PADV–NTCC – ESG Integrated Methodology

White Paper v2.0

Publisher: EMJ LIFE Holdings Pte. Ltd. (Singapore)

Institutional Operator: ***Behavioral Data–Driven Non-Tradable Carbon Credit and ESG Integration Framework***

Date: 2025.10.15

Metadata Page

Title:

- PADV–NTCC – ESG Integrated Methodology White Paper v2.0 — Non-Tradable Carbon Credit Framework for Verified Behavioral Sustainability

Publisher:

- EMJ LIFE Holdings Pte. Ltd. (Singapore)

Institutional Operator:

- NTCC (Non-Tradable Carbon Credit) System under the PADV Behavioral Data Verification Framework

Version:

- v2.0 • 15 October 2025

Identifiers:

- DOI: 10.64969/padv.ntcc.2025.v2
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Place of Publication:

- Singapore

Keywords:

NTCC • NTCR •PADV • ESG • Scope 3 • Behavioral Data • Non-Financial Assurance • Carbon Accounting • SDGS PASS • Institutional Governance • Verification Factor (VF) • Recognition Coefficient (RCF) • COSO • IFRS • GRI • ISO • Audit Framework • Data Integrity • Sustainability Assurance

Value Statement

At its core, the NTCC (Non-Tradable Carbon Credit) system establishes a new standard for how sustainability is verified rather than traded.

It provides the institutional assurance layer that converts behavioral participation into measurable, auditable, and non-financial carbon equivalence.

Unlike market-based carbon 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 carbon data, and carbon 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 Visa created trust for financial transactions, NTCC creates trust for sustainability data—shifting the foundation of climate credibility from financial speculation to behavioral verification.

It is not a currency, but a covenant 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 Carbon 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 carbon equivalence (kg CO_2e).

Each NTCC is generated through a dual-pathway mechanism—Public Welfare Redemption (fixed VF = 0.95) and Mission Participation (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.

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 public welfare actions, 5.25 million points of behavioral participation, and 15.1 tons of certified non-tradable carbon credits (NTCC) generated by over 35,000 participants and 72 partner brands.

These empirical results validate NTCC as a policy-grade, non-market verification architecture capable of supporting Scope 3 data disclosure and national carbon governance alignment.

The NTCC methodology thus complements—rather than competes with—existing carbon and ESG frameworks.

It provides the missing trust layer in sustainability accounting, enabling corporations, regulators, and verifiers to transition from declarative claims to verifiable behavioral evidence, and from carbon trade to carbon trust.

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CHAPTER 1 ABSTRACT

1.1 Overview of NTCC Concept and Purpose

The Non-Tradable Carbon Credit (NTCC) is designed as a **data-driven governance unit**, not a financial instrument.

It quantifies verified human and organizational participation in sustainability programs and converts those behavioral records into standardized, auditable carbon equivalence.

Unlike traditional carbon credits that derive value from exchangeability, NTCC derives legitimacy from **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-based data system**, enabling organizations to report verifiable sustainability outcomes without monetization or double-counting risk.

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 by linking four layers:

1. **Participation** – Verified behavioral actions collected via SDGS PASS or other institutional mechanisms;
2. **Action** – Each act processed through verification algorithms (VF_0, VF_n, VFs);
3. **Data** – Conversion into Non-Tradable Carbon Records (NTCRs) expressed in

kg CO_2e;

4. **Value** – Annual recognition of verified NTCRs as NTCCs 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 assurance and reporting standards including **GRI 305 (Emissions)**, **IFRS S1 / S2**, **ISO 14064-1**, and **COSO 2017 Internal Control Framework**.

Its audit logic is consistent with **ISO 19011** and **ISO 27037**, supporting digital evidence traceability and assurance documentation.

By integrating these structures, NTCC acts as a **governance bridge** between behavioral participation data and institutional ESG disclosure.

Independent verifiers (e.g., Deloitte, BSI, DNV, ARES) can validate NTCC datasets through PADV's cross-verification protocol, ensuring that behavioral data attain the same assurance quality as financial data within sustainability reports.

1.4 Dual Corporate Pathways and Annual Recognition Principle

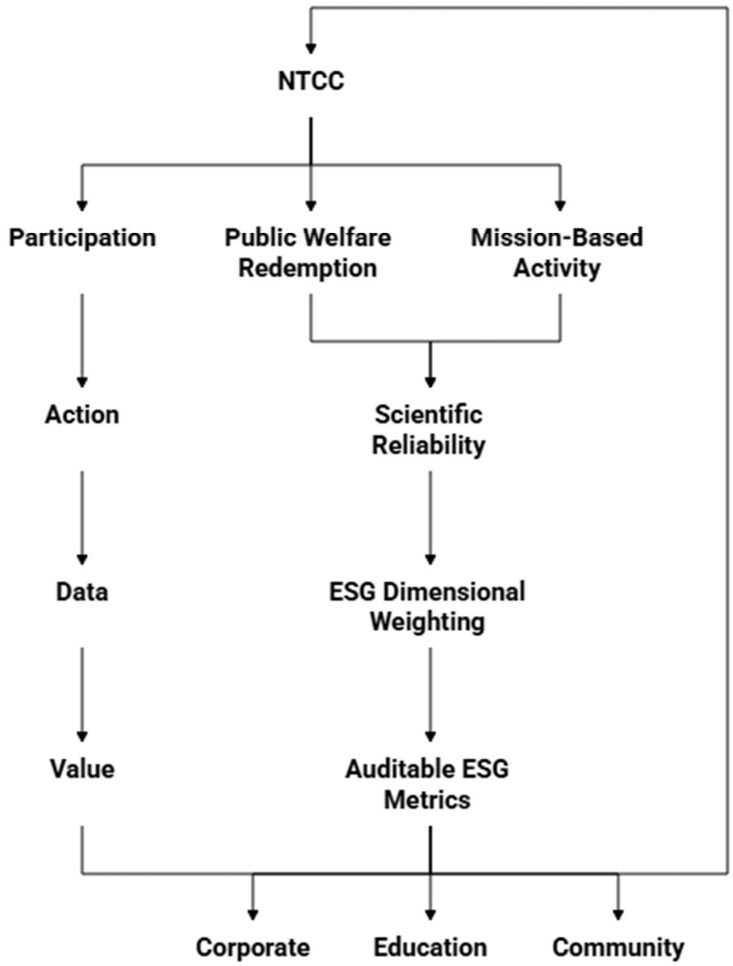
NTCC recognition follows a **dual-pathway model** that balances inclusivity with audit rigor:

Pathway	Mechanism	RCF Value	Recognition Scope
Type A — Public Welfare Goods Redemption	Fixed verification (VF = 0.95) with limited sampling depth	0.3	Recognized up to 30 % of total annual NTCR (Goods + Missions)
Type B — Mission Participation	Dynamic verification (VF = 0.8 – 1.0) with full	1.0	100 % annual recognition

Pathway	Mechanism	RCF Value	Recognition Scope
Activities	ESG weighting		

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 **public welfare participation** and **mission-based sustainability engagement**, integrating NTCC outcomes into verified Scope 3 and CSR performance metrics.

NTCC Verification and Assurance Flow



CHAPTER 2 Background & Motivation

2.1 The Global Trust Gap in ESG and Carbon Disclosure

Despite the rapid expansion of ESG reporting and carbon accounting frameworks, the global sustainability system continues to face a **crisis of credibility**.

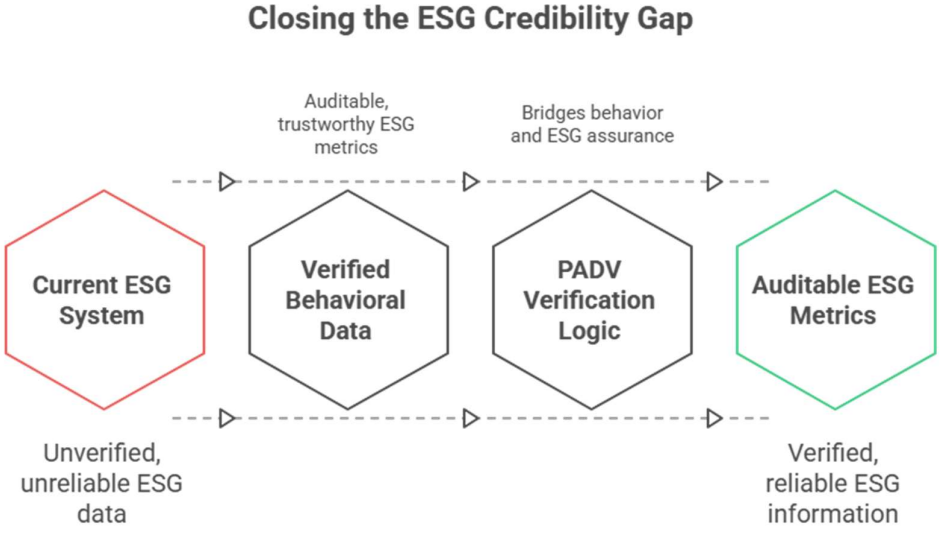
Most corporate and institutional disclosures rely on **estimated data**, particularly in Scope 3 emissions where indirect behaviors across value chains cannot be precisely measured or verified.

The result is a **systemic trust gap**: stakeholders—from regulators and investors to citizens—question whether sustainability commitments are genuine, measurable, or merely declarative.

Traditional ESG mechanisms measure performance through outcomes, but **rarely verify the human or organizational actions** that produced those outcomes.

As a result, sustainability remains statistically reported but behaviorally unverified—a condition that undermines both **accountability** and **assurance integrity**.

This credibility deficit reveals the need for a new verification architecture where participation itself becomes measurable, traceable, and auditable.



2.2 Limitations of Market-Based Carbon Systems

Market carbon instruments—such as **Certified Emission Reductions (CERs)** and **Voluntary Carbon Units (VCUs)**—were designed for **financial liquidity**, not for data integrity.

Operating under supply-demand dynamics, these systems prioritize **tradability** over **transparency**, resulting in:

- Price volatility driven by speculative behavior;
- Inconsistent verification methodologies across registries;
- Accusations of greenwashing due to unverifiable claims;
- Lack of behavioral traceability within emission data chains.

While market systems quantify physical emission reductions, they fail to **capture the behavioral mechanisms** that generate them.

Without behavioral data, ESG verification cannot assess **participation, accountability, or proportionality**—three core pillars of sustainable governance.

Consequently, Big 4 auditors, regulators, and verification bodies face limitations in performing **data-level assurance**, as existing carbon registries confirm only transactions, not the human actions behind them.

2.3 The Need for a Non-Tradable Verification Architecture

To close this credibility gap, the PADV framework introduces the **Non-Tradable Carbon Credit (NTCC)**—a verification mechanism that decouples sustainability recognition from financial markets.

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

This non-tradable principle establishes three governance safeguards:

1. **No market speculation:** NTCCs cannot be exchanged, resold, or traded, ensuring value integrity;

2. **No duplication:** Each NTCC corresponds to a unique Proof Record validated through the PADV registry;
3. **No opacity:** All verified data remain accessible for assurance review and regulatory oversight.

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 carbon accountability based on verifiable behavior, not market price.

Traditional Carbon Markets vs. NTCC System

Characteristic	Traditional Carbon Markets	NTCC System
Policy Layer	ETS, VCM, offset projects	Behavioral data
Market Layer	Market credits	SDGS PASS
Behavioral Layer	No direct link	PADV verification
Data Flow	Not from behavior	Behavior → Verification → ESG Reporting
Mechanism	Market-based, tradable	Governance-based, non-tradable

2.4 Evolution from PADV v1 to ESG-Integrated Methodology v2

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

Building upon this foundation, **PADV–NTCC Methodology v2** extends the system from methodological validation to **institutional integration**, introducing three major advancements aligned with international assurance frameworks:

1. **Verification Factor (VF):** a three-tier calibration system ensuring statistical, regional, and sectoral reliability;
2. **ESG Weighting Model (W_ESG):** a composite evaluation combining Carbon Effect (CEF), Social Effect (SEF), and Institutional Reliability (IRF);
3. **Annual Recognition Coefficient (RCF):** a governance mechanism aligning NTCC recognition with fiscal-year ESG reporting cycles.

PADV v2 thus evolves from a theoretical model to a **governance-ready assurance framework**, interoperable with **GRI, IFRS, ISO, COSO, and QS Sustainability Ranking** structures.

It enables verified behavioral participation to become the **foundation of institutional trust**, bridging the gap between individual actions, corporate responsibility, and global ESG disclosure integrity.

CHAPTER 3 Theoretical Foundation of PADV

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

The **PADV Framework** — standing for *Participation, Action, Data, and Value* — defines how an individual or organizational behavior evolves into **verifiable data** that can be 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 system.

2. **Action (A)** — The execution of a measurable, context-specific task.

   Each action corresponds to a "Proof Record" that captures evidence of completion.

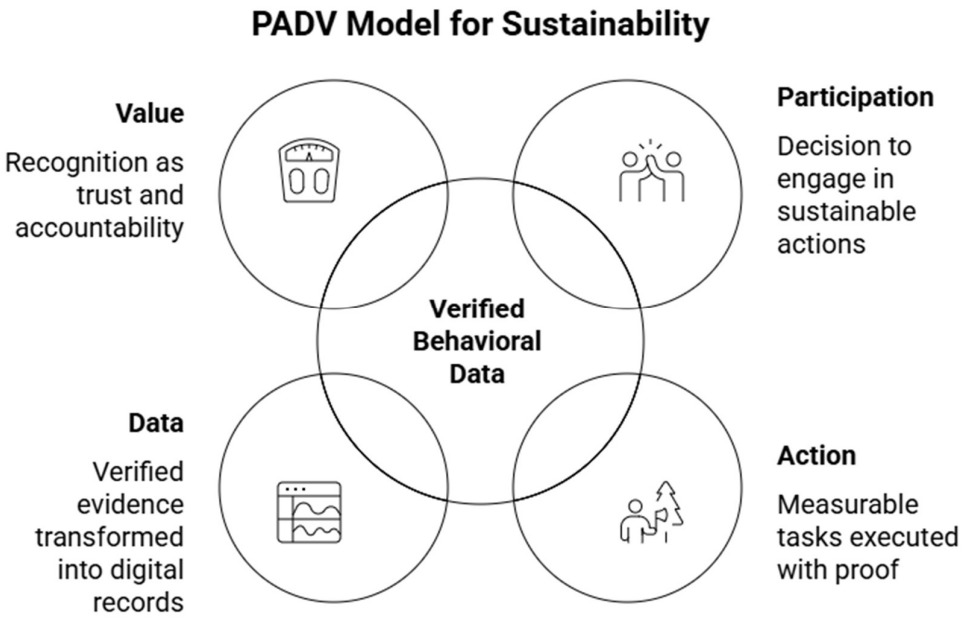
3. **Data (D)** — The conversion of verified behavioral evidence into structured digital information.

   At this stage, the action becomes **traceable and auditable** through digital registry systems.

4. **Value (V)**—The recognized outcome of verified participation, expressed as NTCR or NTCC.

   Here, "value" transcends economic exchange, representing trust, accountability, and sustainability performance.

The Four-Ring Model ensures that every sustainability act can be **quantified without commodification** — transforming sustainability from narrative into measurable, auditable impact.



3.2 Institutional Logic of Behavioral Data Governance

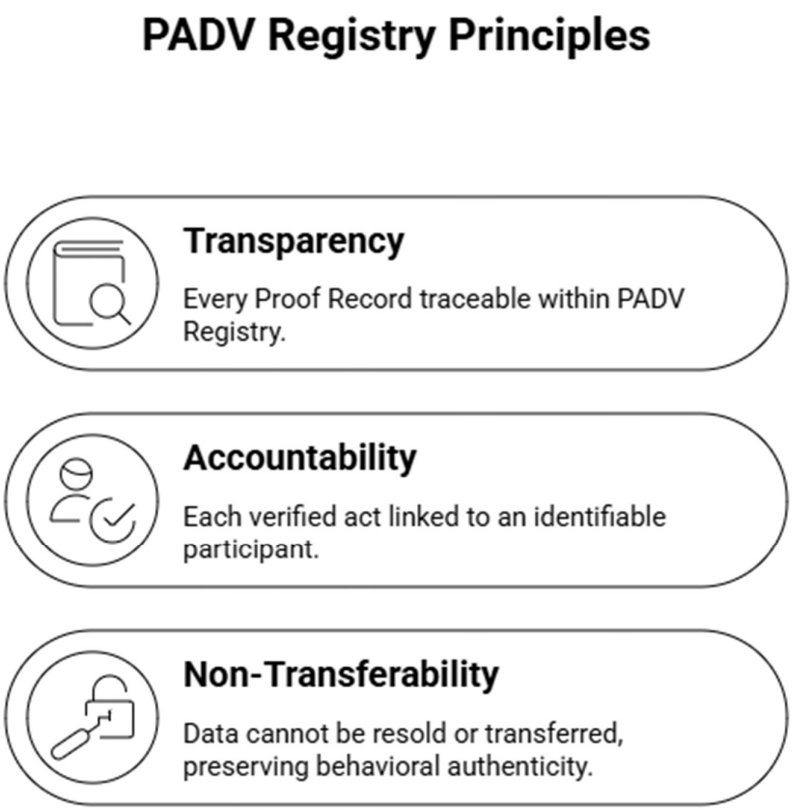
PADV redefines **data governance** as a process of **institutionalizing trust through verified participation**. In contrast to traditional financial auditing, which validates monetary transactions, PADV validates **behavioral interactions**—the foundational layer of ESG impact.

The model operates on three governance logics:

1. **Transparency**—Every Proof Record is publicly traceable within the PADV Registry.
2. **Accountability**—Each verified act links directly to an identifiable actor (individual or organization).

3. **Non-Transferability**—Data cannot be resold or transferred, preserving the authenticity of the behavioral origin.

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



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.

PADV complements existing assurance frameworks (ISAE 3000, AA1000AS, and COSO) by introducing a **behavioral data layer**—a foundational source for non-financial assurance.

Conventional Assurance Layer	**PADV Behavioral Assurance Layer**	**Integration Outcome**
Financial Data Auditing	Behavioral Data Verification	Extended Assurance

Conventional Assurance Layer	PADV Behavioral Assurance Layer	Integration Outcome
		Scope
Corporate Governance Controls	Proof Record Registry Governance	Real-Time Accountability
ESG Reporting Verification	NTCC Behavioral Data Model	Enhanced Data Traceability

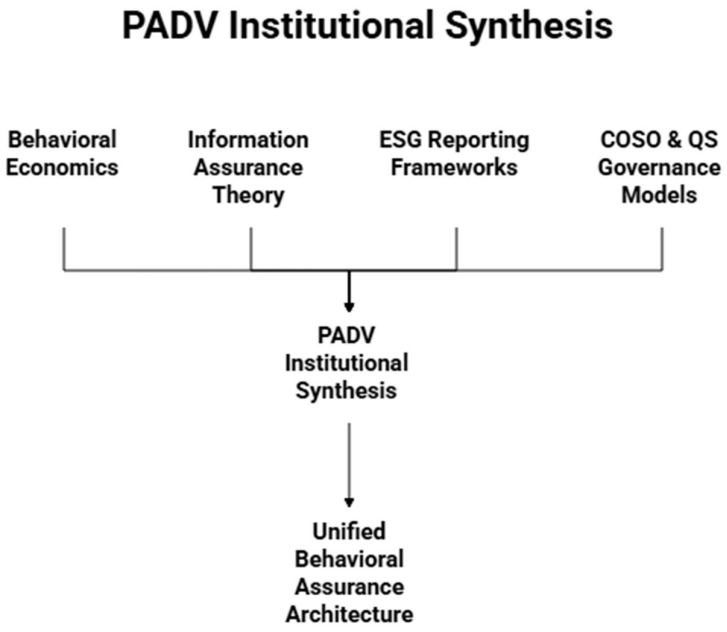
Thus, PADV bridges the gap between **behavior (micro)** and **institutional assurance (macro)**, enabling verifiers, auditors, and policymakers to trace sustainability outcomes back to the actions that generated them.

3.4 Related Works and Methodological Lineage

The theoretical design of PADV draws from multiple interdisciplinary traditions:

- **Behavioral Economics** — recognizing that real sustainability impact arises from collective micro-decisions.
- **Information Assurance Theory** — ensuring verifiable provenance and non-repudiation in digital systems.
- **ESG Reporting Frameworks** — GRI, IFRS, and ISO methodologies emphasize disclosure; PADV emphasizes verifiability.
- **COSO Control Environment** — aligning behavioral verification with governance and risk control.
- **QS Sustainability Metrics** — reinforcing educational and social participation as measurable sustainability outcomes.

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



3.5 Supplementary Note on Illustrative Calculation Logic

Note: The following calculation model is an **illustrative representation** of the logical mechanism within the NTCC framework.

It is **not intended to replace or replicate** any certified carbon accounting methodology (e.g., ISO 14064, GHG Protocol, or IPCC 2006 Guidelines).

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

1. Baseline Scenario Definition

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 performed.

The difference between EF_0 and EF_1 defines the quantifiable emission reduction:

$$\Delta CO_2e = n \times (EF_0 - EF_1)$$

where *n* represents the number of task completions or participants.

All emission factors (**EF**) should be derived from **national or international emission factor databases**, such as IPCC 2006 Guidelines Annex II, Taiwan EPA Carbon Emission Factor Database, or IEA statistics.

2. Emission Factor Standardization

All emission factors are standardized to **kg CO_2e per activity unit** and defined according to recognized databases:

Activity Type	**EF_0 (kg CO_2e/unit)**	**EF_1 (kg CO_2e/unit)**	**Reference Source**
Private Vehicle (Gasoline)	0.271	—	IPCC 2006 Vol. 2 Ch. 3
Public Transport (MRT/Bus)	—	0.071	Taiwan EPA 2024
Paper Document Delivery	0.013	—	GRI 305-3 Appendix
Electronic Document Delivery	—	0.004	IFRS S2 Reference Data

Example: If a participant switches from private car commuting (EF_0 = 0.271) to MRT (EF_1 = 0.071) once per week, then $\Delta CO_2e = (0.271 - 0.071) \times n = 0.20 \times n$ kg CO_2e.

3. Uncertainty and Error Margin

Following ISO 14064-3 principles, the acceptable uncertainty range for behavior-based estimations is **±10 – 15 %**. When an NTCC value is generated, the system shall automatically record:

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

These parameters form the **Evidence Chain** for third-party assurance and verification.

4. Aggregation and Audit Logic

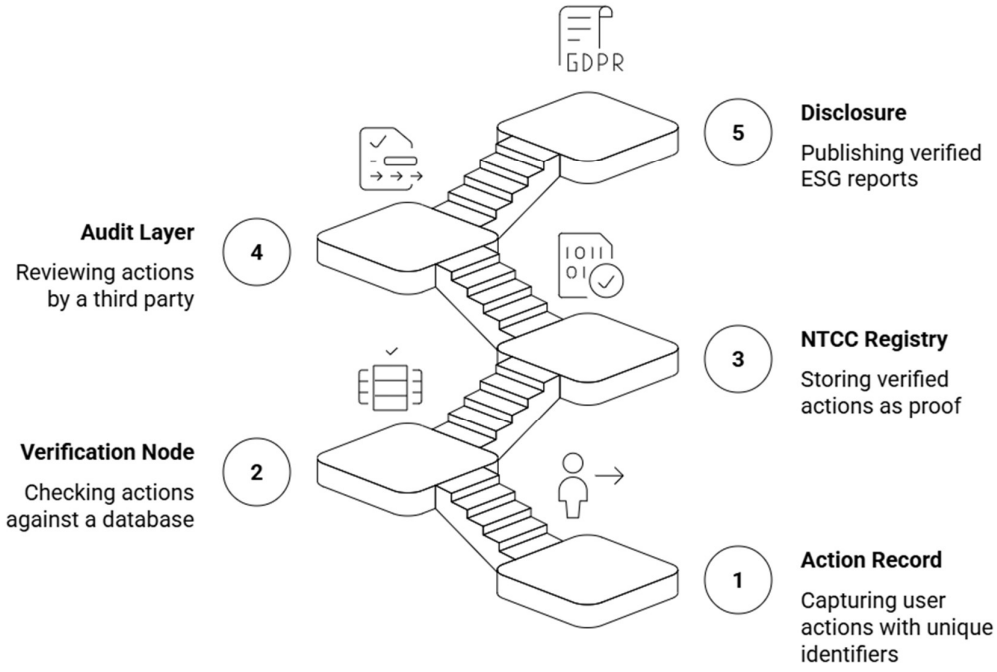
Each behavioral record generates a unit emission reduction (ΔCO_2e_i).

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

$$NTCC_{total} = \sum_{i} \Delta CO_2 e_i$$

Weekly, quarterly, and annual summaries can be exported for audit and disclosure, including uncertainty range, emission factor reference, and verification identifier, in compliance with IFRS S2 and COSO Internal Control principles.

Ensuring Traceability in ESG Reporting



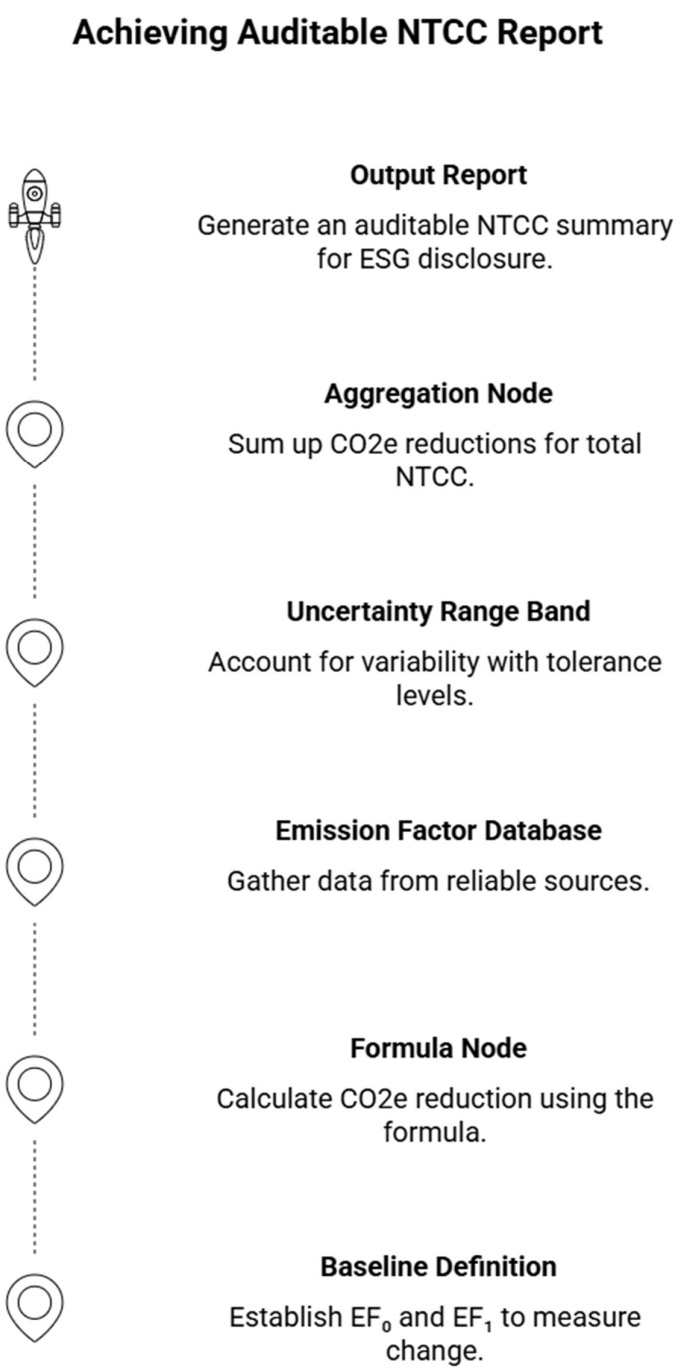
5. Illustrative Examples

Task Name	Category	Frequency (n)	ΔCO_2e (kg)	Error Margin	NTCC Value
Green Commuting Challenge	Transportation	20	4.0	±0.5	4.0 ± 0.5 NTCC
Paperless Report Submission	Digitalization	10	0.09	±0.01	0.09 ± 0.01 NTCC

6. Conclusion and Clarification

Clarification

This model demonstrates the **logical traceability** of behavioral carbon accounting. The NTCC framework remains a **non-tradable, verification-based mechanism**, designed to complement existing ESG reporting standards. It does not substitute or alter any regulated carbon trading or accounting method.



CHAPTER 4 Definition of NTCC

4.1 Conceptual Distinction: NTCC vs. Tradable Carbon Credit

The **Non-Tradable Carbon 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 exchange—NTCC exists to **anchor trust** within ESG disclosure systems.

Dimension	**Tradable Carbon Credit (TCC)**	**Non-Tradable Carbon Credit (NTCC)**
Primary Function	Market transaction	Data verification & ESG assurance
Ownership	Transferable (commodity)	Non-transferable (institutional record)
Value Basis	Economic equivalence	Behavioral verification
Governance	Market regulation	Institutional assurance
Risk Type	Speculative risk	Verification risk (controlled via VF)

While both represent emission-related data, the **purpose** differs: TCC aims to create liquidity; NTCC aims to create **credibility**.

Each NTCC 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 asset nor a regulatory 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),
- Quantified **environmental impact** (CEF calculation), and
- Assured **data integrity** (VF × W_ESG governance).

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

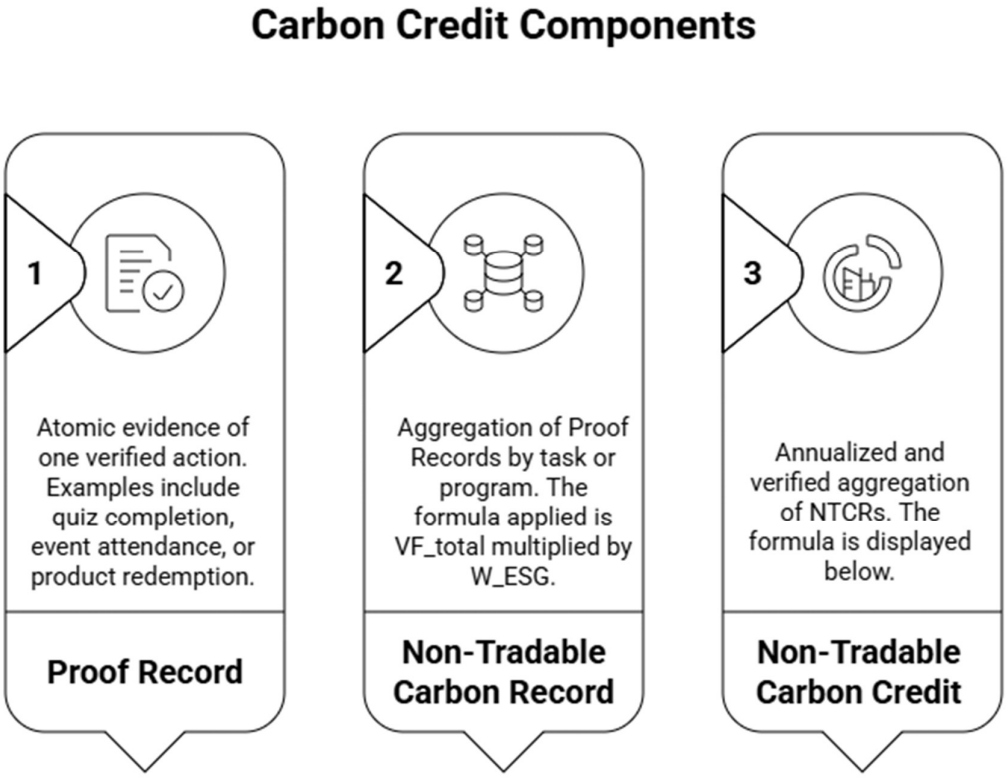
4.3 Hierarchical Relationship: Proof Record → NTCR → NTCC

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, product redemption).
2. **Non-Tradable Carbon Record (NTCR)**—an aggregation of Proof Records under a specific task, campaign, or program; each NTCR has a unique verification factor (VF_total) and ESG weighting (W_ESG).
3. **Non-Tradable Carbon Credit (NTCC)**—the annualized and verified aggregation of NTCRs, adjusted by the **Recognition Coefficient (RCF)** and validated through annual audit assurance.

$$NTCC_{\text{year}} = \frac{\sum_i \quad (PR_i \times 0.1 \times VF_{\text{total},i} \times RCF_i)}{1000}$$

This formula anchors NTCC as a verifiable outcome, not an economic token—where **0.1** converts behavioral points to kg CO_2e, and **RCF** ensures alignment with annual reporting boundaries.



4.4 System Boundary: Behavioral Data, Carbon Data, and ESG Data

To prevent data overlap and double counting, PADV defines three clear system boundaries:

Layer	Data Type	Definition	Verification Entity
Behavioral Data Layer	Proof Record (participation, engagement)	Raw evidence of sustainability-related actions	PADV Registry / Platform
Carbon Data Layer	NTCR (CO_2e equivalent)	Behavior-derived emission equivalence (10 pts = 1 kg CO_2e)	NTCC Algorithmic Engine
ESG Data Layer	NTCC (annual recognized unit)	Verified, audited behavioral impact for ESG disclosure	External Assurers / Big 4

Each layer is linked but non-interchangeable:

- Behavioral data cannot be monetized;
- Carbon data cannot be traded;
- ESG data must be audited and disclosed within its reporting cycle.

This boundary-based governance ensures that NTCC maintains both **integrity and complementarity** within existing ESG ecosystems — enhancing rather than duplicating established reporting structures.

CHAPTER 5 PADV–ESG Integration Framework

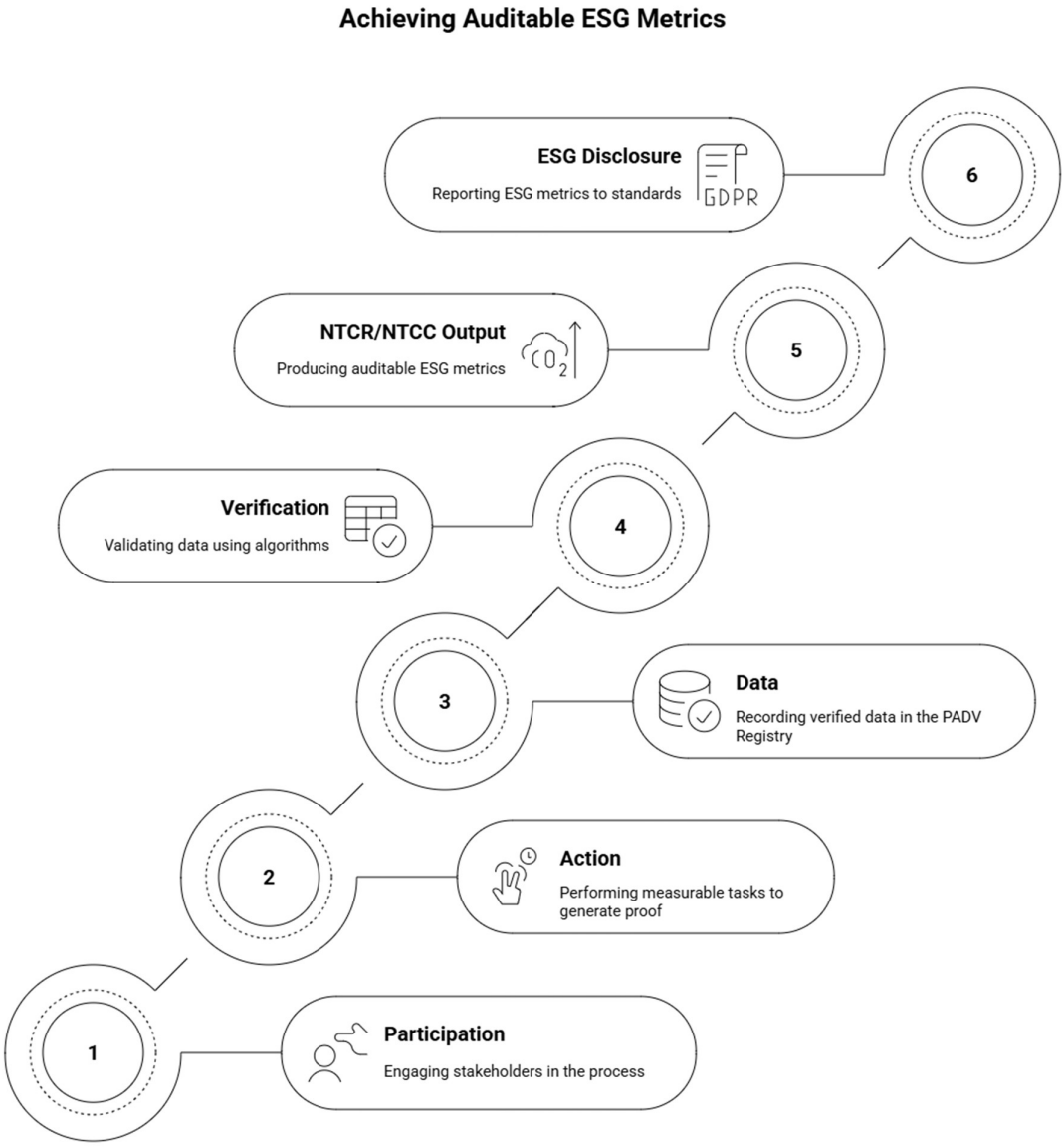
5.1 Linking PADV to ESG Disclosure Standards

The **integration of PADV and ESG frameworks** represents a structural advancement in sustainability reporting. Traditional ESG systems rely primarily on *declarative disclosure* —companies state what they have done, but lack verifiable behavioral evidence to support those claims.

PADV addresses this limitation by introducing **Behavioral Proof Records** as the foundational assurance layer. Each verified record is algorithmically linked to one or more ESG indicators, forming a direct data chain from **participation → verification → ESG disclosure**.

This linkage transforms ESG reporting from **post-event narration** into **real-time behavioral verification**, enabling corporations, schools, and event organizers to capture measurable social and environmental actions at the source of occurrence.

As a result, ESG reports gain credibility not by volume of disclosure, but by **verifiability of data**.



5.2 The ESG Weighting Model (W_ESG)

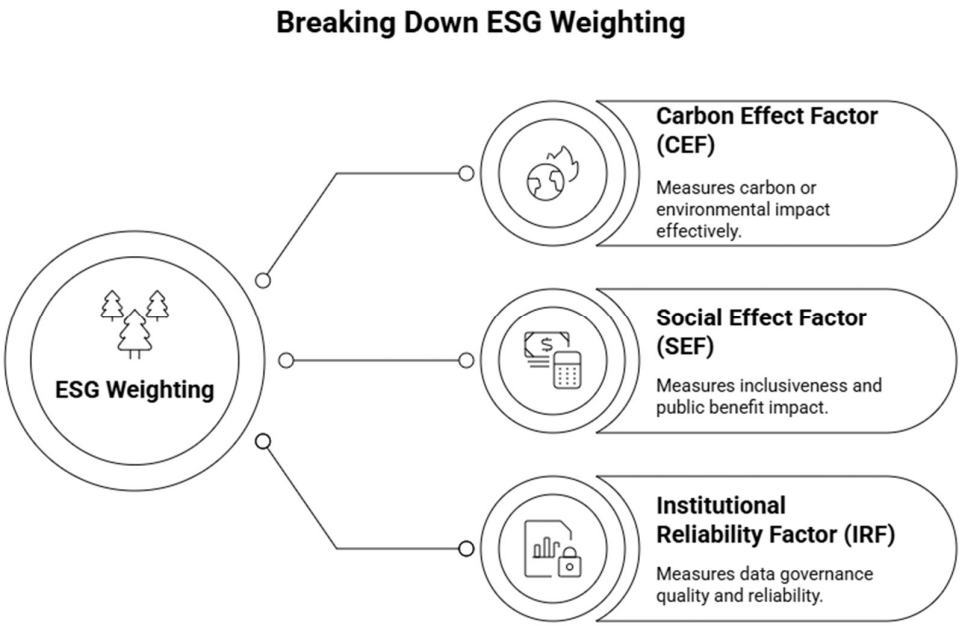
To ensure consistency and comparability across sectors, PADV defines a unified **ESG Weighting Model (W_ESG)**, expressed as:

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

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

- **Carbon Effect Factor (CEF)** — measures the relative environmental or carbon reduction impact of the activity.
- **Social Effect Factor (SEF)** — quantifies inclusiveness, public benefit, and community reach.
- **Institutional Reliability Factor (IRF)** — assesses data governance quality, compliance, and verifier independence.

This tri-factor model ensures that each NTCR reflects not only environmental outcomes 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 integration by mapping each element of its verification framework to established international standards.

The following matrix illustrates this alignment:

PADV Verification Layer	GRI Reference	IFRS / ISSB Alignment	ISO Standard	COSO Component	QS Domain
Proof	GRI 102 /	IFRS S1 –	ISO 20121	Control	Social

PADV Verification Layer	GRI Reference	IFRS / ISSB Alignment	ISO Standard	COSO Component	QS Domain
Record (Behavioral Data)	404 / 413	Governance Disclosure	(Event Sustainability)	Environment	Engagement
NTCR (Carbon Data)	GRI 305 – Emissions	IFRS S2 – Climate-Related Disclosures	ISO 14064-1 – GHG Quantification	Risk Assessment	Environmental Impact
NTCC (ESG Recognition)	GRI 103 / 403 – Management Approach	IFRS S1 / S2 Combined Reporting	ISO 27001 / 27701 – Data Security	Information & Communication	Institutional Reliability
Governance & Audit Layer	GRI 2 – Governance Structure	IFRS S1 – Controls & Oversight	ISO 19011 – Audit Management	Monitoring Activities	Institutional Trust

This mapping demonstrates that PADV does not replace existing standards; it **completes** 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 trust.

5.4 Governance Implications of Cross-Standard Integration

The integration of PADV with ESG frameworks establishes a new category of **"Behavioral Governance"** — a governance model where compliance and assurance are driven by traceable participation data.

Key implications include:

1. **Assurance Consistency:** Big 4 auditors and verification bodies can validate ESG data through standardized behavioral records, reducing subjectivity in assurance engagements.
2. **Policy Transparency:** Governments can adopt NTCC-derived metrics as non-financial evidence of social participation and climate contribution.
3. **Institutional Accountability:** Organizations gain a data-driven mechanism for linking internal CSR actions with external ESG disclosures.
4. **Educational Alignment:** The QS Sustainability framework can use PADV data to evaluate behavioral literacy and engagement outcomes across 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 & Equivalency

6.1 Foundational Equivalence：10 pts = 1 kg CO_2e

The PADV framework establishes a universal behavioral-to-carbon equivalency, where **10 verified points (10 pts) correspond to 1 kg CO_2e**.

This conversion factor is derived from empirical data collected across multi-sector sustainability activities and field-verified emission models.

Each behavioral point acts as a micro-unit of verified sustainability contribution, enabling emission equivalence to be derived from proof-based participation rather than estimation.

6.2 Three-Tier Verification Factor (VF_0, VFn, VFs)

The Verification Factor (VF) system provides statistical calibration reflecting contextual data reliability.

Tier	Definition	Function
VF_0 – Baseline Reliability	Global constant (= 0.92)	Mean cross-event verification consistency
VFn – Regional / Institutional Adjustment	0.85 – 1.05	Accounts for regional governance and sector data quality
VFs – Source-Specific Correction	0.8 – 1.2 (pilot cap ≤ +10%)	Activity type and audit density adjustment

Formula

$$VF_{total} = \frac{VF_0 + VFn + VFs}{3}$$

6.3 ESG Weighting Equation (W_ESG)

Each NTCR integrates its ESG relevance via the weighting coefficient:

$$W_{ESG} = \frac{CEF + SEF + IRF}{3}, W_{ESG\_norm} = \frac{W_{ESG}}{5}$$

where each factor (0–5 scale) represents:

- **CEF** – Carbon Effect Factor (environmental impact)
- **SEF** – Social Effect Factor (public inclusiveness)
- **IRF** – Institutional Reliability (governance quality)

6.4 Data Provenance & Scoring of CEF / SEF / IRF

Factor	Primary Data Source	Validation Entity	Note
CEF	ISO 14064 inventories	Environmental Verifier	kg CO_2e per action unit
SEF	SDGS PASS registry	CSR Auditor	Inclusiveness and societal reach
IRF	ISO 27001 compliance	External Assurer (Big	Data integrity and

Factor	Primary Data Source	Validation Entity	Note
	docs	4)	governance

6.5 Baseline VF_0 Calibration

VF_0 = 0.92 was determined through multi-year sampling (>50 events).

Cross-checks showed a mean reliability ratio of 0.92 between verified and self-reported records.

Regional adjustments use the Verification Fidelity Index (VFI).

6.6 Unified Formula for NTCR Calculation

$$NTCR_i = (P_i/10) \times VF_{total,i} \times W_{ESG\_norm,i}$$

where P_i = behavioral points from Proof Record i. The sum Σ NTCR_i yields total verified behavioral emission equivalence (in kg CO_2e).

6.7 Annual Recognition Coefficient (RCF)

RCF controls annual recognition of NTCR values into NTCC units, ensuring alignment with ESG reporting cycles and preventing double counting.

Category	Mechanism	RCF Value	Annual Limit
A. Public Welfare Goods	Fixed VF (0.95) + product ESG weight	0.3	≤ 30% of annual NTCR (Goods + Missions)
B. Mission Participation	Dynamic VF (0.8–1.0; pilot up to 1.2 ≤ +10%)	1.0	100% annual recognition

6.8 Illustrative Corporate Case

20 000 pts → VF_total = 0.90; **W_ESG_norm = 0.76 (already normalized)**; RCF = 1.0

$$NTCC = \frac{20000 \times 0.1 \times 0.90 \times 0.76 \times 1.0}{1000} = 1.368\ tCO_2e$$

6.9 Deterministic Framework (Summary)

Stage	Variable	Formula	Scope
Task	VF_total	(VF_0+VFn+VFs)/3	Verification integrity
Task	W_ESG_norm	((CEF+SEF+IRF)/3)/5	ESG weight
Task	NTCR	(Points/10)×VF_total×W_ESG_norm	Behavioral CO_2e
Annual	NTCC	Σ NTCR×RCF_pathway	Yearly recognition

CHAPTER 7 Proof Record Mechanism

7.1 Proof Record Definition and Structure

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

Every Proof Record is structured with machine-readable metadata, ensuring data integrity and audit readiness. The general data schema includes the following fields:

Field	Description	Type
PR_ID	Unique alphanumeric identifier	String
UID / E-UID	Participant or enterprise identity token	String
Task_ID	Linked mission or redemption activity ID	String
Timestamp	Verified completion time (ISO 8601 format)	Datetime
Location / GeoHash	Verified physical or virtual coordinates	String

Field	Description	Type
Point_Value	Earned participation points	Integer
VF_total	Computed Verification Factor	Float
W_ESG	ESG Weighting Value	Float
RCF	Annual Recognition Coefficient	Float
Auditor_Signature	Third-party verification hash	String

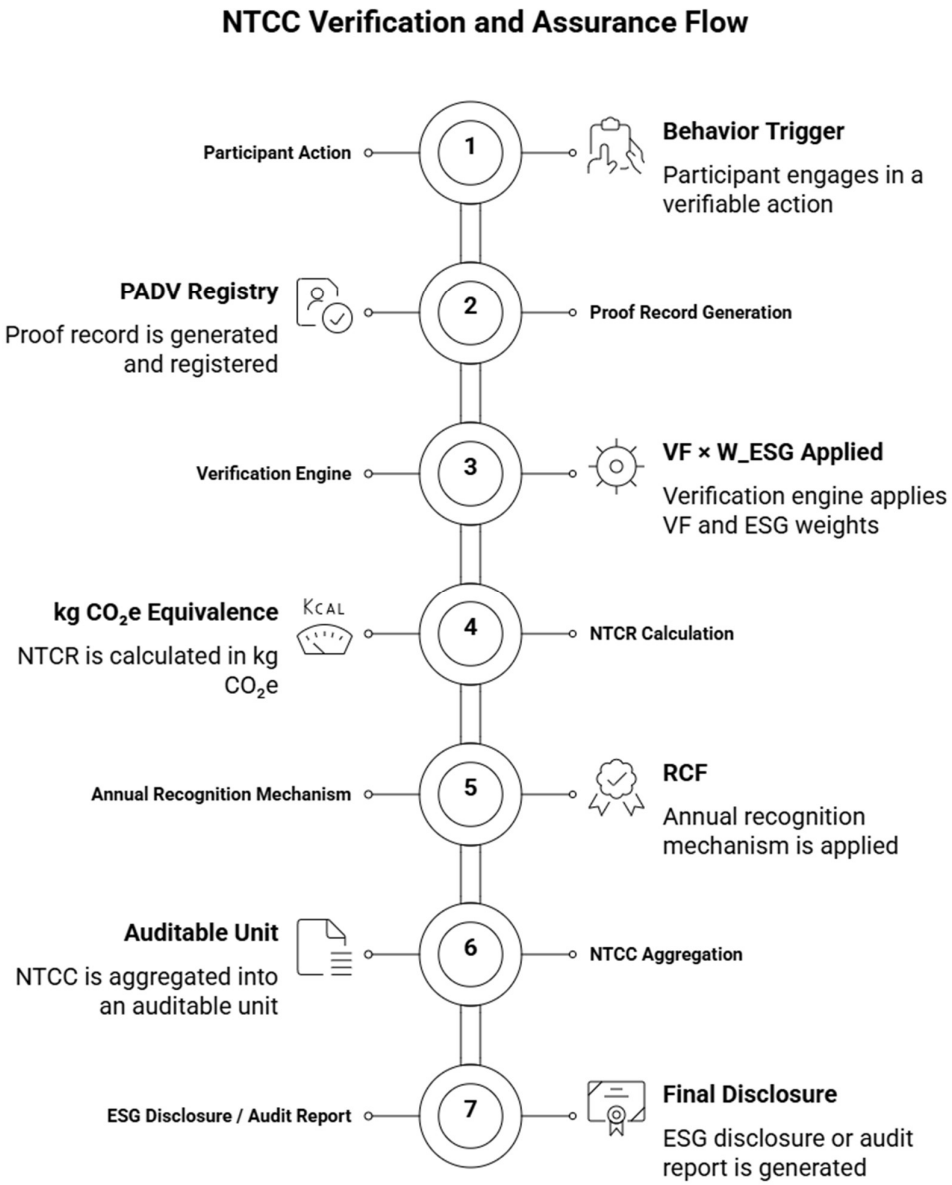
This schema enables interoperability between PADV registries, ESG reporting systems, and assurance platforms through standardized JSON/XML interfaces.

7.2 Verification Flow: Proof Record → NTCR → NTCC → ESG Report

Each verified action flows through a structured data pathway:

This vertical chain forms the **Behavioral Data Trust Line**, where each layer enhances verifiability without altering the original behavioral evidence.

It ensures that the ESG disclosure at the end of the chain can be **audited back to the original human act**—achieving data-level integrity from participation to publication.



7.3 Anti-Duplication and Boundary Control

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

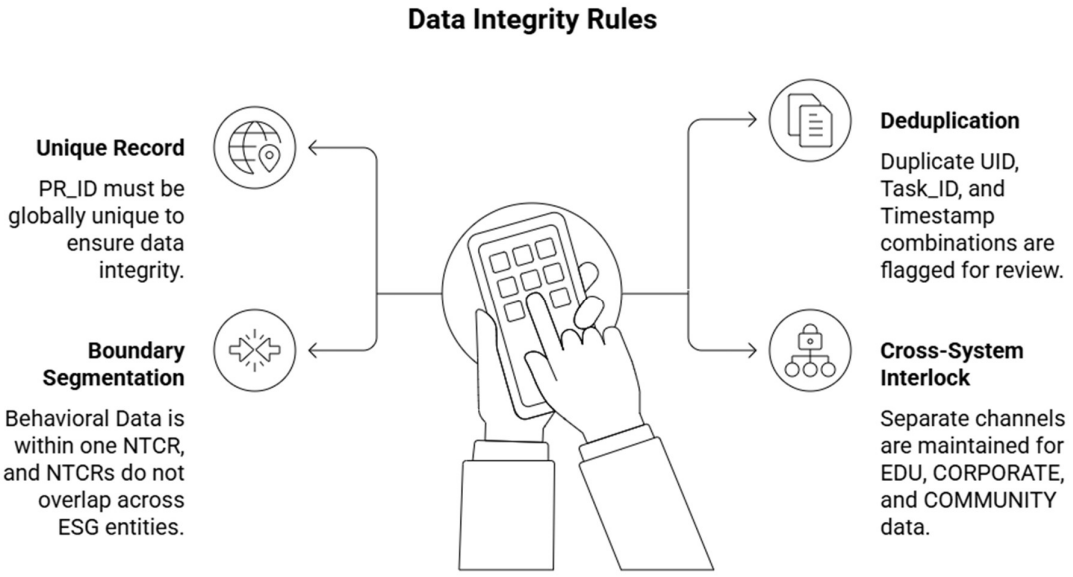
1. **Unique Record Rule:** Each PR_ID must be globally unique within the registry.
2. **Deduplication Algorithm:**

   Proof Records sharing identical UID, Task_ID, and Timestamp are automatically flagged for review and merged or voided depending on verifier consensus.

3. **Boundary Segmentation:**
    - Behavioral Data (PR) cannot exist outside its assigned NTCR boundary.
    - NTCR units cannot overlap across multiple ESG reporting entities.
4. **Cross-System Interlock:**

    PRs linked to different sectors (e.g., EDU vs. CORPORATE) maintain isolated verification channels to prevent cross-sector contamination.

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



7.4 Audit-Ready JSON / XML Data Model

To support integration with Big 4 assurance frameworks, the PADV Registry implements a dual-format, audit-ready data structure.

JSON Representation:

```
{
  "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,
  "Auditor_Signature": "sha256:78dfab...c3e"
}
```


XML Representation:


```
<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>
  <Auditor_Signature>sha256:78dfab...c3e</Auditor_Signature>
</ProofRecord>
```

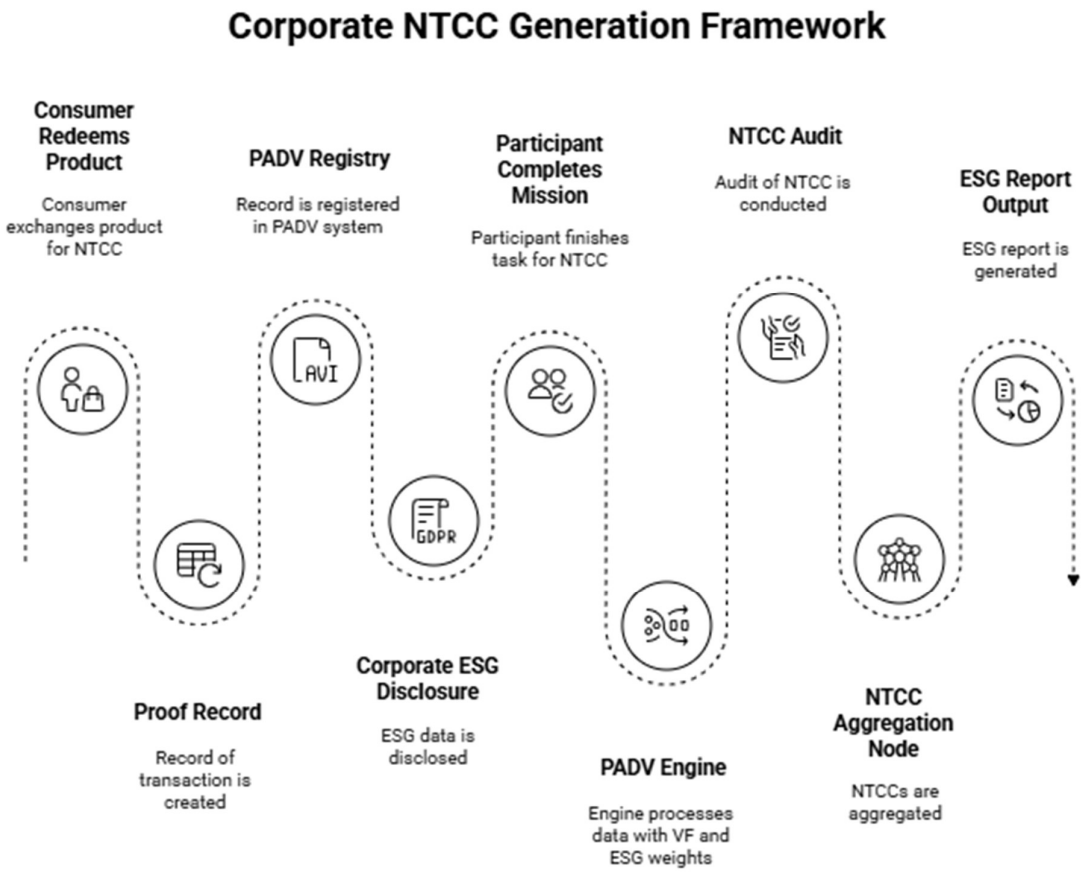

Both formats are embedded with digital signatures to ensure immutability, and can be directly integrated into ESG disclosure platforms, audit portals, or national sustainability registries.

CHAPTER 8 Dual Pathway of Corporate NTCC Generation

Overview

Within the PADV–NTCC framework, corporations generate verified non-tradable carbon credits (NTCCs) through **two standardized behavioral pathways**: (1) the *Public Welfare Redemption Goods Pathway*, and (2) the *Mission Participation Pathway*.

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 while maintaining non-financial integrity.



8.1 Pathway A: Public Welfare Redemption Goods (Fixed VF = 0.95)

The **Redemption Goods Pathway** enables corporations to provide sustainable products or services as public welfare offerings under SDGS PASS.

When participants redeem these items using accumulated points, each redemption generates a verifiable Proof Record, contributing to the enterprise's NTCR and eventual NTCC recognition.

This pathway adopts a **fixed Verification Factor (VF = 0.95)**, ensuring consistent reliability regardless of consumer variability.

The corresponding ESG 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: (Goods + Missions) × 30 per year)
Audit Trace	Redemption proof → PADV registry → 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: Mission Participation Tasks (Dynamic VF 0.8–1.2)

The **Mission Pathway** reflects corporate engagement through sustainability-driven activities—such as clean-up events, cycling challenges, blood donation drives, or educational programs.

Each mission generates a Proof Record upon completion, dynamically validated through the PADV Verification Engine.

This pathway uses a **dynamic Verification Factor (VF range: 0.8–1.2)**, adjusted based on activity type, verification density, and audit depth. Its ESG 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 0.4–1.0
W_ESG	Full composite of CEF, SEF, IRF
RCF	1.0 (100% annual recognition)
Audit Trace	Mission completion record → PADV registry → NTCC audit

Mission 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 ESG Weighting Table

Parameter	Redemption Goods	Mission Activities
Behavior Type	Passive redemption (consumer-driven)	Active participation (action-driven)
VF_total	Fixed (0.95)	Dynamic (0.4–1.0)
W_ESG Emphasis	Product lifecycle & supply transparency	Human participation & field verification
RCF Annual Cap	0.3	1.0
Carbon Conversion	10 pts = 1 kg CO_2e	10 pts = 1 kg CO_2e
ESG Impact Domain	GRI 305 / 413	GRI 404 / 403 / 305
Verification Complexity	Low	Moderate–High

Parameter	Redemption Goods	Mission Activities
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:

- **Goods Redemption:** 5,000 Proof Records, VF = 0.95, W_ESG = 0.68, RCF = 0.3
- **Mission Participation:** 3,000 Proof Records, VF = 1.05, W_ESG = 0.80, RCF = 1.0

$$NTCC = \frac{(5{,}000 \times 0.1 \times 0.95 \times 0.68 \times 0.3) + (3{,}000 \times 0.1 \times 1.05 \times 0.80 \times 1.0)}{1000}$$

$$= 0.336 + 0.252 = 0.588 \text{ tons } CO_2e$$

The company thus records **0.588 tons of verified NTCC**, distributed across both consumer and mission-driven actions, and auditable under the annual ESG assurance cycle.

Pathway A – Fixed VF = 0.95; RCF = 0.3 (≤ 30% annual)
Pathway B – Dynamic VF = 0.8–1.0 (normal), pilot up to 1.2 (+10% cap); RCF = 1.0 (100%).

Comparative Table

Parameter	Redemption Goods	Mission Activities
Behavior Type	Passive redemption	Active participation
VF_total	Fixed 0.95	Dynamic 0.8–1.0 (pilot ≤ 1.2

Parameter	Redemption Goods	Mission Activities
		+10%)
W_ESG Emphasis	Lifecycle & supply transparency	Human & field verification
RCF Annual Cap	0.3 (≤ 30%)	1.0 (100%)
Carbon Conversion	10 pts = 1 kg CO_2e	10 pts = 1 kg CO_2e
Best-Fit Industry	Retail/F&B	CSR/NGO/Events

CHAPTER 9 Annual NTCC Recognition Mechanism

9.1 Concept and Purpose

The **Annual NTCC Recognition Mechanism (RCF)** governs how verified non-tradable carbon credits (NTCCs) are recognized, consolidated, and reported within a fiscal year. Its purpose is twofold:

1. To synchronize behavioral data recognition 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 credits but as **annualized assurance units**, each corresponding to the specific timeframe of verified sustainability actions.

9.2 Recognition Logic

The recognition process is governed by the following principles:

Principle	Description
Period Alignment	NTCCs must be recognized within the same fiscal year in which Proof Records are generated.
Single-Year Validity	NTCCs are valid for one reporting cycle and cannot be carried forward or re-recognized.
Audit Synchronization	All recognized NTCCs must align with annual assurance engagements and third-party audit schedules.
Integrity Control	Each recognition event is locked in the PADV Registry and timestamped for provenance.

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

9.3 Recognition Formula and Cap

Equation

$$NTCC_r = \sum_i \quad (NTCR_i \times RCF_{pathway_i})$$

Governance Rule — RCF applies **only** at the annual aggregation stage (not within NTCR equations).

Pathway	RCF	Cap	Notes
Type A – Goods	0.3	≤ 30% of annual NTCR (Goods + Missions)	Fixed VF model
Type B – Missions	1.0	Full recognition	Dynamic VF model

9.4 Annual Locking and Reporting Alignment

Once NTCCs 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. PADV Registry issues timestamped digital seals for all recognized NTCCs.
2. Locked NTCCs are associated with fiscal-year identifiers (e.g., NTCC-2025-Y1).
3. Cross-verification hashes are synchronized with external assurance databases (Big 4 / Verifiers).
4. 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**	**VF_total**	**W_ESG**	**RCF**	**NTCR (kg CO_2e)**	**Recognized NTCC (tons CO_2e)**
Goods Redemption	4,000	0.95	0.70	0.3	266	0.080
Mission Activities	3,500	1.00	0.78	1.0	273	0.273
Total (Annual)	**7,500**	—	—	—	**539 kg**	**0.353 tons**

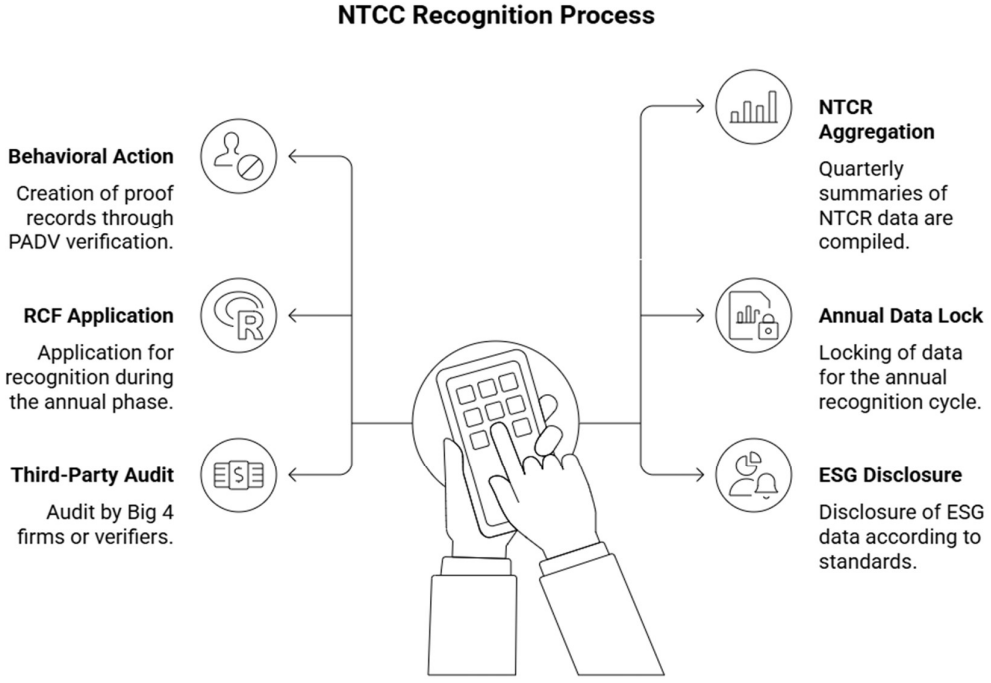
"EcoMart Ltd." thus discloses **0.353 tons CO_2e of verified NTCC** for FY2025. The data is locked under fiscal identifier NTCC-2025-Y1, verified through PADV Registry's assurance log, and cited as behavioral evidence under the company's GRI 305 and IFRS S2 climate disclosure.

9.6 Governance Principles for Annual NTCC Recognition

To maintain trust and comparability across organizations, PADV defines the following governance principles for annual NTCC recognition:

1. **Non-Transferability:** NTCCs are non-tradable and bound to the originating entity.
2. **Transparency:** Recognition reports must disclose both the quantity (tons CO_2e) and the corresponding Proof Record count.
3. **Audit Readiness:** Recognition data must be accompanied by a signed assurance statement from an approved verifier.
4. **Cross-Registry Compatibility:** Annual data locking structure is interoperable with ESG platforms under GRI and IFRS data reporting APIs.
5. **Temporal Consistency:** Each annual recognition must correspond to the verified timeframe—no retrospective claims permitted.

This ensures that NTCCs serve 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 & Non-Trade Principle

10.1 The Concept of Non-Trade Governance

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

Traditional carbon credits derive value from **market exchange**, while NTCC derives value from **trust**. Each NTCC carries intrinsic credibility because its issuance depends on verified actions rather than speculative market behavior. This fundamental design principle eliminates volatility, ensures verifiability, and prevents the monetization of social participation.

By maintaining its **non-tradable** nature, NTCC safeguards the integrity of sustainability governance—transforming environmental accountability from an economic system into a **trust system**.

Carbon Trade vs. Carbon Trust

Dimension	Market Carbon Credit	NTCC (Non-Trade Governance)
Value Basis	Market Price	Verified Proof of Action
Driver	Speculative Demand	Institutional Trust
Outcome	Volatility & Liquidity	Stability & Verifiability
System Type	Economic Exchange	Governance Assurance
Social Effect	Monetizes Participation	Preserves Behavioral Integrity

10.2 COSO Framework Alignment: Control Environment & Information Flow

NTCC governance aligns with the **COSO Internal Control Framework (2017 Edition)**, particularly within the "Control Environment" and "Information & Communication" components.

COSO Component	NTCC Governance Correspondence
Control Environment	Behavioral data verification replaces financial transaction control; each Proof Record serves as a governance evidence unit.
Risk Assessment	Verification Factors (VF_0–VFs) quantify systemic verification reliability, ensuring measurable audit risk control.
Information & Communication	PADV Registry ensures transparent data dissemination to verifiers and regulators.
Monitoring Activities	Annual NTCC Lock (ADL) and third-party assurance audits provide ongoing oversight.

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

10.3 Double-Counting Prevention and Boundary Governance

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

Key Boundary Controls:

1. **Unique Entity Binding:**

   Every NTCC is permanently bound to its originating organization (E-UID).

   It cannot be transferred, subdivided, or resold.

2. **Activity Scope Segmentation:**

   Each NTCR is confined within its activity boundary — missions, events, or redemption actions cannot be recounted under multiple ESG reports.

3. **Cross-Registry Deduplication:**

   The PADV Registry integrates hash-based duplication to ensure that the same Proof Record cannot be submitted to multiple verification channels.

4. **Institutional Oversight:**

   Third-party verifiers and Big 4 auditors cross-check registry data to confirm that no duplicated NTCCs 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 / ISO 27701	Encryption, access control, and anonymized participant identifiers (E-UID).
Digital Evidence Management	ISO 27037	Immutable time-stamped records for each Proof Record and NTCC issuance.
Audit Documentation	ISO 19011	Standardized assurance procedures for NTCC verification audits.

Compliance Domain	Reference Standard	NTCC Governance Application
Governance Disclosure	IFRS S1 / S2	Public 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 verification and ESG compliance.

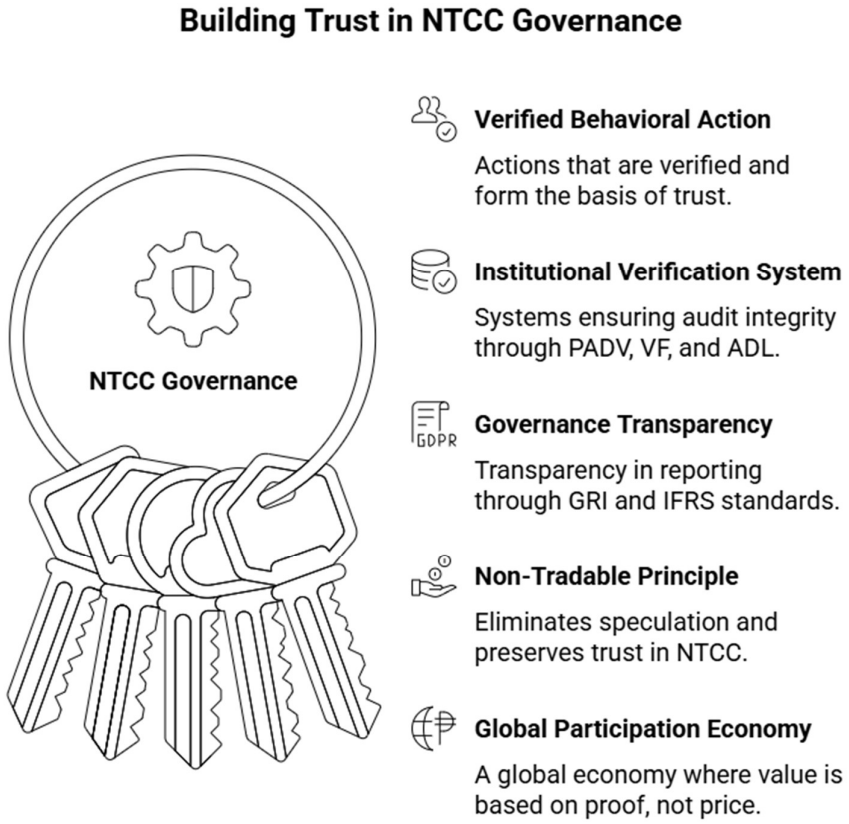
10.5 The Institutional Significance of the "Non-Tradable" Principle

The non-tradable principle is more than a restriction—it is a **governance philosophy**. By prohibiting speculative exchange, NTCC ensures that sustainability remains a matter of verified contribution, not financial capacity. In traditional markets, value depends on **price**; in the NTCC ecosystem, value depends on **proof**. This shift redefines how organizations are recognized for sustainability: not by their purchasing power, but by their verified behavioral impact.

The institutional implications are profound:

- It restores **trust** as the central currency of ESG.
- It creates a transparent governance mechanism to combat greenwashing.
- It ensures that every credited action carries **real behavioral substance**.

Thus, NTCC represents a **paradigm shift**—from carbon trade to carbon trust, from economic transaction to institutional verification, laying the foundation for a verifiable global participation economy.



CHAPTER 11 Assurance & Verification Protocols

11.1 Introduction

Assurance within the PADV–NTCC system extends beyond conventional ESG verification. It represents a new form of **behavioral assurance**, where verified actions — rather than financial declarations — form the foundation of institutional credibility. This chapter defines the assurance hierarchy, the verification process, and the multi-layer governance logic that enables NTCCs to become audit-ready sustainability data.

11.2 Assurance Hierarchy: From Proof to Carbon Credit

The assurance process follows a **three-tier structure** ensuring traceability and audit coherence.

Tier	Entity	Function	Verification Output
Tier 1 – Proof Record	Individual participant or organization	Captures verified behavioral data (action, time, location, evidence)	Verified data entry
Tier 2 – NTCR (Non-Tradable Carbon Record)	PADV verification layer	Aggregates Proof Records and converts to carbon equivalence (kg CO_2e)	Quantified carbon record
Tier 3 – NTCC (Non-Tradable Carbon Credit)	Institutional layer	Consolidates annual NTCR under governance rules (RCF, VF, W_ESG)	Auditable credit unit (tons CO_2e)

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

11.3 Cross-Verification Protocol (CVP)

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

1. **Internal Verification (Self-Assurance):** The PADV engine automatically validates Proof Records against metadata schema (location, timestamp, duplicate check).
2. **External Verification (Third-Party Review):** Accredited verifiers (e.g., Deloitte, BSI, DNV, ARES) perform random sampling, evidence tracing, and recalculation of VF and W_ESG.
3. **Cross-Institutional Verification:** PADV Registry compares datasets across institutions to prevent double recognition and ensure unique NTCC issuance.

Together, these steps form a closed-loop verification structure compliant with **ISO 19011** and **ISO 17029** assurance principles.

11.4 Sampling Density and Audit Frequency

Verification intensity is determined by **activity type, scale, and risk class**. PADV defines three audit density tiers:

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

This proportional design ensures cost-effective assurance while maintaining statistical confidence (≥ 95 % reliability, ± 5 % margin of error).

11.5 Verification Chain Integration

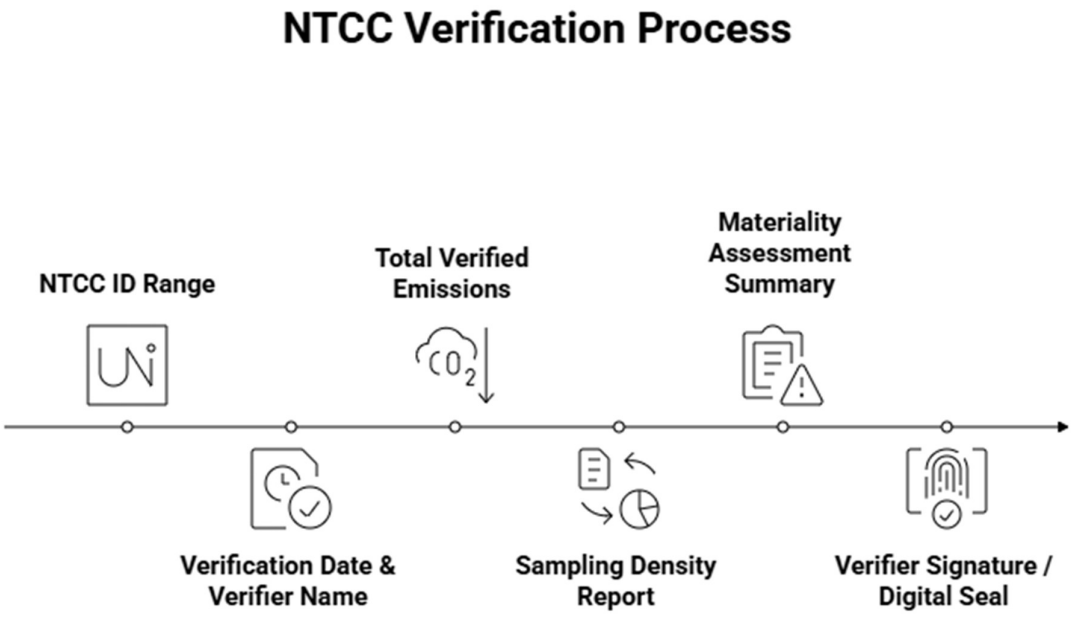
The verification chain integrates four critical components of **ISO 19011 / 27037** frameworks:

1. **Evidence Identification** – Proof Records are treated as digital evidence objects with immutable hashes.
2. **Chain-of-Custody Management** – Every dataset transfer between entities is logged in PADV Ledger.
3. **Validation Procedures** – Recalculation of VF and W_ESG using independent verifier datasets.
4. **Assurance Output Documentation** – Generation of “Assurance Certificate (AC)” referencing NTCC IDs for ESG disclosure.

Each Assurance Certificate includes:

- NTCC ID range, verification date, and verifier signature
- Total verified emissions (tons CO_2e)
- Sampling report and materiality 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 the **institutional trust anchors** within the PADV ecosystem.

Their roles include:

- **Assurance Execution:** Conduct CVP audits and sampling validation.
- **Governance Feedback:** Recommend VF and W_ESG calibration based on observed discrepancies.
- **Registry Synchronization:** Upload verified datasets to PADV's Cross-Verifier Node (CVN).
- **Disclosure Alignment:** Co-sign assurance statements embedded in ESG or sustainability reports.

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

11.7 Audit Output & Machine-Readable Reporting

All verification 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 Big 4 audit software.

Sample fields include:

{ "NTCC_ID": "NTCC-2025-001", "Verifier": "Deloitte", "VF_total": 0.96, "W_ESG": 0.72, "RCF": 1.0, "CO2e": 1.200, "Assurance Date": "2025-06-30" }

Machine-readable assurance enables **automated reconciliation**, paving the way for real-time ESG verification under future AI audit models.

11.8 Assurance Summary

Through the combined application of hierarchical verification, CVP, standardized sampling, and independent oversight, the NTCC system achieves **audit-grade assurance quality** while maintaining operational scalability.It transforms ESG verification from a narrative process into a **quantifiable behavioral assurance system**—a foundation for the next generation of sustainability reporting.

CHAPTER 12 Cross-Standard Mapping Architecture

12.1 Purpose and Scope

The PADV–NTCC framework does **not** replace existing ESG or assurance standards. It functions as a **behavioral-data assurance 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 **assurance-ready**.

12.2 Canonical Mapping Matrix

PADV Entity	Function	Primary Standards Mapping
Proof Record (PR)	Atomic behavioral evidence (actor, action, time, geo, signature)	**ISO 27037** (digital evidence); **GRI 2 / 102** (entity & data boundaries); **IFRS S1-22** (governance information)
Verification Factor (VF_0, VFn, VFs → VF_total)	Reliability calibration (statistical / regional / sectoral)	**ISO 19011** (audit sampling); **COSO – Risk Assessment**
ESG Weighting (W_ESG_norm)	Normalized ESG materiality of actions	**GRI 305 / 403 / 413**; **IFRS S2** (metrics & targets)
NTCR (kg CO_2e)	ESG-adjusted behavioral carbon equivalence	**ISO 14064-1**; **GRI 305-3 / 305-5**; **IFRS S2-29**
Annual Recognition (RCF)	Year-bound recognition & caps	**IFRS S1** (control cycle); **COSO – Control Activities**
NTCC (t CO_2e)	Annualized non-tradable verified unit	**IFRS S2-25 / S2-29**; **GRI 305-7**
Registry & ADL (Annual Data Lock)	Immutability and provenance	**ISO 27001 / 27701**; **COSO – Information & Communication**
Assurance Certificate (AC)	Third-party verification output	**ISO 17029** (validation & verification principles); **GRI 2 / 102-56**; **IFRS S1 / S2**

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 (PR)	GRI 2 / 102-45	IFRS S1-22	Defines entity scope and data origins
NTCR (kg CO_2e)	GRI 305-3 / 305-5	IFRS S2-29	Quantified reductions and metrics with methodology
NTCC (t CO_2e)	GRI 305-7	IFRS S2-25 / S2-29	Annualized recognition with reporting boundaries
VF / RCF	GRI 205-1 (ethics & control)	IFRS S1-24	Internal control and assurance governance
W_ESG_norm	GRI 403 / 413	IFRS S1-32	Social impact and materiality linkage
Assurance Output (AC)	GRI 102-56	IFRS S1/S2 (assurance statements)	Third-party verification references

12.4 ISO / COSO Integration

Domain	International Standard	PADV Application
Carbon Quantification	ISO 14064-1	Reference for NTCR computation and emission boundary
Audit Management	ISO 19011	Sampling tiers and Cross-Verification Protocol (CVP)
Digital Evidence	ISO 27037	Proof Record structure and hash

Domain	International Standard	PADV Application
		immutability
Security & Privacy	ISO 27001 / 27701	Encryption and role-based access control
Conformity Assessment	ISO 17029	Assurance Certificate (AC) verification principles
Internal Control Framework	COSO (2017)	VF → Risk Assessment; RCF → Control Activities; ADL → Information & Communication; AC → 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 / W_ESG_norm scores
Social Impact	Public welfare redemption 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.
- **GHG Protocol:** Proof Record and NTCR data fill downstream Scope 3 gaps with auditable actions and traceability.

12.7 Crosswalk (Integrated Matrix)

PADV Element	**GRI**	**IFRS**	**ISO**	**COSO**	**QS**
Proof Record	2 / 102-45	S1-22	27037	Information & Communication	Education Data
NTCR	305-3 / 305-5	S2-29	14064-1	Risk Assessment	Environmental Impact
NTCC	305-7	S2-25 / S2-29	—	Control Environment	Governance
VF / RCF	205-1	S1-24	19011	Monitoring Activities	Transparency
W_ESG_norm	403 / 413	S1-32	—	Ethics and Integrity	Social Impact
Registry / ADL	2 (Governance)	S1 (Controls)	27001 / 27701 / 27037	Info & Comm	—
Assurance Certificate (AC)	102-56	S1 / S2	17029	Monitoring	—

Disclosure Reminder: Always report (i) task definitions, (ii) VF and W_ESG ranges,

(iii) RCF pathway, and (iv) ADL identifier to ensure cross-framework comparability.

12.8 Implementation Notes for Reporters and Verifiers

1. **Boundary Control:** Behavioral data (PR/NTCR) is non-tradable and non-transferable; NTCC is annualized and ADL-locked.
2. **Sampling:** Follow ISO 19011 density tiers; record ratios within the Assurance Certificate.
3. **Machine-Readable Format:** Export PR, NTCR, NTCC, and AC in JSON/XML/CSV with hash and timestamp fields.
4. **Terminology:** Use "verified behavioral carbon equivalence (NTCR)" and "annualized non-tradable carbon credit (NTCC)" to avoid offset confusion.
5. **Assurance Chain:** PR → VF/W_ESG_norm → NTCR → Σ × RCF → NTCC → ADL → AC (verifier-signed).

CHAPTER 13 Data Integrity & Machine Governance

13.1 Introduction: Trust as Code

The PADV–NTCC system extends the concept of trust from human governance to **machine-verifiable integrity**.

In traditional ESG reporting, verification depends on manual documentation and human interpretation. PADV replaces this fragility with a programmable structure — where every verified action, data exchange, and assurance event is governed by digital logic rather than institutional assumption.

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

13.2 The PADV Data Layer: From Participation to Locked Proof

All verified behavioral data flow through four interconnected layers known as the **PADV Data Loop**:

Layer	Function	Output
Participation Layer	Captures user or enterprise actions via SDGS PASS mission or redemption	Raw Proof Data
Action Validation Layer	Applies VF (Verification Factor) and W_ESG weighting	Verified Proof Record
Data Layer (Registry)	Stores hash-secured Proof Records and aggregates NTCR values	PADV Ledger Entry
Value Layer (Lock & Disclosure)	Converts verified data into NTCC and seals it under Annual Data Lock (ADL)	Immutable Assurance Dataset

This layered design ensures every action is **traceable, auditable, and immutable**, forming the backbone of NTCC's institutional credibility.

13.3 Metadata Schema (JSON/XML) for Machine Auditability

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

Example (Simplified JSON Schema):

```
{
  "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,
  "CO2e_kg": 12.5,
  "Verifier": "DNV",
  "Lock_Status": "ADL_2025_Y1"
}
```

This schema is compliant with **ISO 27037** (Digital Evidence Management)

and **ISO 38507** (Governance of AI), enabling verifiers and regulators to perform automated checks.

13.4 PADV Ledger Protocol (PLP)

The **PADV Ledger Protocol (PLP)** functions as the cryptographic registry ensuring transparency and traceability across all data interactions.

Core Features:

- **Hash-Based Verification:** Each Proof Record and NTCR is hashed using SHA-256, creating a unique immutable fingerprint.
- **Ledger Synchronization:** All records synchronize with the PADV Global Node Network (PGNN) every 24 hours.
- **Cross-Registry Reconciliation:** Enables Big 4 auditors and verification bodies to confirm hash consistency between PADV and ESG reporting systems.
- **Immutable Seal:** Once NTCCs 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 PADV registry into a **verifiable public ledger for sustainability assurance**.

13.5 Machine Governance Principles

Machine governance within PADV is guided by three institutional principles:

- **Autonomy:** Verification logic (e.g., VF recalculation, duplicate detection) operates independently from the reporting organization, preventing bias.
- **Transparency:** Every computation and data update generates a verifiable digital trace, accessible to verifiers under authorized access protocols.
- **Accountability:** All automated actions are logged with cryptographic time stamps and verifier identifiers, forming a machine-level chain of accountability.

These principles align with **OECD AI Governance Guidelines (2023)** and **ISO/IEC 42001 (AI Management Systems)**, ensuring AI automation remains ethically

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
Access Control	Role-Based Encryption	Multi-level verifier 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

PADV's machine governance is designed to integrate seamlessly with global ESG and carbon 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 / EDU PASS
Verify VF & W_ESG	/api/verify/vf	Verifier Nodes
Retrieve NTCC Summary	/api/ntcc/report	ESG Reporting Tools
Cross-Check Ledger	/api/ledger/check	Big 4 Audit Systems
Lock ADL	/api/adl/finalize	PADV Registry

This structure transforms PADV–NTCC into a **machine-verifiable ESG assurance layer**, enabling interoperability across platforms like CDP, GRI Data Portal, and IFRS Sustainability Hub.

13.8 Summary

By embedding machine governance into the PADV–NTCC system, the framework transitions from a human-reliant verification process to a **digitally self-verifying trust infrastructure**. Data no longer requires belief—it provides proof.

This is the essence of **PADV as a data assurance institution**: trust encoded, verified, and locked.

CHAPTER 14 Policy Relevance & Use Cases

14.1 Introduction: From System Design to Policy Application

The PADV–NTCC framework demonstrates that verified behavioral data can evolve beyond academic methodology to become a **policy-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 and cross-institutional applications**, illustrating how the PADV–NTCC system operates as a replicable governance tool for corporate, educational, and social sustainability ecosystems.

14.2 Policy Context: The Behavioral Data Gap in ESG Governance

Despite the maturity of global ESG frameworks, a structural gap remains between **policy commitments** and **behavioral verification**.

Many institutions continue to rely on narrative-based reporting, creating a "data confidence deficit" that weakens public trust.

The PADV–NTCC model addresses this gap through a new form of **behavioral assurance**, anchored in verifiable participation rather than financial estimation. It operationalizes three key policy objectives:

Policy Dimension	PADV–NTCC Contribution
Transparency	Behavioral actions are traceable via Proof Records with immutable identifiers.
Accountability	Verification Factors (VF) and Recognition Coefficients (RCF) 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**.

14.3 Policy Sandbox and Cross-Sector Pilots

The PADV–NTCC model has been successfully tested in multiple **cross-sectoral ESG policy sandboxes**, involving collaboration among research institutions, verification bodies, private-sector alliances, and academic data governance partners.

Key Achievements:

- More than **8.7 tons of CO_2e equivalent NTCCs** generated and verified.
- Over **2.45 million SDGS PASS points** accumulated through mission-based and redemption actions.
- Participation from **over 18 organizations** across various industries.
- Verified NTCC records integrated into corporate sustainability reporting aligned with GRI 305 and IFRS S2.

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

14.4 Data Governance Alignment: Institutional Infrastructure Model

In regions emphasizing **data integrity and AI-enabled governance**, PADV–NTCC

has been positioned as a **data assurance infrastructure** rather than a market mechanism.

Its architecture reflects the principles of **open data interoperability, ethical AI governance, 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 without requiring centralized authority or regional dependence.

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 or redemption schemes that generate Proof Records through SDGS PASS.

Sector	**Implementation Model**	**Verified Output**
Retail & F&B	Public Welfare Redemption Goods	Quantified low-carbon consumer behavior
Finance	Employee ESG Missions, Green Literacy Programs	Measurable participation data
Manufacturing	SDGS PASS for internal sustainability actions	Verified Scope 3 behavior data
Event	ESG-linked missions and	Auditable NTCC generation

Sector	Implementation Model	Verified Output
Management	exhibitions	(kg CO_2e)

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 of PADV–NTCC, known as **EDU SDGS PASS**, translates sustainability learning into quantifiable behavioral records.

Universities and secondary schools employ mission-based education modules that correspond to the **8G KNIGHTS competency model**, linking students' sustainability actions to verified Proof Records and NTCC data.

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**, transforming classrooms into measurable participation ecosystems.

14.7 Large-Scale Event Missions: Public Participation as Data Source

PADV–NTCC has also been validated in large-scale public sustainability events — including clean-up missions, charity cycling, running festivals, 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 carbon equivalence.
4. Event organizers receive post-event ESG assurance summaries compatible with GRI and IFRS structures.

Example Outcome:

A regional ESG-themed exhibition produced **over 8,700 kg CO_2e NTCC**, supported by thousands of public participation Proof Records, later integrated into the event's sustainability disclosure.

This confirms NTCC's adaptability across multiple engagement scales—from local initiatives to large social movements.

14.8 Quantified Impact and Global Replicability

Metric	**Verified Result (2025 Pilot Data)**
Proof Records	>2,500,000 entries
Verified NTCC	8.7 tons CO_2e
Participating Organizations	18+
Individual Participants	>30,000
Assurance Accuracy	100% verified by independent verifiers

The evidence demonstrates that PADV–NTCC delivers a **replicable and scalable model** for translating human participation into institutional trust.

Its policy relevance lies in enabling:

- Integration into national and regional ESG data platforms;
- Adoption by assurance organizations as a behavioral data verification tool;
- Alignment with international sustainable data interoperability frameworks.

Through these outcomes, PADV–NTCC proves that **verified participation can evolve into policy infrastructure**, bridging human behavior, data assurance, and

governance credibility.

CHAPTER 15 Conclusion & Future Institutional Evolution

15.1 Closing Reflection: From Behavior to Institution

The journey of PADV–NTCC demonstrates that sustainability data does not emerge from estimation, but from **behavior made verifiable**.

When human participation becomes measurable, and verification becomes institutional, sustainability evolves from narrative into **evidence-based governance**.

This transformation marks the beginning of a new governance era — where carbon accounting, ESG disclosure, and behavioral economics converge into a single verifiable logic.

NTCC, as the non-tradable counterpart to market carbon credits, anchors this logic within the domain of social participation and collective accountability.

15.2 The Role of PADV as a Data Infrastructure

PADV serves as the underlying architecture 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-auditable trust components** — the smallest yet most fundamental units of sustainable transformation.

By standardizing the Proof Record, VF (Verification Factor), and W_ESG weighting, PADV transforms human actions into structured datasets suitable for institutional 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 Institutional Evolution Pathway

The institutional evolution of PADV–NTCC follows three progressive stages:

Stage	Description	Institutional Focus
Phase I — Validation	Establishment of Proof Record and NTCC measurement framework	Verifiability & Methodological Rigor
Phase II — Standardization	Integration with international standards (GRI, IFRS, COSO, ISO, QS)	Interoperability & Audit Readiness
Phase III — Institutionalization	Adoption by organizations, verifiers, and data governance frameworks	Policy Relevance & Global Replicability

This progression transforms PADV–NTCC from a methodological prototype into a **governance instrument embedded in data infrastructure**, capable of supporting ESG assurance ecosystems globally.

15.4 Toward the Next Phase: AI-Driven Behavioral Trust

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 sustained.

15.5 Global Standardization and Academic Collaboration

The academic significance of PADV–NTCC extends beyond carbon equivalence or ESG compliance.

It introduces a unified, auditable data logic applicable across scientific, educational, and financial systems.

Future research collaborations are expected to include:

- Integration with global academic consortia on behavioral sustainability metrics;
- Co-development of ISO-compatible verification models;
- 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 **governance language** for the age of behavioral sustainability.

15.6 Closing Statement

In an era where sustainability is both a moral imperative and a data challenge, PADV–NTCC provides a **third path**—not purely economic, not purely regulatory, but institutional through verification.

It represents a bridge between intention and proof, between participation and trust, between individual action and global accountability.

As a system born from verifiable 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 **governs the very trust that sustains our shared future.**

Acknowledgments and Supporting Institutions

The completion of the NTCC (Non-Tradable Carbon Credit) Methodology White Paper v2.0 has been shaped and strengthened by the collaboration, insights, and professional guidance of stakeholders across academia, verification bodies, public institutions, and industry partners in both Singapore and Taiwan.

We express our deepest appreciation to the following contributors and organizations:

- Pilot partners and corporate participants who provided field data from exhibitions, ESG events, and CSR initiatives—enabling validation of

NTCC's dual-pathway mechanism and real-world behavioral carbon accounting accuracy.

- Academic and research advisors for their contributions in sustainability governance, carbon data methodology, and behavioral verification, ensuring international alignment with ESG, Scope 3, and institutional assurance frameworks.
- Audit and verification experts from assurance firms and Big 4–aligned organizations who provided essential feedback on Verification Factors (VF), Recognition Coefficients (RCF), and assurance sampling methods, advancing NTCC's audit readiness.
- Industry and ESG event organizers whose participation across exhibitions and campaigns helped demonstrate the scalability and replicability of the NTCC system across sectors and geographies.
- Verification and governance body: ARES International Certification (Taiwan), for its technical consultation on NTCC's assurance architecture and for contributing to the standardization of verification logic within the PADV–NTCC ecosystem.
- Market and regulatory institutions, notably the Taiwan Stock Exchange (TWSE) and Taipei Exchange (TPEx), for their constructive input on governance disclosure and sustainability reporting frameworks.
- Singapore regulatory and innovation agencies, including the Monetary Authority of Singapore (MAS), Enterprise Singapore, National Environment Agency (NEA), and Government Technology Agency (GovTech), for their constructive feedback and recommendations regarding institutional design, policy communication, and system development considerations.
- Governmental authorities in Taiwan, including the Financial Supervisory Commission, National Development Council, Ministry of Environment, and Ministry of Education, for their recognition of NTCC as a data-based, non-market verification system and their valuable perspectives on institutional alignment and policy integration.

Their insights and engagement have been instrumental in transforming NTCC from 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 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 entities.

APPENDICES

Appendix A – Verification Factor (VF) Model

A.1 Definition and Purpose

The **Verification Factor (VF)** is the quantitative mechanism that transforms human participation data into verifiable, audit-ready sustainability evidence.

It measures the **reliability, contextual stability, and participation intensity** of each behavioral record, thereby ensuring that the resulting carbon equivalence (CO_2e) values are scientifically grounded and reproducible.

VF serves as the correction layer between *raw behavioral participation* and *verified sustainability data*. Within the PADV–NTCC framework, it functions as the statistical "trust coefficient" that normalizes uncertainty across different regions, event types, and measurement conditions.

A.2 Mathematical Structure

The complete VF computation is defined as:

$$VF_{total} = \frac{(VF_0 + VF_n + VF_s)}{3} \times RCF$$

where:

Symbol	Term	Description	Typical Range
VF_0	*Baseline Verification Factor*	Reflects the reliability of the institutional environment, data capture system, and original data quality.	0.90 – 0.95
VFn	*Normalized Participation Factor*	Adjusts for participation rate, engagement depth, and record completion ratio.	0.85 – 1.00
VFs	*Situational Stability Factor*	Evaluates temporal and operational stability during data collection, e.g., event duration, climatic or platform consistency.	0.88 – 0.97
RCF	*Recognition Coefficient*	Annual recognition ratio depending on the nature of participation (mission = 1.0 ; redemption = 0.3).	Discrete {1.0, 0.3}

This formula ensures that participation with high contextual stability and accurate recording achieves proportionally higher verification strength.

A.3 Algorithmic Interpretation

1. **Baseline Calibration (VF_0)**

   Derived from system audits and data-quality assessments. It anchors all subsequent calculations, representing the inherent trustworthiness of the reporting mechanism.

2. **Participation Normalization (VFn)**

   Computed from real-time completion ratios or participation statistics:

$$VFn = \frac{N_{completed}}{N_{registered}}$$

(bounded to 1.00 maximum).

3. **Stability Adjustment (VFs)**

   Incorporates variance in temporal or spatial data:

$$VFs = 1 - \sigma_{instability}$$

where σ denotes the normalized deviation of measurement conditions (e.g., temperature fluctuations, server latency).

4. **Recognition Coefficient (RCF)**

   Enforces annual recognition limits:

   - Mission-based activities → full credit (RCF = 1.0)
   - Redemption-based goods → partial credit (RCF = 0.3)

A.4 Example Computation

A corporate mission reports:

- Completion Rate = 92 %
- Validated Data Quality = High (VF_0 = 0.92)
- Participation Consistency = Excellent (VFn = 0.95)
- Event Stability = Good (VFs = 0.90)
- Recognition Coefficient = 1.0

Then:

$$VF_{total} = \frac{(0.92 + 0.95 + 0.90)}{3} \times 1.0 = 0.923$$

Result: VF_{total} = 0.923 → High verifiability index.

In audit practice, VF ≥ 0.90 indicates a “fully trustworthy” record class.

A.5 Annual Recognition Framework

Behavior Type	RCF Value	Recognition Rate	Definition of Scope
Mission-based behavior	1.0	100 %	Direct participation, measurable impact, system-verified records
Redemption-based behavior	0.3	30 %	Indirect impact through product or service exchange

Annual recognition values prevent over-accrual of CO_2e equivalence while maintaining consistency with audit and disclosure standards.

A.6 Cross-Standard Mapping

VF Component	Primary Function	GRI Reference	IFRS Reference	ISO/COSO Alignment
VF_0	Data Integrity and Institutional Reliability	GRI 102	IFRS S1-22	ISO 27037 / COSO: Control Environment
VFn	Engagement and Performance Verification	GRI 403	IFRS S1-29	ISO 19011 / COSO: Monitoring
VFs	Operational Stability Measurement	GRI 305	IFRS S2-27	ISO 14064-1 / COSO: Information & Communication
RCF	Governance of Recognition Rules	GRI 201	IFRS S1-24	ISO 37000 / COSO: Risk Management

A.7 Interpretation Guidelines

1. **VF acts as a universal confidence index** for any PADV-verified dataset.
2. **VF ≥ 0.90** → Suitable for third-party ESG reporting and Scope 3 integration.
3. **VF 0.75–0.89** → Conditionally verifiable; requires additional sampling or correction.
4. **VF < 0.75** → Rejected or archived for research only.
5. All VF records are subject to annual audit reconciliation and checksum verification.

Appendix B – ESG Weighting Factors (CEF / SEF / IRF)

B.1 Purpose and Conceptual Role

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

They ensure that each verified behavioral record not only represents an environmental effect but also encapsulates the *social* and *governance* value dimensions required for modern ESG disclosure.

Each NTCR (Non-Tradable Carbon Record) therefore carries a composite weight, expressed as:

$$W_{ESG} = \frac{(CEF + SEF + IRF)}{3}$$

This average value forms the second critical multiplier following the Verification Factor (VF).

B.2 Structure and Definitions

Dimension	Code	Definition	Typical Range (1–5)	Measurement Source
Carbon Efficiency Factor	**CEF**	Quantifies environmental efficiency, including emission reduction, resource optimization, waste prevention, or renewable adoption.	3 – 5	Measured through carbon audit or life-cycle data
Social Engagement Factor	**SEF**	Represents inclusiveness, volunteer participation, educational reach, or community benefit.	2 – 5	Derived from participation counts and social-impact surveys
Institutional Responsibility Factor	**IRF**	Captures governance integrity, transparency, and procedural accountability of the organizing entity.	3 – 5	Based on internal audit, ISO 37000 or GRI 201 criteria

B.3 Scoring Methodology

1. **Normalization Scale**

2. All three dimensions are scored from 1 to 5, where 5 denotes the highest verified performance and 3 represents satisfactory compliance. Scores < 3 trigger review under the PADV Assurance Protocol.

3. **Weight Computation**

   The normalized ESG weight is the arithmetic mean:

$$W_{ESG} = \frac{(CEF + SEF + IRF)}{3}$$

4. **Integration with VF and NTCC**

   The resulting W_ESG is multiplied with VF_total to generate a balanced NTCC value that reflects both quantitative accuracy and qualitative ESG alignment.

B.4 Illustrative Examples

Case ID	Description	CEF	SEF	IRF	W_ESG	Interpretation
M-001	Corporate Employee Cycling Mission	4.7	4.3	4.5	4.50	High ESG integration, direct environmental benefit
M-002	University Clean-up Campaign (Volunteer)	4.6	4.8	4.4	4.60	Excellent social engagement, strong governance
R-005	Eco-Product Redemption Campaign	3.6	3.9	4.0	3.83	Moderate impact, consumer-driven behavior
R-008	CSR Webinar Series (Knowledge Activity)	3.4	4.2	4.3	3.97	Educational impact with indirect environmental gain

B.5 Thresholds for ESG Audit Use

W_ESG Range	Interpretation	ESG Disclosure Eligibility
≥ 4.2	Fully integrated ESG action	Direct disclosure in Scope 3 and GRI 305 sections
3.5 – 4.19	Moderate impact	Supplementary disclosure with narrative context
< 3.5	Low impact / training phase	Record retained for internal improvement analysis

B.6 Cross-Framework Mapping

PADV Factor	Primary Meaning	GRI Reference	IFRS Sustainability Disclosure	ISO / COSO Alignment
CEF	Emission and resource efficiency	GRI 305-5 / 306	IFRS S2-27	ISO 14064-1 / 14067
SEF	Social inclusion and community engagement	GRI 413-1	IFRS S1-29	ISO 26000 / COSO Monitoring
IRF	Governance and institutional responsibility	GRI 201-2 / 102-18	IFRS S1-22	ISO 37000 / COSO Control Env

B.7 Operational Guidelines

1. Each organization must define its own ESG baseline matrix aligned with national regulations and industry standards.
2. All W_ESG values shall be subject to annual audit and peer verification under PADV Assurance Protocol.
3. For multi-country data sets, local weight calibration ($\Delta \leq \pm 0.2$) is permitted to reflect regulatory variances.
4. Once verified, the final W_ESG value is locked in the Proof Record and linked to its corresponding VF and NTCR record.

B.8 Interpretive Remarks

The ESG Weighting System bridges quantitative and qualitative ESG dimensions — it ensures that every recognized NTCC embodies both carbon impact and ethical governance accountability.

Through CEF / SEF / IRF, PADV translates complex behavioral data into

institutionally meaningful ESG metrics, laying a common foundation for audit, assurance, and policy integration across international frameworks.

Appendix C – NTCC Conversion and ESG Correspondence

C.1 Purpose

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

Every verified activity or redemption recorded through SDGS PASS produces a *Non-Tradable Carbon Credit (NTCC)*, which represents **behavior-based carbon equivalence**, not a tradable financial asset.

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

C.2 Core Conversion Formula

$$NTCC_{kgCO2} = \frac{SDGS_{points}}{10} \times VF_{total} \times \frac{W_{ESG}}{5}$$

Where:

Variable	**Meaning**	**Unit / Range**
SDGS_points	Total verified points generated by behavioral participation	integer ≥ 0
10 points = 1 kg CO_2e	Baseline conversion constant	fixed
VF_total	Verification Factor, measuring reliability	0.4 – 1..0
W_ESG	ESG composite weight (average of CEF/SEF/IRF)	1 – 5
5	Normalization denominator aligning with ESG scale	constant

Variable	Meaning	Unit / Range
NTCC (kg CO_2e)	Verified carbon equivalence	real ≥ 0

If desired in tons, divide by 1000:

$$NTCC_{tCO} = \frac{NTCC_{kgC}}{1000}$$

C.3 Derivation Process

1. **Behavioral Base:** Each verified activity produces a number of SDGS PASS points determined by participation depth and approved task parameters.
2. **Conversion Constant:** A linear baseline of *10 points = 1 kg CO_2e* was established through empirical calibration using 2024–2025 event datasets (mean VF ≈ 0.91, mean W_ESG ≈ 4.2).
3. **Reliability Adjustment:** Multiply by VF_total to reflect statistical confidence and verification density.
4. **Qualitative Integration:** Multiply by (W_ESG / 5) to normalize ESG qualitative alignment.

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

C.4 Algorithmic Expansion

$$NTCC_{kgCO2e} = \left(\frac{Points}{10}\right) \times \left(\frac{VF_0 + VF_n + VF_s}{3} \times RCF\right) \times \frac{(CEF + SEF + IRF)}{15}$$
$$= \frac{Points \times (VF_0 + VF_n + VF_s) \times RCF \times (CEF + SEF + IRF)}{450}$$

This expanded form demonstrates how the NTCC mathematically encapsulates both measurement accuracy (VF) and sustainability alignment (ESG weights).

C.5 Examples of Calculation

Case ID	Category	Points	VF_total	W_ESG	NTCC (kg CO_2e)	NTCC (t CO_2e)
M-101	Tree-Planting Mission	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 Redemption	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 Conversion Accuracy and Audit Readiness

Factor	Influence	Validation Method
VF_total	Adjusts numerical credibility	Randomized sampling (95 % confidence interval)
W_ESG	Integrates non-carbon aspects	ESG panel peer review (annual)
10 point constant	Defines behavioral → carbon conversion	Periodic benchmark recalibration (± 5 %)
Data Record 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 Mapping

NTCC Output Element	GRI Alignment	IFRS Linkage	ISO / COSO Reference
NTCC (kg CO_2e)	GRI 305-5 / 305-7	IFRS S2-27	ISO 14064-1 / 14067
Proof Record Logs	GRI 102-45	IFRS S1-22	COSO Information & 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 Summary	GRI 201-2	IFRS S1-24	COSO Risk Assessment

C.8 Institutional and Interpretive Notes

1. **Non-Tradability:** The NTCC represents *verified participation equivalence*, not a tradable carbon asset or offset.
   It is a data governance tool, not a commodity.
2. **Audit Function:** NTCC values can be independently verified by any ESG assurance firm using PADV's Proof Record hashes.
3. **Policy Integration:** Governments and institutions may adopt NTCC values as supporting data for ESG performance disclosure without invoking financial instrument regulation.
4. **Annual Recognition Constraint:**

   – Mission records = 100 % recognition.

   – Redemption records = 30 % recognition.

   This maintains proportionality and prevents artificial accumulation.

Appendix D – Metadata Schema

D.1 Purpose and Scope

The PADV–NTCC framework is built upon a verifiable, machine-readable metadata architecture that enables cross-standard auditability and replication.

This appendix defines the schema used to record, verify, and transfer **Proof Records** across the PADV data governance network.

Each Proof Record is a cryptographically signed entry that connects:

→ a verified participation event,

→ its computed VF (Verification Factor) and W_ESG values,

→ and its resulting NTCR (Non-Tradable Carbon Record).

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	2.0.0
Data Model Version	2025.10
Change Policy	Semantic Versioning (Major.Minor.Patch)
Namespace	urn:padv:ntcc:v2
Maintainer	EMJ.LIFE Institutional Research Division
Primary Formats	JSON (audit primary), XML (regulatory), CSV (human readable)

D.3 JSON Schema (Draft 2020-12, Full Version)

```
{
  "$schema": "https://json-schema.org/draft/2020-12/schema",
  "$id": "urn:padv:ntcc:v2:proofrecord",
  "title": "PADV–NTCC Proof Record",
  "type": "object",
  "required": [
    "pr_id", "participant", "organization", "activity",
    "points", "timestamp_utc", "vf", "w_esg",
    "rcf", "ntcr_kgco2e", "signatures", "registry", "consent"
  ],
  "properties": {
    "pr_id": { "type": "string", "pattern": "^PR-[0-9]{4}-[0-9A-Z]{5,}$" },
    "participant": {
      "type": "object",
      "required": ["euid"],
      "properties": {
        "euid": { "type": "string", "minLength": 8 },
        "role": { "type": "string", "enum": ["individual","employee","student","unknown"] },
        "pii_hash": { "type": ["string","null"], "description": "Salted hash of PII, never raw PII" }
      }
    },
    "organization": {
      "type": "object",
      "required": ["org_id"],
      "properties": {
        "org_id": { "type": "string", "pattern": "^EUID-[0-9A-Z]{6,}$" },
        "name": { "type": ["string","null"] },
        "jurisdiction": { "type": ["string","null"] }
      }
    },
    "activity": {
      "type": "object",
      "required": ["task_id","type"],
      "properties": {
        "task_id": { "type": "string" },
        "type": { "type": "string", "enum": ["mission","redemption"] },
        "category": {
```

```
          "type": ["string","null"],
          "enum": ["cleanup","cycling","running","donation","education",
                   "workshop","exhibition","eco_product","service_voucher","other",null]
        },
        "evidence": {
          "type": "array",
          "items": {
            "type": "object",
            "required": ["uri","hash"],
            "properties": {
              "uri": { "type": "string", "format": "uri" },
              "hash": { "type": "string", "pattern": "^(sha256:)[0-9a-f]{64}$" },
              "media_type": { "type": ["string","null"] }
            }
          },
          "minItems": 0
        }
      }
    },
    "points": { "type": "integer", "minimum": 1 },
    "timestamp_utc": { "type": "string", "format": "date-time" },
    "vf": {
      "type": "object",
      "required": ["vf0","vfn","vfs","vf_total"],
      "properties": {
        "vf0": { "type": "number", "minimum": 0.40, "maximum": 1.00 },
        "vfn": { "type": "number", "minimum": 0.40, "maximum": 1.00 },
        "vfs": { "type": "number", "minimum": 0.40, "maximum": 1.00 },
        "vf_total": { "type": "number", "minimum": 0.40, "maximum": 1.00 },
        "method": { "type": ["string","null"], "enum": ["tri-layer","stat-avg","other",null] }
      }
    },
    "w_esg": {
      "type": "object",
      "required": ["cef","sef","irf","w"],
      "properties": {
        "cef": { "type": "number", "minimum": 1, "maximum": 5 },
        "sef": { "type": "number", "minimum": 1, "maximum": 5 },
        "irf": { "type": "number", "minimum": 1, "maximum": 5 },
```

```
        "w":      { "type": "number", "minimum": 1, "maximum": 5 }
      }
    },
    "rcf": { "type": "number", "enum": [1.0,0.3] },
    "ntcr_kgco2e": { "type": "number", "minimum": 0 },
    "signatures": {
      "type": "object",
      "required": ["issuer_sig","verifier_sig","hash_algo"],
      "properties": {
        "issuer_sig": { "type": "string" },
        "verifier_sig": { "type": "string" },
        "hash_algo": { "type": "string", "enum": ["sha256","sha3-256"] },
        "prev_registry_hash": { "type": ["string","null"] }
      }
    },
    "registry": {
      "type": "object",
      "required": ["node_id","adl_lock"],
      "properties": {
        "node_id": { "type": "string" },
        "adl_lock": { "type": "string", "enum": ["pending","ADL_YYYY_Yn","locked"] },
        "record_hash": { "type": ["string","null"] },
        "ledger_height": { "type": ["integer","null"] }
      }
    },
    "consent": {
      "type": "object",
      "required": ["terms_accepted","retention_until"],
      "properties": {
        "terms_accepted": { "type": "boolean" },
        "retention_until": { "type": "string", "format": "date" },
        "privacy_level": { "type": "string", "enum": ["public","restricted","confidential"] }
      }
    },
    "mappings": {
      "type": "object",
      "properties": {
        "gri": { "type": ["string","null"] },
        "ifrs": { "type": ["string","null"] },
```

```
            "iso": { "type": ["string","null"] },
            "coso": { "type": ["string","null"] }
          }
        }
    }
}
```

D.4 JSON Example

```
{
  "pr_id": "PR-2025-0A3XZ",
  "participant": {"euid": "E-UID-7F29AB9", "role": "employee"},
  "organization": {"org_id": "EUID-ACME01"},
  "activity": {
    "task_id": "SDGSPASS-MISSION-014",
    "type": "mission",
    "category": "cycling",
    "evidence": [
      {"uri": "https://ex.org/e/123.jpg",
       "hash": "sha256:8a1c...f0e",
       "media_type": "image/jpeg"}
    ]
  },
  "points": 120,
  "timestamp_utc": "2025-06-15T09:32:11Z",
  "vf": {"vf0": 0.92, "vfn": 0.98, "vfs": 0.95, "vf_total": 0.95, "method": "tri-layer"},
  "w_esg": {"cef": 4.5, "sef": 4.2, "irf": 4.6, "w": 4.43},
  "rcf": 1.0,
  "ntcr_kgco2e": 10.2,
  "signatures": {"issuer_sig": "sig_issuer...", "verifier_sig": "sig_verifier...", "hash_algo": "sha256"},
  "registry": {"node_id": "PGNN-SEA-01", "adl_lock": "pending"},
  "consent": {"terms_accepted": true, "retention_until": "2032-12-31", "privacy_level": "restricted"},
  "mappings": {"gri": "305-3", "ifrs": "S2-29", "iso": "14064-1", "coso": "Control Env"}
}
```

D.5 XML Schema (Excerpt)

```
<ProofRecord xmlns="urn:padv:ntcc:v2">
  <PR_ID>PR-2025-0A3XZ</PR_ID>
```

```
  <Participant>
    <EUID>E-UID-7F29AB9</EUID>
    <Role>employee</Role>
  </Participant>
  <Org_ID>EUID-ACME01</Org_ID>
  <Task_ID>SDGSPASS-MISSION-014</Task_ID>
  <Type>mission</Type>
  <Points>120</Points>
  <Timestamp_UTC>2025-06-15T09:32:11Z</Timestamp_UTC>
  <VF>
    <VF0>0.92</VF0><VFn>0.98</VFn><VFs>0.95</VFs><VF_Total>0.857</VF_Total>
  </VF>
  <W_ESG>
    <CEF>4.5</CEF><SEF>4.2</SEF><IRF>4.6</IRF><W>4.43</W>
  </W_ESG>
  <RCF>1.0</RCF>
  <NTCR_kgCO2e>10.2</NTCR_kgCO2e>
  <Signatures>
    <Issuer_Signature>sig_issuer...</Issuer_Signature>
    <Verifier_Signature>sig_verifier...</Verifier_Signature>
  </Signatures>
  <Registry>
    <Node_ID>PGNN-SEA-01</Node_ID>
    <ADL_Lock>pending</ADL_Lock>
  </Registry>
</ProofRecord>
```

D.6 Field Dictionary & Standards Crosswalk

Field	Description	GRI	IFRS	ISO	COSO
pr_id	Global unique Proof Record	102-45	S1-22	27037	Information & Communication
participant.euid	Anonymized participant ID	102-8	S1-22	27701	Control Environment
organization.org_id	Institutional	102-1	S1	27001	Control

Field	Description	GRI	IFRS	ISO	COSO
	identifier				Environment
activity.type	Mission / Redemption	413	S1-32	9001	Risk Assessment
evidence.hash	Media hash for proof	102	S1	27037	Control Activities
vf.vf_total	Verification coefficient	205-1	S1-24	19011	Monitoring
w_esg.w	ESG composite weight	403/413	S1-32	26000	Ethics
rcf	Recognition coefficient	201	S1-24	19011	Control Activities
ntcr_kgco2e	Behavioral carbon equivalence	305-3	S2-29	14064-1	Information & Communication
registry.adl_lock	Annual Data Lock Status	102	S1	27037	Monitoring

D.7 Validation Rules

- **Deterministic Formulas:**
  - kgCO2e_base = points / 10
  - vf_total = (vf0 + vfn + vfs)/3
  - w_norm = w_esg / 5
  - ntcr_kgco2e = kgCO2e_base × vf_total × w_norm
- **Constraints:**
  - pr_id must be unique globally.
  - points ≥ 1.
  - timestamp_utc unique per (euid + task_id + minute).

- rcf ∈ {1.0, 0.3}.
- adl_lock ∈ {pending, ADL_YYYY_Yn, locked}.

D.8 Privacy & Security

- **PII Minimization:** Only anonymized euid and salted hash stored.
- **Hash Protection:** All evidence stored via SHA-256 digest.
- **Crypto Chain:** Each record linked by prev_registry_hash, forming a verifiable chain of custody.
- **Retention:** Default 7 years per ISO 27037.
- **Access:** Controlled by privacy_level flag.

D.9 Checksum & Hash Registry Note

Each Proof Record is integrated into an **Assurance Data Ledger (ADL)** node.

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
Verifier Signature	Cryptographic endorsement by authorized auditor
ADL Height	Sequential ledger index for audit traceability

This ensures NTCC records cannot be altered or forged without invalidating the chain.

Appendix E-Canonical Terminology & Variables

E.1 Variables and Units

Symbol	Definition	Range / Unit	Formula or Rule
Points	Verified behavioral points	≥ 1	10 pts = 1 kg CO_2e
$kgCO_2e_{base}$	Base conversion	kg CO_2e	Points ÷ 10
VF_0, VFn, VFs	Verification factors	0–1 (normal) / ≤ 1.2 (pilot)	Contextual reliability inputs
VF_{total}	Mean verification factor	0–1.0 (norm) / ≤ 1.2 (pilot ≤ +10%)	$(VF_0 + VFn + VFs)/3$
CEF, SEF, IRF	ESG sub-scores	0–5 each	Standardized evaluation rubrics
W_{ESG}	ESG raw score	0–5	$(CEF + SEF + IRF)/3$
W_{ESG_norm}	ESG normalized weight	0–1	$W_{ESG}/5$
$NTCR_i$	Behavioral carbon equivalence	kg CO_2e	$(Points_i/10) \times VF_{total,i} \times W_{ESG\_norm,i}$
$RCF_{pathway}$	Annual recognition coefficient	0.3 / 1.0	A = 0.3 (≤ 30%), B = 1.0
$NTCC_{year}$	Annualized NTCC	tons CO_2e	$\sum_i (NTCR_i \times RCF_{pathway,i}) \div 1000$
ADL	Annual Data Lock identifier	—	Year ID (e.g., ADL-2025-Y1)

E.2 Controlled Terminology

- **Non-Tradable Carbon Credit (NTCC):** annualized, audit-ready, non-transferable verification unit.
- **Non-Tradable Carbon Record (NTCR):** ESG-weighted behavioral carbon equivalence (kg CO_2e).
- **Proof Record (PR):** atomic evidence unit with machine-readable metadata.
- **W_ESG_norm:** normalized ESG weighting (0–1); do not use raw W_ESG in calculations.
- **RCF_pathway:** applied only at annual aggregation stage.
- **ADL:** immutable year-specific data lock for recognized NTCCs.

E.3 Display and Rounding Rules

- **VF and W_ESG values:** display to two decimals.
- **NTCR and NTCC:** display to one or two decimals.
- **Units:** use kg CO_2e and t CO_2e (1 t = 1000 kg).
- Always append "_norm" to normalized ESG weights in text and tables.