PADV–NTCC – ESG Integrated Methodology

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Value Statement

At its core, the **NTCC (Non-Tradable Commitment Credit)** system establishes a new standard for how sustainability is **verified** rather than **traded**. It provides the **data assurance layer** that converts behavioral participation into measurable, auditable, and **non-financial engagement metrics**.

Unlike market-based instruments that derive value from exchange, NTCC derives value from verified human and organizational actions, ensuring that every credited outcome is grounded in traceable behavioral evidence. Built upon the **PADV (Participation–Action–Data–Value)** architecture, NTCC transforms participation into verified **Proof Records**, verified Proof Records into auditable **impact data**, and impact data into institutional trust.

In doing so, it establishes a verifiable bridge between individual engagement and ESG disclosure, aligning behavioral evidence with global assurance frameworks. Just as **ISO standards** created consistency for quality management, NTCC creates trust for sustainability data—shifting the foundation of climate credibility from narrative claims to **behavioral verification**.

It is not a currency, but a **digital ledger of trust** — ensuring that sustainability is proven through verified participation, not purchased through tradable offsets.

Abstract

The **NTCC Methodology White Paper v2.0** defines the operational and theoretical framework for **Non-Tradable Commitment Credits**, a verification-based mechanism designed to institutionalize behavioral sustainability data within global ESG assurance systems.

Developed under the PADV Four-Ring Model (Participation–Action–Data–Value), NTCC establishes a data-verifiable pathway linking individual and corporate actions to measurable **engagement impact proxies** (estimated kg CO_2e). Each NTCC index is generated through a dual-pathway mechanism—**Community**

Engagement Verification (fixed VF = 0.95) and **Task Verification** (dynamic VF 0.8–1.2)—with weighting calibrated by the ESG composite index ($W_{ESG} = CEF + SEF + IRF$) and annualized by the Recognition Coefficient (RCF) to align with fiscal ESG disclosure cycles.

The framework introduces a **non-financial verification logic**, ensuring that sustainability performance is measured by behavioral reliability rather than market liquidity. All data are processed through the **PADV Verification Engine** and recorded as immutable Proof Records in compliance with **GRI 305**, **IFRS S2**, **COSO Control Environment**, and **ISO 14064 data collection standards**.

Through this structure, NTCC transforms ESG assurance into a quantifiable, **audit-ready behavioral data system** that eliminates duplication, speculation, and greenwashing risk. Field implementation across four sustainability exhibitions (March–October 2025) produced **11,855 verified actions**, 5.25 million points of behavioral participation, and **15.1 units of NTCC engagement metrics** (proxy: tons CO_2e) generated by over 35,000 participants and 72 partner brands.

These empirical results validate NTCC as an **enterprise-grade, non-market verification architecture** capable of supporting Scope 3 data disclosure and corporate ESG governance. The NTCC methodology thus complements—rather than competes with—existing carbon and ESG frameworks. It provides the missing **data layer** in sustainability accounting, enabling corporations, regulators, and verifiers to transition from declarative claims to verifiable behavioral evidence.

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CHAPTER 1: ABSTRACT

Note: This document defines a technical data standard for behavioral engagement estimation. It does not constitute financial advice, carbon credit issuance, or a prospectus for securities. All metrics are non-financial proxies for management accounting purposes.

1.1 Overview of NTCC Concept and Purpose

The **Non-Tradable Commitment Credit (NTCC)** is designed as a data-driven governance unit, serving as a standardized **Engagement Index**. It quantifies verified human and organizational participation in sustainability programs and converts those behavioral records into auditable **impact proxies** (estimated carbon avoidance effort).

Unlike market-based instruments that derive value from exchange, NTCC derives legitimacy from **data verifiability**. Each unit represents **behavioral evidence** rather than speculative market value—anchoring ESG disclosure in measurable trust.

Through this non-tradable design, NTCC redefines environmental accountability as a **Trust Infrastructure**, enabling organizations to report verifiable sustainability outcomes without monetization risks or double-counting ambiguity.

1.2 PADV Behavioral Data Assurance Logic

The NTCC system operates under the **PADV (Participation–Action–Data–Value)** methodology. PADV transforms human participation into auditable data assets by linking four layers:

- **Participation:** Verified behavioral actions collected via SDGS PASS or other

institutional mechanisms.

- **Action:** Each act processed through verification algorithms (VF_0, VF_n, VF_s).
- **Data:** Conversion into **Non-Tradable Commitment Records (NTCRs)**, expressed in standardized engagement units (proxy: $kgCO_2e$).
- **Value:** Annual recognition of verified NTCRs as **NTCC Indices** under ESG reporting cycles.

This process ensures that every verified act contributes to a **Behavioral Data Assurance Framework (BDAF)**, allowing sustainability performance to be governed by measurable evidence rather than declarative reporting.

1.3 Integration with ESG Verification Frameworks

NTCC aligns with international data collection and reporting standards, supporting alignment with **GRI 305** (Emissions), **IFRS S1 / S2**, **ISO 14064-1**, and the **COSO 2017 Internal Control Framework**.

Its audit logic is consistent with **ISO 19011** (Auditing Management Systems) and **ISO 27037** (Digital Evidence), supporting digital traceability and assurance documentation. By integrating these structures, NTCC acts as a **data bridge** between behavioral participation logs and institutional ESG disclosure.

Independent verifiers (e.g., Big 4 firms, BSI, DNV, SGS) can validate NTCC datasets through PADV's cross-verification protocol, ensuring that behavioral data attain the same **audit-readiness** as financial data within sustainability reports.

1.4 Dual Corporate Pathways and Annual Recognition

Principle

NTCC recognition follows a **Dual-Pathway Model** that balances inclusivity with audit rigor:

Pathway	Mechanism	RCF Value	Recognition Scope
Type A — Community Interaction Verification	Fixed verification (VF = 0.95) with limited sampling depth	**0.3**	Recognized up to **30%** of total annual NTCR (Interaction + Missions)
Type B — Direct Task Verification	Dynamic verification (VF = 0.8 – 1.0) with full ESG weighting	**1.0**	**100%** annual recognition

The **Annual Recognition Coefficient (RCF)** ensures that only data verified within the fiscal year are converted into NTCCs. This prevents duplication across ESG reporting periods while maintaining alignment with audit cycles and sustainability disclosures. Through this dual structure, corporations can quantify both **broad community engagement** (Type A) and **direct operational sustainability** (Type B), integrating NTCC outcomes into verified Scope 3 and CSR performance metrics.

CHAPTER 2: Background & Motivation

2.1 The Data Integrity Gap in ESG Disclosure

Despite the rapid expansion of ESG reporting frameworks, the global sustainability ecosystem faces a critical **data integrity gap**. Most corporate disclosures, particularly regarding **Scope 3 emissions**, rely heavily on spend-based estimates and secondary databases, where indirect behaviors across value chains cannot be precisely measured or verified.

The result is a systemic **"Black Box" problem**: stakeholders—from regulators and auditors to investors—often question whether sustainability commitments are backed by measurable execution or merely declarative narratives.

Traditional ESG mechanisms measure performance through **outcomes** (e.g., total energy bills), but rarely verify the **human or organizational actions** that produced those outcomes. As a result, sustainability remains statistically estimated but **behaviorally unverified**—a condition that undermines auditability and precision.

This evidence deficit reveals the need for a new **Verification Infrastructure** where participation itself becomes measurable, traceable, and legally auditable.

2.2 Limitations of Outcome-Based Estimation Models

Current environmental instruments—such as voluntary carbon offsets or estimated GHG inventories—were designed for **outcome accounting**, not for **process verification**. Operating under post-facto calculation models, these systems prioritize final aggregation over granular transparency, resulting in:

- **Data Granularity Issues:** Inability to trace specific behavioral sources within aggregated datasets.
- **Verification Inconsistency:** Diverse methodologies across registries leading to comparability challenges.
- **Greenwashing Risk:** Claims based on theoretical estimates rather than proven actions.
- **Lack of Audit Trails:** Missing digital evidence chains linking specific actors to emission reductions.

While these systems quantify physical emission results, they fail to capture the **behavioral mechanisms** that generate them. Without verifiable behavioral data, ESG assurance cannot fully assess participation, accountability, or proportionality. Consequently, **Big 4 auditors** and verification bodies face limitations in performing data-level assurance, as existing registries confirm only the final tally, not the **human actions** behind them.

2.3 The Need for a Non-Tradable Data Architecture

To close this data gap, the PADV framework introduces the **Non-Tradable Commitment Credit (NTCC)**—a verification mechanism that decouples sustainability measurement from financial speculation.

NTCC does not function as a tradable asset or currency. Instead, it serves as a **Standardized Unit of Verified Engagement**, directly linking human or institutional behavior to ESG outcomes through **auditable data structures**.

This non-tradable principle establishes three **Data Integrity Safeguards**:

- **Data Stability:** NTCCs cannot be exchanged, resold, or traded, ensuring that the **Engagement Index** remains a stable metric of effort;
- **Anti-Duplication:** Each NTCC corresponds to a unique **Proof Record** validated through the PADV registry, preventing double-counting;
- **Full Transparency:** All verified data remain accessible for **assurance review** and regulatory oversight, creating a permanent audit trail.

By transforming sustainability verification from an economic transaction into a **trust-based data process**, NTCC converts participation into measurable **governance evidence**—creating a new form of accountability based on verifiable behavior, not market price.

2.4 Evolution from PADV v3 to ESG-Integrated Methodology v3

The first generation of PADV established the conceptual and algorithmic foundation for **behavioral data logging**. It defined how participation could be recorded, verified, and structured into digital **Proof Records**.

Building upon this foundation, **PADV–NTCC Methodology v3** extends the system from methodological validation to **institutional interoperability**, introducing three major technical advancements aligned with international assurance frameworks:

- **Verification Factor (VF):** A three-tier data calibration system ensuring statistical, regional, and sectoral **data reliability**;
- **ESG Weighting Model (W_{ESG}):** A composite evaluation algorithm combining **Carbon Effect (CEF)**, **Social Effect (SEF)**, and **Institutional Reliability (IRF)**;
- **Annual Recognition Coefficient (RCF):** A governance mechanism aligning NTCC data validity with **fiscal-year ESG reporting cycles**.

PADV v3 thus evolves from a theoretical model to a **governance-ready assurance framework**, interoperable with **GRI, IFRS, ISO, COSO, and QS** data structures. It enables verified behavioral participation to become the foundation of **institutional trust**, bridging the gap between individual actions, corporate responsibility, and

global ESG data compliance.

CHAPTER 3: Theoretical Foundation of PADV

3.1 The PADV Four-Ring Model: From Behavior to Verifiable Evidence

The **PADV Framework**—standing for **Participation, Action, Data, and Value**—defines the structural evolution of behavioral events into verifiable data assets recognized within ESG assurance systems[1].

- **Participation (P):** The decision or intent to engage in a sustainability-related behavior. This marks the entry point of human agency into the data ecosystem[2].
- **Action (A):** The execution of a measurable, context-specific task. Each action corresponds to a **"Proof Record"** that captures immutable evidence of completion[3].
- **Data (D):** The conversion of verified behavioral evidence into structured digital information. At this stage, the action becomes traceable and auditable through the **V-Layer Registry**[4].
- **Value (V):** The recognized outcome of verified participation, expressed as **NTCR (Non-Tradable Commitment Records)** or **NTCC Engagement Indices**. Here, "value" signifies **Trust and Accountability**, representing a quantifiable metric of sustainability performance rather than economic exchange[5].

The Four-Ring Model ensures that every sustainability act can be quantified as a **Performance Indicator** without commodification—transforming sustainability from narrative into measurable, auditable impact[6].

3.2 Institutional Logic of Behavioral Data Governance

PADV redefines data governance as a process of **institutionalizing trust** through verified participation[7]. In contrast to traditional financial auditing, which validates

monetary transactions, PADV validates **behavioral interactions**—the foundational layer of ESG impact[8].

The model operates on three governance logics[9]:

1. **Transparency:** Every Proof Record is publicly traceable within the PADV Registry[10].
2. **Accountability:** Each verified act links directly to an identifiable actor (Individual UID or Enterprise UID)[11].
3. **Non-Transferability:** Data cannot be resold, transferred, or traded. This restriction preserves the **authenticity of the behavioral origin**, ensuring that the credit remains permanently attached to the actor who performed the action[12].

Through these principles, PADV extends governance from organizational disclosure to **citizen-level accountability**, forming a multi-actor data assurance ecosystem[13].

3.3 Relationship Between PADV and Data Assurance Theory

Data assurance, in the context of ESG, refers to the verification of data quality, origin, and reliability prior to disclosure[14]. PADV complements existing assurance frameworks (ISAE 3000, AA1000AS, and COSO) by introducing a **Behavioral Data Layer**—a foundational source for non-financial assurance[15].

Conventional Assurance Layer	**PADV Behavioral Assurance Layer**	**Integration Outcome**
Financial Data Auditing	**Behavioral Data Verification**	Extended Assurance Scope [16]
Corporate Governance Controls	**Proof Record Registry Governance**	Real-Time Accountability [17]
ESG Reporting Verification	**NTCC Engagement Data Model**	Enhanced Data Traceability [18]

Thus, PADV bridges the gap between behavior (micro) and institutional assurance (macro), enabling verifiers, auditors, and policymakers to trace sustainability outcomes back to the **verified actions** that generated them[19].

3.4 Related Works and Methodological Lineage

The theoretical design of PADV draws from multiple interdisciplinary traditions[20]:

- **Behavioral Economics:** Recognizing that real sustainability impact arises from collective micro-decisions[21].
- **Information Assurance Theory:** Ensuring verifiable provenance and non-repudiation in digital systems[22].
- **ESG Reporting Frameworks:** Aligning with GRI, IFRS, and ISO methodologies to emphasize **verifiability** over mere disclosure[23].
- **COSO Control Environment:** Aligning behavioral verification with internal control and risk management[24].
- **QS Sustainability Metrics:** Reinforcing educational and social participation as measurable sustainability outcomes[25].

PADV therefore represents an **institutional synthesis**—linking human behavior, digital verification, and organizational accountability into a unified assurance architecture[26].

3.5 Supplementary Note on Illustrative Calculation Logic

Disclaimer:

The following calculation model is an illustrative representation of the logical mechanism within the NTCC framework27.

It is designed as a Management Accounting Tool for estimating engagement impact28. It is not intended to replace or replicate any certified carbon accounting methodology (e.g., ISO 14064, GHG Protocol, or IPCC 2006 Guidelines) for regulatory offset purposes29.

The purpose of this section is to clarify the logical consistency and traceability of behavioral data within the NTCC system30.

1. Baseline Scenario Definition (Proxy Logic)

Each NTCC task defines a baseline emission factor (EF_0), representing the average emissions prior to behavioral change, and a post-action emission factor (EF_1) after the sustainable action is performed31.

The difference between EF_0 and EF_1 defines the estimated impact proxy:

\Delta CO_2e_{proxy} = (EF_0 - EF_1) \times n

where n represents the number of verified task completions[32].

All emission factors (EF) are derived from recognized databases, such as IPCC 2006 Guidelines, local EPA Carbon Emission Factor Databases, or IEA statistics, serving as **benchmarks for estimation**[33].

2. Emission Factor Standardization (Reference Data)

All emission factors are standardized to kg CO_2e per activity unit for consistent internal scoring34:

Activity Type	**EF0 (kg CO_2e/unit)**	**EF1 (kg CO_2e/unit)**	**Reference Source**
Private Vehicle (Gasoline)	0.271	—	IPCC 2006 Vol. 2 Ch. 3 [35]
Public Transport (MRT/Bus)	—	0.071	Local EPA Data [36]
Paper Document Delivery	0.013	—	GRI 305-3 Appendix [37]
Electronic Document Delivery	—	0.004	IFRS S2 Reference Data [38]

Example: If a participant switches from private car commuting (EF_0 = 0.271) to MRT (EF_1 = 0.071) once per week, the **Engagement Index** contribution is calculated as \Delta CO_2e = 0.20 \times n units[39].

3. Uncertainty and Error Margin

Following ISO 14064-3 principles, the system acknowledges an acceptable uncertainty range for behavior-based estimations (typically ±10 – 15%)40.

When an NTCC index is generated, the system automatically records the Evidence Chain:

- EF Database Version
- Timestamp (Date and Time of Action)
- User UID and Activity ID [41]

4. Aggregation and Audit Logic

Each behavioral record generates a unit of estimated reduction (\Delta CO_2e_i)42.

The system aggregates all units periodically to calculate the total NTCC Engagement Index43:

NTCC_{total} = \sum (\Delta CO_2e_i)

Weekly, quarterly, and annual summaries can be exported for **internal audit and disclosure**, including uncertainty ranges and verification identifiers, in compliance with **COSO Internal Control principles**[44].

5. Illustrative Examples

Task Name	**Category**	**Frequency (n)**	**Estimated ΔCO2e**	**NTCC Index Value**
Green Commuting Challenge	Transportation	20	4.0 kg	**4.0 ± 0.5 Units** [45]
Paperless Report Submission	Digitalization	10	0.09 kg	**0.09 ± 0.01 Units** [46]

6. Conclusion and Clarification

This model demonstrates the logical traceability of behavioral impact estimation. The NTCC framework remains a non-tradable, verification-based mechanism,

designed to complement existing ESG reporting standards as a data collection tool. It does not substitute for regulated carbon trading or certified offset issuance47.

CHAPTER 4: Definition of NTCC

4.1 Conceptual Distinction: NTCC Engagement Index vs. Tradable Carbon Assets

The **Non-Tradable Commitment Credit (NTCC)** is not a market asset but an **institutional data unit** that represents verified behavioral contributions to sustainability. Unlike tradable carbon instruments—which exist to facilitate financial exchange—NTCC exists to anchor **trust and comparability** within ESG disclosure systems.

Dimension	**Tradable Carbon Asset (Offset)**	**NTCC Engagement Index (Metric)**
Primary Function	Market Transaction & Offsetting	**Data Verification & Management KPI**
Ownership	Transferable (Commodity)	**Non-transferable (Institutional Record)**
Value Basis	Economic Scarcity	**Behavioral Verification (Proof of Effort)**
Governance	Financial Market Regulation	**Internal Control & Audit Assurance**
Risk Type	Speculative Market Risk	**Data Integrity Risk** (Controlled via VF)

While both relate to sustainability performance, the purpose differs fundamentally: Tradable assets aim to create **liquidity**; NTCC aims to create **credibility**. Each NTCC unit is backed by a verified behavioral act, traceable

through a Proof Record chain, ensuring that its value arises from **verified participation** rather than financial demand.

4.2 Institutional and Non-Financial Nature of NTCC

NTCC functions within a **non-financial assurance domain**. It is neither a tradable security nor a regulatory carbon offset, but a **verifiable behavioral metric** aligned with international ESG disclosure frameworks.

This distinction ensures NTCC's compliance with governance principles under **COSO**, **IFRS S1/S2**, and **GRI 305**—where data reliability, not marketability, defines institutional credibility. Each NTCC reflects the convergence of:

- **Verified Behavioral Participation** (PADV Layer),
- **Estimated Impact Proxy** (CEF Calculation), and
- **Assured Data Integrity** (VF × Weighting Governance).

Thus, NTCC bridges the gap between personal participation and institutional ESG reporting, making **behavioral proof** a measurable component of corporate accountability.

4.3 Hierarchical Relationship: Proof Record → NTCR → NTCC

The PADV verification system operates through a three-tier **data hierarchy**:

1. **Proof Record (PR):** The atomic evidence unit representing one completed behavior (e.g., quiz participation, event attendance, verified task execution).
2. **Non-Tradable Commitment Record (NTCR):** An aggregation of Proof Records under a specific task, campaign, or program. Each NTCR carries a unique verification factor (VF_{total}) and ESG weighting.
3. **Non-Tradable Commitment Credit (NTCC):** The annualized and verified aggregation of NTCRs, adjusted by the **Recognition Coefficient (RCF)** and validated through annual internal audit cycles.

Formula Logic:

NTCC = \sum (NTCR \times RCF)

This formula anchors NTCC as a **verifiable outcome metric**, not an economic token. The conversion factor (e.g., 0.1 coefficient) transforms behavioral points into **standardized impact proxies**, and RCF ensures alignment with annual reporting boundaries.

4.4 System Boundary: Behavioral Data, Proxy Data, and Disclosure Data

To prevent data overlap and ensure clarity, PADV defines three clear system boundaries:

Layer	Data Type	Definition	Verification Entity
Behavioral Data Layer	**Proof Record** (Participation Logs)	Raw digital evidence of sustainability-related actions.	PADV Registry / V-Layer
Impact Proxy Layer	**NTCR** (Engagement Units)	Behavior-derived impact estimation (Proxy: 10 pts ≈ 1 unit impact).	NTCC Calculation Engine
Disclosure Data Layer	**NTCC** (Annualized Index)	Verified, audited behavioral metrics for ESG reporting.	External Auditors / Internal Control

Each layer is linked but distinct in function:

- Behavioral data serves as **operational logs**;
- Impact Proxy data serves as **management accounting estimates**;
- Disclosure data serves as **formal reporting evidence**.

This boundary-based governance ensures that NTCC maintains **integrity and complementarity** within existing ESG ecosystems—enhancing transparency without duplicating established financial or carbon accounting structures.

CHAPTER 5: PADV–ESG Integration Framework

5.1 Linking PADV to ESG Disclosure Standards

The integration of PADV protocols with global ESG frameworks represents a structural enhancement in data granularity. Traditional ESG systems often rely on declarative disclosure—where organizations state *what* they have done, but may lack verifiable **behavioral evidence** to support those claims at the individual or transactional level.

PADV addresses this limitation by introducing **Behavioral Proof Records** as the foundational **digital evidence layer**. Each verified record is algorithmically linked to specific ESG reporting indicators, forming a direct **Data Chain of Custody** from participation \rightarrow verification \rightarrow ESG disclosure.

This linkage transforms ESG reporting from post-event narration into **real-time data logging**, enabling corporations, academic institutions, and event organizers to capture measurable social and environmental actions at the source of occurrence. As a result, ESG reports gain credibility not just by the volume of disclosure, but by the **traceability of underlying data**.

5.2 The ESG Weighting Model (W_{ESG})

To ensure consistency and comparability across diverse sectors, PADV defines a unified **ESG Weighting Model (W_{ESG})**, which serves as a scoring algorithm for engagement intensity:

W_{ESG} = \frac{CEF + SEF + IRF}{15}

Where each component is scored from 0 to 5, based on standardized evaluation protocols:

- **CEF (Carbon Effect Factor):** Measures the relative contribution to environmental goals or emission avoidance behaviors.
- **SEF (Social Effect Factor):** Quantifies inclusiveness, public benefit, and community engagement reach.
- **IRF (Institutional Reliability Factor):** Assesses data governance quality,

internal control compliance, and verifier independence.

This tri-factor model ensures that each **NTCR (Non-Tradable Commitment Record)** reflects not only environmental proxies but also social accountability and institutional robustness, thereby aligning behavioral verification with the **multidimensional logic** of ESG.

5.3 Mapping to Global Standards: GRI / IFRS / ISO / COSO / QS

PADV achieves full cross-standard interoperability by mapping each element of its data structure to established international standards.

The following matrix illustrates this **Data Alignment**:

PADV Data Layer	**GRI Reference**	**IFRS / ISSB Alignment**	**ISO Standard Support**	**COSO Component**	**QS Domain**
Proof Record (Behavioral Log)	GRI 102 / 404 / 413	IFRS S1 – Governance Disclosure	ISO 20121 (Event Sustainability)	Control Environment	Social Engagement
NTCR (Impact Proxy)	GRI 305 – Emissions	IFRS S2 – Climate-Related Metrics	ISO 14064-1 – Data Collection	Risk Assessment	Environmental Impact
NTCC (Engagement Index)	GRI 103 / 403 – Management Approach	IFRS S1 / S2 Combined Reporting	ISO 27001 / 27701 – Data Security	Information & Communication	Institutional Reliability
V-Layer	GRI 2 – Governanc	IFRS S1 – Controls &	ISO 19011 – Audit	Monitoring	Institutional

PADV Data Layer	GRI Reference	IFRS / ISSB Alignment	ISO Standard Support	COSO Component	QS Domain
(Audit Trail)	e Structure	Oversight	Managemen t	Activities	Trust

This mapping demonstrates that PADV does not replace existing standards; it **operationalizes** them by providing the behavioral verification layer previously absent in ESG reporting. It bridges the operational gap between human action and institutional assurance, allowing global frameworks to interoperate under a unified logic of **verifiable data**.

5.4 Governance Implications of Cross-Standard Integration

The integration of PADV with ESG frameworks establishes a new category of **"Data-Driven Internal Control"**—a governance model where compliance and assurance are driven by traceable participation logs.

Key implications include:

- **Assurance Consistency:** Auditors and verification bodies (e.g., Big 4) can validate ESG data through standardized behavioral records, reducing subjectivity in assurance engagements.
- **Stakeholder Trust:** Regulators and investors can adopt NTCC-derived metrics as **non-financial evidence** of social participation and climate contribution.
- **Institutional Accountability:** Organizations gain a data-driven mechanism for linking internal CSR actions with external ESG disclosures.
- **Educational Alignment:** The **QS Sustainability** framework can use PADV data to evaluate behavioral literacy and engagement outcomes across higher education institutions.

By embedding behavioral verification within ESG logic, PADV–NTCC establishes the missing **Trust Infrastructure** of sustainability—a data governance mechanism where every claim is anchored to a verified human act.

CHAPTER 6: Computation Logic & Engagement Algorithms

6.1 Standardized Proxy Benchmark: 10 pts ≈ 1 Unit of Impact

The PADV framework establishes a universal **behavioral-to-impact proxy**, where 10 verified engagement points (10 pts) correspond to an estimated **1 Unit of Engagement Impact** (Proxy reference: 1 kg CO_2e avoidance effort).

This conversion factor is derived from empirical data collected across multi-sector sustainability activities and field-verified engagement models. Each behavioral point acts as a **micro-unit of verified sustainability contribution**, enabling impact estimation to be derived from **proof-based participation** rather than broad spend-based estimation.

Note: This proxy serves as an internal Key Performance Indicator (KPI) for management accounting. It does not constitute a certified carbon offset for regulatory trading.

6.2 Three-Tier Verification Factor (VF_0, VF_n, VF_s)

The **Verification Factor (VF)** system provides statistical calibration reflecting contextual data reliability and audit density.

Tier	Definition	Value / Range	Function
VF_0	**Baseline Reliability**	Global Constant (**0.92**)	Mean cross-event verification consistency baseline.
VF_n	**Regional / Institutional Adjustment**	**0.85 – 1.05**	Accounts for regional governance maturity and sector data quality.
VF_s	**Source-Specific Correction**	**0.8 – 1.2** (Cap: ±10%)	Adjustment based on activity type (digital vs. physical) and audit

Tier	Definition	Value / Range	Function
			density.

Formula:

VF_{total} = \frac{VF_0 + VF_n + VF_s}{3}

6.3 ESG Weighting Equation (W_{ESG})

Each **NTCR (Non-Tradable Commitment Record)** integrates its ESG relevance via the weighting coefficient:

W_{ESG} = \frac{CEF + SEF + IRF}{15}

Where each factor (0–5 scale) represents:

- **CEF – Carbon Effect Factor:** Relative environmental impact or emission avoidance potential.
- **SEF – Social Effect Factor:** Public inclusiveness and community reach.
- **IRF – Institutional Reliability:** Governance quality and internal control strength.

6.4 Data Provenance & Scoring of CEF / SEF / IRF

Factor	Primary Reference Source	Validation Entity	Note
CEF	ISO 14064 Inventory Data	Environmental Engineer	Proxy kg CO_2e per action unit.
SEF	SDGS PASS Registry Logs	CSR Assurance Team	Inclusiveness and societal reach metrics.
IRF	ISO 27001 Compliance Docs	Internal Auditor	Data integrity and governance robustness.

6.5 Baseline VF_0 Calibration

The baseline **VF_0 = 0.92** was determined through multi-year sampling of over 50 pilot events. Cross-checks showed a mean data reliability ratio of 92% between verified logs and self-reported records. Regional adjustments are further calibrated using the **Verification Fidelity Index (VFI)**.

6.6 Unified Formula for NTCR Calculation

The **Non-Tradable Commitment Record (NTCR)** calculates the verified engagement impact of a specific task:

NTCR_i = \left(\frac{P_i}{10} \right) \times VF_{total} \times W_{ESG}

- **P_i:** Verified Behavioral Points from Proof Record i
- **Result:** The sum \sum NTCR_i yields the total **verified behavioral engagement index** (Unit: Proxy kg CO_2e).

6.7 Annual Recognition Coefficient (RCF)

The **RCF** controls the annual recognition of NTCR values into finalized **NTCC Indices**, ensuring alignment with ESG reporting cycles and preventing data inflation.

Category	**Mechanism**	**RCF Value**	**Annual Recognition Limit**
Type A: Indirect Interaction (e.g., Community Redemption)	Fixed Verification (VF=0.95)	**0.3**	**Capped at 30%** of Total Annual NTCR (to prevent over-attribution).
Type B: Direct Task Execution (e.g., Commuting, Recycling)	Dynamic Verification (VF=0.8-1.2)	**1.0**	**100%** Annual Recognition.

6.8 Illustrative Calculation Case

- **Input:** 20,000 points earned.
- **Parameters:** VF_{total} = 0.90; Normalized W_{ESG} = 0.76; RCF = 1.0 (Type B).
- Calculation:

NTCR = \left(\frac{20,000}{10} \right) \times 0.90 \times 0.76 = 1,368~\text{Units}

- **Final Output: 1,368 NTCC Engagement Units** (Proxy: 1,368 kg CO_2e).

6.9 Deterministic Framework (Summary)

Stage	Variable	Formula	Scope
Task	**VF_{total}**	(VF_0 + VF_n + VF_s) / 3	Verification Integrity
Task	**W_{ESG}**	(CEF + SEF + IRF) / 15	ESG Relevance Weighting
Task	**NTCR**	(Points \times 0.1) \times VF_{total} \times W_{ESG}	Behavioral Impact Proxy
Annual	**NTCC**	\sum (NTCR \times RCF_{pathway})	Yearly Index Recognition

CHAPTER 7: Proof Record Mechanism

7.1 Proof Record Definition and Data Schema

A **Proof Record (PR)** is the fundamental **digital evidence unit** within the PADV infrastructure. Each record represents a verified behavioral occurrence—an individual or collective act that contributes to sustainability and meets specific **validation criteria**.

Every Proof Record is structured with **machine-readable metadata**, ensuring data integrity and system interoperability. The standardized data schema includes the following fields:

Field	Description	Type
PR_ID	Unique alphanumeric identifier (Global Unique ID)	String
UID / E-UID	Participant or Enterprise Identity Token	String
Task_ID	Linked mission or verification activity ID	String
Timestamp	Verified completion time (ISO 8601 format)	Datetime
Location / GeoHash	Verified physical or virtual coordinates	String
Point_Value	Earned engagement points	Integer
VF_total	Computed Verification Factor (Data Quality Score)	Float
W_ESG	ESG Weighting Value	Float
RCF	Annual Recognition Coefficient	Float
Validator_Hash	Third-party verification hash signature	String

This schema enables **API interoperability** between PADV registries, corporate ESG dashboards, and external assurance platforms through standardized JSON/XML interfaces.

7.2 Data Processing Pipeline: PR → NTCR → NTCC → Disclosure

Each verified action flows through a structured **Data Chain of Custody**:

1. **Proof Record (PR):** Raw behavioral log generated at the point of action.
2. **NTCR (Record):** Aggregated engagement metric for a specific task.
3. **NTCC (Index):** Annualized, recognized engagement index for reporting.
4. **ESG Disclosure:** Final integrated data output for GRI/IFRS reporting.

This vertical chain forms the **Behavioral Data Trust Line**, where each layer

enhances data structure without altering the original behavioral evidence. It ensures that the ESG disclosure at the end of the chain can be **traced back** to the original human act—achieving data-level integrity from participation to publication.

7.3 Anti-Duplication and Boundary Protocols

To maintain **Data Integrity**, each Proof Record is governed by strict anti-duplication and data boundary protocols:

- **Unique Record Rule:** Each PR_ID must be globally unique within the registry.
- **Idempotency Algorithm:** Proof Records sharing identical UID, Task_ID, and Timestamp are automatically flagged for review to prevent double-logging.
- **Boundary Segmentation:**
    - Behavioral Data (PR) cannot exist outside its assigned NTCR boundary.
    - NTCR units cannot overlap across multiple ESG reporting entities (Data Isolation).
- **Cross-System Interlock:** PRs linked to different sectors (e.g., EDU vs. CORPORATE) maintain isolated validation channels to prevent cross-sector contamination.

These controls ensure **non-redundant verification** while preserving full audit traceability, aligned with **ISO 27001** data integrity standards.

7.4 Interoperability Standards (JSON / XML Models)

To support integration with enterprise ERP systems and audit frameworks, the PADV Registry implements a dual-format, **audit-ready data structure**.

JSON Representation:

JSON

```
{
```

```
  "PR_ID": "PR-2025-00123",
  "UID": "EUID-7F29AB9",
  "Task_ID": "SDGSPASS-MISSION-014",
  "Timestamp": "2025-06-15T09:32:11Z",
  "Location": "25.033N,121.565E",
  "Point_Value": 50,
  "VF_total": 0.91,
  "W_ESG": 0.78,
  "RCF": 1.0,
  "Validator_Hash": "sha256:78dfab...c3e"
}
```

XML Representation:

```
XML
<ProofRecord>
  <PR_ID>PR-2025-00123</PR_ID>
  <UID>EUID-7F29AB9</UID>
  <Task_ID>SDGSPASS-MISSION-014</Task_ID>
  <Timestamp>2025-06-15T09:32:11Z</Timestamp>
  <Location>25.033N,121.565E</Location>
  <Point_Value>50</Point_Value>
  <VF_total>0.91</VF_total>
  <W_ESG>0.78</W_ESG>
  <RCF>1.0</RCF>
  <Validator_Hash>sha256:78dfab...c3e</Validator_Hash>
```

</ProofRecord>

Both formats are embedded with **digital signatures** to ensure immutability, and can be directly integrated into ESG disclosure platforms, audit portals, or national sustainability registries via **Open API**.

CHAPTER 8: Dual Pathway of Corporate Engagement Verification

Overview

Within the PADV–NTCC framework, corporations generate verified **Non-Tradable Commitment Credits (NTCC)** through two standardized behavioral pathways:

1. **Indirect Interaction Pathway** (formerly Public Welfare Redemption)
2. **Direct Task Execution Pathway** (formerly Mission Participation)

These dual mechanisms create measurable, auditable links between corporate sustainability initiatives and behavioral verification outcomes, allowing enterprises to convert public engagement and CSR actions into verifiable **ESG data assets** while maintaining **non-financial integrity**.

8.1 Pathway A: Indirect Interaction (Fixed VF = 0.95)

The Indirect Interaction Pathway enables corporations to provide sustainable products or services as **Public Welfare Offerings** under SDGS PASS. When participants interact with these items using accumulated points, each interaction generates a verifiable **Proof Record**, contributing to the enterprise's engagement index.

- **Mechanism:** Fixed Verification Factor (VF = 0.95), ensuring consistent reliability regardless of consumer variability.
- **Weighting:** W_{ESG} is derived primarily from product attributes, supplier transparency, and lifecycle impact assessment.

Parameter	Description
VF_{total}	**Fixed = 0.95**
W_{ESG}	Derived from product-level CEF, SEF, IRF scoring
RCF	**0.3** (Annual recognition limit: Capped at **30%** of Total Annual Index)
Audit Trace	Interaction log \rightarrow PADV registry \rightarrow Corporate ESG disclosure

This model is particularly suitable for retailers, shopping centers, F&B chains, and brand-driven CSR campaigns, providing a **low-barrier entry** into verifiable ESG participation data.

8.2 Pathway B: Direct Task Execution (Dynamic VF 0.8–1.2)

The Direct Task Pathway reflects corporate engagement through **active sustainability-driven activities**—such as clean-up events, green commuting challenges, or internal compliance tasks. Each task generates a Proof Record upon completion, dynamically validated through the **V-Layer Verification Engine**.

- **Mechanism:** Dynamic Verification Factor (VF range: 0.8–1.2), adjusted based on activity type, verification density, and audit depth.
- **Weighting:** W_{ESG} integrates all three factors (CEF, SEF, IRF) at full resolution, representing the complete spectrum of behavioral sustainability impact.

Parameter	Description
VF_{total}	**Dynamic Range 0.8–1.2** (Cap: ±10%)
W_{ESG}	Full composite of CEF, SEF, IRF
RCF	**1.0** (100% annual recognition)
Audit Trace	Task completion record \rightarrow PADV registry \rightarrow Internal Audit Log

Direct Task Pathways are ideal for enterprises with **active CSR programs**, NGOs, and event organizers, providing **high-verifiability behavioral datasets** suitable for assurance reporting and ESG disclosures.

8.3 Comparative Data Logic Table

Parameter	**Indirect Interaction (Pathway A)**	**Direct Task Execution (Pathway B)**
Behavior Type	Passive interaction (consumer-driven)	**Active participation** (action-driven)
VF_{total}	Fixed (0.95)	**Dynamic (0.8–1.2)**
W_{ESG}Emphasis	Product lifecycle & supply transparency	Human participation & field verification
RCF Annual Cap	**0.3** (Capped at 30%)	**1.0** (100% Recognition)
Impact Proxy	10 pts ≈ 1 unit impact	10 pts ≈ 1 unit impact
ESG Impact Domain	GRI 305 / 413	GRI 404 / 403 / 305
Verification Complexity	Low	Moderate–High
Best-fit Industry	Retail / F&B / Shopping Malls	CSR / NGO / Events / Manufacturing

Both pathways share the same data foundation but differ in **participation intensity**, **verification density**, and **ESG relevance**. This dual-structured model allows NTCC generation to remain equitable across diverse industries, ensuring that small and large enterprises alike can contribute to measurable ESG outcomes.

8.4 Calculation Example: Mixed Corporate Case

Scenario:

A retail brand participates in both pathways within one fiscal year:

- **Indirect Interaction:** 5,000 Proof Records, VF = 0.95, W_{ESG} = 0.68, RCF = 0.3
- **Direct Task Execution:** 3,000 Proof Records, VF = 1.05, W_{ESG} = 0.80, RCF = 1.0

Result:

The company records Standardized Engagement Units (proxy: 0.588 tons CO_2e impact), distributed across both consumer and mission-driven actions, and auditable under the annual ESG assurance cycle.

(Note: This calculation provides a management accounting estimate, not a certified carbon credit balance.)

CHAPTER 9: Annual Engagement Index Recognition Protocol

9.1 Concept and Purpose

The **Annual Recognition Protocol (RCF)** governs how verified **NTCC Engagement Indices** are recognized, consolidated, and locked within a fiscal year. Its purpose is two-fold:

1. To synchronize behavioral data logs with **annual ESG disclosure cycles**.
2. To maintain the **temporal integrity** of verified data by preventing cross-year duplication.

The RCF mechanism ensures that NTCCs are treated not as perpetual financial assets, but as **annualized assurance metrics**, each corresponding strictly to the timeframe of verified sustainability actions.

9.2 Recognition Logic

The recognition process is governed by the following data integrity principles:

Principle	Description
Period Alignment	Data must be recognized within the same fiscal year in which Proof Records are generated.
Single-Year Validity	Indices are valid for **one reporting cycle** and represent performance for that specific year (cannot be carried forward as "savings").
Audit Synchronization	All recognized data must align with annual assurance engagements and third-party audit schedules.
Integrity Control	Each recognition event is **digitally locked** in the PADV Registry and timestamped for provenance.

The process thus converts dynamic behavioral logs into **year-bound verified outcomes**, aligning data verification, reporting, and governance cycles.

9.3 Recognition Formula and Cap

Governance Rule: The Recognition Coefficient (RCF) applies only at the annual aggregation stage to finalize the reporting index.

Pathway	RCF Value	Cap Limit	Note
Type A – Indirect Interaction (e.g., Welfare Pool)	**0.3**	**≤ 30%** of Annual Total	Fixed VF Model
Type B – Direct Task Execution (e.g., Operational Tasks)	**1.0**	**100%** Recognition	Dynamic VF Model

Formula: NTCC_{Annual} = \sum (NTCR_{Type A} \times 0.3) + \sum (NTCR_{Type B} \times 1.0)

Capped at 30% of Total Annual NTCC Index (Type A + Type B)

9.4 Annual Locking and Reporting Alignment

Once NTCC indices are recognized under the RCF rule, they enter the **Annual Data Lock (ADL)** phase. This process ensures that verified results cannot be altered retroactively, preserving both historical traceability and audit confidence.

Annual Lock Procedure:

1. **Digital Sealing:** PADV Registry issues timestamped digital seals for all recognized datasets.
2. **Fiscal Identification:** Locked data is associated with fiscal-year identifiers (e.g., NTCC-2025-Y1).
3. **Audit Synchronization:** Cross-verification hashes are synchronized with external assurance databases (e.g., Auditor Portals).
4. **Reference Locking:** ESG Reports reference ADL-sealed datasets to guarantee disclosure integrity.

Each lock event generates an immutable audit trail compliant with **ISO 27037 (Digital Evidence Management)** and aligns with **IFRS S1 / S2** disclosure governance principles.

9.5 Example: Annual Recognition Report

Corporate Case: "EcoMart Ltd."

Pathway	**Proof Records**	**VFtotal**	**WESG**	**RCF**	**NTCR (Raw Units)**	**Recognized Index (Proxy tons CO_2e)**
Indirect Interaction	4,000	0.95	0.70	**0.3**	266	**0.080**
Direct Task Execution	3,500	1.00	0.78	**1.0**	273	**0.273**
Total (Annual)	**7,500**	—	—	—	**539 Units**	**0.353 Units**

Result: "EcoMart Ltd." discloses **0.353 Standardized Units** (Proxy: tons CO_2e impact) for FY2025. The data is locked under fiscal identifier NTCC-2025-Y1, verified through the PADV Registry's assurance log, and cited as **behavioral evidence** under the company's GRI 305 and IFRS S2 climate disclosure.

9.6 Governance Principles for Annual Recognition

To maintain trust and comparability across organizations, PADV defines the following governance principles:

- **Entity-Bound (Non-Transferable):** Data belongs to the originating entity and cannot be traded.
- **Transparency:** Reports must disclose both the final Index Quantity and the corresponding **Proof Record Count**.
- **Audit Readiness:** Recognition data must be accompanied by a signed **Assurance Pack** ready for external review.
- **Interoperability:** Annual data locking structure is compatible with ESG platforms under GRI and IFRS data reporting APIs.
- **Temporal Consistency:** Each annual recognition must correspond to the verified timeframe—no retrospective claims permitted.

This ensures that NTCC serves as a true, **time-bound representation** of verified behavioral sustainability contributions, establishing a standardized audit logic that aligns participation data with global ESG assurance systems.

CHAPTER 10: Governance & Entity-Bound Data Protocols

10.1 The Concept of Entity-Bound Data Governance

The **Non-Tradable Commitment Credit (NTCC)** is intentionally designed to exist outside financial markets. Its purpose is not to serve as a tradable commodity but as a **verifiable data unit**—anchored in behavioral authenticity, institutional governance, and audit transparency.

Unlike market-based instruments that derive value from exchange, NTCC derives value from **Data Integrity**. Each NTCC index carries intrinsic credibility because it represents **verified internal performance** rather than speculative market assets.

Core Principle: Just as a university degree or a credit rating cannot be sold to another party, NTCC is **Entity-Bound**. It remains permanently attached to the organization that performed the sustainability action, ensuring that the metric reflects **true organizational effort** rather than financial purchasing power.

10.2 COSO Framework Alignment: Internal Control over Sustainability Reporting

NTCC governance aligns with the **COSO Internal Control Framework (2017)**, integrating behavioral data into the enterprise's broader risk management structure.

COSO Component	NTCC Governance Application
Control Environment	**Digital Evidence** replaces manual estimation; each Proof Record serves as an immutable governance log.
Risk Assessment	**Verification Factors ($VF_0–VF_s$)** quantify data quality risks, ensuring measurable reliability for management decision-making.
Information & Communication	The **V-Layer Registry** ensures transparent data dissemination to internal auditors and external stakeholders.
Monitoring Activities	**Annual Data Lock (ADL)** and third-party verification checks provide continuous oversight of the data pipeline.

Through this structure, NTCC introduces a **data-driven control system**, where verified participation becomes an auditable component of institutional integrity.

10.3 Data Integrity & Boundary Governance

To uphold transparency and prevent data duplication across reporting entities, the system implements **Boundary Governance Protocols (BGPs)** based on data segregation and provenance tracking.

Key Boundary Controls:

- **Unique Entity Binding:** Every NTCC is permanently bound to its originating organization (**Enterprise UID**). It cannot be transferred, subdivided, or resold.
- **Activity Scope Segmentation:** Each NTCR is confined within its activity boundary—internal tasks or supply chain interactions cannot be double-counted under multiple reporting entities.
- **V-Layer Deduplication:** The registry integrates **hash-based deduplication algorithms** to ensure that the same Proof Record cannot be submitted to multiple verification channels.
- **Institutional Oversight:** Third-party verifiers cross-check registry logs to confirm that no duplicated indices appear across parallel ESG disclosures.

These boundary controls ensure that NTCC data remains unique, traceable, and institutionally trustworthy, allowing its inclusion in verified ESG reports under **GRI 305** and **IFRS S2** frameworks without duplication risk.

10.4 Data Integrity Oversight and Compliance Mechanisms

NTCC governance extends beyond verification—it establishes a continuous **Data Integrity Ecosystem**. PADV enforces compliance with internationally recognized standards, ensuring that all verified behavioral data meets assurance-grade requirements.

Compliance Domain	Reference Standard	NTCC Governance Application
Data Security	**ISO 27001 /**	Encryption, access control, and anonymized

Compliance Domain	Reference Standard	NTCC Governance Application
	ISO 27701	participant identifiers (E-UID).
Digital Evidence	**ISO 27037**	Immutable time-stamped records for each Proof Record and Index issuance.
Audit Protocol	**ISO 19011**	Standardized assurance procedures for behavioral data verification audits.
Disclosure Governance	**IFRS S1 / S2**	Standardized disclosure of NTCC quantities, audit statements, and data assurance summaries.
Ethical Conduct	**GRI 2 / GRI 205**	Integrity and anti-corruption controls in behavioral data processing.

By integrating these standards, NTCC establishes an **assurance-ready governance model**, bridging the operational divide between behavioral logs and ESG compliance reporting.

10.5 The Strategic Value of the "Non-Tradable" Principle

The non-tradable principle is more than a restriction—it is a **Value Proposition**. By prohibiting speculative exchange, NTCC ensures that sustainability remains a matter of **Verified Contribution**, not financial capacity.

In traditional markets, value often depends on price (buying offsets); in the NTCC ecosystem, value depends on **Proof (executing actions)**. This shift redefines how organizations are recognized for sustainability: not by their purchasing power, but by their **verified behavioral impact**.

Institutional Implications:

- **Anti-Greenwashing:** It creates a transparent mechanism where "effort" cannot be faked through financial transactions.
- **Supply Chain Trust:** Anchor buyers prefer suppliers who "do" sustainability

over those who just "buy" credits.

- **Data Stability:** It ensures that every credited action carries real behavioral substance, serving as a stable baseline for year-over-year comparison.

Thus, NTCC represents a paradigm shift—from **Outcome Estimation** to **Behavioral Verification**, laying the foundation for a verifiable **Global Trust Infrastructure**.

CHAPTER 11: Data Validation & Pre-Audit Protocols

11.1 Introduction

Data Validation within the PADV–NTCC system represents a standardized form of **behavioral evidence management**. Unlike financial auditing which verifies monetary transactions, this framework verifies **actions**—forming the foundation of institutional trust. This chapter defines the validation hierarchy, the processing logic, and the multi-layer governance structure that enables NTCC indices to become **audit-ready sustainability data**.

11.2 Data Integrity Hierarchy: From Log to Index

The validation process follows a three-tier structure ensuring traceability and data coherence.

Tier	Entity	Function	Data Output
Tier 1 – Proof Record	Individual or Organization	Captures verified behavioral data (action, time, location, evidence).	**Verified Data Log**
Tier 2 – NTCR (Commitment Record)	V-Layer Processing	Aggregates Proof Records and converts to engagement impact proxy (Unit: Impact).	**Quantified Engagement Record**

Tier	Entity	Function	Data Output
Tier 3 – NTCC (Engagement Index)	Institutional Reporting	Consolidates annual NTCR under governance rules (RCF, VF,).	**Auditable Index Metric**

Each tier carries its own validation responsibility and is sequentially linked by cryptographic registry identifiers (PR-ID NTCR-ID NTCC-ID). This hierarchy allows auditors to trace data at any granularity—from single behavioral proof to organization-wide sustainability outcomes.

11.3 Data Validation Protocol (DVP)

The **Data Validation Protocol (DVP)** is the central mechanism that ensures data integrity across verifiers, organizations, and reporting frameworks. It operates on three coordinated layers:

1. **System Logic Check (Automated):** The V-Layer engine automatically validates Proof Records against metadata schema (location, timestamp, duplicate check).
2. **Third-Party Review (External Validation):** Accredited partners (e.g., Verification Bodies) perform random sampling, evidence tracing, and recalculation of VF and parameters.
3. **Registry Reconciliation:** The PADV Registry compares datasets across institutions to prevent double-counting and ensure unique Index issuance.

Together, these steps form a closed-loop validation structure compliant with **ISO 19011 (Auditing Management Systems)** principles.

11.4 Sampling Density and Review Frequency

Validation intensity is determined by activity type, scale, and risk class. PADV defines three data review tiers:

Risk Class	Typical Use Case	Sampling Ratio	Review Depth
A (High)	Large-scale events, national programs	**15–20 %**	On-site + full data trace
B (Medium)	Corporate CSR missions	**5–10 %**	Document + random site review
C (Low)	Interaction pool, digital activities	**1–3 %**	Automated data validation

This proportional design ensures cost-effective validation while maintaining statistical confidence (≥ 95% reliability).

11.5 Digital Evidence Chain Integration

The validation chain integrates four critical components of **ISO 27037 (Digital Evidence)** frameworks:

- **Evidence Identification:** Proof Records are treated as digital objects with immutable hashes.
- **Chain-of-Custody:** Every dataset transfer between entities is logged in the V-Layer Ledger.
- **Validation Procedures:** Recalculation of indices using independent verifier datasets.
- **Assurance Output:** Generation of an **"Assurance Pack"** referencing NTCC IDs for ESG disclosure.

Each Assurance Pack includes:

- NTCC ID range, validation date, and hash signatures.
- Total engagement proxy metrics.
- Sampling report and data quality assessment.

This standardized output allows seamless integration with ESG reporting

templates under **IFRS S2** and **GRI 305**.

11.6 Role of Independent Verifiers

Independent verifiers function as **data quality assurance partners** within the ecosystem. Their roles include:

- **Validation Execution:** Conduct DVP reviews and sampling checks.
- **Governance Feedback:** Recommend parameter calibration based on observed discrepancies.
- **Registry Synchronization:** Upload validated datasets to PADV's verification node.
- **Disclosure Support:** Provide data quality statements embedded in the Assurance Pack.

This arrangement establishes a triangular trust structure—data producers (enterprises), validators (independent bodies), and registry operators (PADV)—each reinforcing the other's credibility.

11.7 Audit-Ready Data Reporting

All validation outputs are generated in both human-readable and **machine-readable formats** (CSV / XML / JSON). This dual reporting structure ensures interoperability across digital ESG platforms and enterprise audit software.

Sample Data Structure:

JSON

```
{
  "NTCC_ID": "NTCC-2025-001",
  "Validator": "Independent_Verifier_A",
  "VF_total": 0.96,
  "W_ESG": 0.72,
  "RCF": 1.0,
```

"Engagement_Proxy": 1.200,

"Validation_Date": "2025-06-30"

}

Machine-readable formats enable automated reconciliation, paving the way for real-time ESG data monitoring.

11.8 Summary

Through the combined application of hierarchical validation, DVP protocols, and independent oversight, the NTCC system achieves **audit-grade data quality** while maintaining operational scalability. It transforms ESG reporting from a narrative process into a quantifiable **behavioral evidence system**—a foundation for the next generation of data-driven sustainability.

CHAPTER 12: Cross-Standard Interoperability Architecture

12.1 Purpose and Scope

The PADV–NTCC framework does not replace existing ESG or assurance standards. It functions as a **behavioral-data integrity layer** that connects verified participation evidence to global disclosure and audit frameworks.

This chapter codifies how PADV elements align with **GRI, IFRS (ISSB), ISO, COSO, and QS Sustainability**, ensuring that NTCC datasets are universally **interpretable**, **machine-verifiable**, and **audit-ready**.

12.2 Standardized Data Mapping Matrix

PADV Data Entity	Function	Primary Standards Mapping
Proof Record (PR)	Atomic behavioral evidence (actor, action, time, geo, signature).	**ISO 27037** (Digital Evidence); GRI 2 / 102 (Data Boundaries); IFRS S1-22 (Governance Info)

PADV Data Entity	Function	Primary Standards Mapping
Verification Factors ()	Reliability calibration (statistical / regional / sectoral).	**ISO 19011** (Audit Sampling); COSO – Risk Assessment
ESG Weighting ()	Normalized ESG materiality of actions.	GRI 305 / 403 / 413; IFRS S2 (Metrics & Targets)
NTCR (Engagement Proxy)	Verified behavioral impact estimation.	ISO 14064-1 (Data Collection); GRI 305-3; IFRS S2-29
Annual Recognition (RCF)	Year-bound recognition & data caps.	IFRS S1 (Control Cycle); COSO – Control Activities
NTCC (Index Unit)	Annualized engagement index for reporting.	IFRS S2-25 / S2-29; GRI 305-7 (Non-Financial Metrics)
V-Layer Registry (ADL)	Immutability and provenance tracking.	**ISO 27001 / 27701**; COSO – Information & Communication
Assurance Pack (AP)	Third-party verification output package.	**ISO 17029** (Validation Principles); GRI 102-56; IFRS S1 Assurance

Result: Each NTCC dataset can be recognized as **verified Scope 3 behavioral evidence** with full chain-of-custody and audit traceability.

12.3 GRI / IFRS Alignment Details

PADV Data Point	GRI Reference	IFRS (ISSB) Reference	Alignment Purpose
Proof Record	GRI 2 / 102-45	IFRS S1-22	Defines entity scope and data origins.
NTCR (Proxy	GRI 305-3 /	IFRS S2-29	Quantified engagement metrics

PADV Data Point	GRI Reference	IFRS (ISSB) Reference	Alignment Purpose
Data)	305-5		with methodology.
NTCC (Index)	GRI 305-7	IFRS S2-25	Annualized recognition with reporting boundaries.
VF / RCF	GRI 205-1	IFRS S1-24	Internal control and assurance governance.
	GRI 403 / 413	IFRS S1-32	Social impact and materiality linkage.
Assurance Pack	GRI 102-56	IFRS S1/S2	Third-party verification support references.

12.4 ISO / COSO Integration

Domain	International Standard	PADV Application
Data Collection	**ISO 14064-1**	Reference for NTCR data schema and boundary definition.
Audit Management	**ISO 19011**	Sampling tiers and Data Validation Protocol (DVP).
Digital Evidence	**ISO 27037**	Proof Record structure and hash immutability.
Security & Privacy	**ISO 27001 / 27701**	Encryption and role-based access control.
Conformity Assessment	**ISO 17029**	Assurance Pack verification principles.

Domain	International Standard	PADV Application
Internal Control	**COSO (2017)**	VF Risk Assessment; RCF Control Activities; ADL Info & Comm; AP Monitoring.

12.5 QS Sustainability and Educational Mapping

QS Dimension	PADV Behavioral Mapping	Typical Evidence
Environmental Impact	Mission-based NTCR (clean-ups, mobility, energy saving).	PR logs + VF / scores.
Social Impact	Public welfare interaction programs.	SEF score + participation breadth.
Governance & Ethics	PADV Registry integrity protocols.	IRF documentation + verifier signatures.
Education for Sustainability	**EDU SDGS PASS** modules.	Student missions PR counts NTCR data.
Research Engagement	Cross-institutional datasets.	Anonymized behavioral records for research analysis.

12.6 Extended Interoperability (CDP / SBTi / GHG Protocol)

- **CDP:** NTCC serves as **third-party verified behavioral evidence** supporting Scope 3 engagement metrics.
- **SBTi:** PADV datasets support tracking of employee and community participation targets (Engagement Targets).
- **GHG Protocol:** Proof Record and NTCR data fill downstream Scope 3 data gaps with **auditable actions**.

12.7 Crosswalk (Integrated Matrix)

PADV Element	GRI	IFRS	ISO	COSO	QS
Proof Record	2 / 102-45	S1-22	27037	Info & Comm	Education Data
NTCR	305-3	S2-29	14064-1	Risk Assessment	Environmental Impact
NTCC	305-7	S2-25	—	Control Environment	Governance
VF / RCF	205-1	S1-24	19011	Monitoring	Transparency
	403 / 413	S1-32	—	Ethics	Social Impact
V-Layer / ADL	2 (Gov)	S1 (Control)	27001	Info & Comm	—
Assurance Pack	102-56	S1 / S2	17029	Monitoring	—

Disclosure Reminder: Always report (i) task definitions, (ii) VF and ranges, (iii) RCF pathway, and (iv) ADL identifier to ensure cross-framework comparability.

12.8 Implementation Notes for Reporters and Verifiers

- **Boundary Control:** Behavioral data (PR/NTCR) is entity-bound and non-transferable; NTCC is annualized and ADL-locked.
- **Sampling:** Follow ISO 19011 density tiers; record sampling ratios within the Assurance Pack.
- **Machine-Readable Format:** Export PR, NTCR, NTCC, and AP in JSON/XML/CSV with hash and timestamp fields.
- **Terminology:** Use **"verified behavioral impact proxy (NTCR)"** and **"annualized engagement index (NTCC)"** to avoid offset confusion.

- **Validation Chain:** PR VF/ NTCR NTCC ADL AP (Verifier-Signed).

CHAPTER 13: Data Integrity & Automated Verification Protocols

13.1 Introduction: Trust as Code

The PADV–NTCC system extends the concept of trust from manual verification to **automated integrity**. In traditional ESG reporting, data reliability often depends on spreadsheet documentation and human interpretation. PADV replaces this fragility with a **programmable structure**—where every verified action, data exchange, and validation event is governed by digital logic rather than manual entry.

This transformation defines **"Trust as Code"**—a state where data integrity, auditability, and compliance are embedded within the system architecture itself.

13.2 The V-Layer Data Pipeline: From Log to Lock

All verified behavioral data flow through four interconnected processing stages known as the **V-Layer Data Loop**:

Layer	Function	Output
Participation Layer	Captures user or enterprise actions via SDGS PASS mission or digital interaction.	**Raw Data Log**
Verification Logic Layer	Applies VF (Verification Factor) and weighting algorithms.	**Verified Proof Record**
V-Layer Registry	Stores hash-secured Proof Records and aggregates engagement metrics.	**Immutable Data Entry**
Reporting Layer (ADL)	Converts verified data into annualized indices and seals it under Annual Data Lock.	**Auditable Assurance Dataset**

This layered design ensures every action is traceable, auditable, and immutable,

forming the digital backbone of the **Engagement Index**.

13.3 Interoperability Schema (JSON/XML) for Automated Auditing

To achieve cross-platform verification, PADV defines a **machine-readable metadata schema** for all Proof Records and datasets.

Example (Simplified JSON Schema):

JSON


```
{
  "ProofRecord_ID": "PR-2025-04589",
  "Participant_UID": "E-UID-000129",
  "Action_Type": "Mission_Cycling_Event",
  "Location_Geo": "25.0340,121.5621",
  "Timestamp_UTC": "2025-06-10T04:45:20Z",
  "VF_total": 0.96,
  "W_ESG": {"CEF": 4.2, "SEF": 4.5, "IRF": 4.0},
  "RCF": 1.0,
  "Engagement_Proxy": 12.5,
  "Validator": "Independent_Verifier_A",
  "Lock_Status": "ADL_2025_Y1"
}
```


This schema is compliant with **ISO 27037 (Digital Evidence)** and supports automated checks by external assurance software.

13.4 V-Layer Ledger Protocol (VLP)

The **V-Layer Ledger Protocol (VLP)** functions as the secure registry ensuring

transparency and traceability across all data interactions.

Core Features:

- **Hash-Based Integrity:** Each Proof Record and data entry is hashed using SHA-256, creating a unique digital fingerprint.
- **Ledger Synchronization:** All records synchronize with the PADV Verification Node Network every 24 hours.
- **Audit Reconciliation:** Enables auditors to confirm hash consistency between PADV exports and enterprise internal logs.
- **Immutable Seal:** Once indices are locked under ADL, the ledger generates a permanent block hash, preventing any retroactive modification.

This protocol ensures that behavioral data cannot be altered without detection—turning the V-Layer into a verifiable **Digital Audit Trail**.

13.5 Automated Integrity Principles

Automated integrity within PADV is guided by three institutional principles:

1. **Autonomy:** Verification logic (e.g., duplicate detection) operates independently from the reporting organization to prevent bias.
2. **Transparency:** Every computation and data update generates a verifiable digital log, accessible to auditors under authorized access protocols.
3. **Accountability:** All automated actions are logged with cryptographic timestamps and validator identifiers, forming a machine-level chain of custody.

These principles align with **ISO/IEC 42001 (AI Management Systems)**, ensuring automated processing remains compliant and auditable.

13.6 Security & Privacy Controls

PADV integrates robust data protection and compliance frameworks:

Domain	Standard	Implementation
Data Security	ISO 27001 / 27701	End-to-end encryption & anonymized UID system.
Privacy Protection	PDPA / GDPR	Consent-based data collection & deletion rights.
Evidence Retention	ISO 27037	7-year archival period for Proof Records (Audit requirement).
Access Control	Role-Based Access	Multi-level permissions (Enterprise / Verifier / Regulator).

This ensures that data assurance is achieved without compromising privacy, balancing transparency with individual and institutional rights.

13.7 Interoperability Framework (API Standards)

PADV's data architecture is designed to integrate seamlessly with global ESG reporting platforms. The **Interoperability Framework (IFW)** defines standard API endpoints for data exchange:

Function	API Endpoint	Integration Partner
Upload Proof Record	/api/pr/upload	SDGS PASS / Enterprise ERP
Verify Parameters	/api/verify/vf	Verification Bodies
Retrieve Index Report	/api/ntcc/report	ESG Reporting Tools
Cross-Check Ledger	/api/ledger/check	External Audit Systems
Lock ADL	/api/adl/finalize	PADV Registry Admin

This structure transforms PADV–NTCC into a machine-verifiable **ESG data layer**, enabling interoperability across platforms like CDP, GRI Data Portal, and corporate sustainability dashboards.

13.8 Summary

By embedding automated integrity into the system, the framework transitions from a human-reliant verification process to a **digitally self-verifying infrastructure**. Data no longer requires belief—it provides **proof**. This is the essence of PADV as a data assurance solution: trust encoded, verified, and locked.

CHAPTER 14: Industry Use Cases & Compliance Applications

14.1 Introduction: From System Design to Industry Adoption

The PADV–NTCC framework demonstrates that verified behavioral data can evolve beyond academic methodology to become a **business-compatible infrastructure** for sustainability assurance. Rather than depending on estimated disclosures or self-declared achievements, it provides measurable, auditable, and standardized evidence of participation.

This chapter presents a set of cross-sectoral applications, illustrating how the PADV–NTCC system operates as a replicable **Data Governance Tool** for corporate, educational, and supply chain ecosystems.

14.2 The Data Gap in ESG Governance

Despite the maturity of global ESG frameworks, a structural gap remains between policy commitments and **execution verification**. Many institutions continue to rely on narrative-based reporting, creating a **"Data Confidence Deficit"** that weakens stakeholder trust.

The PADV–NTCC model addresses this gap through a new form of **Behavioral Assurance**, anchored in verifiable data logs rather than financial estimation. It operationalizes three key compliance objectives:

Compliance Dimension	PADV–NTCC Contribution
Transparency	Behavioral actions are traceable via Proof Records with immutable identifiers.
Accountability	Verification Factors (VF) and Recognition Protocols ensure proportional and auditable outcomes.
Participation	SDGS PASS mechanisms incentivize measurable engagement across citizens, employees, and organizations.

This structure converts intangible sustainability intent into **quantifiable, time-bound, and auditable data assets**.

14.3 Cross-Sector Pilot Validations

The PADV–NTCC model has been successfully tested in multiple ESG data pilots, involving collaboration among verification bodies, private-sector alliances, and academic partners.

Key Achievements:

- Generated **8.7 units** of verified NTCC engagement metrics (proxy: tons CO_2e).
- Accumulated over **2.45 million** engagement points through task-based actions.
- Participation from over **18 organizations** across various industries.
- Integrated verified records into corporate sustainability reporting aligned with **GRI 305** and **IFRS S2** data requirements.

These results confirm that behavioral data verification can function as an **enterprise-grade assurance layer**, bridging the space between voluntary participation and institutional accountability.

14.4 Data Governance Alignment

In regions emphasizing data integrity and digital governance, PADV–NTCC is positioned as a **Data Assurance Infrastructure** rather than a market mechanism. Its architecture reflects the principles of open data interoperability and sustainability assurance by design.

Key characteristics include:

- A registry framework enabling **cross-verifier data synchronization**.
- Compatibility with **digital trust** and open data frameworks adopted internationally.
- Scalability for **SME digital transformation** and ESG data readiness.

Through these features, NTCC functions as a **Trust Layer** for sustainability data, supporting regulators, corporations, and verifiers in creating unified ESG assurance ecosystems.

14.5 Corporate Implementation: Behavioral Verification in Practice

Corporations adopt PADV–NTCC primarily through two operational channels:

1. **ESG Integration:** Using NTCC as verified **Scope 3 behavioral datasets** in sustainability reports.
2. **CSR and Stakeholder Programs:** Launching mission-based activities that generate **Proof Records** through SDGS PASS.

Sector	Implementation Model	Verified Output
Retail & F&B	Indirect Interaction (Welfare Pool)	Quantified low-carbon consumer behavior logs
Finance	Employee ESG Missions, Green Literacy	Measurable participation data for internal control

Sector	Implementation Model	Verified Output
Manufacturing	SDGS PASS for Supply Chain Actions	Verified Scope 3 behavioral data
Event Management	ESG-linked Missions and Exhibitions	Auditable NTCC engagement metrics

This approach ensures that corporate sustainability is proven through **verified participation**, not merely through expenditure or policy declarations.

14.6 Educational Applications: From Learning to Measurable Impact

The academic adaptation, **EDU SDGS PASS**, translates sustainability learning into quantifiable behavioral records. Universities employ mission-based education modules that link students' sustainability actions to verified Proof Records.

Demonstrated Outcomes:

- Integration with **QS Sustainability Ranking** through verified participation indicators.
- Collaboration among academic institutions to standardize sustainability literacy benchmarks.
- Behavioral data exportable to PADV Registry for **ESG-compatible assurance**.

This framework converts educational engagement into a verifiable component of institutional sustainability performance.

14.7 Large-Scale Event Missions

PADV–NTCC has been validated in large-scale public sustainability events—including clean-up missions, charity cycling, and ESG exhibitions.

Typical Data Flow:

1. Participants register via QR-based mission onboarding.

2. Proof Records generated automatically through on-site or IoT-linked validation.
3. NTCC calculated based on participation volume and VF-weighted impact proxy.
4. Event organizers receive **Post-Event Assurance Summaries** compatible with GRI and IFRS structures.

Example Outcome:

A regional ESG-themed exhibition produced verified engagement metrics equivalent to 8,700 kg CO_2e proxy impact, supported by thousands of public participation Proof Records. This confirms NTCC's adaptability across multiple engagement scales.

14.8 Quantified Impact and Scalability

Metric	**Verified Result (2025 Pilot Data)**
Proof Records	> 2,500,000 entries
Verified NTCC Index	**8.7 units** (Proxy: tons CO_2e)
Participating Organizations	18+
Individual Participants	> 30,000
Data Accuracy	**100%** validated by system logic

The evidence demonstrates that PADV–NTCC delivers a replicable and scalable model for translating human participation into **institutional trust**. Its relevance lies in enabling:

- Integration into **corporate ESG data platforms**;
- Adoption by assurance organizations as a **pre-audit tool**;
- Alignment with international **sustainable data interoperability** frameworks.

Through these outcomes, PADV–NTCC proves that verified participation can evolve

into **industry infrastructure**, bridging human behavior, data assurance, and governance credibility.

CHAPTER 15: Conclusion & Future Ecosystem Evolution

15.1 Closing Reflection: From Behavior to Infrastructure

The journey of PADV–NTCC demonstrates that sustainability data does not emerge from estimation, but from **verified behavior**. When human participation becomes measurable, and verification becomes standardized, sustainability evolves from narrative claims into **evidence-based compliance**.

This transformation marks the beginning of a new **Data Era**—where impact estimation, ESG disclosure, and behavioral science converge into a single verifiable logic. **NTCC**, as the standardized **Engagement Index**, anchors this logic within the domain of social participation and collective accountability, distinct from financial carbon markets.

15.2 The Role of PADV as Data Infrastructure

PADV serves as the underlying **Operating System (OS)** that operationalizes NTCC: a four-ring model that ensures Participation (P), Action (A), Data (D), and Value (V) are continuously linked.

Through this structure, verified behaviors become **machine-readable trust components**—the fundamental units of sustainable transformation. By standardizing the Proof Record, VF (), and weighting, PADV transforms human actions into structured datasets suitable for **enterprise governance**.

Each verified act, whether individual or organizational, thus contributes to a larger **Behavioral Data Assurance Framework (BDAF)** supporting ESG integrity at scale.

15.3 Ecosystem Evolution Pathway

The adoption roadmap of PADV–NTCC follows three progressive stages of **Infrastructure Maturity**:

Stage	Description	Strategic Focus
Phase I — Validation	Establishment of Proof Record and NTCC measurement framework.	**Data Integrity & Methodological Rigor**
Phase II — Interoperability	Integration with international standards (GRI, IFRS, ISO, QS).	**API Connectivity & Audit Readiness**
Phase III — Ecosystem Scale	Adoption by supply chains, verifiers, and global data platforms.	**Industry Standardization & Global Replicability**

This progression transforms PADV–NTCC from a methodological prototype into a **Data Infrastructure** embedded in the global supply chain, capable of supporting ESG assurance ecosystems globally.

15.4 Toward the Next Phase: AI-Driven Automated Compliance

The next evolution of PADV lies in the intersection of **AI Governance** and **Behavioral Data Validation**. Machine-verifiable integrity will enable **autonomous ESG reporting systems**, where Proof Records are generated, verified, and disclosed without human bias or delay.

In this future, NTCC functions as the **Trust Unit** for autonomous sustainability systems, while PADV provides the **Data Logic** ensuring that every machine decision remains accountable to human values and international standards. This paradigm redefines "trust"—from being declared, to being **computed, verified, and locked**.

15.5 Global Standardization and Open Data Collaboration

The significance of PADV–NTCC extends beyond compliance. It introduces a unified, auditable **data logic** applicable across scientific, educational, and corporate systems.

Future collaborations are expected to include:

- **Integration** with global academic consortia on behavioral sustainability metrics.
- **Co-development** of ISO-compatible verification models for Scope 3.
- **Cross-validation studies** on Proof Record reliability and VF calibration.
- **Establishment of PADV Open Repository** for global academic access.

Through these initiatives, PADV–NTCC is envisioned not merely as a data framework, but as a **standardized language** for the age of behavioral sustainability.

15.6 Closing Statement

In an era where sustainability is both a business imperative and a data challenge, PADV–NTCC provides a third path—not purely economic (trading), not purely regulatory (forcing), but **infrastructural** (enabling).

It represents a bridge between intention and proof, between participation and trust, between individual action and global accountability. As a system born from **verified human behavior**, NTCC will continue to evolve as a cornerstone of future **ESG Assurance**, while PADV stands as its enduring foundation—a framework where data is not merely collected, but secures the very trust that sustains our shared future.

Acknowledgments and Supporting Institutions

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a conceptual methodology into an **operational verification framework** bridging behavioral data, ESG assurance, and cross-border institutional governance.

Disclaimer: The inclusion of the above institutions acknowledges their participation through **technical consultation and feedback**. The final content, interpretations, and recommendations expressed in this white paper are the sole responsibility of the author and **do not constitute formal endorsement** by any of the listed parties.

APPENDICES

Appendix A – Verification Factor (VF) & Data Quality Model

A.1 Definition and Purpose

The Verification Factor (VF) is the quantitative algorithm that transforms raw participation logs into high-fidelity engagement metrics. It measures the reliability, contextual stability, and data completeness of each behavioral record, thereby ensuring that the resulting Impact Proxy values are statistically grounded and reproducible.

VF serves as the **Data Quality Score (DQS)** between raw behavioral inputs and verified ESG datasets. Within the PADV–NTCC framework, it functions as the statistical **"Integrity Coefficient"** that normalizes data variance across different regions, event types, and measurement conditions.

A.2 Mathematical Structure

The complete VF computation is defined as:

VF_{total} = \frac{VF_0 + VF_n + VF_s}{3}

Symbol	Term	Description	Typical Range
VF_0	**Baseline Reliability**	Reflects the inherent reliability of the data capture system (e.g., API vs. manual entry) and institutional environment.	**0.90 – 0.95**

Symbol	Term	Description	Typical Range
VF_n	**Participation Fidelity**	Adjusts for completion rate, engagement depth, and record validation ratio.	**0.85 – 1.00**
VF_s	**Contextual Stability**	Evaluates temporal and operational stability during data collection (e.g., system latency, event continuity).	**0.88 – 0.97**
RCF	**Recognition Protocol**	Annual recognition cap depending on the nature of participation (Direct Task = 1.0; Indirect Interaction = 0.3).	**{1.0, 0.3}**

This formula ensures that participation with high contextual stability and accurate recording achieves proportionally higher **data weight**.

A.3 Algorithmic Interpretation

- **Baseline Calibration (VF_0):** Derived from system audits and **ISO 27001** security assessments. It anchors all subsequent calculations, representing the inherent trustworthiness of the reporting infrastructure.
- Participation Fidelity (VF_n): Computed from real-time validation logs:

VF_n = \frac{\text{Verified Records}}{\text{Total Attempts}}

(Bounded to 1.00 maximum).

- Stability Adjustment (VF_s): Incorporates variance in operational conditions:

VF_s = 1 - \sigma

Where \sigma denotes the normalized deviation of measurement conditions.

- **Recognition Protocol (RCF):** Enforces annual data integrity limits (Applied at aggregation stage):
    - **Type B (Direct Task Execution)** \rightarrow Full Recognition (RCF = 1.0)

- **Type A (Indirect Interaction)** \rightarrow Capped Recognition (RCF = 0.3)

A.4 Example Computation (Data Quality Scoring)

A corporate compliance task reports:

- **Completion Rate** = 92%
- **System Quality** = High (VF_0 = 0.92)
- **Participation Consistency** = Excellent (VF_n = 0.95)
- **Operational Stability** = Good (VF_s = 0.90)

VF_{total} = \frac{0.92 + 0.95 + 0.90}{3} = \mathbf{0.923}

Result: VF_{total} = 0.923 \rightarrow High Data Integrity.

In audit practice, a score of \ge 0.90 indicates a "Fully Trustworthy" record class suitable for external reporting.

A.5 Annual Recognition Framework

Behavior Type	**RCF Value**	**Recognition Rate**	**Definition of Scope**
Direct Task Execution	**1.0**	**100%**	Direct operational participation, measurable impact, system-verified logs.
Indirect Interaction	**0.3**	**30%**	Indirect engagement through community pool or product interaction.

Annual recognition values prevent **data inflation** (over-accrual) while maintaining consistency with conservative audit and disclosure standards.

A.6 Cross-Standard Mapping

VF Component	Primary Function	GRI Reference	IFRS Reference	ISO/COSO Alignment
VF_0	**Data Integrity & Reliability**	GRI 102	IFRS S1-22	ISO 27037 / COSO: Control Environment
VF_n	**Performance Verification**	GRI 403	IFRS S1-29	ISO 19011 / COSO: Monitoring
VF_s	**Stability Measurement**	GRI 305	IFRS S2-27	ISO 14064-1 / COSO: Info & Communication
RCF	**Recognition Governance**	GRI 201	IFRS S1-24	ISO 37000 / COSO: Risk Management

A.7 Interpretation Guidelines

- **VF acts as a universal confidence index** for any PADV-verified dataset.
- **VF \ge 0.90** \rightarrow **High Fidelity:** Suitable for third-party ESG reporting and Scope 3 integration.
- **VF 0.75 – 0.89** \rightarrow **Medium Fidelity:** Conditionally verifiable; requires additional sampling or reconciliation.
- **VF $< 0.75** \rightarrow **Low Fidelity:** Rejected or archived for internal research only (Non-Disclosure Grade).

All VF records are subject to annual **audit reconciliation** and checksum verification to ensure the immutability of the Engagement Index.

Appendix B – ESG Engagement Weighting Model (W_{ESG})

B.1 Purpose and Conceptual Role

Within the PADV–NTCC framework, the **ESG Weighting Factors** translate qualitative sustainability attributes into quantitative, verifiable **algorithmic coefficients**.

They ensure that each verified behavioral record not only represents a proxy for environmental effect but also encapsulates the **Social** and **Governance** value dimensions required for holistic ESG disclosure.

Each NTCR (Non-Tradable Commitment Record) carries a composite weight, calculated as:

W_{ESG} = \text{Average}(CEF, SEF, IRF)

This value forms the second critical multiplier following the Verification Factor (VF), ensuring that the final **Engagement Index** reflects the multidimensional quality of the action.

B.2 Structure and Definitions

Dimension	Code	Definition	Typical Range (1–5)	Measurement Source
Environmental Impact Proxy	**CEF**	Quantifies the relative environmental efficiency, including emission avoidance effort, resource optimization, or waste prevention.	**3 – 5**	Derived from ISO 14064 inventory data or LCA benchmarks
Social Engagement Factor	**SEF**	Represents inclusiveness, volunteer participation depth, educational reach, or community benefit.	**2 – 5**	Derived from participation logs and social impact surveys
Institutional Reliability Factor	**IRF**	Captures data governance integrity, process transparency, and internal control strength of the organizing entity.	**3 – 5**	Based on ISO 27001 compliance or Internal Audit logs

B.3 Scoring Algorithm

1. Normalization Scale

All three dimensions are scored from 1 to 5, where:

- **5** = High-Performance / Best Practice
- **3** = Baseline Compliance
- **< 3** = Trigger for Quality Review (Data Flagged)

2. Weight Computation

The normalized ESG weight is the arithmetic mean:

W_{ESG} = \frac{CEF + SEF + IRF}{15}

3. Integration with Engagement Index

The resulting W_{ESG} is multiplied with VF_{total} to generate a balanced NTCC Index that reflects both quantitative accuracy (VF) and qualitative ESG alignment (W_{ESG}).

B.4 Illustrative Scoring Examples

Case ID	Description	CEF	SEF	IRF	WESG	Interpretation
M-001	**Corporate Green Commuting Mission**	4.7	4.3	4.5	**0.90**	High integration; direct environmental benefit with strong governance.
M-002	**University Clean-up Campaign**	4.6	4.8	4.4	**0.92**	Excellent social engagement backed by institutional validation.
R-005	**Eco-Product Interaction**	3.6	3.9	4.0	**0.76**	Moderate impact; consumer-driven behavioral change.
R-008	**CSR Webinar (Education)**	3.4	4.2	4.3	**0.79**	High educational value with indirect environmental gain.

(Note: W_{ESG} values are normalized decimals used in the NTCC formula.)

B.5 Data Utility Classification (Thresholds)

WESG Score	Data Utility Class	Disclosure Eligibility
\ge 0.85	**High Fidelity**	**Primary Evidence** for Scope 3 and GRI 305 reporting.
0.70 – 0.84	**Medium Fidelity**	**Supporting Evidence** with narrative context.
$<$ 0.70	**Low Fidelity**	**Internal Management Use** (Retained for improvement analysis).

B.6 Cross-Framework Interoperability

PADV Factor	Primary Meaning	GRI Reference	IFRS Reference	ISO / COSO Alignment
CEF	Emission and resource efficiency	GRI 305-5 / 306	IFRS S2-27	ISO 14064-1 / 14067
SEF	Social inclusion and engagement	GRI 413-1	IFRS S1-29	ISO 26000 / COSO Monitoring
IRF	Governance and data integrity	GRI 201-2 / 102-18	IFRS S1-22	ISO 27001 / COSO Control Env

B.7 Operational Guidelines

- **Baseline Definition:** Each organization must define its own ESG baseline matrix aligned with national regulations and industry standards.
- **Periodic Review:** All W_{ESG} parameters shall be subject to annual review under the **Data Validation Protocol (DVP)**.
- **Regional Calibration:** For multi-country datasets, local weight calibration (\Delta \le \pm 0.2) is permitted to reflect regulatory variances.

- **Immutability:** Once verified, the final W_{ESG} value is **locked** in the V-Layer Proof Record.

B.8 Interpretive Remarks

The ESG Engagement Weighting System bridges quantitative and qualitative ESG dimensions. It ensures that every recognized NTCC index embodies not just a numerical score, but **ethical governance accountability**.

Through CEF / SEF / IRF, PADV translates complex behavioral data into **institutionally meaningful management metrics**, laying a common foundation for audit, assurance, and policy integration across international frameworks.

Appendix C – NTCC Engagement Metrics and ESG Data Correspondence

C.1 Purpose

The purpose of this appendix is to describe the quantitative logic that links human behavioral participation to measurable and auditable **engagement metrics** within the PADV–NTCC framework.

Every verified activity or interaction recorded through SDGS PASS produces a **Non-Tradable Commitment Credit (NTCC)**, which represents behavior-based **engagement impact**, not a tradable financial asset.

The NTCC functions as a verifiable data unit that can be integrated into ESG reporting as **supporting evidence** under GRI 305 (Emissions) and IFRS S2 (Climate-related Disclosures).

C.2 Core Calculation Formula

The NTCC Engagement Index is calculated using the following algorithm:

$$NTCC\sim(Proxy\sim kgCO_2e) = \frac{Points}{10} \times VF_{total} \times \frac{W_{ESG}}{5}$$

Where:

Variable	Meaning	Unit / Range
Points	Total verified engagement points generated by behavioral participation	Integer ≥ 0
10 pts ≈ 1 Unit	**Proxy Benchmark** (10 pts ≈ 1 kg CO_2e avoidance effort)	Fixed Constant
VF_{total}	**Data Quality Score** (Verification Factor)	0.4 – 1.0
W_{ESG}	**ESG Relevance Score** (Composite of CEF/SEF/IRF)	1 – 5
5	Normalization denominator aligning with ESG materiality scale	Constant
NTCC	**Verified Engagement Index** (Proxy Value)	Real ≥ 0

Note: If reporting in standardized tons, divide by 1000.

C.3 Logic Derivation Process

1. **Behavioral Base:** Each verified activity produces a number of SDGS PASS points determined by participation depth and approved task parameters.
2. **Proxy Benchmark:** A linear baseline of **10 points ≈ 1 unit of impact** was established through empirical calibration using 2024–2025 pilot datasets.
3. **Reliability Adjustment:** Multiply by VF_{total} to reflect statistical confidence and data validation density.
4. **Qualitative Integration:** Multiply by (W_{ESG} / 5) to normalize qualitative alignment with ESG goals.

The final NTCC is thus a product of **quantitative participation intensity** and **qualitative sustainability coherence**.

C.4 Algorithmic Expansion

NTCC = \left(\frac{Points}{10} \right) \times \left(\frac{VF_0 + VF_n + VF_s}{3} \right) \times \left(\frac{CEF + SEF + IRF}{15} \right)

This expanded form demonstrates how the NTCC mathematically encapsulates

both measurement accuracy (VF) and sustainability alignment (ESG weights).

C.5 Illustrative Calculation Examples

Case ID	Category	Points	VFtotal	WESG	NTCC Index (Proxy kg)	NTCC Index (Proxy tons)
M-101	Tree-Planting Task	1,000	0.93	4.5	**83.7**	0.0837
M-205	Employee Green Challenge	500	0.90	4.2	**37.8**	0.0378
R-310	Eco-Cup Interaction	1,000	0.91	3.8	**69.2**	0.0692
K-420	Online ESG Seminar	300	0.89	4.1	**21.9**	0.0219

C.6 Data Integrity and Pre-Audit Readiness

Factor	Influence	Validation Method
VF_{total}	Adjusts numerical credibility	Randomized sampling (95% confidence interval)
W_{ESG}	Integrates non-financial aspects	Internal ESG panel review (annual)
Proxy Constant	Defines behavioral $\rightarrow$ impact conversion	Periodic benchmark recalibration (± 5%)
Traceability	Ensures audit reproducibility	Hash checksum & Proof Record signature

All computations are logged and time-stamped within the PADV registry; each NTCC record contains a verifiable hash of its source Proof Records.

C.7 Cross-Framework Data Mapping

NTCC Output Element	GRI Alignment	IFRS Linkage	ISO / COSO Reference
NTCC Index	GRI 305-5 / 305-7	IFRS S2-27	ISO 14064-1 (Data Support)
Proof Record Logs	GRI 102-45	IFRS S1-22	COSO Info & Communication
W_{ESG} Weights	GRI 413-1	IFRS S1-29	ISO 26000 / 37000
VF Components	GRI 403-2	IFRS S1-24	ISO 19011 / COSO Monitoring
Annual Recognition	GRI 201-2	IFRS S1-24	COSO Risk Assessment

C.8 Institutional and Interpretive Notes

- **Non-Tradability:** The NTCC represents verified **participation equivalence**, not a tradable carbon asset or offset. It is a **Data Governance Tool**, not a commodity.
- **Audit Function:** NTCC values can be independent verified by any ESG assurance firm using PADV's Proof Record hashes as **supporting evidence**.
- **Policy Integration:** Governments and institutions may adopt NTCC values as **non-financial data** for ESG performance disclosure without invoking financial instrument regulation.
- **Annual Recognition Constraint:**
    - Direct Task Records = **100% recognition**.
    - Indirect Interaction Records = **30% recognition**.
    - *Rationale: This maintains proportionality and prevents artificial data accumulation.*

Appendix D – V-Layer Metadata Schema

D.1 Purpose and Scope

The PADV–NTCC framework relies on a **verifiable, machine-readable metadata architecture** that enables cross-standard auditability. This appendix defines the schema used to record, verify, and transfer **Proof Records** across the V-Layer data validation network.

Each Proof Record is a cryptographically signed entry that connects:

- A verified **participation event**;
- Its computed **VF (Verification Factor)** and **W_{ESG} values**;
- Its resulting **NTCR (Non-Tradable Commitment Record)** Engagement Index.

All records comply with **ISO 19011 (Audit Management)**, **ISO 27037 (Digital Evidence Handling)**, and **COSO Control Environment** standards.

D.2 Versioning & Governance

Field	**Description**
Schema ID	padv.ntcc.schema
Schema Version	**3.0.0**
Data Model Version	**2025.12**
Change Policy	Semantic Versioning (Major.Minor.Patch)
Namespace	urn:padv:ntcc:v3
Maintainer	EMJ.LIFE Technical Operations Division
Primary Formats	**JSON** (API Primary), **XML** (Enterprise Integration), **CSV** (Bulk Audit)

D.3 JSON Schema (Simplified for Readability)

JSON

```
{
  "$schema": "https://json-schema.org/draft/2020-12/schema",
  "$id": "urn:padv:ntcc:v3:proofrecord",
  "title": "PADV–NTCC Proof Record",
  "type": "object",
  "properties": {
    "pr_id": { "type": "string", "pattern": "^PR-[0-9]{4}-[0-9A-Z]{5,}$" },
    "participant": {
      "type": "object",
      "properties": {
        "euid": { "type": "string", "minLength": 8 },
        "role": { "type": "string", "enum": ["individual","employee","student"] }
      }
    },
    "activity": {
      "type": "object",
      "properties": {
        "task_id": { "type": "string" },
        "type": { "type": "string", "enum": ["direct_task","indirect_interaction"] },
        "evidence_hash": { "type": "string", "pattern": "^(sha256:)[0-9a-f]{64}$" }
      }
    },
    "metrics": {
```

```
            "type": "object",
            "properties": {
                "points": { "type": "integer", "minimum": 1 },
                "vf_total": { "type": "number", "minimum": 0.40, "maximum": 1.00 },
                "w_esg": { "type": "number", "minimum": 1, "maximum": 5 },
                "ntcr_proxy_value": { "type": "number", "description": "Engagement
Impact Proxy" }
            }
        },
        "audit_trail": {
            "type": "object",
            "properties": {
                "timestamp_utc": { "type": "string", "format": "date-time" },
                "validator_sig": { "type": "string" },
                "ledger_lock": { "type": "string", "enum":
["pending","ADL_YYYY_Yn","locked"] }
            }
        }
    }
}
```

D.4 JSON Example (Audit-Ready)

JSON

```
{
    "pr_id": "PR-2025-0A3XZ",
    "participant": {"euid": "E-UID-7F29AB9", "role": "employee"},
```

```
  "organization": {"org_id": "EUID-ACME01"},
  "activity": {
    "task_id": "SDGSPASS-MISSION-014",
    "type": "direct_task",
    "category": "green_commuting",
    "evidence_hash": "sha256:8a1c...f0e"
  },
  "metrics": {
    "points": 120,
    "vf_total": 0.95,
    "w_esg": 4.43,
    "ntcr_proxy_value": 10.2
  },
  "audit_trail": {
    "timestamp_utc": "2025-06-15T09:32:11Z",
    "validator_sig": "sig_verifier...",
    "ledger_lock": "pending"
  },
  "mappings": {"gri": "305-3", "ifrs": "S2-29", "iso": "14064-1"}
}
```

D.5 XML Schema (Excerpt)

```
XML
<ProofRecord xmlns="urn:padv:ntcc:v3">
  <PR_ID>PR-2025-0A3XZ</PR_ID>
  <Participant>
```

```
    <EUID>E-UID-7F29AB9</EUID>
    <Role>employee</Role>
  </Participant>
  <Metrics>
    <Points>120</Points>
    <VF_Total>0.95</VF_Total>
    <W_ESG>4.43</W_ESG>
    <NTCR_Proxy_Value>10.2</NTCR_Proxy_Value>
  </Metrics>
  <Audit_Trail>
    <Timestamp_UTC>2025-06-15T09:32:11Z</Timestamp_UTC>
    <Validator_Signature>sig_verifier...</Validator_Signature>
    <Ledger_Lock>pending</Ledger_Lock>
  </Audit_Trail>
</ProofRecord>
```

D.6 Field Dictionary & Standards Crosswalk

Field	Description	GRI	IFRS	ISO	COSO
pr_id	Global Unique Proof Record	102-45	S1-22	27037	Info & Comm
participant.euid	Anonymized Participant ID	102-8	S1-22	27701	Control Env
vf.vf_total	Verification Coefficient	205-1	S1-24	19011	Monitoring
w_esg	ESG Composite Weight	403/413	S1-	26000	Ethics

Field	Description	GRI	IFRS	ISO	COSO
			32		
ntcr_proxy_value	**Behavioral Impact Proxy**	305-3	S2-29	14064-1	Info & Comm
ledger_lock	Annual Data Lock Status	102	S1	27037	Monitoring

D.7 Validation Rules

- **Deterministic Formulas:**
  - base_proxy = points / 10
  - vf_total = (vf0 + vfn + vfs) / 3
  - w_norm = w_esg / 5
  - ntcr_proxy_value = base_proxy × vf_total × w_norm
- **Constraints:**
  - pr_id must be globally unique.
  - points ≥ 1.
  - timestamp_utc unique per (euid + task_id).
  - ledger_lock ∈ {pending, ADL_YYYY_Yn, locked}.

D.8 Privacy & Security (GDPR/PDPA Compliance)

- **PII Minimization:** Only anonymized euid and salted hashes are stored.
- **Hash Protection:** All evidence is stored via **SHA-256 digest**.
- **Crypto Chain:** Each record is linked by prev_registry_hash, forming a verifiable chain of custody.
- **Retention:** Default **7 years** per ISO 27037 requirements for digital evidence.
- **Access:** Controlled by privacy_level flag (Public / Restricted / Confidential).

D.9 Checksum & Ledger Registry Note

Each Proof Record is integrated into the **V-Layer Assurance Ledger**. A rolling Merkle tree is maintained to validate record immutability.

Component	**Function**
Record Hash	SHA-256 digest of serialized Proof Record
Prev Registry Hash	Previous Merkle root for chain continuity
Validator Signature	Cryptographic endorsement by authorized partner
Ledger Height	Sequential index for audit traceability

This ensures NTCC records cannot be altered or forged without invalidating the entire **Data Chain**.

Appendix E – Canonical Terminology & Data Variables

E.1 Variables and Units

Symbol	**Definition**	**Range / Unit**	**Formula or Rule**
Points	Verified engagement points generated by user action	Integer \ge 1	Benchmark: **10 pts \approx 1 Unit Impact Proxy**
Base	Base Proxy Conversion Value	Standardized Units	Base = Points \div 10
VF_0, VF_n, VF_s	Data Quality Factors (Baseline, Participation, Stability)	0.80 - 1.20	Contextual reliability inputs defined in Chapter 6
VF_{total}	**Computed Data Quality Score** (Verification Factor)	0.40 - 1.00	VF_{total} = (VF_0 + VF_n + VF_s) \div 3
CEF, SEF, IRF	ESG Impact Sub-scores	1 - 5 (Likert Scale)	Standardized evaluation rubrics

Symbol	Definition	Range / Unit	Formula or Rule
W_{raw}	ESG Composite Raw Score	1 - 5	W_{raw} = (CEF + SEF + IRF) \div 3
W_{ESG}	**Normalized ESG Weighting**	0.20 - 1.00	W_{ESG} = (CEF + SEF + IRF) \div 15
NTCR	**Verified Engagement Record** (Single Activity)	Proxy Units	NTCR = Base \times VF_{total} \times W_{ESG}
RCF	Annual Recognition Coefficient	\{0.3, 1.0\}	**Type A** (Indirect) = 0.3; **Type B** (Direct) = 1.0
NTCC	**Annualized Engagement Index** (Aggregated)	Index Units	NTCC = \sum (NTCR \times RCF)
ADL	Annual Data Lock Identifier	String Format	Format: ADL-YYYY-UniqueHash

E.2 Controlled Terminology

To ensure compliance and clarity, the following terms are strictly defined:

- **Non-Tradable Commitment Credit (NTCC):** An annualized, audit-ready **Engagement Index** used for management accounting. It is **not** a tradable financial instrument.
- **Non-Tradable Commitment Record (NTCR):** A single unit of ESG-weighted behavioral impact proxy (Unit: Standardized Engagement Proxy).
- **Proof Record (PR):** An atomic digital evidence unit containing machine-readable metadata and hash signatures.
- **Impact Proxy:** An estimated value (e.g., kgCO_2e avoidance) used as a **KPI**, distinct from certified carbon offsets.
- **V-Layer:** The data verification infrastructure that processes validation logic.

E.3 Display and Rounding Rules

- **VF and W parameters:** Display to **two decimal places** (e.g., 0.95).
- **NTCR and NTCC:** Display to **two decimal places** in reports.
- **Units:** Use **"Standardized Units"** or **"Proxy Units"** in public disclosures to avoid confusion with regulatory carbon credits.
- **Notation:** In technical documentation, always distinguish between **Raw Score (1-5)** and **Normalized Weight (0-1)** clearly in formula annotations.