Digital Measurement, Reporting & Verification (dMRV) Framework

VERSION 3.0

GBBC
InterWork
Alliance

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INTRODUCTION

FOREWORD

The second version of the Digital Measurement, Reporting & Verification (dMRV) Framework was published in late 2023. Since that time, the membership of Global Blockchain Business Council (GBBC) and its InterWork Alliance (IWA) initiative have shared the framework broadly throughout the sustainability ecosystem and put it through its paces to find missing elements, refine definitions, and strive to establish common ground to help unify the way ecological and environmental products like voluntary carbon credits are manufactured or originated.

Version 3.0 of the dMRV Framework introduces targeted but important updates that enhance the framework's usability and scalability. The most significant change is the modularization of MRV Extensions into reusable Extension Sets. This enables third parties to independently digitize methodologies and contribute them back to the framework, reducing duplication and ensuring consistency. This will allow future projects using the same methodology to reuse previously-created Extension Sets, saving time and resources while ensuring that two projects using the same methodology are using the same formulae and variables, promoting further interoperability and comparability across the ecosystem.

This document, once published in final form, will replace its predecessor in its entirety due to the hard work and collaboration of its contributors. But we are not done. There are still improvements to be made and refinements to be discovered as we all set forth to implement these specifications and commit to returning the lessons learned back for the next version of this specification in the future.

We invite you to join us on this journey to help scale these markets by shoring up its foundations through the creation of consistent, comparable, interoperable, and hopefully higher-quality digital environmental assets to help all of us achieve our personal, organizational, and global goals.

DISCLAIMER: This document is intended as an introduction and basis for further dialogue and cooperation with all relevant stakeholders. Neither the individual taskforce members nor their organizations have agreed to or adopted this document in its entirety. The following is an incomplete, pioneering work-in-progress intended to cultivate further cooperative effort on the keystone elements and best practices with the intention to align around a common governance set of standards, specifications and classification systems. We encourage participation and collaboration with other organizations and actors within the industry as well as regulators, and we welcome their feedback and commentary for the next version. The taskforce members do not presently endorse any specific regulatory treatment, and do not formally endorse or ratify any particular independent efforts to develop market governance frameworks.

We encourage those that wish to join us in GBBC, or that are already members not currently active in our group, to reach out and engage with us.

EXECUTIVE SUMMARY

To scale environmental markets we need to digitize the origination, or manufacturing, process and products. This new digital approach will enable the creation of standardized, comparable, and differentiated products from a wide variety of sources and lower their creation costs to make them more accessible and trustworthy.

The Digital MRV (dMRV) Framework defines the terminology, roles, process workflows, generic evidence packaging, and attestations that dMRV solutions should follow to originate these next generation digital assets. The framework defines a generic roles-based process along with an extensible data model to facilitate a consistent taxonomy across infrastructure and asset classes and allow for customization of the diverse array of activities that can produce these new assets.

The framework can better enable investments in, and generation of, high-quality, well-documented environmental assets at scale. This framework defines the variables that enable the application of a wide variety of standards, protocols, and technologies that can be used in combination to create high-quality projects and claims, ready for validation and verification.

A harmonized and standardized framework, agreed upon by market participants, will enable investors, buyers, and other participants in global environmental markets to ensure the credibility and integrity of outcomes while maintaining the rigor and the requisite documented evidence to indisputably track impacts. Additionally, the dMRV Framework, when implemented, can help ensure that double-counting and double-crediting do not occur – safeguarding market integrity. Tokenization alone will not and does not prevent double-counting, only tokens with corresponding, cryptographically-linked MRV audit trails have the opportunity to prove, on a public ledger, a lack of double-counting.

The biggest change in Version 3.0 is the introduction of MRV Extension Sets, a grouping of templates which encompass entities, messages, formulae, and variables that are specific to the Quality Standard or Methodology that the Activity Impact Module is bound to. They are typically composed of multiple MRV Extensions for modules or activities and can be defined by the supplier, verifier, and issuer based on a set of methodology modules. Extension Sets can be organized into Extension Set Modules that act as a shared library of MRV Extensions available to participants in the dMRV process.

Through this process, we aim to create reusable libraries that dMRV participants can use while allowing for the contribution of new Extension Sets from third parties as methodologies are further digitized. Version 3.0 also includes the renaming and grouping of certain data fields for clarity based on feedback received by the IWA from various stakeholders.

HOW IT WORKS

- **Open Standards:** Shared roles, processes, and data structures allow all project types to issue credits that are consistent and comparable.
- **Tokenized Trust:** Verification events and audit trails are cryptographically recorded and traceable.
- **Modular by Design:** Each credit is backed by a Quality Standard (like a protocol or methodology) and tailored via MRV Extensions.
- **Continuous Verification:** Especially important for technology-based projects, enabling faster and more reliable credit issuance.

WHO IT IS FOR

- **Project Developers:** Can create digital, verifiable claims faster and more efficiently.
- **Corporate Buyers:** Gain confidence in the credibility and traceability of the credits they purchase.
- **Standards Bodies and Registries:** Can integrate existing methodologies into a digitized, future-proof system.
- **Investors and Auditors:** Rely on data-backed claims and digital audit trails to reduce risk and improve transparency.

While this paper is focused on the business aspects of the framework, the InterWork Alliance has also produced a technical specification that delves deeper into the details for those implementing solutions based on the framework.

This specification can be found at:
https://interworkalliance.github.io/TokenTaxonomyFramework/dmrv/spec/index.html

PURPOSE

The Digital MRV (dMRV) Framework outlines the terminology, roles, process workflows, generic evidence packaging, and attestations that digital MRV solutions should follow. It describes an asset origination supply chain (dMRV network), where different roles are responsible for different parts of the process. Through the establishment of a common roles-based process and a standardized, extensible data model, the framework aims to support the creation of data-backed environmental assets using a variety of standards, protocols, and technologies.

TARGET AUDIENCE

The dMRV Framework serves to benefit many different stakeholders in the environmental markets space. For Project Developers, the framework allows for faster and more efficient creation of digital, verifiable claims and provides guidance for the use of dMRV in production. Corporate Buyers can have increased confidence in the credibility and traceability of the credits they purchase. Investors and Auditors can rely on data-backed claims and digital audit trails to reduce risk and improve transparency. Standards Bodies and Registries can also integrate existing methodologies into a digitized, future-proof system and enable easier re-use for future projects using those methodologies.

The framework recognizes the distinction between nature-based[1] and engineered/technology-based projects and provides the digital infrastructure for both types to coexist under a shared, modular system. The IWA also recognizes that there are projects which are not wholly captured in the categories of nature-based and technology-based solutions, such as carbon credit projects for plastics recycling. Those projects can also leverage the dMRV Framework for their implementations through its extensible structure.

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1   https://www.unep.org/topics/nature-action/nature-based-solutions/overview-nature-based-solutions

SUMMARY OF VERSION 3.0 CHANGES

Version 3.0 of the dMRV Framework introduces targeted but important updates that enhance the framework's usability and scalability. The most significant change is the introduction of MRV Extensions Sets, a grouping of templates which encompass entities, messages, formulae, and variables that are specific to the Quality Standard or Methodology that the Activity Impact Module is bound to. These MRV Extension Sets can be defined by the supplier, verifier, and issuer as part of a collaborative process based on a set of methodology modules.

By allowing MRV Extensions to be modularized, third parties can independently digitize methodologies and contribute them back to the framework, reducing duplicative efforts and ensuring consistency and interoperability between systems. This enables the creation of a publicly-available library of modules that other dMRV participants can use in their own operations. These MRV Extension Sets can be defined by the supplier, verifier, and issuer based on a set of methodology modules.

Version 3.0 also includes the renaming and grouping of certain data fields for clarity based on feedback received by the IWA from various stakeholders.

dMRV FRAMEWORK OVERVIEW

Before getting into the technical architecture of the dMRV Framework, this section provides a high-level definition of dMRV, why it matters, and how it addresses critical gaps across both nature-based and technology-based project ecosystems.

WHAT IS dMRV?

Digital, or digitized, Measurement, Reporting, and Verification (dMRV) is an approach to MRV which implements digital technologies and automation to streamline the MRV process, increase the reliability and accuracy of environmental data, and increase transparency around environmental impacts and claims. Examples of dMRV features include: sensors and satellites used to collect data, blockchain to tokenize environmental claims and carbon credits, and software to analyze environmental data and package it for validation/verification purposes.

WHY USE dMRV?

Traditional MRV systems are often manual, fragmented, and costly - especially for nature-based projects that rely on long validation timelines and often indirect measurements. As environmental markets scale and technology-based solutions like renewables and CDR require fast, continuous verification, there is growing demand for real-time, evidence-backed, and interoperable systems. Digital MRV was developed to help meet this need by enabling stakeholders to better understand who is providing and attesting to each piece of environmental project data. This enables environmental assets to be digitized from the point of origination. dMRV is an objective tool used to quantify environmental impacts and is complementary to traditional MRV implementations.

The dMRV Framework addresses both types of projects:

- For nature-based projects, it streamlines validation and enables transparent measurement over longer timeframes.
- For technology-based projects, it supports rapid, automated verification cycles with near real-time data capture.

KEY BENEFITS

- **Market Integrity -** Verifiable provenance for every claim, reducing double-counting
- **Transparency -** Enables digitally auditable and traceable project outcomes
- **Flexibility -** Supports multiple methodologies for both nature- and technology-based projects
- **Scalability -** Modular workflows reduce costs and speed credit issuance
- **Accuracy -** Enables granular monitoring - from field sensors to industrial systems - and allows for built-in validation, decreasing calculation errors
- **Trust -** Linking between methodology and unit (intersection of data and unit of value) enables greater trust; tokenization alone does not guarantee trustworthiness
- **Efficiency -** Certification workflows can be accelerated from weeks to hours through automation[2]

While dMRV has the potential to offer these benefits, the degree to which they are realized is dependent on implementation. dMRV does not guarantee the above benefits inherently, as using dMRV will not make up for inefficient implementations. Additionally, regular audits of measurement devices, collected data, methodologies, and the systems being built - as well as standardization around the data collection itself - contribute to the realization of these benefits.

STAKEHOLDERS

Stakeholder	What dMRV Enables
Project Developers	Faster reporting and credit issuance across nature- and technology-based projects; Better data quality and supporting evidence
Buyers	Confidence in integrity and ESG alignment
Registries & Standards	Integration of both traditional and innovative methodologies into a common data model
Investors & Auditors	Transparent, traceable claims and reduced risk across asset classes

VALUE PROPOSITION FOR STAKEHOLDER GROUPS

## WHAT IS THE dMRV FRAMEWORK?

The dMRV Framework provides the high-level, implementation-neutral, specification for creating a solution that creates standardized claims into an open ecosystem for validation, verification, and crediting. This framework builds off the "Voluntary Ecological Markets Overview Version 2" standard[3] that was previously published by the InterWork Alliance to enhance global agreement on terms, definitions, and basic understanding of the process for creating ecological or environmental assets like carbon credits.

This framework brings Process, Data, and interchangeable science-based Quality Standards together that can operate under a governance framework to facilitate adjustments and create an inclusive and fair playing field for all participants.

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2   https://guardian.hedera.com/methodology-digitization/methodology-digitization-handbook/part-1/chapter-1
3   https://assets.ctfassets.net/so75yocayyva/2hDgOuwSInFmXaKDWB7r7v/496b5c751a3c18c3b7eb4ce7ccf5ad1d/Voluntary_Ecological_Markets_VEM_2_-_IWA.pdf
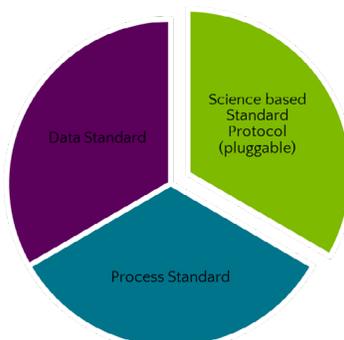
The pluggable Quality Standard, which may include multiple modules, is specific to the type of activity being implemented and the source of beneficial claims. These Quality Standards are typically modular in themselves and combine: a "methodology", or "protocol", that is specific for the activity being measured or monitored; a generic program or process; and options for implementation that enable optimal methods for measuring and qualifying project claims (e.g., additionality, permanence, etc.). Quality Standards define steps to establish a valid project and detail the required evidence and calculations used to quantify the benefit of the project's activity (e.g., tonnes of CO2 equivalent (tCO2e) removed).

The Quality Standard that a project follows will set the guidelines for what data collection requirements exist for a dMRV solution. For instance, the Quality Standard will specify the evidence that should be collected, from which sources the evidence should be gathered, and at what cadence the evidence will be reported. The Process and Common Data Standard remain the same across Accountable Impact Organizations.

Traditionally, Quality Standards have been governed by accredited registries (e.g., by ICROA) as options that project developers can choose from. However, recent advancements and innovation have led to the development of new "methodologies" and "protocols" by consortia, start-ups, and academia that are accelerating time to market and issuing credits using non-traditional techniques. This is likely a symptom of the traditional market infrastructure being unable to scale to meet the advancements and governance of new techniques. As Quality Standards and market participants become digitized and optimized, it is likely that the future form factor of environmental markets will resemble a convergence of traditional and innovative solutions.

POSITIONING

This section provides an overview of some of the key standards, frameworks and initiatives relevant to dMRV. The IWA dMRV Framework is designed to complement these other efforts. It provides a technical data foundation that supports initiatives focused on aggregation, labeling, governance and market integrity.

Note: the list below is not exhaustive since new working groups continue to emerge. If you are part of a group that is not represented here, please reach out to **iwa@gbbc.io** for inclusion.

POSITIONING WITH OTHER STANDARDS, FRAMEWORKS, AND INITIATIVES

Name	Type	Purpose	IWA's Complementary Role
CDOP (Carbon Data Open Protocol)	Standards	Aims to create a standardized, open data schema for the pre-issuance phase of carbon projects. Standardizes outputs into a consistent format for registries, crediting programs, and market participants.	Provides the granular, methodology-specific evidence that CDOP consumes and aggregates.
Carbon Standards and Registries (such as Verra, Gold Standard, ACR, etc)	Standards	Defines methodologies and/or issues credits.	Carbon registries and standards bodies benefit from digital extensibility and machine readable formats for methodologies and issuance data.
G20 Sustainable Finance Working Group (SFWG)	Framework	Develops policy frameworks, sustainable finance roadmaps, and standards at a macro-financial level.	Offers the foundation of data integrity and methodology linkage, enabling credible implementation of high-level policy frameworks.
ICVCM (Integrity Council for the Voluntary Carbon Market)	Standards	Defines Core Carbon Principles (CCPs) to set quality standards for credits, crediting programs, and methodologies.	ICVCM's CCPs can be grounded by IWA's methodology-based data attributes.
IETA (International Emissions Trading Association) – Digital MRV Working Group	Initiative	Builds industry consensus for digital carbon market infrastructure.	Provides the technical data foundation to support consensus building.
VCMI (Voluntary Carbon Markets Integrity) Initiative	Framework	Provides a framework for companies to make credible claims about carbon credit use.	VCMI's claims framework is strengthened by machine verifiable proof to support credible corporate claims and disclosures.
World Bank Carbon Markets Infrastructure Working Group	Initiative	Publishes reference papers and policy guidance for digital carbon markets	Reinforces alignment with World Bank Knowledge Hub outputs and provides policy-linked technical building blocks.

A LAYERED VIEW OF THE ECOSYSTEM

This layered approach illustrates how IWA's dMRV Framework provides the technical foundation, enabling interoperability and trust across the broader carbon market ecosystem.

Layer 4	**Market and Application Layer** Examples – Registries, Corporate Disclosures, World Bank Guidance, G20 SFWG	Issues credits, supports compliance reporting, and informs investment or policy decisions.
Layer 3	**Governance and Integrity Layer** Examples – VCMI, ICVCM, IETA	Establishes market-wide integrity principles, usage rules, and governance standards.
Layer 2	**Aggregation and Labeling Layer** Examples – CDOP	Consumes data to generate comparable statistics, indexes and labels which can be aligned with IWA guidance.
Layer 1	**Evidence and Methodology Layer** IWA dMRV Framework	Defines attributes, protocols and technical specifications for origination of credits through a multi-party workflow. Provides granular evidence that is independently verified and creates a new level of trust through transparency and attestations throughout the process.

ARCHITECTURE SNAPSHOT

You can view a PDF version of the full dMRV Framework architecture **here**.

FRAMEWORK COMPONENTS AND DEFINITIONS

The dMRV Framework defines components that represent roles, process artifacts, and subsystems that work together to package evidence in a claim that can be independently verified in standard processes. Each of these components provides a placeholder or variable that can be replaced with a specific actor, artifact, or subsystem, allowing the framework to be generic and support a wide and diverse set of implementations.

For example, solutions using the framework for soil carbon sequestration through agricultural practices would have different standards and sources of evidence than a direct air capture program, but each solution would create a standard claim that plugs into a standard process.

ROLES & INSTITUTIONS

Accounting & Environmental Claims Registry
An organization that maintains and governs a portfolio of protocols or methodologies which certifies Validation and Verification Bodies (VVBs) to validate projects and verify their claims based on the protocol or methodology. The Accounting & Environmental Claims Registries then issue credits from these validated and verified claims. There is ongoing **debate** regarding the legal definition of a registry, which we will not delve into in this publication.

Certification Standards Body
An organization that creates and certifies science-based standards, e.g., protocols and methodologies, for measuring environmental impacts and benefits. This may be an industry consortium, academic partnerships, or a single organization.

Validation & Verification Body (VVB)
An organization that is contracted to validate and verify impact claims, based on a standard, to ensure that the protocols and methodologies were followed and that the evidence collected supports the claims. The VVB first validates the AIO's plan against the Quality Standard being followed; once completed, the claims verification process can begin. In conjunction with the Verification Automations, VVBs' work can be scaled or enhanced.

PROCESSES & INFRASTRUCTURE

Standard Program (with a Methodology)

A methodology is comprised of forms, workflows, and calculations (parameters); these roll up into a methodology which is in turn governed by a standard program. For example, Verra runs the Verified Carbon Standard (VCS) Program, a GHG crediting program. The VCS Program is made up of:

- the VCS Standard: lays out the rules and requirements that projects must follow in order to be certified;
- independent auditing: conducted by both Verra staff and qualified third parties to ensure that "a project meets the standard's rules and requirements; that its methodologies are properly applied; that it complies with local laws and regulations; and that no local stakeholders experience negative repercussions because of the project;
- accounting methodologies: sets out detailed procedures and formulae for quantifying environmental benefits for a specific set of activities within a distinct project type;
- and a registry system: where all information related to a project is stored and made publicly available, also tracks the generation and retirement of all Verified Carbon Units (VCUs)

A science-based standard, often called a methodology, is incorporated in a Quality Standard for making a claim that a specific activity leads to a quantifiable environmental impact. For example, that a project activity caused the removal of a specified quantity of carbon over a certain period. A protocol is specific to the type of activity and can vary based on its location, time, duration, etc. It defines the kind, amount, and frequency of evidence collected from required source(s) and formulae for using the evidence to determine the values of the claim. For example, determining the amount of carbon removal as well as other attributes like durability, additionality, co-benefits, etc.

The terms "protocol" and "methodology" are often used interchangeably. The protocol is the framework, and defines principles (e.g., accuracy or conservatism). The methodology is the step-by-step process to define the scope, gather the data, quantify the environmental impacts, and report the evidence.

A combination of methodologies may be grouped together into modules to facilitate credits that are derived from multiple steps in the process that may be carried out by different parties. Carbon Capture and Storage, as an example, requires that there is a methodology for measuring the quantity of carbon captured, that then needs to be transported to a storage facility or medium. Each phase of capture, transport and storage has its own module that must be combined together to prove that carbon was removed and for how long (i.e., durability). The combination of these modules become a part of the Quality Standard.

Verification Automations

Solutions, platforms, services, etc., designed to accelerate the verification of claims. Depending on the Quality Standard, it may be able, with appropriate audit requirements, to perform full verification of claims issuance for impact credits. For other Quality Standards, these platforms or services may automate and prepare findings data that are evaluated by a VVB in order to speed up and support a continuous verification process.

Project Validation

Before an Activity Impact Module can begin creating claims for verification, the project must be validated by a certified VVB against the Quality Standard being followed. This process can vary, but usually includes several steps and requires the production of documents, like a Project Design Document (PDD), and may also include legal documents to be submitted, such as proof of ownership, title, lease, etc.

Project Design Document (PDD)

An Activity Impact Module needs to be validated or approved by an appropriate authority (i.e., the validation body or issuing registry) before the claims verification process can begin. This is when a project's baseline is established and the activities of the project will be tracked and reported. This traditionally has been done in a PDD, a word processing document that follows a template provided by the issuing registry.

MRV Network

A shared set of infrastructure where the Data and Process standards are implemented that provides storage, compute, ledgering, and other capabilities for all participants.

A Data standard includes the generic data elements that all activities should generate as well as specific "Quality Standard" data properties required by the standard.

A Process standard includes the generic "lifecycle" of originating claims and workflow elements to enable automation.

Digital MRV Solution

An implementation of this framework that follows a protocol using a combination of technical devices, services, data sources, and applications to automate as much of the claim creation process as possible.

A digital MRV solution is comprised of 2 parts:

- A Digital Measurement and Reporting Solution that an Accountable Impact Organization uses to create Impact Claims by checking evidence in via checkpoints.
- A Verification solution that the VVB uses to verify Impact Claims created by the Accountable Impact Organization via the Digital Measurement and Reporting Solution.

These 2 solutions integrate and communicate with each other using MRV transactions, extensions, messages, and events.

Long Term Monitoring Solution

A solution that monitors AIMs that have had credits issued which looks for events that would impact those issued credits, such as a reversal event.

For example, a Monitoring Solution may use geospatial data and analysis to detect a forest fire, early harvest, or disease that causes a significant decrease or reversal of an issued carbon credit's durability and quantity.

DATA COMPONENTS

Accountable Impact Organization (AIO)

The identity and metadata about a program or project that will be hosting or sponsoring one or more Activity Impact Modules (AIMs). The AIO is a way to group multiple modular projects logically to support different business models. Each AIO has one or more "owners" that references the accountable identity (i.e., individual or organization).

For example, an AIO can represent a single farm operating a project that will make carbon removal claims and another that will make water claims. Each claim type is associated with a different Quality Standard and will result in different credit types being issued, but are managed by a single organization.

Or an AIO can represent an organization that will host multiple AIMs in different geographic locations, like solar deployments in different countries or states.

Examples:

- A farm that will have one or more AIMs for each Quality Standard it will implement for its location
- A solar company that will have an AIM for each solar deployment they will make renewable energy claims from
- A Carbon Capture and Storage project will have an AIM for each phase of the sequestration process: capture, transport and storage. Further, each of these AIMs may be operated by different AIOs (organizations) that have their impact claims combined into a single issuance process

The Accountable Impact Organization establishes an organizational identity for one or more 'child', or 'sub', Activity Impact Module(s) and only contains basic organizational information primarily used for identification. Establishing a hierarchical project structure allows for organizational and benefit projects to be arranged logically, enabling many different business scenarios.

Activity Impact Module (AIM)

An Activity Impact Module, is a 'child' of an Accountable Impact Organization, and serves as the system of record for the actual type of project work that generates an impact being measured. An AIM is a unique combination of a location, land area or facility, and a Quality Standard - or one or more modules in it - that will be followed for the location. The AIM is a Project Module in the Origination Process Agreement, where the Quality Standard is identified as well as the verifier(s) and issuing registry.

AIMs are the source for the claims process and is where the evidence is provided for creating one or more claims about beneficial impact, such as a claim of carbon removal. For example, an AIO may want to create claims for carbon removal and water for the same location, thus having an AIM for each. An AIM must be validated before it can begin submitting claims for verification.

An AIM contains information about who the developers or workers are, the project's geographical boundary, its link to a Quality Standard or module, etc. It can have one or more "developers" and "sponsors", where a developer is the party performing activities and a sponsor can be the party financing the activities. AIM developers, or their automations, are responsible for submitting claim checkpoints.

Quality Standard

Requirements for measuring outcomes, based on approved methodologies or protocols, that result in high-quality credits being issued. A Quality Standard, often an independent crediting standard, can encompass one or more Standard Protocols or Methodologies, a crediting program, measurement tools, and certification requirements for a VVB.

Claim Sources

Activity Impact Modules produce claims that contain evidence. In order for the contained evidence's provenance to be established, a 'Claim Source' must be registered with the AIM. These sources are registered with the Impact Claim as valid sources of evidence. Some examples of claim sources would be:

- A device or sensor that takes measurements
- An application that runs on a mobile device that uses the device's sensors, GPS, etc., and the authenticated user to collect and submit evidence
- A 'reference' source could be a Factor Library like the US EPA, IPCC, etc. libraries and version
- A 'service' like a geospatial or satellite provider to provide biomass estimates or other remote sensing capabilities

Because the capabilities of these sources of evidence can vary, the method for establishing an identity for them to register will as well. There are several techniques for identifying a source and various ways to ensure evidence integrity to prove that evidence came from a registered source. Newer methods for establishing identity and integrity of data will be more thorough and trusted, but we also need to support older, less capable sources of evidence that can be phased out over time in favor of fully identified and validated sources.

For example, newer devices can establish an identity based on Decentralized Identities and Verifiable Credentials[4] and are able to attest to their own evidence, see **Attestation**. Other devices may be able to support public key infrastructure (PKI) and digitally sign their evidence. And in many cases, only a device make, model and serial number are available. In this specification we provide a general framework to support as wide a range of sources and compatibility as possible, while recommending that sources migrate over time to higher trust capabilities.

MRV Extensions

MRV Extensions are templates that describe a methodology module-specific data extension that allows for the framework to be customized to work in detail across various crediting and methodology programs.

There are currently 4 types of MRV Extension Templates:

- **EntityExtensionTemplate -** allows for any entity in the specification to be extended with custom properties
- **FormulaTemplate -** defines a methodology specific formula that all parties participating in the MRV will use to calculate outcomes
- **VariableTemplate -** defines a parameter/variable that is recorded and used in formulae as inputs
- **MessagePair -** defines a request/response set of messages to allow for customization of creation of new workflows within the process

When a template is used, it creates an instance of that type, which refers to its template for identification and details about its meaning. Each of these templates contains a custom, user-defined data type that is implemented in the instance, which is stored on the ledger.

MRV Extensions allow for the creation of a custom "language" that is spoken by each participant in the dMRV process, enabling participants to be very specific about their activities while still using common infrastructure.

MRV Extension Set

An MRV Extension Set is a collection of MRV Extension Templates that can be organized further into Extension Set Modules. If a project has multiple modules, the templates used by each module are contained within its Extension Set Module. If there are not multiple modules, all templates can simply be defined in the root Extension Set.

See **Section 4** for more detail on MRV Extension Sets and Template types.
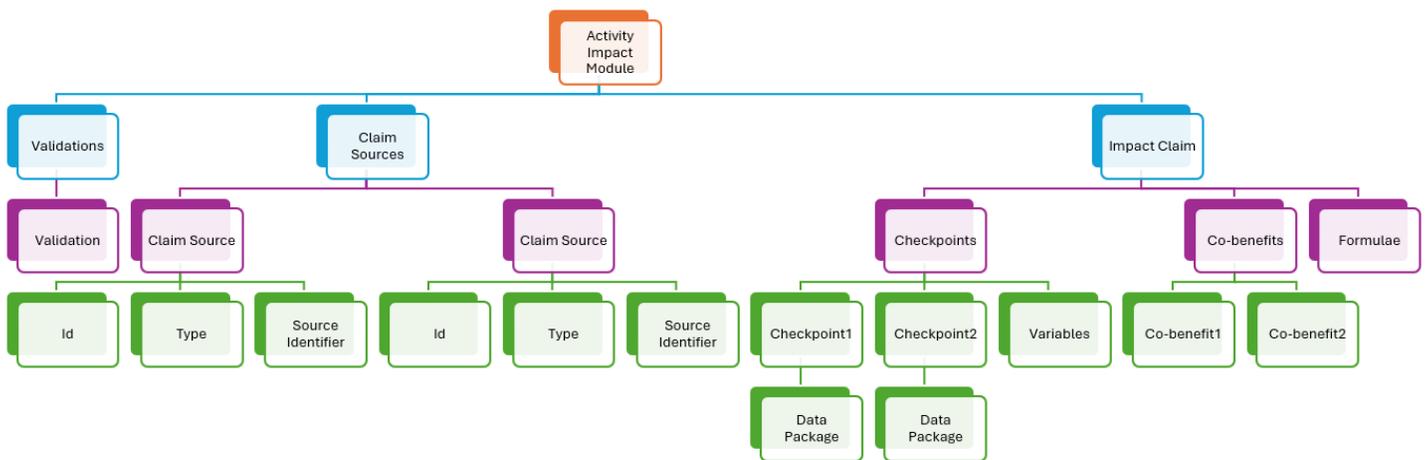
Impact Claim

The Impact Claim is the standard foundation for dMRV solutions to create and submit a claim on the MRV network. It has metadata about the claim and collections of children entities such as sources, checkpoints, and co-benefits. An Impact Claim is made by an Activity Impact Module in accordance with its validated Project Design Document (PDD), The PDD follows the requirements of a quality standard, an applicable methodology, and protocols required to generate the necessary evidence for validation of the claim.

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4   https://www.w3.org/TR/vc-data-model/#introduction

Impact Claims are established for a claim period, typically the same as the issuance period (i.e. annually or monthly), and contain checkpoints where evidence is submitted as it is collected. Impact Claims also can contain any formulae to document how outcomes during the period are determined. A completed claim output is similar to a Monitoring Report, except that it is primarily intended to be machine readable, whereas a Monitoring Report is designed to be human readable. Some solutions may generate both machine and human readable output.

The Impact Claim, once it is open for verification, notifies the VVB/Verification Automations to begin verification. Although it is likely that only a single VVB/Verification Automation would be verifying a claim, because claims are composed of checkpoints, it is possible for multiple VVBs/Verification Automations to split verification across checkpoints. An AIM would support multiple VVBs/Verification Automations and would have these parties identified as signatories to the Origination Process Agreement. Validation and verification can be conducted by separate entities.

IMPACT CLAIM WITHIN AN AIM

Impact Claim Checkpoint
A submission of prescribed evidence data made towards an impact claim based on a cadence or schedule required by the standard methodology or protocol being followed. An impact claim is made of a collection of checkpoints. The checkpoint is a cryptographic fingerprint of the evidence data contained within a Data Package (DP) to establish the provenance and integrity of the evidence being submitted. A checkpoint can also contain variables that can provide a summary snapshot of specific measurements used in the calculation of benefits. Meaning that the checkpoint's data package contains the granular evidence (i.e. measurements), and the checkpoint's variable can provide the sum of that evidence. These variables provide checkpoint summaries and are not intended to be used for verification, which requires that the data package be examined and independently summed.

Once the digital MRV solution creates a DP, it will need to submit it to the Impact Claim as a Claim Checkpoint. The DP will be securely stored and a cryptographic fingerprint for the DP acts as a receipt embedded in the checkpoint.

Data Package (DP)
A Data Package is a file package (e.g., .zip file, etc.) that contains data from registered sources that is to be stored as evidence for a claim and used to create a claim checkpoint over a specific time span. It is up to the dMRV solution as to the actual data format(s) so long as it is agreed to and understood by the parties involved in the verification process.

Each DP has a "manifest.json" file in the root of the package that contains metadata about the files included and the sources the evidence originates from. The manifest.json is extensible to allow for specific extensions for digital MRV solutions and Quality Standards, allowing each protocol or methodology to have a customized digital MRV implementation while also co-existing with other digitized protocols or methodologies. This includes identifiers like the Accountable Impact Organization, the Activity Impact Module, and the Claim that the DP is for, as well as extensible MRV and Quality Standard metadata that is defined by the participants and stored on the MRV network. It can also include digital signatures of claim sources. The DP is immutably stored, and its cryptographic fingerprint is recorded in the claim checkpoint.

Claim sources are registered with the Impact Claim and provided an ID. This ID is used to validate and verify that the data contained within the DP is from the registered source. Some sources may be capable of digitally signing their evidence, in which case the source's public key would be registered with its ID.

Example claim sources that can be registered: IoT Sensors, Reference Data (e.g., Satellite, Remote Sensing, etc.), In-person Sources (e.g., an application, device, or human)

DATA PACKAGE
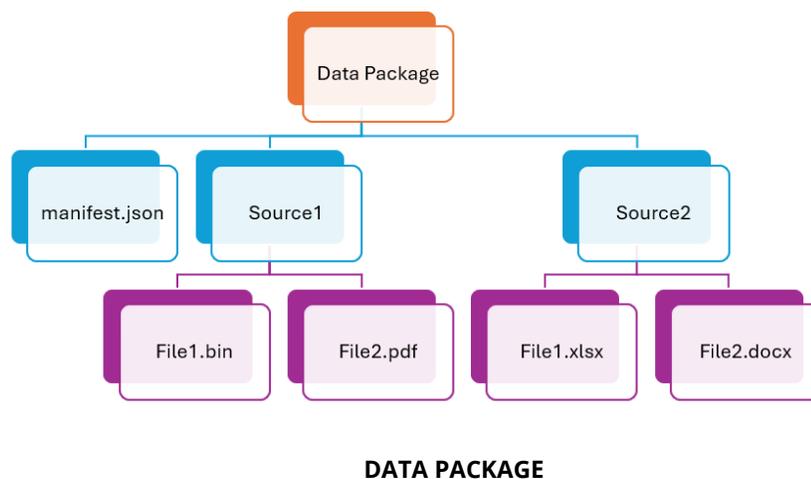
Processed Claim

The Processed Claim is created by the Verification Automations or VVB to record its findings during the validation and verification process. Once an Impact Claim is open for verification, the verifier (e.g., VVB) will begin processing the Impact Claim it is verifying and will open a Processed Claim to document the process. To support continuous verification, an AIM developer(s) can continue submitting checkpoints throughout the claim period, and the VVB can add Checkpoint Results as they are verified. Once the Processed Claim is completed, the platform and/or VVB finalizes the Impact Claim and provides the necessary data in the request for issuance for the issuing registry to consider. Like the Impact Claim, Processed Claims can also have a Formula representing the Verified Formula, while the Formula attached to the Impact Claim is from the "Supplier" which is not yet verified by the VVB. The data review process is captured in the Processed Claim and recorded in the Checkpoint Result.
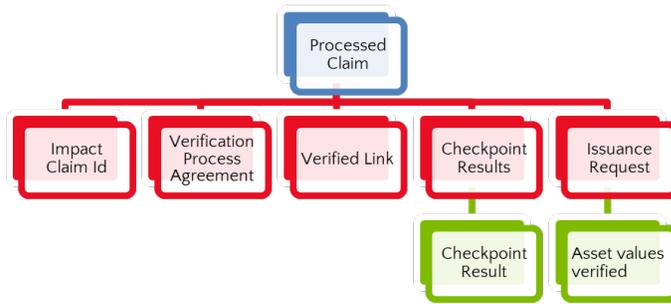
PROCESSED CLAIM

Checkpoint Result

To support continuous verification, a VVB may create a Checkpoint Result for each Claim Checkpoint that is verified. This Checkpoint Result may contain communications, via Message Pairs, between the VVB and the Accountable Impact Organization about the data contained in the checkpoint, such as a request for clarification. Like the Checkpoint, Checkpoint Results can also have Variables, where a Variable attached to the Checkpoint is from the "Supplier" as a claimed value and the Checkpoint Result Variable is the Verified value. The Checkpoint Result could contain a verified link to a package of verification data, similar to the Data Package, as well as variable summaries that provide a verified sum for the variable or parameter contained within the Checkpoint Result.

Claim Group

A group of Impact and Processed Claim pairs from different AIMs that are grouped together in order to combine claims from multiple projects , potentially from different organizations, into a single claim group for processing (e.g., Carbon Capture and Storage modules or a project with modules for both soil and water claims). Claim Groups can only be associated with a single Origination Process Agreement.

Origination Process Agreement

The Origination Process Agreement is central to the origination or manufacturing process and brings together the parties, rules, policies, and procedures between the parties involved. A single AIM, or optionally multiple AIMs in multi-module Quality Standards, are identified as Project Modules within the agreement along with the VVB(s) for validation and verification, Quality Standard, Issuing Registry, and/or other required parties for the issuance of credits for claims made under the agreement. Every artifact created in this process is linked back to the Origination Process Agreement. There is the potential for the Origination Process Agreement to be implemented as a set of smart contracts or other processes.

The details, such as the Standard, Version, Protocol, and Extension Set(s), are all agreed to and documented by the signatories of the agreement. A project AIM may choose to switch standards or VVBs, which would require a new Origination Process Agreement to be executed and the old agreement archived.
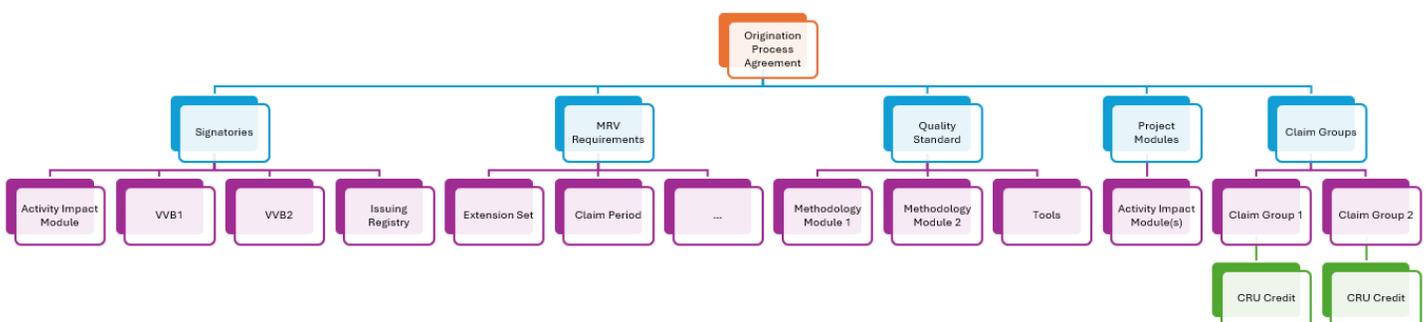
PROPERTIES OF AN ORIGINATION PROCESS AGREEMENT

Impact Benefit Token Example: Carbon Removal Unit

The IWA VEM Overview generically describes a tokenized value representing an impact benefit token. It provides an example of a carbon reduction/removal unit:

- Carbon Removal or Reduction Unit token (CRU) – is for removals or reductions and is non-fungible with other tokens of any type.

There is another token designed for distribution or markets called a Carbon Reference Token (CRT) that references CRUs; it is not covered in this framework.

The credit that is issued by the standard (registry) upon final verification of a Processed Claim. This creates a chain of lineage from the issued credit to its Processed Claim and to the source Impact Claim.

Today's voluntary carbon credits often have "co-benefits" attached that map to one or more of the UN Sustainable Development Goals (SDGs). There are some co-benefits, and others in development, that are intended to be able to stand on their own and be either bundled with a credit or traded separately. These independent co-benefits should follow the same process as an Activity Impact Module, meaning they are sourced from the same Accountable Impact Organization, but are defined in their own AIM that is mapped to a Quality Standard for the Co-benefit type, and need validation and verification of claims.

Dependent co-benefits are defined within the AIM for the credit they are dependent upon, and independent co-benefits are defined in their own AIM.
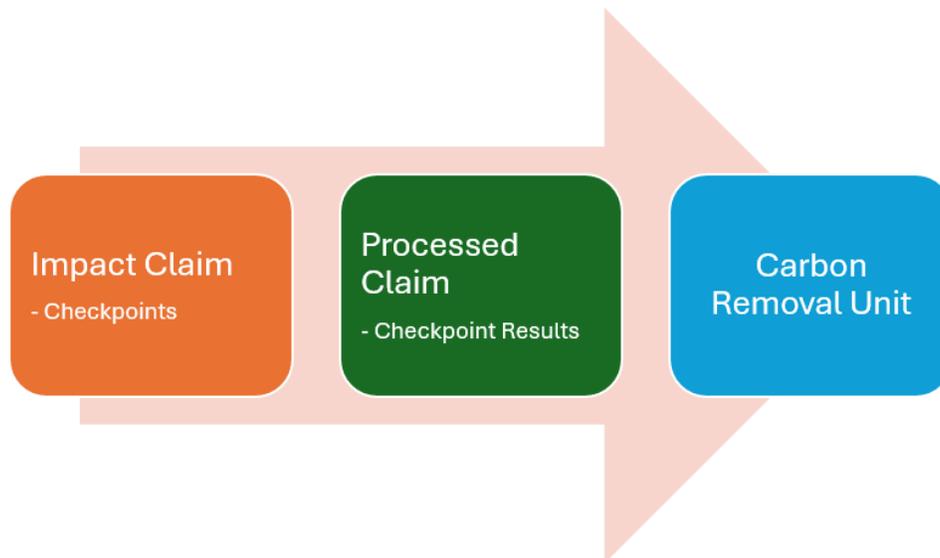
CARBON REMOVAL UNIT GENERATION

MODULARIZATION AND MRV EXTENSION SETS

Environmental assets, like carbon credits, can be originated by the work of many different project activity types. Projects usually fall into either nature- or technology-based projects, or some mixture of the two, by performing activities and presenting evidence of results in radically different ways. Because of this, a project follows a Quality Standard that governs a project's activities and the data they need to produce in order for a credit to be issued. The dMRV specification supports this diverse set of activities using Extension Sets which allow for the participants in the origination process to define very specific workflows and data schemas to support the project's activities. This allows for an implementation of the specification to support a wide range of projects and for those performing the dMRV process to have a customized experience while using the same infrastructure.

WHAT ARE MRV EXTENSION SETS?

Version 3.0 introduces MRV Extension Sets, a grouping of templates which encompass entities, messages, formulae, and variables that are specific to the Quality Standard or Methodology that the Activity Impact Module is bound to. They are typically composed of multiple MRV Extensions for modules or activities and can be defined by the supplier, verifier, and issuer based on a set of methodology modules. To support Quality Standards that have multiple modules or phases of a process (e.g., Carbon Capture, Transport and Storage or projects which are making claims related to both soil and water), Extension Sets can be organized into Extension Set Modules that act as a shared library of MRV Extensions available to participants in the dMRV process. Through this process, we aim to create reusable libraries that dMRV participants can use as a starting place for conversations with registries and other relevant stakeholders while allowing for the contribution of new Extension Sets from third parties as methodologies are further digitized.

HOW TO BUILD AND USE EXTENSION SETS

Issuing Registries govern a set of methodologies under their issuing programs for specific types of projects. These methodologies are large documents that describe the process a project must follow in order to have credits issued based on their activities. For example, methodologies use formulae and parameters, or variables, to determine the quantity of credits that will be issued that all the parties involved use to document and verify activity outcomes.

An Extension Set is rooted in these methodology documents and puts it into a digital, machine readable format so that most of the activities in the process can be automated. Extension Sets should be created collaboratively by the supplier, VVB, and Issuer, usually as an iterative process.

Each methodology, or modules of a methodology, is used to extract Extension Templates:

- **Entity Extension Templates -** are data that are needed for an entity, like an Activity Impact Module, that does not exist in the dMRV schema. These extensions allow for the customization of the pre-defined entities in the specification that the methodology requires
- **Formula Templates -** are pulled from the documentation and used to record the formula syntax and additional documentation that is agreed upon by all parties in the dMRV process
- **Variable Templates -** individual parameters/variables that are used in formulae that represent a data point used in the calculation of the formulae
- **Message Pairs -** a set of request and response messages that allow for custom workflows to be introduced and recorded in the dMRV process
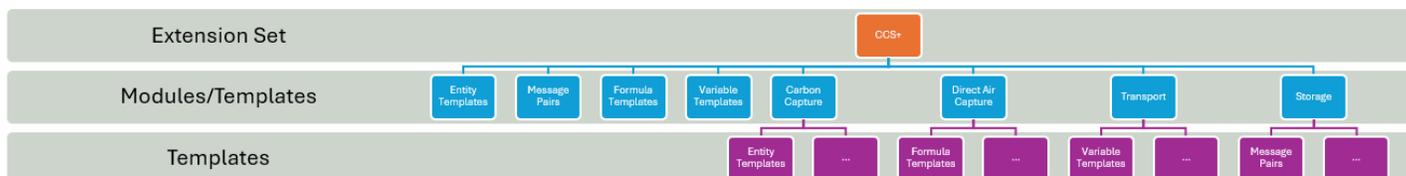
EXAMPLE OF MRV EXTENSION SET FOR CCS+

Each template is given a globally "static" identifier, meaning it will never change, and is then added to the Extension Set or Extension Set Module. Once added, it becomes a registered "type" that all parties in the dMRV process will be able to understand and agree upon. Each template usually contains a custom defined user type where the actual extension data is stored. Templates are essential for establishing these custom data types so that they are understood by all parties in the dMRV process.

Parties in the dMRV process use the templates to create instances that reference their parent template, and record those instances in the dMRV data. When another party wants to read the data, they will use the parent template to understand the instance.

Once an Extension Set is created, it can be contributed back to the IWA where it can exist in a publicly-available repository of other extension sets. This contribution must include data, which can be sample data, to allow for testability and show that the input data is properly handled within the Extension Set. This allows for others using the same methodology to more easily re-use the Extension Set as a way to begin conversations with their chosen registry. The IWA has made available a **sample** MRV Extension Set and will publish a full implementation example in 2026.

HOW TO CONTRIBUTE AN EXTENSION SET

Once an Extension Set has completed development alongside the relevant stakeholders, it can be contributed to the IWA's repository of Extension Sets by issuing a pull request to this folder in the IWA's GitHub repository: **https://github.com/InterWorkAlliance/TokenTaxonomyFramework/tree/main/dmrv/extensions**

In addition to the Extension Set itself, the submission MUST include:

- The name of all organizations involved in the development of the Extension Set
- A valid email address of the person making the pull request to facilitate any follow-up
- The date the Extension Set was created
- Sample data for users to test the validity of the Extension Set

The IWA will review the Extension Set submission for completeness and to ensure that sample data has been provided. If approved, the pull request will be accepted and the Extension Set will be added to the library. If not approved, the IWA will reach out with feedback on what changes need to be made for the submission to be approved.

GOVERNANCE AND REUSE STRATEGY

Example MRV Extension Sets will be contributed as they are developed. It is expected that Extension Sets for different registry programs and methodologies will develop organically and be open source to encourage reuse and improve overall quality, helping bring both stability and consistency of origination to environmental markets.

Once contributed, the extension sets will be reviewed by the IWA's working group for completeness and added to the public repository. The IWA will not verify the accuracy of the formulae, variables, entities, or messages contained in the Extension Sets as they are often the product of lengthy conversations between multiple parties. Due to the complexity and differentiation between methodologies and registries, organizations looking to use the Extension Sets to accelerate their development cycles should perform due diligence when using the Extension Sets to ensure alignment with existing registry requirements.

SECTION V
FRAMEWORK LIFECYCLE AND WORKFLOWS

Components in the framework work together following a process that generates artifacts documenting and attesting each step along the way. Participants in this process are actors fulfilling a role, either contributing data, verification, and/or providing attestations that are cryptographically and immutably recorded by the MRV network.

The MRV network is the system of record for the participants in the process where entities like the Accountable Impact Organization, Activity Impact Module, and Impact Claims are recorded.

PROJECT VALIDATION: STEP 1

Activity Impact Modules are required to be validated by a VVB according to the Quality Standard the AIM is following. The validation of an AIM may include multiple steps that usually have associated documentation that is generated or supplied. For example, an AIM will usually be required to produce a Project Design Document (PDD), which provides details about the project, what activities are to be conducted, and how evidence about these activities and their results will be collected. Additionally, an AIM may need to produce documents that prove land ownership or a lease to ensure that the AIM is properly licensed by authorities to conduct the activities.

Because the validation process can vary based on the Quality Standard (e.g., one that is for a nature-based project type vs.a technology-based project), the process is flexible to allow for Quality Standard-specific validation processes to fit within the generic framework.

Each AIM will have a collection of Validations that establishes the time the validation was performed, when it expires, as well as links to all of the steps that occurred or are in progress with verified links to any documents those steps produce.

CLAIMS PROCESS: STEP 2 – IMPACT CLAIMS

1. An Accountable Impact Organization, the identity of a source project that can make different types of claims, establishes an Activity Impact Module for each type of claim, or module, the host project will make (e.g., Carbon Removal, Carbon Transport, water, soil, etc.)

2. An Activity Impact Module selects a Quality Standard from a Standard Registry that matches the activity they will conduct to make a claim (e.g., Direct Air Capture, Soil – Crop Rotation & Covering, Forestry, etc.)

    a. There is a lot of development and refinement needed for Quality Standards for Carbon Removals and Reductions to digitize the protocols
    b. There may be scenarios where a Quality Standard is not under management of a Standard Registry, but another organization on the network would support the standard and issue credits for it

3. The Quality Standard will lay out a "methodology" that prescribes the sources and types of evidence (i.e., parameters and formulae) that are used to measure and monitor activities. This is presented in document format, usually a PDF.

   a. Development of AIM applications that will collect and submit the prescribed evidence, and a corresponding Verification Service or Platform to help automate the verification, is expected as quality standards digitize

4. Based on the selected Quality Standard, an MRV Extension Set should be developed that creates digital representations of the sources, data types (e.g., parameters or variables), formulae, and any additional data required that is not included in the dMRV Framework. These extensions are used by the participants in the process to customize the dMRV environment for the activities being monitored and verified.

5. An Origination Process Agreement is created, documenting the organizations participating, their role(s), the Extension Set, claim period, etc. Once the Origination Process Agreement is "signed" by all parties, the process can begin.

6. Activity Impact Modules begin creating an Impact Claim for the issuance period for the targeted credit. A claim will have a collection of formulae that are supported from the formula templates in the Extension Set.

   a. An Impact Claim is made up of a collection of Checkpoints, where each checkpoint can contain multiple variables (parameters) that are being reported as well as more finely grained evidence in a Data Package that could include things like hourly sensor readings.

   b. A Checkpoint is a submission of evidence as prescribed by the methodology.

   c. Protocol developers are encouraged to define a regular or event-based cadence for the creation of checkpoints for continuous verification and to provide claim progress downstream.

7. The MRV Network stores the evidence and records its cryptographic fingerprint in the ledger as checkpoints.

8. This process defines the Digital Measurement and Reporting Solution area for MRV.

9. There can potentially be a many-to-many ratio between Quality Standard and Digital Measurement and Reporting Solution, meaning that a dMRV Solution may be able to support multiple types of Quality Standards AND a Quality Standard may be supported by multiple dMRV Solutions.

CLAIMS PROCESS: STEP 3 – PROCESSED CLAIMS

1. An Impact Claim needs to be verified by a Validation & Verification Body (VVB) and may be assisted by a Verification Automation or Service that automates verification of evidence as much as possible. A VVB is certified by the Standard Registry that governs the selected Quality Standard for the Impact Claim.

2. Once an Impact Claim is open for verification, it will notify the Verification Automations/VVB that it is ready to begin processing, and a corresponding Processed Claim is created.

   a. The Impact Claim is verified by the Verification Automations/VVB as defined in the Origination Process Agreement and should not be processed by any other party.

   b. The AIM can continue to submit Checkpoints to the claim for continuous verification for the duration of the claim period.

3. The Verification Automations/VVB will verify each of the Impact Claim's checkpoints, creating a corresponding Checkpoint Result, recording their findings (e.g., variable value verification, etc.). The MRV network provides the chain of custody and cryptographic evidence for authenticity of the evidence and the actions taken by participants.

4. The verification process will record findings in the Processed Claim.

   a. The Processed Claim is linked to the Impact Claim.

   b. For each Checkpoint, a Checkpoint Result is created to record verification results and provide matching verified variables for those submitted in the Checkpoint.

   c. Once the reporting period and final checkpoint has been processed, the Verification Automations and/or VVB finalizes the Processed Claim and provides the necessary data in the request for issuance (e.g. monitoring or verification report), for the issuing registry to consider, containing the property values that were verified (e.g., total tonnes, co-benefits, etc.).

   d. The Processed and Impact Claim, or Claim Pair, are finalized.

5. The Issuing Registry that governs the Quality Standard used is notified of the Processed Claim.

6. The Verification solutions may be built and operated by Standard Registries or operated by independent organizations. There will be consolidation of these solutions aligned to the types of Quality Standards being used (e.g., Verification Automations focused on Forest Carbon, Soil Carbon, etc.).

7. These solutions align to the Digital Measurement and Reporting Solutions via the Quality Standard and Extension Set being followed (data formats, data sources, factors, etc.).

CLAIMS PROCESS: STEP 4 – ISSUING CREDITS

1. The Processed Claim can only be used to request issuance from the registry in the Issuing Registry role in the Origination Process Agreement, preventing any other registry from issuing credits.

2. The Registry may perform an additional KYC/Compliance check for the Accountable Impact Organization to ensure that compliance has been maintained.

3. Credits are issued based on the Processed Claim's findings/proposed credit (e.g., a Carbon Removal Unit equal to 20tCO2e).

   a. The credit issued on the network may be a token referencing the credit on the Issuing Registry. Implementors of the integration with the Issuing Registry should make sure that the credit on the Issuing Registry is locked, or moved to a controlled account, to prevent its transfer or retirement separately from the reference credit on the network.

   b. These credits become the property of the Accountable Impact Organization.

4. Credits may be enlisted in a Long-Term Monitoring solution (e.g., for nature-based carbon removals like soil and forestry). This monitoring system can determine deviations in durability or permanence that can result in the revocation and replacement of credits issued.

SECTION VI
CONCLUSION

The dMRV is a continual work-in-progress as the working group explores new areas, new developments emerge in the environmental markets space, and new information is brought to the group's attention. As such, collaboration is key to continue to improve and refine the framework so that it can help establish a common understanding of the Process and Data standards needed to support interchangeable Quality Standards. This modular approach to standardization, along with a foundation based on common terms and shared data descriptions, should aid in the development of new Quality Standards for a wide range of products in the future.

Thank you to the working group participants and to those external organizations and individuals who have provided feedback on the framework. For the continued development and evolution of the dMRV Framework, the working group welcomes and appreciates your feedback on Version 3.0 as we look to provide robust guidance to implementers and those interested in understanding how a digital MRV solution functions.

If you have feedback you would like to provide on the framework, please send that to **iwa@gbbc.io** and the group will consider that feedback for future iterations of the framework.
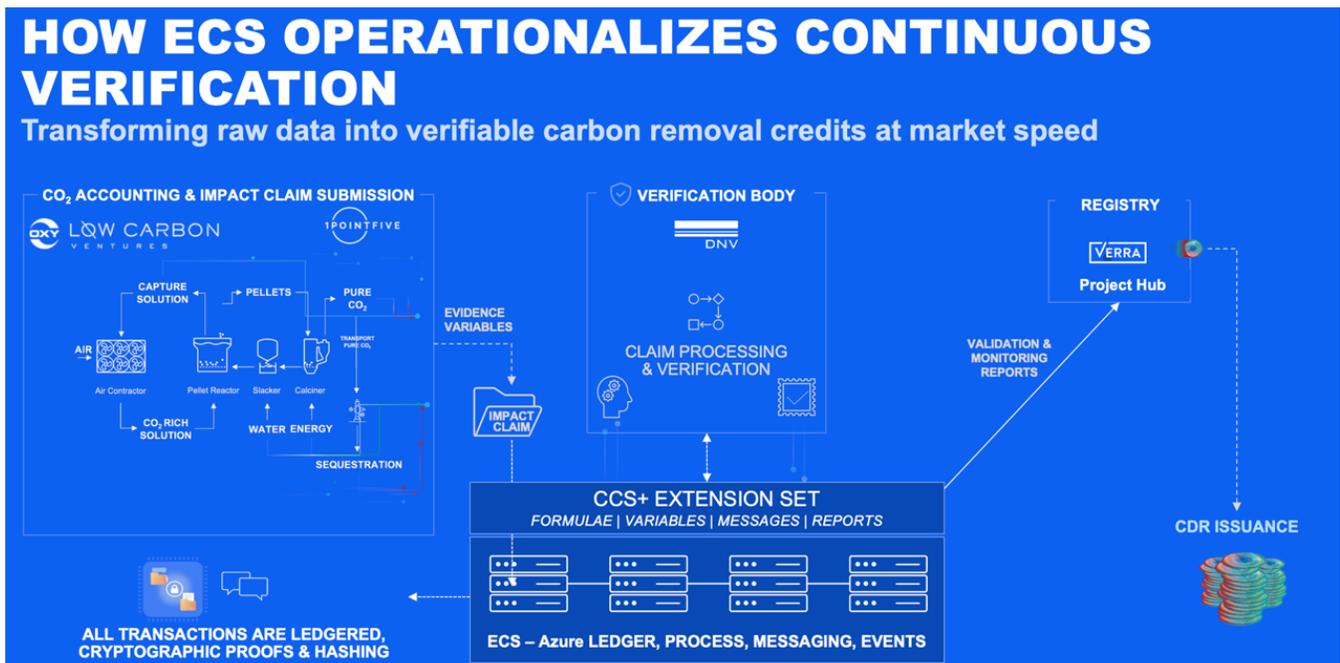
APPENDIX A: REFERENCE/IMPLEMENTATION EXAMPLES

1POINTFIVE - ENVIRONMENTAL CREDIT SERVICE & CCS+

1PointFive is developing a Carbon Dioxide Removal (CDR) crediting platform for their Carbon Capture and Storage (CCS) operations, beginning with the STRATOS Direct Air Capture project. Once fully operational, the STRATOS project is designed to capture, transport, and sequester up to 500,000 tonnes of CO_2 annually. The supporting infrastructure includes mechanisms that will provide highly accurate measurements of both the captured CO_2 and any emissions generated during the capture, transportation, and storage processes.

1PointFive selected the Environmental Credit Service (ECS)—originally developed by Microsoft and based on the DMRV (Digital Measurement, Reporting and Verification) Specification—and is collaborating, for the early stage of STRATOS, with a validation/verification body (VVB), DNV, and a certification body, Verra's VCS program, thereby digitizing the process for the issuance of CDR credits.

A CCS+ Extension Set has been established by extracting and digitizing several modules under Verra's methodology framework **VM0049 Carbon Capture and Storage, v1.0** (VMD0056 CO_2 Capture from Air, v1.0; VMD0057 CO2Transport for CCS Projects, v1.0; and VMD0058 CO_2 Storage in Saline Aquifers and Depleted Hydrocarbon Reservoirs, v1.0) capture, transport, and storage into Formula, Variable, Message, and Data Extension templates. This enables the ECS network to be specifically tailored to support these processes. Adhering to the DMRV Specification allows integration and interoperability among applications from different stakeholders. The implementation of the DMRV Specification on ECS, along with the CCS+ Extension Set, has automated the origination process by integrating with standard facility operations and monitoring.

HOW ECS OPERATIONALIZES CONTINUOUS VERIFICATION
Transforming raw data into verifiable carbon removal credits at market speed

This approach is expected to result in several key benefits:

- The issuance of high-integrity CDRs, substantiated by precise sensor data, providing transparency via the ECS framework's DMRV implementation.
- A reduced issuance timeline, shifting from annual to shorter cycles, is expected to start with monthly cycles in the case of STRATOS, which accelerates return on investment for capital-intensive carbon capture innovations.
- The establishment of a repeatable framework that expedites time-to-market for new Direct Air Capture (DAC) facilities.
- Monetization opportunities for third-party carbon transport and storage through a modular framework, enabling consolidation of claims from multiple entities into a unified issuance process.

Once the automation of the DMRV process and issuance of CDRs is operational and refined, the ECS-based network for CCS will allow additional participants to join to scale the production of engineered CDR credits worldwide.

HEDERA

Hedera has published a **handbook** on methodology digitization in the Hedera Guardian ecosystem. The handbook covers foundational concepts around methodology digitization before exploring a practical example using VM0033 ("Methodology for Tidal Wetland and Seagrass Restoration"). The handbook then explores the breakdown of a methodology and the mapping of equations and parameters and the development and design of various schemas, from project design document (PDD) schemas to monitoring report schemas, used in the creation and implementation of dMRV systems for specific projects.

EARTHXCG

EarthXCG has successfully implemented the IWA's Digital Measurement, Reporting, and Verification (dMRV) Framework through their recently-launched Environmental Credit Service (ECS), demonstrating the framework's real-world viability for enterprise-scale environmental credit markets. EarthXCG addresses the critical challenge of originating high integrity environmental credits for the global energy transition through data management and automated verification analytics.

EarthXCG's ECS implementation follows a Software-as-a-Service (SaaS) model, leveraging standardized APIs and data schemas supported by the IWA's dMRV Framework and specifications. The use of these standardized schemas enables cross-platform compatibility with external systems and faster onboarding for participants.

Project Central, an integrated project and inventory management tool, allows for administrative interfaces which act as an orchestration layer for dMRV operations. Standardized data schemas enable the use of guided forms for the onboarding of participants, while also enabling a comprehensive data analytics dashboard with role-based access control.

EarthXCG's architecture demonstrates the framework's flexibility through its modular design:

- **Quality standard agnostic -** supports any environmental crediting standard or methodology
- **Registry neutral -** integrates with existing registries while maintaining data sovereignty
- **Methodology flexible –** accommodates any renewable energy, carbon dioxide removal, or other ecological remediation method
- **Extensible MRV framework -** supports custom data collection requirements per standard

EarthXCG's ECS implementation leverages this standardization of data to enable: advanced verification analytics, automations throughout various stages of the lifecycle of a project, standardized APIs for interoperability, roles-based access controls, immutable audit trails, and more.

Learn more at: **https://www.earthxcg.com/**

APPENDIX B: ATTESTATIONS, REPUTATION, & CONFIDENTIALITY

ATTESTATIONS

Attestations provide opportunities for context in MRV data. Conceptually, attestations can be the data within the project or the commentary around the project. For project data, "Direct Data Attestations" can come from individuals, project developers, verifiers, and/or directly from devices asserting an event that is represented digitally on the public ledger.

Attestations, metadata, or "Tags" describing digital entities, such as actors, calculations, or their quantifiable outcomes, allow for more context to exist about Accountable Impact Organizations within the market, which inherently have a relationship with credit pricing and can describe overall project effectiveness.

For these "Tags" about the project to have further meaning they need to have an understanding of the real-world activity and the digital data model. This brings to light both "High-Definition" workflow data in digital MRV and its relationship within data models to "Low-Definition" attributes, which form higher order concepts that act as metrics for the market and environmental outcomes. Attributes are formed by providing a relationship of specific schemas, data, and calculations to higher order concepts such as Additionality, Durability, and Leakage, but can span to much broader concepts including co-benefits and SDG-oriented statistics.

The level of granularity, accuracy, and the breadth of information covered, in addition to the consistency of the information, form the basis for reputation of both the project and actors involved in the Accountable Impact Organization. Some examples of attestations surrounding a project can be represented in Tags as described below:

- tags can be created by any actor with a valid ID (recommended to be a DID).
- created tags should be credentialed, i.e., it should be clear who and when created or added to a particular tag.
- tags can have cumulative scores, e.g., two people independently creating/assigning the same tag to the same artifact results in both tagging actions recorded (credentialed etc.), and the 'tag score' is then counted as 2.
- It is possible for users to untag the item; however, this action does not remove the record of tagging in the first place, it just records the action of untagging (also credentialed) and reduces the score by 1.
- tags should be able to be associated with any identifiable entity/thing/artifact that uses and/or produces, such as:
    - actors, including SRs (e.g., DIDs)
    - schemas
    - policies and policy modules
    - VCs/VPs
    - tokens
    - smart contracts (e.g., addresses).

- tags can be created after the (immutable) artifacts are produced, therefore tags are external to artifacts.
- it should be possible to create and/or follow tag ontologies containing the definition or description of tags.
- tag registry[-ies] should be discoverable and usable by automated indexing systems.

An example of tags in the Hedera ecosystem can be found below. While the IWA and the participants do not prescribe or endorse Hedera specifically, it is important to include a reference implementation to demonstrate what tagging might look like.

REPUTATION

For reputation to take effect, based on digital MRV data and attestations, it is suggested to use a credential model that is fully traceable and contextually aware. Although reputation is often thought of in the context of projects, companies, or individuals, reputation should be considered to be extensible to devices, methodologies, or even specific sections of a methodology. This allows for a more complex understanding of a project and substantive details. Although this is often price-focused, reputation can also facilitate discourse on effectiveness of a project or any element or actor involved in a project. There should not need to be a single data model; however, using public ledgers and associated tooling, there should be an opportunity for reputation systems to form based on open standards and access to non-confidential information.

CONFIDENTIALITY IN ATTRIBUTES & ASSET GENERATION

The data associated with a project that may be relevant to reputation will likely be limited as we transition to a more digitally native format. However, there are also privacy and confidentiality considerations that may not have been fully considered in the analog format.

To enable confidentiality in MRV data, there are multiple approaches to privacy; however, there are specific requirements to enable this in the requirements of an MRV workflow. The below example is not an endorsement of a specific approach, but shows an example reference based on W3C standards.

REFERENCE EXAMPLE

In a reference example for generating Digital Ecological Assets, the Hedera Guardian uses the W3C standards of Decentralized Identifiers (DIDs), Verifiable Credentials (VCs), and Verifiable Presentations (VPs) in order to capture digitally signed documents that are stored on the decentralized InterPlanetary File System (IPFS).

Guardian uses VCs & VPs for a variety of data types - particularly:

- Monitoring, Reporting & Verification (MRV) data capturing the actual carbon reduction, removals, or renewable energy generation.
- The policies that digitize the methodology. In this context of carbon debits & credits, a methodology is a framework document that defines the rules governing the MRV process and the criteria for minting tokens corresponding to that MRV process.

The current Guardian model publishes MRV data as a VC and creates a corresponding VP, a priori from that VC, and stores the VP on IPFS. The VP (and the VC within) can be retrieved from IPFS at any time and are, by default, unencrypted.

While this default transparency enables easy validation of provenance chains, it may not be acceptable to all enterprises considering using Guardian to track emissions of their manufacturing processes. While a business may recognize the need to be fully transparent about the amount of CO_2 emissions associated with their business processes, they may wish to keep some details of those processes less than fully public to protect associated intellectual property and confidentiality.

Separately, confidentiality may be required to protect an individual's information. For instance, a homeowner that installed solar panels may not want their street address public, but recognize that the approximate location is important for assessing the credibility of energy production.

This sort of confidentiality can be challenging to reconcile with the desired transparency and composability and the fundamental choice of using a public Distributed Ledger Technology (DLT), like Hedera, to track the provenance of Environmental, Social, and Governance (ESG) assets.

Below is an example of attestations with selective disclosure. This model enables delivery of digital MRV generated attributes that include information which may not be publicly disclosed due to confidentiality concerns.
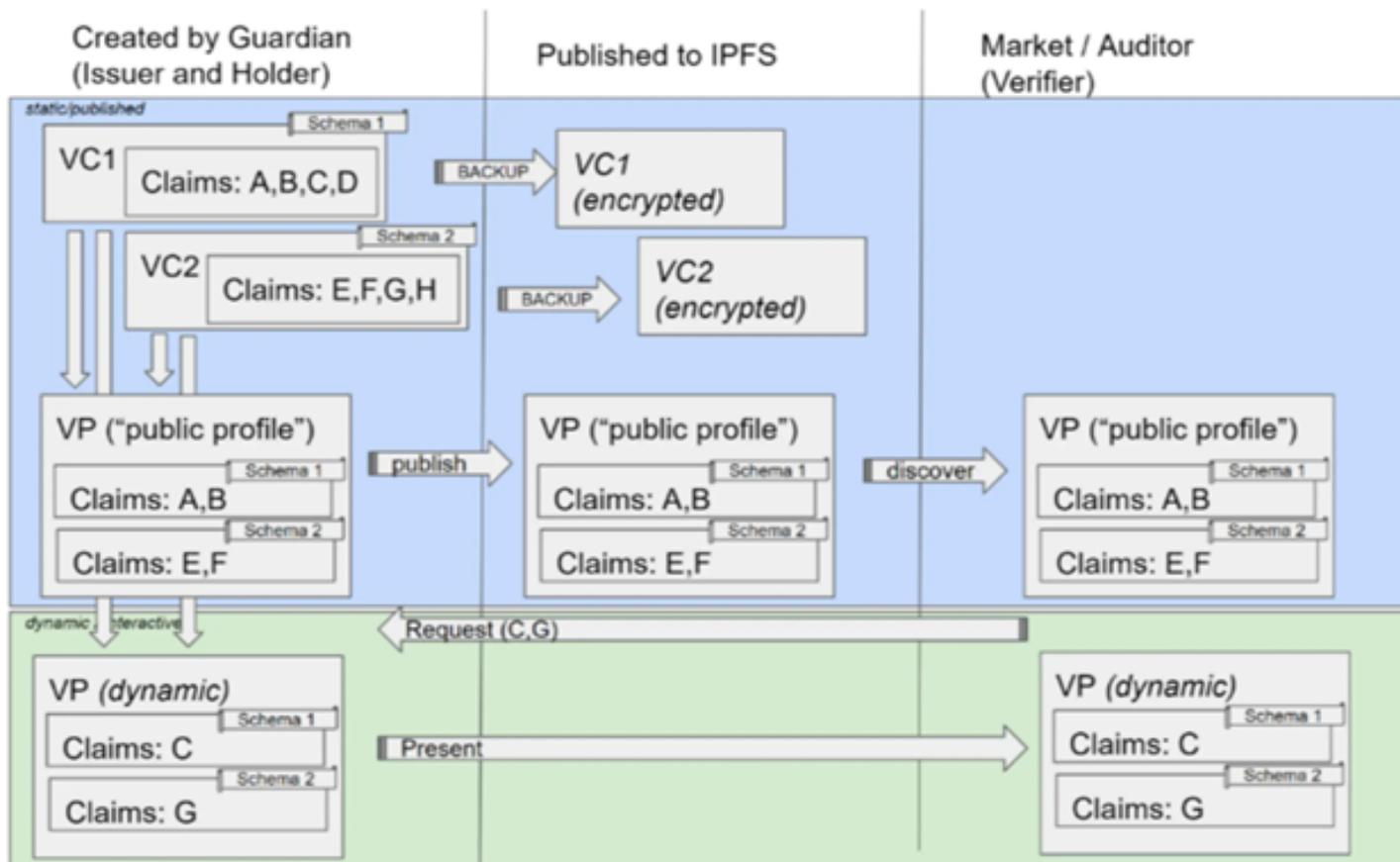
APPENDIX C: TAGGING EXAMPLE

An example of tags can be seen **here** regarding Energy efficiency measures in thermal applications of non-renewable biomass. The below example demonstrates a Hedera-based implementation of a technology standards-based tagging architecture which can cover all public artifacts produced by Guardian instances. This is not advocating for a specific platform for implementation, but serves as an example of how tagging could be represented.

Methodologies (which are represented digitally as policies) can be tagged with additional contextual information on parameters such as "Estimating biomass fuel savings (B_y)".

A **working paper** published by the Stockholm Environment Institute (SEI) detailed several issues with cookstove methodologies such as CDM's AMS II.G, specifically related to the following parameters:

- Estimating biomass fuel savings (B_y)
- Fraction of nonrenewable biomass (f_{NRB})
- Default emission factors ($EF_{projected\_fossilfuel}$)

Regarding Estimating biomass fuel savings (B_y), this parameter is calculated based on the efficiency of old devices to be replaced and the efficiency of project devices. Under the CDM methodology *AMS-II.G.: Energy efficiency measures in thermal applications of non-renewable biomass*, there are three methods that a project proponent can choose from to estimate device efficiency, the Kitchen Performance Test (KPT), Water Boiling Test (WBT), or Controlled Cooking Test (CCT).

However, there have been some considerable criticisms and concerns related to the WBT outlined by the SEI working paper. In general, the WBT —which is performed in a lab — results do not translate well to actual performance in the field. The KPT, by contrast, involves testing the devices by local cooks in actual households based on actual cooking tasks to provide a more accurate efficiency test.

In this use case, a project proponent conducting a cookstove project, using AMS-II.G., and opting to use the KPT method can tag the parameter *'Efficiency of the project device i and batch j ($n_{new,i,j}$)'* to provide additional information about how the parameter was estimated and how this impacts the parameter's value. Within this tag, the project proponent can have a description of the KPT and monitoring approach implemented, and the benefits relative to the WBT option. They can also specify what the parameter's value (project device efficiency) would have been under the WBT method.

This tag can be discoverable and linked to the project and parameter to provide useful information for interested stakeholders such as other project proponents seeking more accurate alternatives to the WBT, or marketplaces and purchasers looking to identify projects that have more robust monitoring and quantification approaches.

INFORMATION CAPTURED BY TAG

Tag Name	Cookstove Efficiency Test and Monitoring Method
Project ID	XYZ321
Methodology	AMS-II.G.: Energy efficiency measures in thermal applications of non-renewable biomass
Associated Parameter	Efficiency of the project device i and batch j $(n_{new,i,j})$
Method Implemented	Kitchen Performance Test (KPT) and Monitoring
Description	Under the CDM methodology AMS-II.G.: Energy efficiency measures in thermal applications of non-renewable biomass, there are three methods that a project proponent can choose from to estimate device efficiency, the Kitchen Performance Test (KPT), Water Boiling Test (WBT), or Controlled Cooking Test (CCT). However, there have been some considerable criticisms and concerns related to the accuracy of the WBT. In general, laboratory tests results do not translate well to actual performance in the field. The KPT, by contrast, involves testing the devices by local cooks in actual households for actual cooking tasks to provide a more accurate efficiency test. This project implements the KPT method, which is a community test (performed in actual households); measuring fuel use in households based on normal cooking tasks over several days. This approach subtracts the quantity of woody biomass used by project participants (based on a random sample) from the amount of biomass used by a representative sample of non participant households. Both are measured over a three-day period. Total biomass available in the household is weighed at the start and end of each day or meal to measure the weight of fuel used.
Parameter Value Under the Water Boiling Test (WBT) Method	44%

TAGGING IMPLEMENTATION EXAMPLE

Tag actions can be implemented on an immutable ledger, such as Hedera, for tamper-proof, auditable and credentialed event records such as in the following example:

```
{
  "id": "964c9e42-5483-4385-ba2f-71328f17f952",
  "status": "ISSUE",
  "type": "Tag",
  "action": "publish-tag",
  "lang": "en-US",
  "uuid": "ecd3e6b5-e5d9-4111-aadf-e9ea9d5b5763",
  "name": "Cookstove Efficiency Test and Monitoring Method",
  "description": "",
  "owner":
"did:hedera:mainnet:4XjqvXeMYPes1dmPVEfMmewNgER8zedFir3ufZN2gnMP_0.0.3732665",
  "target": "1694106714.582861517",
  "operation": "Create",
  "date": "2023-09-07T17:14:01.904Z",
  "entity": "Policy",
  "cid": "bafkreiaiihlee66mncrzah2her35rjd3srr3rdjuiyzw6uzvyfhsfaejwe",
  "uri": "ipfs://bafkreiaiihlee66mncrzah2her35rjd3srr3rdjuiyzw6uzvyfhsfaejwe"
}
```

Tags can contain or refer to extended information, secured by the cryptographic signature protecting against tampering as the following example demonstrates:

```
{
  "id": "urn:uuid:e7916131-aa98-45fa-ab89-f1fcfceaf033",
  "type": [
    "VerifiableCredential"
  ],
  "issuer":
"did:hedera:mainnet:4XjqvXeMYPes1dmPVEfMmewNgER8zedFir3ufZN2gnMP_0.0.3732665",
  "issuanceDate": "2023-09-07T17:14:01.930Z",
  "@context": [
    "https://www.w3.org/2018/credentials/v1",
    "ipfs://bafkreicx6ecmje427oxss4w4ifw43mu7qezsct6ee3g6vra6fr32yrbda4"
  ],
  "credentialSubject": [
    {
      "methodology": "AMS-II.G.: Energy efficiency measures in thermal
applications of non-renewable biomass",
      "associatedParameter": "Efficiency of the project device i and batch j
(Nnew,i,j)",
      "methodImplemented": "Kitchen Performance Test (KPT) and Monitoring",
      "description": "Under the CDM methodology AMS-II.G.: Energy efficiency
measures in thermal applications of non-renewable biomass, there are three
methods that a project proponent can choose from to estimate device efficiency,
the Kitchen Performance Test (KPT), Water Boiling Test (WBT), or Controlled
Cooking Test (CCT). However, there have been some considerable criticisms and
concerns related to the accuracy of the WBT. In general, laboratory tests
results do not translate well to actual performance in the field.
```

The KPT, by contrast, involves testing the devices by local cooks in actual households for actual cooking tasks to provide a more accurate efficiency test. This project implements the KPT method, which is a community test (performed in actual households); measuring fuel use in households based on normal cooking tasks over several days. This approach subtracts the quantity of woody biomass used by project participants (based on a random sample) from the amount of biomass used by a representative sample of nonparticipant households. Both are measured over a three-day period. Total biomass available in the household is weighed at the start and end of each day or meal to measure the weight of fuel used.",

```
        "parameter": 44,
        "@context": [
          "ipfs://bafkreicx6ecmje427oxss4w4ifw43mu7qezsct6ee3g6vra6fr32yrbda4"
        ],
        "id":
"did:hedera:mainnet:4XjqvXeMYPes1dmPVEfMmewNgER8zedFir3ufZN2gnMP_0.0.3732665",
        "type": "a9f8123a-4ec7-4cb9-a4ba-62170bcb9b08&1.0.0"
      }
    ],
    "proof": {
      "type": "Ed25519Signature2018",
      "created": "2023-09-07T17:14:01Z",
      "verificationMethod": "did:hedera:mainnet:4XjqvXeMYPes1dmPVEfMmewNgER8zedFi
r3ufZN2gnMP_0.0.3732665#did-root-key",
      "proofPurpose": "assertionMethod",
      "jws": "eyJhbGciOiJFZERTQSIsImI2NCI6ZmFsc2UsImNyaXQiOlsiYjY0Il19..
QHHRxHLzT1KmpByZiyweWOPghvZ2B0E_
JNjb7rJNXrM2S0sIq3F2E2p99G7roJYBz3ZbLrgFA3Jo2CaNBx1RBA"
    }
}
```

These code samples are equivalent to the tag example given earlier.

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