-prohibitive, and would likely create increased indirect costs and increased emissions.[2] From a practical point of view, this approach is essentially impossible.

Therefore, the market must adopt an accounting-based chain-of-custody (CoC) model that tracks the environmental attributes of the gas, even when the physical molecules are mixed. The three primary CoC models are Physical Segregation, Trace and Claim (T&C), and Book and Claim (B&C).[1] These can be seen as lying on a spectrum from the most physically accurate representation (Physical Segregation) to the most abstract B&C, with T&C being a natural representation of the physical flows with a reasonable degree of abstraction.

With physical segregation dismissed as impractical, the technical debate for the future of the global gas market centers on the two viable accounting alternatives: B&C and T&C. The choice between these two models is a strategic choice which will determine the future of the natural gas markets and how, or if, companies and nations can participate in them. The data associated with emissions is being transformed from a simple marketing add-on into a prerequisite for a financial transaction, a form of collateral that proves the value and legal standing of the underlying commodity.

3 The "Book and Claim" (B&C) Model: Prioritizing Market Flexibility and Scale



The Book and Claim Model – Market Bifurcation

3.1 Core Mechanics: Decoupling the Attribute from the Physical Product

The "Book and Claim" (B&C) model is a chain-of-custody system in which the administrative record of the environmental attribute flow is intentionally and completely decoupled from the physical flow of the material.[2] The mechanics are straightforward:

- **Book**: A natural gas producer meeting a certain emissions standard (e.g., "certified low-methane") produces a volume of gas. This compliant production is "booked" into a central, third-party registry, which then issues a corresponding tradable certificate.[1] Typically the mid-stream is ignored.
- **Claim**: A gas consumer (e.g., a utility or industrial user) anywhere else in the world can purchase this certificate from the registry.[1] This consumer can then "claim" the environmental benefit of using "certified gas," even if the physical gas they actually receive and combust is uncertified, high-emission gas.[1]

In this model, the environmental attribute is treated as a separate, tradable commodity, fully disassociated from the physical gas molecule.[2] The emissions accounting is based on aggregate, often yearly, estimates of certified production and certified consumption, ensuring only that the total volume "booked" does not exceed the total volume "claimed" on an annual basis. It does not, by design, connect a specific buyer's claim to a specific producer batch or a specific, time-bound transaction. This model effectively creates 2 markets: one for gas, and one for the environmental attributes as a tradable financial instrument entirely decoupled from the gas markets.

3.2 Advantages: Logistical Efficiency and Market Creation

The B&C model's primary advantages stem directly from this decoupling, which in many ways mirrors the structure of carbon credit markets.

First, it offers Logistical Efficiency. By avoiding the need for physical segregation or mass-balance tracking, it eliminates the apparently complex[2] and costly supply chain monitoring. This "facilitates logistical efficiency for reducing cost and emissions"[4], as it does not require producers and consumers to be part of the same confined, interconnected pipeline system.

Second, and most significantly, B&C is an effective tool for Market Stimulation. This is its primary business benefit.[2] By "decoupling low-carbon products from the associated decarbonization claims", B&C allows companies to sell the carbon attributes separately. This "stimulates decarbonization efforts"[2] by allowing a producer who has invested in abatement but is geographically disconnected from willing buyers to still monetize that investment: for example, a Norwegian producer could sell attributes for gas that are used against

gas purchased in Africa. It "expands the potential market for... producers"[4] and allows buyers (operators) who may not have "access to the actual... molecules" to "have facilitated access to the... benefits".[4] This system can also expand the market by allowing claims to be sold in more granular lots than physical products, enabling buyers with lesser purchasing power to participate.[2] It is worth noting that the B&C mechanism mirrors the more distributed point-to-point trading patterns seen in financial markets where the natural gas markets actually tend to be largely centralized or coordinated through bodies like NAESB.

The Sustainable Aviation Fuel (SAF) market is a good analogue for B&C's success. An airline operator at an airport with no physical access to SAF can purchase SAF certificates from producers across the globe.[4] This purchase funds and scales SAF production in general, helping investment in SAF production capacity, even though the airline operator is still physically fueling its planes with conventional jet fuel. In 2023, for example, United Airlines accounted for around 25% of purchases of SAF[19], though with the very distributed nature of operations and the limited geographical availability of SAF, only a small geographically limited number of flights actually used SAF.

3.3 Disadvantages and Critical Limitations for Natural Gas

Despite its advantages in stimulating the market for environmental attributes, the B&C model possesses significant disadvantages that render it unsuitable for the emerging commercial and regulatory landscape of natural gas.

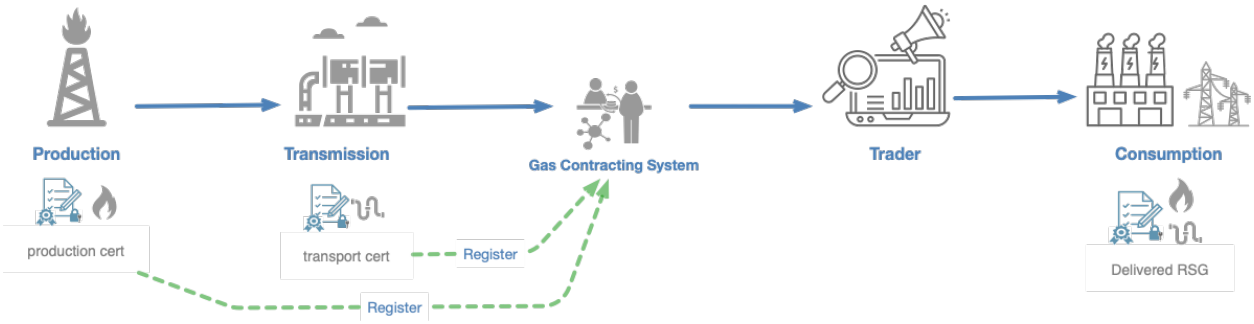
The primary disadvantage of the B&C model is a Gap in Integrity. The very decoupling that provides flexibility also creates a significant risk of "greenwashing". A utility, for example, could claim to its customers and regulators that it is providing "low-emission gas" while, in physical reality, it is sourcing 100% of its supply from the cheapest, highest-emission producer and through a high-emission pipeline. The claim is "covered" by a certificate purchased from a producer or transporter in a different country, creating a disconnect between the company's "green" claims and its actual physical impact on the environment. This is particularly true for natural gas because the “cleanliness” of production and transportation varies significantly based on geography.

A secondary disadvantage is that while the stimulation of the environmental attribute markets is real, it is largely a short-term advantage because the Gap in Integrity will eventually drive the emergence of higher integrity alternatives. Worse, the stimulation can lead to speculation (for example, a company could stockpile all the attributes from Norway as a speculative bet), which can then lead to market destruction. The carbon credit markets, which are a close analogue, show exactly the longer-term effects of this approach, and the SAF markets are already anticipating speculation based on supply limitations. Fundamentally, the B&C mechanism creates two markets (one speculative and one commodity) that are not coordinated or incentive aligned, and which are certainly not aligned with the overall goal of encouraging longer term investment in emissions reduction activities.

Further, another critical limitation is its Regulatory Incompatibility. B&C, by its very design, cannot satisfy the provenance-based requirements of regulations like the EU Methane Regulation.[5] Article 27 and Annex IX of that regulation explicitly require importers to show where the fossil fuels were produced and the transit path they took before being placed on the market.[5] B&C is incompatible with this mandate because it severs the link between the claim and the physical origin/pathway. It is impossible for a B&C system to provide the "granularity of data regarding the major socio-economic region of origin and transit" that the EU regulation demands.[5]

Ultimately, B&C is a market-stimulation mechanism suitable mostly for distributed and decentralized markets. Much as it was applied to the global carbon offsets, B&C is designed to channel general funding into decarbonization in the short-term through loosely coupled financial devices but does not provide good market alignment or longer-term scaling opportunities essential for achieving net-zero. The emerging regimes of fossil fuel regulation around the world, however, demands a supply-chain assurance mechanism that can verify the attributes of the specific product being imported. The SAF/CORSIA B&C model[3] is fundamentally mismatched to the regulatory frameworks, EU natural gas imports using B&C approach are at risk of non-compliance, which may well strand the investments in the system and the associated certificates.

4 The "Trace and Claim" (T&C) Model: Linking Attributes to Physical Transactions



The Trace and Claim Model – Natural Modelling, Single Market

4.1 Core Mechanics: "Following the Money" via Mass Balance

In direct contrast to the decoupled nature of B&C, the "Trace and Claim" (T&C) model is a high-integrity chain-of-custody system designed to create and maintain a durable, auditable link between an environmental attribute and a specific, transacted volume of natural gas. The model does not attempt the impossible "follow the molecules" approach, but rather the more practical "follow the money" strategy.[5]

- It begins at the point of production, where a "digital identity" is assigned to a specific volume of gas.[1] This digital identity is directly bound to the environmental attributes of that gas, such as the quantified emissions intensity of that specific volume of gas (explained in 4.2 below).
- This ID and its associated data are then transactionally tracked as the gas is bought and sold through the supply chain, with the data passing from producer to midstream to importer via Sale and Purchase Agreements (SPAs).[1]
- If a volume of gas is divided and sold to different buyers, the new batches receive a derivative of the original ID.[5]
- Crucially, a buyer can only "claim" the environmental attribute if a "plausible physical delivery path" exists between the origin (producer) and the destination (consumer or liquefaction terminal).[5]

This "transactional binding" where the attributes are linked to the SPA, and the requirement for a plausible physical path, are the key differentiators of T&C.

4.2 The Mass-Balance Foundation

The T&C model is a technology enabled evolution of the "Mass Balance" accounting principle. A traditional mass balance model tracks the ratio of compliant-to-non-compliant fuel within a mixed system. It requires "detailed bookkeeping at every stage in the supply chain"[1] to ensure that the volume of "certified" product claimed at the outlet does not exceed the volume of "certified" product that entered the inlet, accounting for any losses.

Traditional mass balance, as used in the SAF market, is often "tied to a confined (closed) supply system"[9], such as a single pipeline or an airport's co-mingled fueling infrastructure.[10] T&C adapts this concept for the unconfined, continental pipeline grids where gas from all sources are co-mingled.[11] It does this by using the financial transaction (as specified by the SPA) and the physical nomination (the volume of gas "nominated" or bought at a point in time) as the auditable "batch" or "volume" to be mass-balanced. This time-bound, nomination-based quantification is what fundamentally links the claim to a specific, real-world flow of gas,

distinguishing it from B&C's disconnected, yearly aggregate estimates and issuance based solely on production volume.

4.3 Advantages of the T&C Model

The T&C model's advantages lie in its integrity, regulatory fitness, and ability to create correct market incentives.

a. **Regulatory Compliance**: This is its primary advantage. The T&C model is described as "the only appropriate solution" to meet the provenance and transit-path reporting requirements of the EU Methane Regulation (Article 27 / Annex IX).[5] Its ability to track origin and pathway directly addresses the law's requirements.

b. **High Integrity and Verifiability**: By linking claims to SPAs, digital IDs, and plausible physical paths, T&C provides a granular, auditable, and verifiable link between the environmental claim and the physical supply chain.[1] This reduces the "greenwashing" risk inherent in B&C and provides high assurance to regulators and stakeholders. With higher quality data comes increased financial security, much like a “triple A” rated bond.

c. **Direct Producer Incentivization**: This is the model's significant long-term value. T&C ensures that the specific producers and midstream operators who invest in abatement are the "financial beneficiaries" of the value created by that low-intensity gas.[5] Because the attribute is "bundled" with the transaction, buyers "prioritize lower intensity supplies"[5], creating a direct market signal that rewards capital investment in emissions-reduction technologies. B&C's signal, by contrast, is diffuse, rewarding the cheapest certificate, not necessarily the producer in the buyer's actual supply chain.

d. **Flexibility and Durability**: The T&C approach is a natural model of the supply chain and can adapt to the needs of the voluntary and regulatory environments as they evolve over time. A single mechanism can be put into place today using the best currently available data and seamlessly incorporate more stringent market demands for more detailed data as the data becomes available. This is discussed in detail later in this paper.

4.4 Disadvantages of the T&C Model

The primary disadvantages of the T&C model are its apparent complexity and nominal implementation cost.

a. **Complexity**: A robust T&C system is more complex to establish and manage than a simple B&C registry. It requires a "robust and well-maintained data registry of profiles and certificates"[1] and "interoperable digital registries" to track the movement of attributes and prevent double-counting.[5] Note that this complexity is more apparent than real: by their nature, the natural gas markets tend to be largely centralized, so these registries are often already in place.

b. **Cost and Effort**: Compared to the simple trading of decoupled certificates, a system that "requires direct links to be established between the claims and physical supply chain" is nominally more "labor-intensive to audit"[2] and costly. It should be noted that the cost of data acquisition is generally not a factor and the use of distributed ledgers and technology for operational analytics drives the audit costs down, so this is largely a short term cost.

While B&C decouples the environmental attribute from the commodity[2], T&C physicalizes it. It achieves this not by tracking molecules, but by legally and financially binding the attribute to the commodity's transaction.[5] The attribute becomes a non-fungible, auditable characteristic of the gas volume being sold under an SPA. This creates a new and durable basis for global competition in the natural gas market, shifting the focus from price-per-Btu alone to the verified, end-to-end emissions intensity of the delivered product.

4.5 Practical Implementation and Market Adoption

The "Trace and Claim" model is not merely theoretical; it is supported by existing market mechanisms and is already in commercial use in the United States, one of the most complex and diverse natural gas supply chains in the world according to NERA.

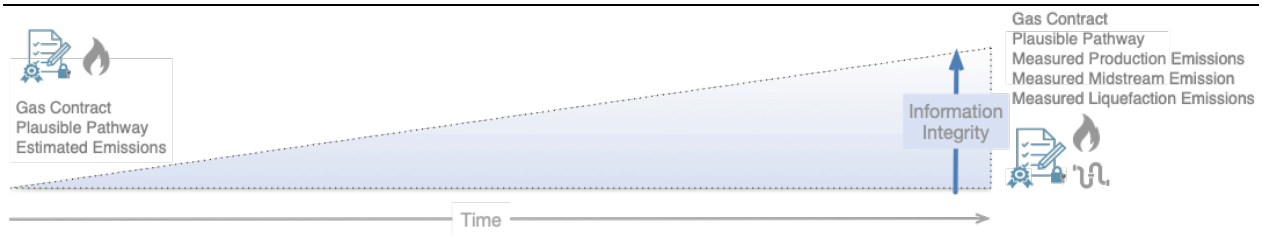
In the United States, approximately 95% of gas traded is via the North American Energy Standards Board (NAESB) contracts. NAESB provides a robust framework and has developed a "Certified Gas Addendum" (CG Addendum) for its Base Contract for Sale and Purchase of Natural Gas. This addendum and an associated digital registry system are designed to allow environmental attributes to be transferred along with the physical gas transaction, effectively binding the data to the Sale and Purchase Agreement (SPA).[5] This existing contractual infrastructure is being adapted to support digital technologies, including distributed ledgers, creating a ready-made accounting mechanism for T&C.

In addition to this, several companies are actively implementing T&C models to create differentiated gas products. For example, Williams, a large mid-stream company transmitting around 30% of the natural gas in the USA (and now also a producer), and Jonah Energy – small producer at full OGMP L5 certification, are using technology platforms to quantify and track emissions across their value chains. Williams' "NextGen Gas" platform is a comprehensive, full value-chain certified gas program utilizing distributed ledger technology to provide transparency and transactability.

These implementations often rely on open methodologies which integrate data from advanced monitoring technologies and data from compliance programs like OGMP 2.0 Level 4 or 5. Consequently, the quantification for creation of environmental attributes is generally cost neutral or cost negative, being covered by the premiums commanded by differentiated gas, or through operational efficiencies.

5 The Data Spectrum of "Trace and Claim"

A key attribute of the "Trace and Claim" model is its flexibility. It is not a single, rigid standard but rather a *framework* that can operate across a wide spectrum of data fidelity. This adaptability allows companies and the market to adopt the T&C model *immediately*, using currently available estimated data, and *evolve* over time to incorporate high-fidelity, measurement-based data as technology and regulations mature. This evolutionary potential is what makes T&C a durable solution.



The Spectrum of Data Requirement and Integrity

5.1 The Low-Fidelity Spectrum: Estimated Data for Initial Regulatory Reporting

At the low-fidelity end of the spectrum, the T&C model functions by linking transacted volumes to the best available *estimated* or factored data. This model is built on three core components:

c. **Contracted Volumes**: The claim is rooted in a bona fide commercial transaction, based on specific volumes of gas nominated or bought at a point in time. This auditable fact basis is tracked via Sale and Purchase Agreements (SPAs), which establish the "follow the money" linkage.[5]

d. **Plausible Physical Pathway**: The system must verify that a physically plausible pathway exists for gas to travel from the specified production facility to the consumption point or liquefaction terminal.[5]

e. **Estimated Emissions Data**: The emissions intensity value assigned to the gas volume is not based on direct, real-time measurement. Instead, it is derived from estimated data based on public reports, regulatory filings, and industry-standard frameworks.[5]

It is worth emphasizing that this requires nothing more than a means to register a contract with these data points, which is arguably simpler than B&C which requires a registry for the contract and a registry for the attributes which are tracked independently. Key sources for this estimated data include:

- **EPA Filings**: In the United States, data from the U.S. Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP) serves as a baseline.[13]
- **OGMP Reports**: The Oil & Gas Methane Partnership (OGMP) 2.0 framework is a critical source.[16] This "comprehensive methane reporting framework"[7] provides a standardized, tiered system for companies to report their methane emissions, improving transparency and accuracy even at estimate-based levels.
- **Voluntary Frameworks**: Data from other programs, such as "responsibly sourced gas" (RSG) certifications[13] and other voluntary reporting initiatives[14], can also be used to establish the estimated emissions profile.

This low-fidelity model is not merely a theoretical starting point; it is what the EU Methane Regulation mandates in its initial phase.[5] Beginning in May 2025, Article 27 and Annex IX of the regulation require importers to report "where the fossil fuels were produced," the "transit path" taken, and the "estimated associated emissions intensity".[5] This is the low-fidelity T&C model. The regulation itself provides

the pathway, establishing this T&C structure as the de facto starting point for regulatory compliance in the world's largest gas-importing market.

5.2 The High-Fidelity Spectrum: Audited, Digitized, and Composable Value Chains

At the other end of the spectrum lies the high-fidelity T&C model, representing a fully mature, digitally enabled, and measurement-based ecosystem. In this model, emissions are quantified on a monthly basis (or even real-time) using direct measurement technologies (e.g., satellites, aerial surveillance, process control systems, continuous monitoring) and are fully audited by independent third parties. This advanced model is implemented through a robust digital architecture:

- **Tokenization and Digital Twins**: Service providers in this space create a "digital twin" of a produced and transported volume of natural gas or LNG.[6] This digital twin is a data packet containing all available information about that volume's characteristics, including its "provenance, energy and water intensity... and emissions measurements/factors of the site".[6] This twin is then "tokenized" to capture these characteristics in an "immutable and distributed fashion"[6], often using distributed ledger (blockchain) technology.
- **Facility and Segment-Level Certification**: In this model, each facility or segment along the value chain is also represented by a “digital twin”. These each receive a "certificate” representing a verified emissions intensity for a specific batch or volume at a specific facility over a particular period. These are often represented as “tokens” with names like "Methane Performance Certifications (MPCs)"[6] or "Certified Environmental Tokens (CETs)".[6]
- **The Composite Certificate**: This is the end-product for the final buyer. The digital T&C system allows for the creation of a "composite certificate" that is composed of individual, sequential tokens (MPCs or CETs) along the audited pathway. For an LNG cargo, a buyer would receive a single, immutable composite certificate that is the digital aggregation of all upstream tokens: for example, production, transmission, and liquefaction certificates. This composite certificate[15] provides a fully audited, measurement-backed, and verifiable end-to-end emissions intensity for the final delivered product, from the wellhead to the import terminal.

This high-fidelity system, built on the same T&C framework of "following the money" and linking attributes to SPAs, provides a high level of assurance, integrity, and data granularity, and is perhaps the ideal solution for natural gas. The environmental attributes are directly attached to, and are inseperable from, a legal instrument (the SPA) rather than being a financial instrument.

The most important point, which is often lost in discussion, is that T&C does not *require* the highest fidelity in order to be practical. It can be implemented today, with very little additional overhead, and evolve with a company’s digital maturity as well as market and regulatory environments. It is the only approach that allows for a true and natural phasing in of increasingly more accurate and verifiable quantification of the product’s emission intensity.

6 Comparative Analysis: Trace and Claim vs. Book and Claim

The fundamental differences between the "Book and Claim" and "Trace and Claim" models are best summarized by a direct comparison of their core attributes, mechanics, and regulatory fitness.

Attribute	"Book and Claim" (B&C)	"Trace and Claim" (T&C)
Link to Physical Product	Decoupled. Attributes are "fully decoupled from its physical molecules".[2] The claim is not linked to the physical gas received by the buyer.	Transactionally Bound. Attributes are linked to specific, nominated volumes via Sale and Purchase Agreements (SPAs) and require a "plausible delivery path".[1]
Data Granularity	Low. Based on aggregated, often yearly estimates of production.[2] No pathway or origin data is provided to the end-user.	High (and Scalable). Provides a scalable spectrum from facility-level estimated data[5] to measured, pathway-specific, monthly/real-time quantification.[6]

Quantification Basis	Certificate Trading. A certificate for an aggregate volume is "booked" by a producer and "claimed" by a consumer.[1] Not a mass-balance system.	Transactional Mass Balance. Emissions are quantified and mass-balanced against nominated volumes at a point in time, linked to a specific producer and pathway.[1]
Primary Advantage	Market Flexibility. "Stimulates decarbonization efforts"[2] and provides "logistical efficiency"[4] by creating a liquid, globally decoupled market for attributes.[2]	Integrity & Incentivization. Provides a high-integrity, auditable claim[5] and ensures financial value flows to the specific producers who abate in a buyer's supply chain.[5] The claim is directly bound to a legal instrument.
Primary Disadvantage	Low Integrity. No link to physical product creates a significant "greenwashing" risk.	High Complexity. Requires "robust and well-maintained data" registries[1] and is more "labor-intensive to audit"[2] than simple certificate trading.
Regulatory Alignment (EU)	Incompatible. Cannot meet EU Methane Regulation (Article 27 / Annex IX) requirements for "origin and transit path" data.[5]	Essential & Evolving. The only model that can meet initial reporting requirements[5] and evolve to meet future performance standards (Article 29).[5]

The comparative analysis reveals a clear and fundamental trade-off: market-scaling flexibility (B&C) versus supply-chain integrity (T&C).

The B&C model is optimized for flexibility. Its purpose is to scale a market and fund decarbonization in general, regardless of geography or physical logistics. This is why it is a suitable tool for markets like Sustainable Aviation Fuel (SAF), where the primary goal is to channel global funding into a nascent industry, often in the context of global offset programs like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).[3]

The T&C model is optimized for integrity. Its purpose is to verify the attributes of a specific, delivered product to prove compliance with a mandatory import standard. This is precisely what is required by the new wave of fossil fuel regulations, exemplified by the EU Methane Regulation.1 In this context, the "flexibility" of B&C is not an advantage; it is a significant liability, as it breaks the chain of provenance that the regulation explicitly demands.

For the global natural gas market, which is not a nascent industry but a mature one facing new, stringent, provenance-based rules, the choice is clear. The T&C model is the only credible framework that can provide the integrity, verifiability, and granularity required to operate in this new regulatory environment.

7 Conclusion

This analysis has examined the two primary chain-of-custody models, "Book and Claim" (B&C) and "Trace and Claim" (T&C), competing to provide the accounting framework for the differentiated natural gas market. The findings reveal a fundamental trade-off: B&C prioritizes market-scaling flexibility, whereas T&C is designed for supply-chain integrity and regulatory compliance.

The B&C model, by decoupling environmental attributes from physical product flow[2], is an effective tool for early stage stimulation of markets, as seen with Sustainable Aviation Fuel.[2] However, this same decoupling renders it structurally incompatible with new, provenance-based regulations like the EU Methane Regulation, which explicitly requires data on origin and transit paths.[5]

The T&C model, conversely, is found to be the only framework that directly addresses these new regulatory requirements. By transactionally binding attributes to physical nominations via SPAs and requiring a plausible physical pathway[1], it creates an auditable link between a claim and a specific, real-world supply chain. As demonstrated by its integration with existing NAESB contracts and its adoption by market participants, T&C is an operationally viable solution, not merely a theoretical one.

The primary strategic value of the "Trace and Claim" model, as identified in this paper, is its inherent evolutionary potential. The framework's "data spectrum" is its key advantage, establishing an essential on-ramp for the global market. It allows for immediate adoption using available, low-fidelity estimated data to satisfy initial reporting rules (Phase 1).[5] From this baseline, the T&C framework is designed to evolve seamlessly to incorporate higher-fidelity, measurement-based, and digitally tokenized data (Phase 3) 6 as monitoring technologies and regulatory performance standards mature.[5]

In conclusion, "Trace and Claim" is more than a simple accounting model. It is the necessary foundational architecture for a high integrity, differentiated natural gas market. It is the only credible solution that both meets the immediate compliance needs of today and provides a durable, scalable framework for the rigorous, measurement-based standards of tomorrow. Most critically, it properly aligns market incentives with physical reality, ensuring that the financial value of differentiated gas flows directly to the specific producers who invest in verifiable emissions abatement.[5]

8 Works Cited

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