OPEN COLLABORATION DIGITAL MRV WORKING GROUP

PUBLIC CONSULTATION DRAFT WHITE PAPER ON DIGITISING VERIFICATION FOR CLIMATE MARKETS

PUBLIC CONSULTATION PERIOD

December 13, 2022 to January 20, 2023

SUBMIT STAKEHOLDER FEEDBACK (online form)

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INTRODUCTION

In 2021, the Open Collaboration partners (Gold Standard, ClimateCHECK, IOTA) published a _ on Next Generation Digital Solutions for MRV. The white paper describes an ambitious vision to leverage emerging technologies to empower MRV that increases the quality and utility of the data inputs and outputs needed by stakeholders to vastly scale up mobilisation of resources to support transformational systems change for high-impact climate actions that catalyse sustainable development. Investing in better MRV systems for climate actions can have a better ROI – financially and for sustainability overall.

In 2022, with the support of Google.org, the Open Collaboration launched three working groups involving over 60 organisations to develop a series of white papers, guidance, and tools for:

— Digital Assets (WG1)
— Digital MRV (WG2)
— Digital Infrastructure and Open APIs (WG3)

The Open Collaboration is guided by a set of core principles including:

— An ecosystem built with open source and public good approaches
— Robust, transparent governance
— An inclusive, participatory global community
— Interoperability for the Digital and Data Economy
— Cost-effective solutions (for example, feeless transactions)
— Technologies that are low energy use and low environmental footprint

Based on stakeholder engagement, research and assessment, the goal of the Open Collaboration is to develop resources that will help advance digitisation for climate markets to achieve tangible benefits for stakeholders, for example:

— achieving higher levels of confidence in GHG claims with higher environmental integrity that could command a price premium
— shortened timelines for MRV that could accelerate market engagement to help scale resources into more climate actions

— streamlined verifications (for example, a rigorous first verification is followed by automated and continuous digital verifications with periodic spot checks)
— in other words, achieve an overall 10x decrease in MRV time and cost and achieve an overall 10x increase in resource mobilisation, high-impact climate actions.

CONTEXT

Carbon Markets are enabled by rigorous MRV, which is a demanding process to provide the necessary assurance for stakeholders that claims about impacts have integrity and are credible. At a high level of assurance, MRV requires substantial costs and time demands. There is always continuous improvement for the standards of practice and resources for auditing and assurance, which is largely transferable to MRV, for example the ongoing transformations in the financial sector towards "digital audit" (e.g., IAASB).

However, many stakeholders continue to be concerned about 'greenwashing', sometimes questioning 'the data' and other times recognising the relative immaturity of sustainability standards and climate MRV (e.g., proliferation and variability of many standards and programs, uncertainty, difficulty of determining a credible baseline from which additionality is determined, lack of resources). To address such concerns, there is considerable work needed to improve methodologies, and also the 'standardisation system' that develops the methodologies and manages the system of methodologies and the resources necessary to successfully implement methodologies.

Digital tools have been an important component of MRV for many years, for example:

— Spreadsheet calculators
— GHG inventory software and data management systems
— Life cycle inventory databases and life cycle assessment software
— Emission factor databases
— Knowledge hubs
— Remote sensing
— GIS (Geographic Information Systems)
— GPS (Global Positioning System)
— Online reporting and registries

— Video-conferencing tools (e.g., remote auditing)

However, there continue to be several challenges and opportunities for improvement in conventional MRV (e.g., World Bank), even with the use of the above digital tools. Examples of specific challenges include:
Current MRV practices in companies, cities, etc. involve substantial manual processes and analog data capture. This also involves in-person visits to audit sites, which is inefficient and costly. Occasional (e.g., annual) visits mean reporters are limited in their ability to monetise climate assets or participate in climate markets in a timely manner.

— Current MRV practices, and even many new efforts to digitise data from climate actions, lack adequate security and trust, thus reducing utility due to a lack of confidence. The existing digital equipment at sites is variable and does not always prevent data manipulation.
— Current MRV practices for data analytics and quality assurance/quality control (QA/QC) are limited: for example, basic visual inspection and spreadsheet calculations.
— Investors, sellers, buyers and other stakeholders are limited from participating in climate markets and climate finance without secure, immutable, reliable source data, available in near real-time via Distributed Ledger Technology (DLT) to climate registries (NDC registry, carbon credit registry) and in accordance with linked MRV standards.
— There are many different types of climate actions with different data and MRV standards that are neither comparable nor consistent and do not add up with confidence as "one version of the truth". This leads to a lack of cohesiveness and confidence, thus limiting the ability to scale NDC climate actions towards efficient and effective transformational change (for example, 50% decarbonisation).

The current conventional verification process ("business as usual") is a process based on existing, mostly non-digital approaches, that rely heavily on the verifier's "professional judgement" (professional scepticism), for example refer to ISO 14064-3 and ISO 14065 and ISO 14066. The conventional verification process is costly and time consuming due to the lack of appropriate automation (digitalisation) and so it cannot be done in "real-time" and therefore periodic delays are the norm, often verification starts after a year of data monitoring and reporting.

More advanced digital technologies that are becoming mainstream could enhance digital verification activities, for example:

— Data APIs
— Big Data Analytics
— Artificial Intelligence (AI), Machine Learning (ML), Natural Language Processing (NLP), Deep Learning
— Robotic Process Automation
— Structured data formats, including eXtensible Business Reporting Language (XBRL)
— Internet of Things (IoT) Networks, Digital sensors and Edge Computing

The combination of these digital technologies has the potential to reduce timelines and costs, while increasing transparency and trust in the entire MRV process.

Furthermore, emerging technologies that can overcome some of the above challenges and improve the utility of MRV outputs, are rapidly advancing and are anticipated to be commercial in the foreseeable, for example:

— Digital twins
— Distributed Ledger Technologies (DLT) and blockchain
— Smart contracts
— Tokenisation (digital assets)

There is growing interest among stakeholders to accelerate progress on the journey from today's conventional MRV, roughly characterised as 90% manual and 10% digital, to transition towards more digital MRV, roughly characterised as 10% manual and 90% digital. Such general vision guides overall efforts, however the extent of potential digital transition varies sector to sector, location to location, over time. Digital MRV will gradually become more and more common over time, however it still has a long way to go before it becomes the dominant form of MRV. As well, some activities (e.g., continuous measurement using a digital sensor of gas flow at a facility) can be more easily digitised than other activities (e.g., raw materials measured and recorded on a piece of paper then delivered by a supplier's truck, i.e., Scope 3). Sometimes the challenges to the ability to digitise MRV are the amount of costs and of benefits (value-added), accessibility, or control, among many other

potential reasons. There is simply not a single “right level” of digitisation for all stakeholders.

The transition to 10% manual and 90% digital remains to be thoroughly defined, however based on current understanding and capabilities there is an expectation that the overall time spent by verifiers doing manual verification activities may not change much. Rather verifiers will reallocate their valuable time away from activities that can be more cost-effectively and thoroughly performed using digital technologies so verifiers can focus on more value-add activities as MRV evolves with more interrelated uses and users of MRV results. With 90% digital it is expected to substantially increase quantity and rigour of verification activities for data trails that will provide greater assurance on data confidence and reported information in GHG statements.

However during the early phase of the digital transformation, costs for digital MRV will be relatively high and most ‘first-time, one-off’ implementations will not likely be cost effective. As with other IT solutions, cost savings are expected with low-cost replication.

OBJECTIVES AND SCOPE

The objectives for this public consultation draft white paper are to:

- present a landscape mapping of relevant standards, guidance, initiatives and other resources for “digitising verification” and “verifying digitisation” to inform development of the next generation of digital MRV for climate markets
- outline scope and proposed next steps and roadmap (activities, priorities, timelines, resources, stakeholders) to develop guidance and resources to advance effective and trusted digital verification solutions for climate markets.
- use this white paper to invite stakeholder feedback via an online survey to inform the subsequent development of a roadmap.

The digital transformation will vary across economic sectors that use various digital technologies, for example, remote sensing and AI are relatively more common in land use, forestry and agriculture. In contrast, digital sensors and IoT are more common in energy and industry. In addition, both across and within sectors there is variability in

the ability to use digital technologies with conventional GHG methodologies. For example, within a specific GHG methodology, some monitoring requirements can use digital technologies such as an onsite wireless gas flow digital sensor whereas other activities such as supplier truck deliveries of feedstock to the site might not be possible to digitise cost effectively or at all.

These inherent variabilities can be characterised in numerous potential scenarios of mixed or hybrid levels of manual and digital MRV. The following table outlines high-level scenarios for determining priority focus areas to propose next steps and roadmaps - refer to Annex 1 for more detailed issues, pros and cons, etc of the scenarios.

Table 1 – High level scenarios for determining scope and priority focus areas

Overview of Different Combination of High-level Scenarios for GHG Methodologies and Verification		GHG Methodology for Data Measurement, Monitoring, QA/QC, Quantification, Reporting		
		Conventional Methodology	Hybrid Methodology (some digital)	Fully Digital Methodology
Verification	Conventional Verification	Scenario 1	Scenario 2	Scenario 3
	Hybrid Verification (some digital)	Scenario 4	Scenario 5	Scenario 6
	Fully Digital Verification	Scenario 7	Scenario 8	Scenario 9

Based on the assessment of existing standards, guidance, frameworks and related resources, as well as research performed by leading initiatives (e.g., IAASB), the priority scenarios identified as in scope include:
Scenario 2: conventional verification following best practices (though limited digital capabilities) applied to hybrid digital GHG methodologies with some digital specifications (i.e., not fully digital)
Scenario 4: hybrid digital verification using more advanced digital tools applied to conventional GHG methodologies (limited digital tools used by the organisation)

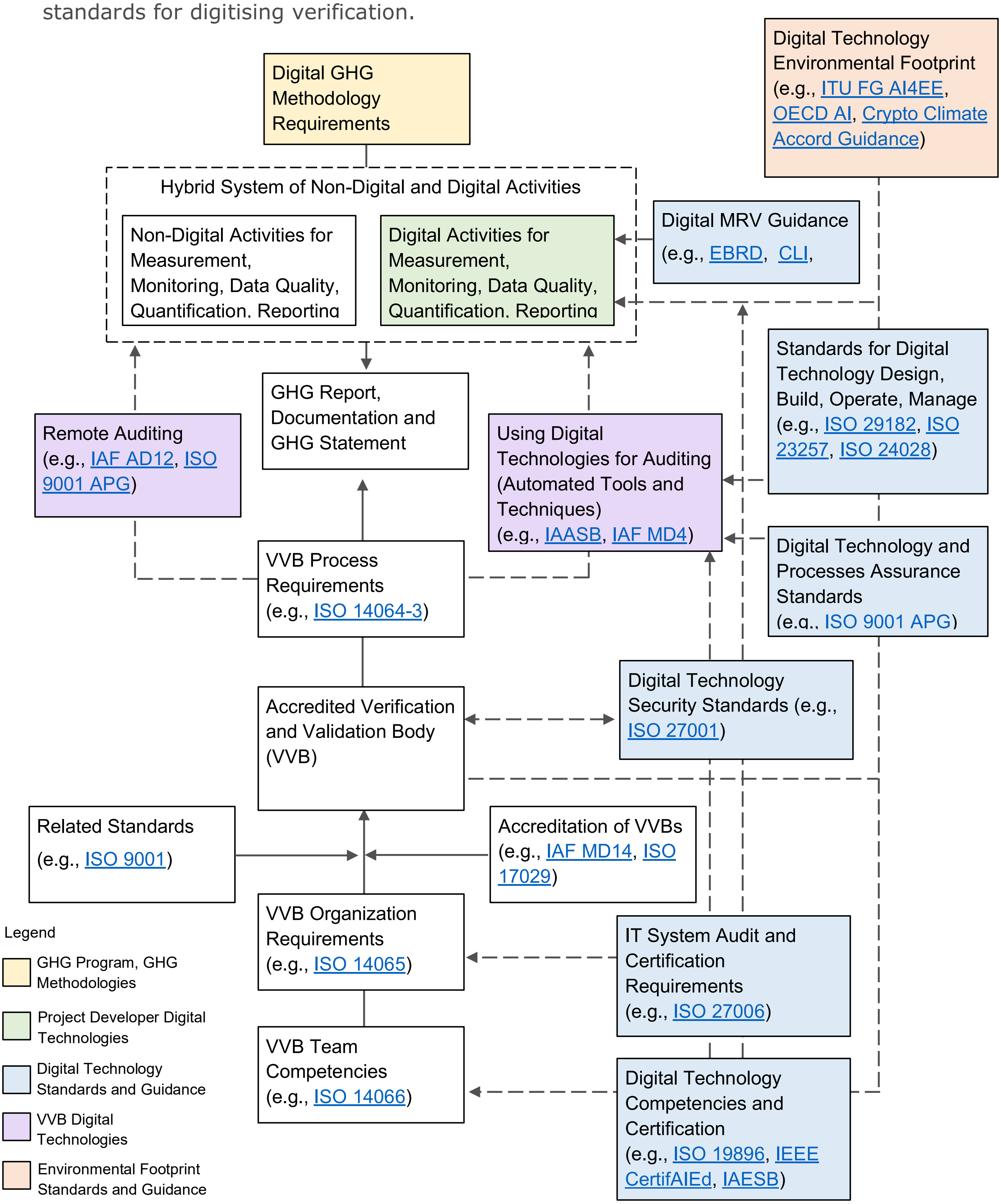
Scenario 5: hybrid digital verification using more advanced digital tools applied to hybrid digital GHG methodologies with some digital specifications (i.e., not fully digital)

These three priority scenarios are high-level and are considered to cover the majority of cases over the short term (within 3-5 years), while digital technologies and guidance continue to be developed and refined. Furthermore, there remains considerable variability for what is considered ‘hybrid’, which is somewhere between 10% and 90% digital. In addition, some sectors that are more advanced will likely prioritise Scenario 5 or even mostly digital situation.

Therefore, a ‘one-size fits all’ roadmap is not an appropriate solution, rather as an initial phase over the short term a combination of a roadmap for common issues supplemented with parallel roadmaps for different sectors represents a balance of establishing a common system for digital MRV while also enabling rapid progress where appropriate. Following the results and lessons learned of the initial phase, a subsequent ‘unified roadmap’ can be developed to help achieve anticipated additional benefits of digital transformation such as greater cohesiveness, interoperability and comparability among digital solutions and the results.

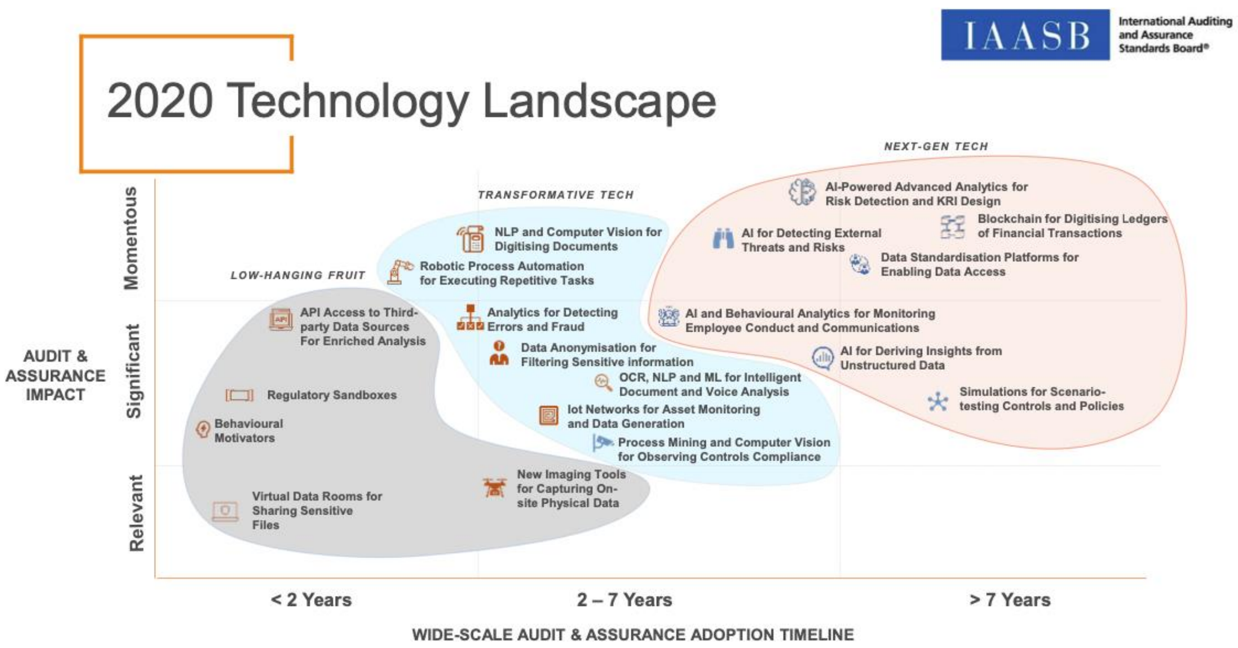
OVERVIEW OF RELEVANT GUIDANCE, STANDARDS AND RESOURCES FOR DIGITISING VERIFICATION

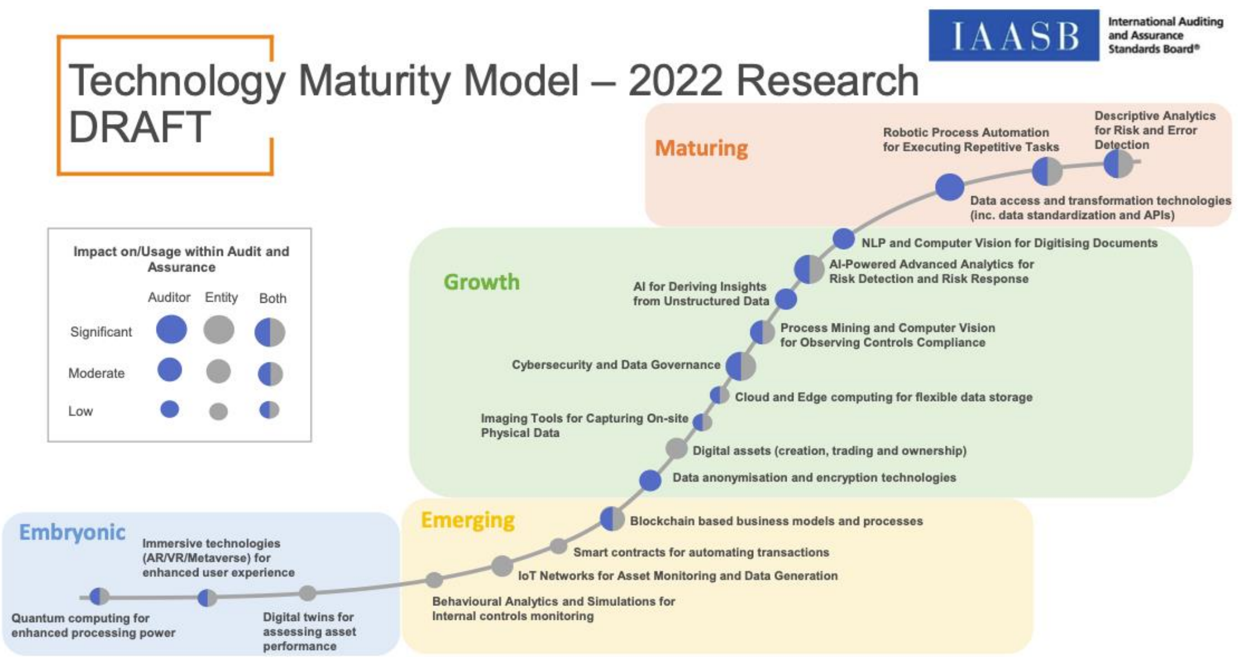
The following figure presents the landscape mapping of relevant guidance and standards for digitising verification.



The above figure was developed based on an extensive review of initiatives, standards, guidance, frameworks, strategies, roadmaps and other resources that are posted in the References list.

For example, the International Auditing and Assurance Standards Board (IAASB) has researched digital technologies (automated tools and techniques) as part of its strategic planning and development of guidance resources. The following figures present IAASB assessments of the relevance and availability of digital technologies for auditing and assurance.





The IAASB information is very relevant to inform development of the proposed next steps and roadmap for digitising verification for climate markets.

— IAASB Technology Focus Area
— Exploring the Growing Use of Technology in the Audit, with a Focus on Data Analytics
— Technology Workstream Plan (Post June 2019)
— Audit Planning When Using Automated Tools and Techniques
— Using Automated Tools and Techniques When Identifying Risks of Material Misstatement in Accordance with ISA 315 (Revised)
— Addressing Risk of Overreliance on Technology Arising from the use of Automated Tools and Techniques and from Information Produced by an Entity's Systems
— Using Automated Tools and Techniques in Performing Audit Procedures
— Audit Documentation When Using Automated Tools and Techniques
— Technology Disruption in Audit and Assurance

Highlights of other selected relevant initiatives advancing guidance, standards and tools for digital verification include:

ISO TC 176 Quality Management and Quality Assurance (ISO 9000)

— ISO 9001 Auditing Practices Group Guidance on Remote Audits
— ISO 9001 Auditing Practices Group Guidance on Auditing Digital Processes

ISO TC 207 SC 7 Greenhouse gas and climate change management and related activities

— ISO 14066 Competence requirements for teams (including technical experts), and independent reviewers involved in the validation and verification of environmental information [Refer to Informative Annex C, Table C.1]

International Accreditation Forum

— IAF MD 4:2022 IAF Mandatory Document for the Use of Information and Communication Technology (ICT) for Auditing/Assessment Purposes
— IAF ID 12:2015 Principles on Remote Assessment

ISO TC 307 Blockchain and Distributed Ledger Technologies

- Strategic Business Plan
- Work Programme
- Governance

ISO/IEC JTC 1/SC 41 Internet of Things and Digital Twin

- Strategic Business Plan
- Work Programme
- Methodology for trustworthiness of IoT system/service

ISO/IEC JTC 1/SC 42 Artificial Intelligence [and Big Data]

- Work Programme
- Artificial intelligence Trustworthiness

OECD Artificial Intelligence

- Tools for Trustworthy AI

In addition, the References list presents a table of standards, frameworks and guidance related to the design, build, operation and management, as well as the assurance of digital technologies. Overall the above system of resources are key building blocks for a foundation up which to develop roadmaps for the development of sector specific guidance and tools for digital MRV in climate markets.

OVERVIEW OF ENVIRONMENTAL FOOTPRINT RESOURCES FOR DIGITAL TECHNOLOGIES

Recent studies (WEF) estimate digital technologies can help achieve 15% of the goals of the Paris Agreement via applications that reduce energy and material use in smart buildings, smart agriculture, smart mobility, smart grid, smart cities, etc. The benefits of digitisation are also attractive to the service sector, for example accounting, auditing, finance, etc.

However, there also remains substantial environmental impact related to digital technologies such as e-waste (electronic waste) and increasing energy use. The internet economy and digital technologies are directly responsible for approximately 2% of global GHG emissions (IEA).

"Green IT" is an ongoing initiative to reduce the environmental footprint of digital technologies. More initiatives are developing the tools, guidance and standards to quantify the environmental footprint (energy consumption, GHG emissions) of digital technologies, as well as solutions to reduce the footprint.

Therefore, with respect to the principle of environmental integrity of GHG claims from climate actions, when such claims involve the use of digital technologies it is reasonable to recognise stakeholder interest to know and to reduce the environmental footprint of digital technologies and to account for those GHG emissions and to deduct those GHG emissions from GHG claims. Standards Development Organisations (SDOs) and international initiatives are developing guidance and standards to help define and quantify the environmental footprint (e.g., energy consumption and GHG emissions) of using digital technologies.

The International Telecommunications Union (ITU) Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE) has 3 working groups:

- Working Group 1: Requirements of AI and other Emerging Technologies to Ensure Environmental Efficiency
- Working Group 2: Assessment and Measurement of the Environmental Efficiency of AI and Emerging Technologies

— Working Group 3: Implementation Guidelines of AI and Emerging Technologies for Environmental Efficiency

The Organisation for Economic Co-operation and Development (OECD) established the OECD AI Policy Observatory encompassing also:

— OECD Measuring the environmental impacts of artificial intelligence compute and applications

There are many more initiatives and resources posted in the References list about the issues and methods for assessing the environmental footprint of digital technologies - if you know of additional resources, please include your feedback in the online survey.

NEXT STEPS AND ROADMAP

Based on the research during the preparation of this white paper, the preliminary proposed “high-level” next steps for an overall roadmap to digitise verification are presented in Table 2.

It is also being considered to follow the approach of the “high-level” next steps to develop a series of main areas and key activities within more pragmatic sector roadmaps as illustrated in Table 1 (non-exhaustive).

The tables will be completed considering the feedback received from the public consultation online survey, and in conjunction with development of the table in the document ”Digitising Methodologies”. Therefore, next steps for sector specific roadmaps to develop resources for digitising verification should be closely aligned with the corresponding planning and development of digital methodologies within sectors.

Table 1 – Main areas and key activities for sector specific roadmaps

Main Areas and Key Activities for Sector Specific Roadmaps	**Sector Specific Roadmaps for Digitising Verification**			
	Energy	Industry	Waste	AFOLU
Developing sector specific guidance for using digital technologies for auditing both non-digital and digital activities				
Developing sector specific guidance for digital technology design, build, operate manage				
Developing sector specific guidance for digital technology assurance and certification				

Developing sector specific guidance for digital technology competency requirements, training and capacity building for VVBs				
Environmental footprints of digital technology applications				
Developing sector specific frameworks, criteria and rating systems for digital solutions				

Table 2 – Proposed “high-level” next steps for an overall roadmap

Next Steps	Priority	Timeline	Resources	Key Stakeholders
Perform detailed stakeholder consultation and research of ongoing activities and available resources about digital tools and standards, and also use cases for digitising verification and verifying digitisation in the financial and non-financial sectors				
Collaborate with standards development organisations to develop work plans to develop the guidance and standards for each digital technology (design, build/implementation, assurance) to digitise activities for digital verification, and if possible for specific applications/sectors				
Assess potential needs to revise or augment existing standards, for example ISO 14064-3, ISO 14065, ISO 14066				

Next Steps	Priority	Timeline	Resources	Key Stakeholders
Collaborate with standards development organisations to develop work plans to revise and enhance existing guidance and standards or to develop new guidance and standards specifically for digital verification in climate markets				
Enhance guidance for VVB team competencies for assessing digital technologies used by the organisation/client/responsible party for measurement, monitoring, data quality, quantification, reporting with respect to the relevant methodology or standard (e.g., GHG quantification)				
Collaborate with standards development organisations to develop work plans to develop environmental footprint guidance and standards for each digital technology				
Develop guidance for the initial integration of existing, mature digital technologies into the current GHG verification process in order to optimise the process				
Enhance guidance for assessing digital technologies used by the organisation/client/responsible party for measurement, monitoring, data management, data quality, quantification, reporting with respect to IT security and governance				
Enhance guidance for accreditation bodies for assessing digital technologies used by the VVBs for performing validation or verification				

Next Steps	Priority	Timeline	Resources	Key Stakeholders
Enhance guidance for product certification bodies for digital technologies used for measurement, monitoring, data quality, quantification, reporting				
Enhance guidance for product certification bodies for assessing and certifying digital technologies used for performing validation or verification				
Develop digital verification requirements or standards to define the appropriate digital tools and techniques to digitise verification tasks/activities, e.g. data, controls, documentation, analytics, observation for Energy				
Develop digital verification requirements or standards to define the appropriate digital tools and techniques to digitise verification tasks/activities, e.g. data, controls, documentation, analytics, observation for Industry				
Develop digital verification requirements or standards to define the appropriate digital tools and techniques to digitise verification tasks/activities, e.g. data, controls, documentation, analytics, observation for Waste				
Develop digital verification requirements or standards to define the appropriate digital tools and techniques to digitise verification tasks/activities, e.g. data, controls, documentation, analytics, observation for AFOLU				

Next Steps	Priority	Timeline	Resources	Key Stakeholders
Develop a proposed work plan to coordinate the road-testing and continuous improvement of solutions for (a) digitised methodologies, (b) system for digitising methodologies, (c) digitised verification, (d) verifying digitisation (methodologies and verification)				
Develop a framework and criteria to assess/rate the various digital verification options and solutions				
Develop self-assessment tools and checklists for digital verification				
Develop a capacity building and outreach program to advance best practices and scale resources				

ANNEX 1: OVERVIEW OF SCENARIOS TO DEFINE BOUNDARIES AND KEY FOCUS AREAS

The table below outlines a series of 'high-level' scenarios of the combination of verification and methodologies (data measurement and monitoring, QA/QC, quantification, reporting)

Overview and Assessment of Different Combination of High-level Scenarios for GHG Methodologies and Verification		GHG Methodology for Data Measurement, Monitoring, QA/QC, Quantification, Reporting		
		Conventional Methodology	Hybrid Methodology (some digital requirements)	Fully Digital Methodology
Verification	Conventional Verification	Scenario 1 (Business as Usual for VVBs, it works but there are issues and limitations, like slow and expensive, so needs improvement)	Scenario 2 (realistic if verifiers have digital experts, but might need new accreditation requirements, unless there is pre-validation or certification of the digital tools)	Scenario 3 (beyond current VVB accreditation, and not yet realistic to verify certain digital tools without digital standards)
	Hybrid Verification (some digital tools used to do verification activities)	Scenario 4 (something like this is happening now with 'digital audit' for financials)	Scenario 5 (depending on which digital tools are used, seems feasible today or near future)	Scenario 6 (beyond current VVB accreditation, and not yet realistic to verify certain digital tools without digital standards)
	Fully Digital Verification	Scenario 7 (not realistic to deploy full automated digital audit with mostly or all manual data and processes onsite, except for some inventories like Climate TRACE doing remote sensing of GHGs in the atmosphere? Need secondary method?)	Scenario 8 (not realistic to deploy full automated digital audit with some or most manual data and processes onsite, except for some inventories like Climate TRACE doing remote sensing of GHGs in the atmosphere? Need secondary method?)	Scenario 9 (ideal future, but feasible for only some projects, and not yet realistic to verify certain digital tools without digital standards)

Elaborating on the above table presenting an overview of high-level scenarios for the combinations of types of verifications and methodologies, the following summarises some key highlights of relevant issues, as well as some pros and cons.

Scenario 1: BAU today, low risk, well understood, available standards, experts; but expensive, slow, usually ‘risk-based partial verification’ (i.e., far from real-time comprehensive data assessment), manual nature of current verification process prone to errors, reduced credibility of resulting offsets

Scenario 2: Modest change, unless there is very limited digitisation, verifiers need to add ‘digital experts’ to assess/verify use of digital tools (e.g., sensor installation, IT security standards, big data analytics tools/algorithms)

Scenario 3: Depending on what digital tools are being used, considering the probability that sometimes standards are not available for emerging/cutting edge digital tools (e.g., AI, DLT), it is most likely beyond current VVB accreditation, and not yet realistic to verify certain digital tools without digital standards.

Scenario 4: Modest change, this hybrid approach would still rely on the verifier's “professional judgement” but to a lesser extent than the current conventional verification process. The hybrid process would be less time consuming and less expensive and some digital tools are currently available that could/would optimise the verification process. There is precedent and some experience of digital audit for the financial sector involving limited use of digital tools within a mainly conventional audit process; verifiers need digital experts and may need to be accredited to use digital tools in audits. The References list some examples explaining the transition in the financial sector towards the use of digital tools to enhance the verification activities.

Scenario 5: Depending on what digital tools are being used, pushing the boundaries of the possibility to verify the digitisation because sometimes standards not available for emerging/cutting edge digital tools (e.g., AI, DLT), however, need to augment the verification team competency for digital tools used for the methodology and for verification.

Scenario 6: Considering the probability that sometimes standards are not available for emerging/cutting edge digital tools (e.g., AI, DLT), it is most likely beyond current

VVB accreditation, and not yet realistic to verify certain digital tools without digital standards.

Scenario 7: Fully digitised and audited verification does not exist (possibly except for some limited applications) in cases that are mostly or all manual data and processes onsite.

Scenario 8: Fully digitised and audited verification does not exist (possibly except for some limited applications) in cases that some or most are manual data and processes onsite.

Scenario 9: Reduced time requirement for both verifier and client; expensive for the first time implementation - then automated and cheaper for follow up verifications; digitised processes would reduce errors due to manual manipulation and "professional judgement"; increased consistency between verifications; increased credibility of resulting offsets.

A more detailed assessment for each of the high-level scenarios by "drilling down into more specific combinations and interactions" of the **methodology** and digitisation could include:

1. Unpacking the methodology general activities (to be more clear and specific on what and how digitisation is involved)
    a. Project design/information
    b. Data measurement and monitoring
    c. QA/QC
    d. Quantification
    e. Reporting
2. Identifying each of the steps and activities for each of the data trails corresponding to operations and GHG sources/sinks relevant to the specific methodology requirements, for example:
    a. Project design (Site construction and operational blueprints and records, PFDs, PandIDs, regulatory permits and approvals, program eligibility of activities and emissions, business and ownership structure, organisational management systems, …)
    b. Data production (digital/analog/manual, sensor, observation, manually produced; sensors/metres are turned on and working, planned and unplanned shutdown…)
    c. Assessment of the means of data production (tamper-proof sensors, qualified installation and independently calibrated sensor, frequency of

sensor diagnostics and maintenance, COI (is it the buyer's sensor or the seller's sensor, or another party's sensor such as the government), staff are trained and uncompromised such as not overloaded with work, or distracted surfing the web, or…)

d. Assessment of the produced data (data anomaly detection… record count, missing data, limits/range of data, valid alphanumeric character check, statistical, historical, technical/operational trends and correlation checks…)
e. Missing data procedures (interpolation, historical, peer operations…)
f. Data management and compilation from sensors and any locally stored data in local software, e.g., manually entered data into spreadsheets and data files, with automated API pulls
g. Data transmission and transfer security (wireless access, encrypted network connections…)
h. Data recording, logging and storage (physical access control to IT rooms, login security and protection, backup servers, cloud based data redundancy and processing.…)
i. Data preliminary processing, data structuring and standardisation, data annotation and metadata
j. Data compartmentalisation using a data management framework to store and manage access to read only data for data subscribers or purchasers.
k. Data access control and checks to preclude data manipulation (password protection, data encryption, read-only data, permissioned author-subscriber controls, decentralised peer-to-peer access controls)
l. Managed and audited local data/IT system (also for remote and cloud systems)
m. Data processing using formulae for calculating and reporting as outputs the emissions and emission reductions (removals and removal enhancements) according to the Methodology
n. QA/QC on calculations (approved methods, emission factors, coefficients…)
o. Uncertainty assessment and data confidence metrics covering the data trail (measurement uncertainty, formulae uncertainty, data/digital system uncertainty)
p. QA/QC on calculated and reported output data (historical, technical/operational trends, correlation checks, profile analysis, industry analysis, confirm conformance with standards and reporting requirements…)
q. First party internal pre-verification process activities and results

3. Identifying the types of digital tools used for digitising the methodology corresponding to both each of the general activities (1) and each of steps and activities along the data trails (2)
    a. Stationary and mobile IoT and Digital Sensors
    b. Operational Management System (SCADA, edge servers, …)
    c. Digital Twins (3D graphical representations with high fidelity of the actual physical object or site)

   d. Big Data Analytics
   e. Artificial Intelligence, Natural Language Processing, Machine Learning
   f. Smart Contracts and other algorithm coding
   g. Tokenisation
   h. Blockchains and DLTs
   i. APIs
   j. Remote sensing
   k. Not a static list, it is constantly growing with other digital tools, some proven and widely adopted, while new emerging technologies to be added
4. Determining the status for each of the digital tools used for digitising the methodology (refer also to the table below)
   a. Digital technology ratings and certifications
   b. Digital technology design standards exist (also important to know if the standards are private/proprietary, industry standards, multi-stakeholder consensus standards, open standards, *de facto* vs *de juris*, current or out of date because technology changes much faster than carbon market standards…)
   c. Digital technology assurance and certification standards and programs exist (for both hardware and software, e.g., smart contract auditing)
   d. Supporting resources (certified experts, related standards and tools, for example, Data Confidence Fabric and Alvarium SDK…)
5. Determining the status of relevant resources and systems, for example how digitised MRV is regarded by governments, financial sector, public; what are the 'technology roadmaps' for the various digital technologies…

Corresponding to the above detailed assessment regarding the methodology, another more detailed assessment for each of the high-level scenarios by "drilling down into more specific combinations and interactions" of the **verification** and digitisation could include:

1. Separating out the verification general activities (to be more clear and specific on what and how digitisation is involved)
   a. Planning
      i. Risk assessments (detection risk x control risk x inherent risk)
      ii. Materiality assessments (quantitative, qualitative), based on initial reviews of controls, procedures and documentation to
      iii. Verification plan for verification activities, data sampling, data testing and assessment, data analysis, verification team competencies, independent experts…
   b. Collecting and assessing evidence
      i. Documentation (records examination)

ii. Data sampling (statistical and non-statistical techniques; random, systematic, stratified, purposive, quota…)
iii. Data testing and assessment (re-performance to vouch traceability of reported data back through the data trail to the data source; as well as re-tracing from the source data through the data trail to the reported data; re-computation of processed data)
iv. Data analysis (triangulation using other/secondary methods, e.g. a formula using input data (fuel consumed) vs a formula using output data (power produced);
v. Personnel enquiries and interviews
vi. Independent expert confirmation (independent lab procedures and records; if verifier cannot directly observe a process, then confirmation by independent experts)
vii. Site tour / walkthrough, visual inspections and observations

c. Assessing evidence against the methodology/verification criteria and Reporting findings, finalising clarifications and documenting verification results/opinion

2. Identifying each of the steps and activities for each of the data trails corresponding to operations and GHG sources/sinks relevant to the verification requirements (refer to #2 above for methodologies)
3. Identifying the types of digital tools for digitising the verification used corresponding to both each of the general activities (1) and each of steps and activities along the data trails (2); (refer to #3 above for methodologies)
4. Determining the status for each of the digital tools used for digitising the verification (refer to #4 above for methodologies)
5. Determining the status of relevant resources and systems, for example (refer to #5 above for methodologies)

ANNEX 2: ADDITIONAL ISSUES AND QUESTIONS FOR STAKEHOLDER FEEDBACK

In regards to examples of digital tools that can be used for digitising verification, especially to enhance the rigor and quality, and save time and money, of verification (e.g., rather than conventional verification sampling and testing a fraction of the data once per year, digital verification could do several types of rigorous tests for all data and in near real-time as a continuous audit), feedback (e.g., links) is welcome in the online survey for examples of digital tools:

— to 'test controls' (penetration tests on IT hardware security to determine if tamper proof)
— to 'test data' (big data analytics, AI, other/external data sets (open, private)…). For example, how big data analytics with datasets at the program registry can be a secondary method for specific project types to confirm data quality (range, trend…) and identify fraud/fraudulent data.
— to 'test documentation' ('machine-to-machine' (M2M) communications, natural language processing (NLP), XBRL, machine learning…)
— for 'interviews' (online meetings, live streaming video cameras)
— for 'observation, site walkthrough' (drones, satellite imagery, GIS…)
— for any other digital tools that could be used digitising verification.

The IAASB has developed a series of guidance documents related to the use of technology for the various step-by-step activities for auditing and assurance (see Reference list)

— Please identify and explain any changes to verification processes due to digitisation. For example, is independent verification better than an independently validated digital verification solution implemented by the owner/project?
— Considering the digital verification solution can change how verification processes are implemented as well as the requirements for accreditation of the verifier (conventional or digital), what variations or changes of roles regarding validation, certification, verification, accreditation provides the best combination of Confidence (no COI) and faster/cost-effective?

— Should the level of IT security audit required be primarily determined by the magnitude of key sources, or should a ‘maximum’ level of IT security audit always apply to the overall project?
— Some digital MRV use smart contacts. Should ‘smart contract auditing’ be part of digitising verification, and verifying digitisation? However, there is no accreditation or widely accepted standard for smart contract auditors and there is not a consistent auditing process as every smart contract can be vastly different.
— What might be the time cycle for a digitised verification? (different than a full annual audit)
— One mega-audit at the start, and small automated digital spot checks?
— Continuous automated digital audit is a minimum requirement?
— How does it matter if the digital methodology solution and/or the digital verification solution has already been pre-certified
— Is there an expiry of the certification of digital methodology solution and/or the digital verification solution?
— How much digitisation of the verification process is optimal? The whole process or a hybrid approach? Does it evolve over time as more digital standards are developed?
— Is it a prerequisite, that a digitised methodology solution is used, in order to use a digital verification solution?
— Do you agree with the following statement: “Enabling these digital verification solutions to be certified according to established standards would greatly reduce the need for verification for each individual installation. Once the digital verification solution is certified and installed - then only a spot verification could be required.”