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PRINCIPLES FOR BEST-PRACTICE DIGITAL VERIFICATION

A contribution to the discussion on digital verification

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Principles for Best-Practice Digital Verification
A Contribution to the Discussion on Digital Verification

White Paper
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EXECUTIVE SUMMARY

TWO PROMISING BLUEPRINTS FOR USING DIGITAL APPROACHES TO VERIFY CARBON PROJECTS ARE PRESENTED AND ASSESSED.

Carbon markets enable companies, governments, and other actors to offset their emissions by buying carbon credits. Such carbon credits are intended to represent greenhouse gas (GHG) emission reductions or removals through project activities such as replacing electricity from fossil fuels with electricity from renewable sources, or GHG removals achieved through the re-forestation of degraded land.

Key to the supply of accurate and high-quality carbon credits is a thorough and independent assessment of the implementation of a project's activities, as well as reported and claimed GHG emission reductions or removals. This should be done through independent verification against a specific set of rules set under a voluntary carbon standard. It is an element of the 'measurement, reporting and verification' (MRV) of climate change mitigation activities.

This White Paper looks in particular at the implications of digitalization for the verification of GHG emission reductions or removals. The degree of digitalization of the verification process can vary. At a lower degree of digitalization, digital tools are used wherever useful in the current verification process, e.g. for data checking, information management, or reporting. At a higher degree of digitalization, the complete verification process is fully digitalized, including automated quantification and checks. An unbroken chain of automated verification allows credits to be issued in real time.

Two promising blueprints for using digital approaches to verify carbon projects are presented and assessed. These blueprints explore the different roles of project participants and verifiers:

- Digitalized reporting and verification (D-VER, see Figure 1): Here, the roles of stakeholders basically remain the same as in the current (non-digitalized) project cycle. The project participant develops a project specific digital verification (D-VER) platform[1] that reduces their transaction costs and allows the verifier to verify projects digitally. Project participants may also hire a third-party service provider to build and operate the D-VER platform.
- Digitalized integrated quantification and verification platform (I-Q&V, see Figure 2): Here, the project participant merely captures the data. All other tasks are shifted to an independent I-Q&V entity that maintains a digital I-Q&V platform providing both quantification and verification services (and not verification only as with a D-VER platform).

[1] The project participant would probably develop a comprehensive digital measurement, reporting, and verification platform (D-MRV platform). However, the focus of this paper is on verification. Thus, the term D-VER platform is used throughout the paper.

USGS - SATELLITE IMAGE OF MISSISSIPPI, USA. Original figure caption: " Small, blocky shapes of towns, fields, and pastures surround the graceful swirls and whorls of the Mississippi River. Countless oxbow lakes and cutoffs accompany the meandering river south of Memphis, Tennessee, on the border between Arkansas and Mississippi, USA. The "mighty Mississippi" is the largest river system in North America."

FIGURE 1 I
VERIFICATION UNDER THE DIGITALIZED D-VER BLUEPRINT

In the D-VER blueprint, the roles of stakeholders in a typical project cycle basically remain the same as with the current approaches. However, the project participant (blue) develops a project specific digital verification platform (D-VER). The verifier (orange) has comprehensive access to the platform to assess all relevant project data and calculations (magnifying glass). Data quality is checked automatically. Quantification is based on the requirements of the standard (green) and the applicable methodology. After a spot-check review by the standard (approval stamp), credits are issued.

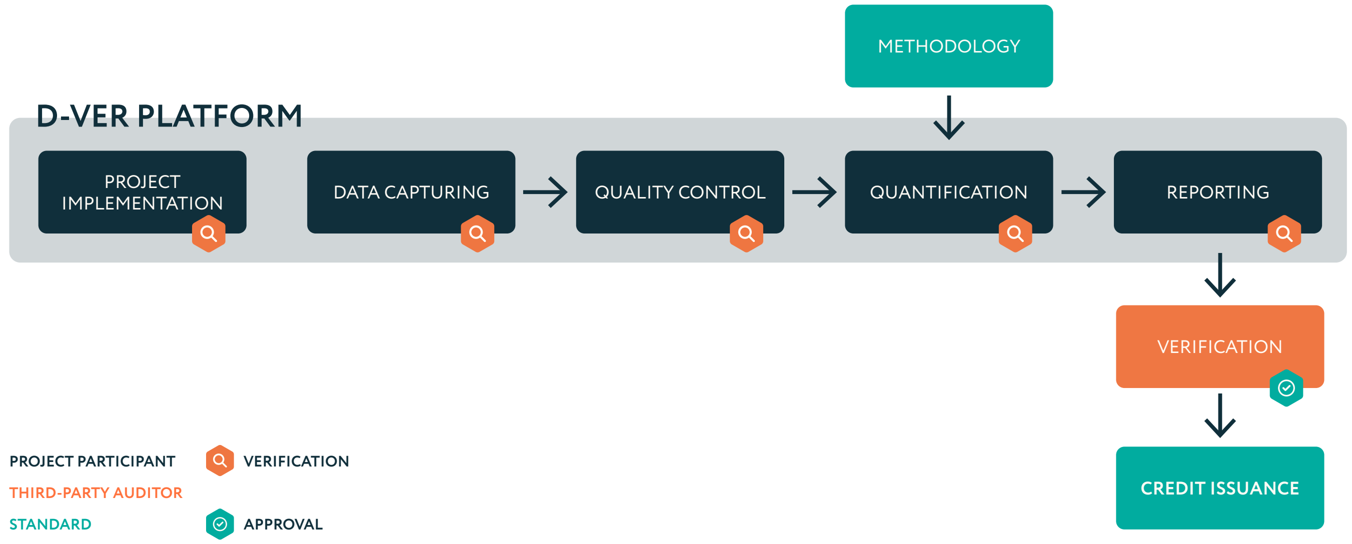
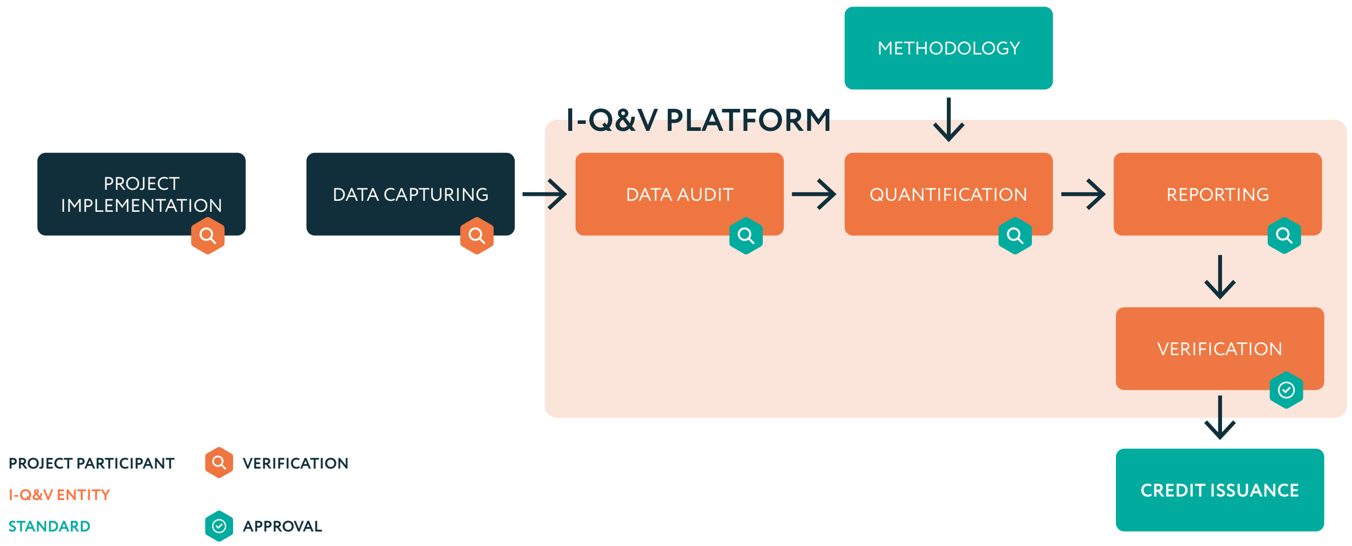


FIGURE 2 I
VERIFICATION UNDER THE DIGITALIZED I-Q&V BLUEPRINT

The I-Q&V blueprint represents a paradigm shift. The project participant (blue) merely captures data. All other tasks are shifted to an independent integrated quantification and verification (I-Q&V) entity (orange) that maintains a digital platform providing both quantification and verification services. Standards (green) still need to make spot checks of reported and claimed emission reductions (green magnifying glass and approval stamp).



The White Paper discusses the above blueprints on the basis of two use cases covering different complexities of project types and digitalization potentials:

- Grid-connected renewable electricity generation, which uses rather simple methodologies and has few parameters that can be straightforwardly measured with accuracy.
- Afforestation/reforestation (A/R) projects that involve modelling and require verification expert input along the verification process.

Based on the assessment of the two blueprints in the use cases and their discussion in two expert workshops (see Acknowledgements), the team of authors drafted the following principles to contribute the discussion and guide further work on D-VER:

TABLE 1 I GENERAL PRINCIPLES FOR DIGITAL VERIFICATION

CATEGORY	PRINCIPLES *(shortened formulation, see Section 4.1 for principles in full length)*
Principle for assessing compliance	• Support assessment of projects' compliance with documentation and the stand-ards' requirements; digitalization does not fully replace site visits, however.
Principles for assessing data	• Use numerical algorithms and machine learning for automated checks on the qual-ity and robustness of data. • Make peer data available as basis for automated data checking. • Build and use cross-institutional open data platforms based on e.g. the IGES pro-ject database or WRI's NDC[2] tracker. • Have digital auditing tools certified by an independent third party.
Principles for assessing quantification	• Use digitalization to facilitate a paradigm shift in quality of quantification methods and their assessment. • Explore immediate potential in the automated assessment of projects with low complexity (e.g. PV). • Be ready to adapt processes and guidelines to automated assessment of projects with higher complexity (e.g. agriculture) in the medium term. • Use open, peer reviewed models; proprietary models need thorough checks. • Have all digital quantification and modelling tools certified by an independent third party. • "Lock in" code of digital platforms. • Make use of digitalization to align quantification with NDCs.
Principles for platform	• Provide verifiers with comprehensive access to the digital platform to assess all relevant project data. • Ensure relevant actors collaborate across institutions in the interest of consistency and interoperability, allowing for digital verification to be scaled up. • Ensure the security and integrity of all data.
Principles for governance	• Have entire digital platforms checked by independent third parties. • "Leave no one behind"; facilitate market access.

Table: IINFRAS. Source: Authors' own analysis.

[2] Nationally Determined Contributions (NDCs) from each country under the Paris Agreement.

There are additional considerations for I-Q&V presented in the White Paper:

- Compared with today's situation, this blueprint brings about a paradigm shift that requires a new governance set-up. The standard or a dedicated meta-verifier would need to conduct comprehensive checks of the digital I-Q&V platform.
- Quantification is not independently verified for individual projects. However, all code that is used for automation has to be certified by a third party prior to use. In this respect the standard would publish a list of requirements that all platforms have to fulfil.
- Having an independent entity providing I-Q&V services has the potential to offer more accurate and more conservative quantification.

If done correctly, digitalization provides the opportunity to strengthen environmental integrity, increase accuracy and the quality of credits, and to increase trust in carbon markets. Greater trust may, in turn, be rewarded by higher prices on the market for such credits. This may compensate for potentially lower volumes of credits issued per project because more accurate approaches may replace default factors that can be very generous. Digital approaches also hold the key to scaling the voluntary carbon markets because of higher efficiency. If the issuing of credits is possible in real time, this enables earlier cash flows and reduces the financial risks for project proponents. Real-time issuance requires the fully automated measuring, reporting, and verification of so-called sustainable development co-benefits, as certified by certain standards.

The set of principles presented in this White Paper should be considered as a contribution to the discussion on digital verification to generate accurate and high-quality carbon credits. There are a lot of working groups, including those from the standards of the voluntary carbon market, and other activities going on to advance the digitalization of verification. Standards want to ensure that their guidelines are adapted to the new possibilities. Verifiers want to understand their role, which might require more IT knowledge but permit a focus on crucial issues that will continue to require human expertise in the future. This ongoing work might in turn help to further refine the blueprints and principles in order to gain a common understanding of how to make the best use of digital verification. ♦

DAVID CLODE - GEORGES BAY, TASMANIA, AUSTRALIA. Original figure caption: "Georges Bay driftwood. Macro photo of the detailed patterns of a log washed up on the beach at Georges Bay in Tasmania, Australia.

1. INTRODUCTION

THE USE OF DIGITAL INNOVATIONS IS EMERGING AS KEY DRIVER INCREASING THE RELIABILITY, EFFICIENCY, AND CREDIBILITY OF MRV ACTIVITIES FOR GHG EMISSION REDUCTIONS OR REMOVALS.

Carbon markets enable companies, governments, and other actors to offset their emissions by buying carbon credits. Such carbon credits are intended to represent greenhouse gas (GHG) emission reductions or removals through project activities such as replacing electricity from fossil fuels with electricity from renewable sources, or GHG removals achieved through the reforestation of degraded land.

Key to the supply of accurate and high-quality carbon credits is a thorough and independent assessment of the implementation of a project's activities, as well as reported and claimed GHG emission reductions or removals. This should be done through independent verification against a specific set of rules set under a voluntary carbon standard. It is an element of the 'measurement, reporting and verification' (MRV) of climate change mitigation activities.

Current MRV in carbon project cycles show a significant digitalization gap. MRV still often involves sending around pdf reports, checklists, and spreadsheets by email, and comprehensive site visits where project implementation and meter readings/calibrations are checked in situ. This conventional approach is labor intensive and costly, and a significant barrier to scaling up and accelerating climate action and access to certified carbon markets. In addition, the reliance on manual interventions for data gathering and checks tends to be error-prone and reduces the credibility of results.

The use of digital innovations is emerging as key driver increasing the reliability, efficiency, and credibility of MRV activities for GHG emission reductions or removals. These technologies include the use of sensors, the internet of things, remote sensing, machine learning, advanced statistics on large datasets, and blockchain, but also smartphones or even simple mobile phone connections to collect and transmit data.[3] This White Paper looks in particular at the implica tions that digitalization has for the verification for GHG emission reductions or removals.

The foundation for accurate and high-quality carbon credits is projects that are designed according to the following principles: additionality, real and measurable abatement, permanence, conservative assumptions and calculations, environmental integrity, allowance for higher ambition, and transparency.[4] Transparency and integrity concerning project contributions to sustainable development can additionally boost credibility.[5] While the sustainable development co-benefits of projects can also be subject to verification, this is not the focus of this White Paper.

The degree of digitalization of the verification process can vary. At a lower degree of digitalization, digital tools are used wherever useful in the current verification process, e.g. for data checking, information management, or reporting. At a higher degree of digitalization, the complete verification process is fully digitalized, including automated quantification and checks. A continuous chain of automated verification would allow credits to be issued in real time.

In this White Paper, two blueprints for digital verification are presented and assessed. They differ regarding the role of the project participant and the verifier:

- Digitalized reporting and verification (D-VER), where the roles of stakeholders basically remain the same as in current (non-digitalized) project cycles.
- Digitalized integrated quantification and verification platform (I-Q&V), where the project participant merely captures the data, and all other tasks are shifted to a certified and independent I-Q&V entity.

The White Paper focuses on two use cases covering different complexities of project types and digitalization potentials to discuss the blueprints:

- Grid-connected renewable electricity generation, which uses rather simple methodologies and has few parameters that can be straightforwardly measured with accuracy.
- Afforestation/reforestation (A/R) projects that involve modelling and require verification expert input along the verification process.

Based on the discussion of the blueprints and use cases, the White Paper presents several principles for best-practice digital verification. The set of principles is intended to provide a contribution to the ongoing discussion on digital verification.

Digital verification is still a nascent field. At the core to the White Paper are selected interviews and discussions with experts from the field, including those from voluntary carbon standards. In addition, the White Paper is based on earlier work by SustainCERT and the Climate Ledger Initiative. Finally, literature on digital verification was analyzed.

Section 2 of the White Paper describes current non-digital verification processes. Section 3 presents the two blueprints for digital verification. Section 4 discusses the blueprints and provides principles to leverage the advantages of digitalization in verification, and increase quality and integrity in carbon markets. Section 5 provides concluding remarks. ♦

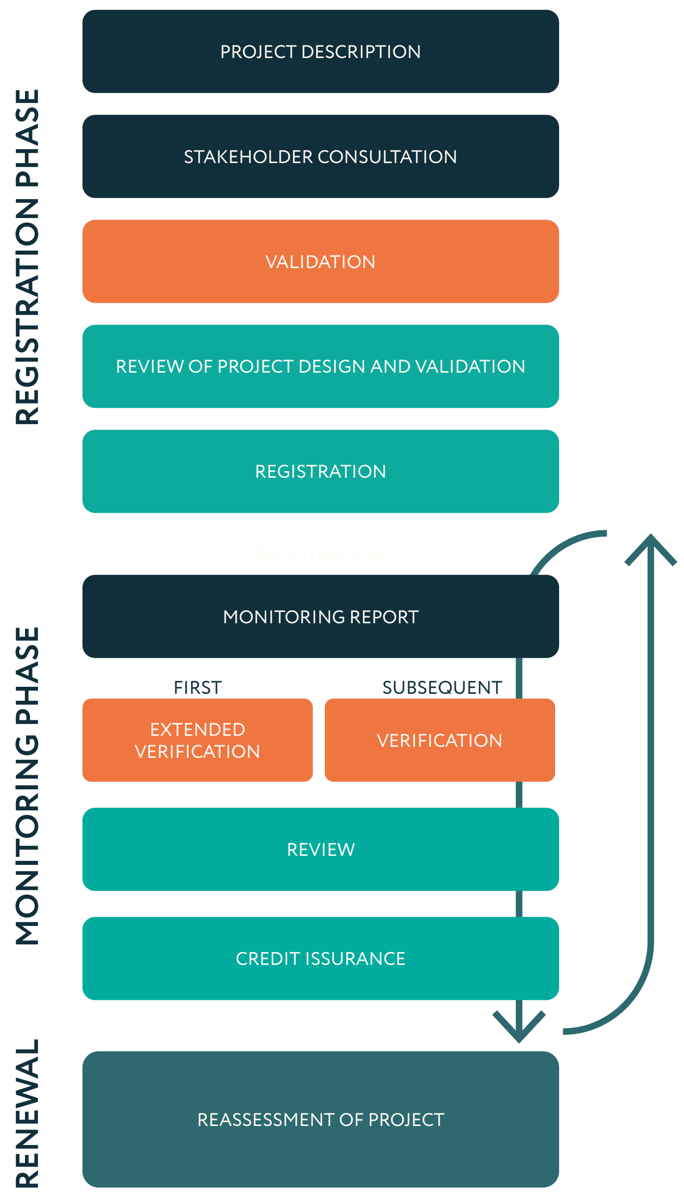
[3] Soini, Kohli, and Fuessler 2022
[4] See e.g. Schneider, Lambert et al. 2017a or the work by the ICVCM for a deeper treatment of these principles.
[5] Gold Standard 2022

2. TODAY'S VERIFICATION PROCESSES

2.1. VERIFICATION PROCESS

The objective of verification is a thorough and independent assessment of the implementation of a project's activity, and the reported GHG emission reductions or removals against the applicable rules and requirements set by the standard.[6] In assessing the information, the verifier applies common auditing techniques, including document review, on-site visit, and sampling approaches. Verification is part of a project cycle to which all projects are subject (see Figure 3). The final goal is the issuance of credits.

FIGURE 3 I
PROJECT CYCLE



PROJECT PARTICIPANT
THIRD-PARTY AUDITOR
STANDARD

Figure: INFRAS. Source: Based on World Bank Group 2021

The project cycle starts with the registration phase, where the project design document is prepared. This defines the quantification approach, which includes system boundaries, the baseline setting, project and leakage emissions, modelling methods and assumptions, default values and specifications with respect to ex-ante fixed parameters, and monitoring parameters[7] The monitoring plan is an important part of the quantification approach and specifies the detailed measurement of monitoring parameters during project implementation. For example, it covers measurement equipment, measurement frequency and calibration requirements. The project design document, and in particular the monitoring plan, are based on the requirements (modalities and procedures) of the standard and the applicable methodology. Whether these requirements are met is validated by a third party. The project participant submits the project documentation and the validation report to the standard, which performs a final review of these documents. The depth of this review differs between standards and project types. The final step of the registration phase is for the standards to register the project.

The project cycle continues with the monitoring phase, which is repeated periodically. After a certain period of operation, the project participant drafts the monitoring report. This describes the implementation of the project, monitoring parameters (including the monitoring methods, frequency of data collection and QA/QC), and the quantification of GHG emission reductions or removals. A crucial part of the project cycle is verification by a certified third-party auditor.[8] Since verification is the focus of this White Paper, Figure 4 shows today's non-digital verification process in more detail. The illustration forms the basis of the description of blueprints later in this White Paper.

It is the verifier's role to guarantee the correctness and compliance of the monitoring report on the monitoring plan for the registered project's design document. This includes the implementation of the project (technologies, facilities, equipment, and devices for monitoring must comply with the specified requirements), data capture (including calibration and maintenance of measuring equipment), quality control and subsequent quantification, and the reporting of emission reductions which serve as a basis for credit issuance. The first verification is particularly important and thus more in depth, as it involves the initial check on actual implementation and the monitoring plan. Some standards review the monitoring documents at this stage, usually using spot checks. Finally, credits are issued.

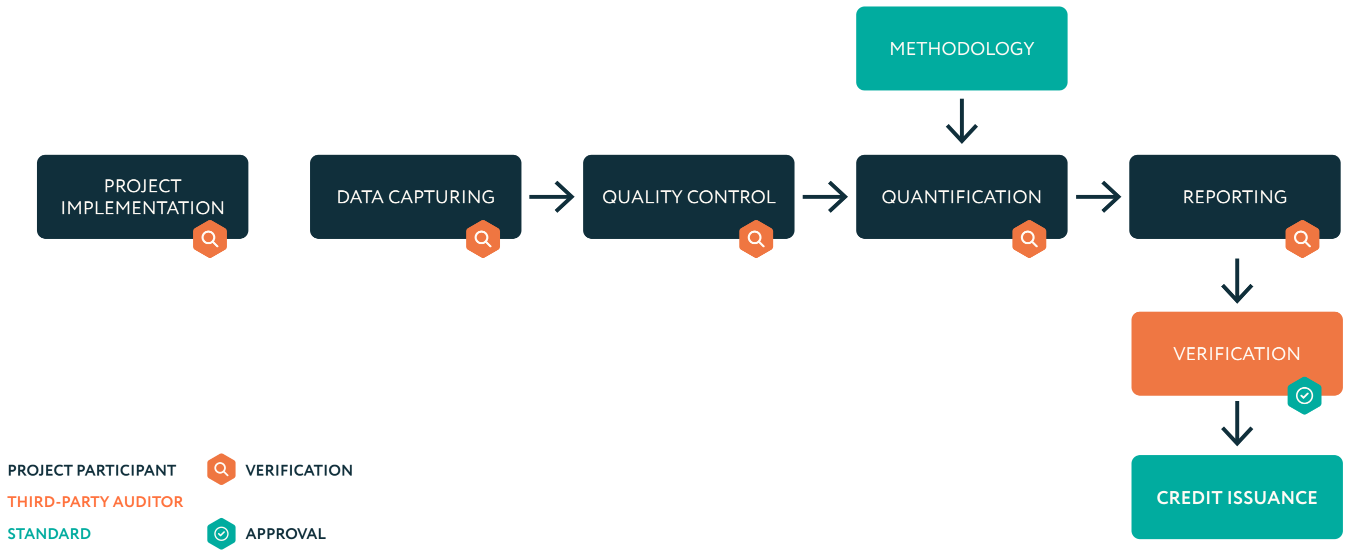
[6] For details of the scope of verification see the validation and verification manuals of the CDM. See also the respective manual from Gold Standard or VERRA (retrieved on 28.06.2022), which also require the checking of safeguards, governance, public con-sultations, SDGs, transparency etc. Finally, the ISO14064 norm provides guidance on the quantification and reporting of green-house gas emissions and removals.

[7] Default parameters are determined by the method used. Ex-ante fixed parameters are determined on a project-specific basis once before the start of the project. Usually, these concern the baseline and cannot be measured during the project (e.g. a sam-ple of the status quo consumption). Monitoring parameters have to be measured during the project.

[8] A third-party audit is conducted by an independent, external organization, which may not have any direct relationship with the organization being audited.

FIGURE 4 I
VERIFICATION OF A CARBON PROJECT TODAY

An important basis for verification by a third-party auditor (red) is a monitoring report by the project participant (blue). It describes the implementation of the project, data capture and quality control, as well as the quantification and reporting of GHG emission reductions or removals. Quantification is based on the requirements of the standard (green) and the applicable methodology. Standards (green) may review the work of the verifiers using spot checks (approval stamp). Finally, credits are issued.



Each project has a certain crediting period (usually 5-10 years, and between 30-50 years for forest projects), in which the quantification approach determined during the registration phase remains fixed to guarantee the project participant investment security. In most cases, standards allow the crediting period to be renewed at least once in a dedicated procedure.[9] Renewal basically repeats the registration phase while re-calculating and updating the baseline. It is leaner, as many elements from former periods can be used.

Under a streamlined approach (not shown), verification also includes validation and thus shifts certain validation tasks to the verification stage. This saves administrative costs but increases the certification risk for project developers, as the project is registered at the verification stage and is thus approved by the standard after implementation has taken place.

Current non-digital verification processes and their characteristics are presented in Table 3 in the Annex.

[9] Sequestration activities mostly have one fixed crediting period with no renewal possible.

2.2. TWO USE CASES

The White Paper presents two use cases: grid-connected renewable electricity generation and afforestation/reforestation (A/R). The former is rather simple with respect to monitoring and verification. Only slightly more complex would be clean cookstove projects that are also briefly mentioned in the White Paper. The latter use case of A/R is more complex. Finally, the White Paper also mentions soil organic carbon projects that can be considered as the most complex case for digitalization.

2.2.1. GRID-CONNECTED RENEWABLE ELECTRICITY GENERATION

Grid-connected renewable electricity projects replace fossil fuel-based electricity with solar energy, wind energy, hydro energy, or biomass power. These projects typically have high up-front capital costs. Renewable energy is carbon-free[10] and replaces carbon-intensive grid electricity. Emission reductions are calculated as the product of electricity produced multiplied by the grid emission factor (GEF).[11] Electricity generation is usually measured accurately. There may, however, be measurement errors and other problems that have to be checked during verification. Currently quality control is approximate, including plausibility checks against previous data, or maximum capacity.

An important element of quantification is determining the GEF. One option is to do this once during the registration phase and later use this fixed value during the full crediting period. Another option is to update the GEF for each monitoring period. Therefore, the GEF is checked and confirmed by the auditor during either validation or verification.

Most projects calculate the GEF using the CDM tool to calculate the emission factor for an electricity system. The tool first requires the electricity grid to be chosen, for which in turn the operating margin and the build margin must be determined. The operating margin represents the emission factor of the total electricity grid.[12] The build margin represents the emission factor of the electricity grid's most recently built plants. The tool allows for various approaches to determine the operating margin and the build margin, using a variety of input data such as the grid's plant distribution, fuel input, power load curves, etc. The GEF corresponds to the combined margin, which is a weighted average of the operating margin and the build margin. With respect to weighting, there are default values for different circumstances, or a project participant may choose an individual weighting.

[10] Some standards may require accounting for emissions of renewable energy, i.e. those that arise from the production of equipment. It is a minor component and thus ignored below. In addition, biomass is only considered carbon free if it arises from a renewable life cycle.
[11] There are also off-grid or mini grid projects, where electricity production is measured in a similar way, albeit with different procedures to determine baseline emissions.
[12] The operating margin excludes the impact of "low-cost/must-run" plants, as they have low marginal generation costs or de-liver energy independent of seasons or actual demand for technical reasons. Hydroelectric and nuclear plants fall into this cate-gory.

2.2.2. AFFORESTATION/REFORESTATION

Afforestation refers to growing trees in areas where previously there have been none. Reforestation describes planting trees in areas that have seen deforestation in the recent past.[13] These two related project types are often grouped together and abbreviated as "A/R." Whereas "technical" projects decrease greenhouse gas emissions into the atmosphere, A/R projects remove CO2 from the atmosphere and convert it to biomass.[14] In both cases the outcome is a lower atmospheric carbon stock.[15]

For quantification purposes, A/R projects usually monitor (i) project removals (also called carbon-fixation), (ii) baseline removals, and (iii) leakage. The following focuses on woody biomass, which is the largest and most discussed component.[16]

Project removals are related to the stock of accumulated woody biomass, which is usually determined during in-field assessments. Measurements include the diameter at chest height, height, and wood density. This data is used to determine the total above-ground biomass using allometric equations. These models exist in a variety of forms and depend on factors such as tree species and climatic conditions. If applied appropriately (for a specific tree species and environment) they provide accurate results. However, allometric equations are not yet available for every tree species such as those found in the tropics. Above-ground biomass is multiplied with the "root to shoot ratio" to determine below-ground biomass.

The sum of above and below-ground biomass is the total woody biomass. Results are extrapolated to a larger area. Standards already allow field measurements to be combined with remote sensing techniques. For an overview on these techniques, see Section 3.3). In the VERRA methodology,[17] for example, the exact procedure is not prescribed, citing the wide range of existing approaches. Remote sensing techniques may be a partial substitute for field measurements if it can be proven that this improves accuracy.

To account for removals that would occur in the baseline, methodologies usually require the growth of woody biomass to be tracked in control plots outside the project boundary.

Verra, for example, allows these control plots to be monitored based on remote sensing alone.[18]

Finally, leakage concerns the shift of agricultural activities (e.g. grazing) from the project area to another. Verra's leakage tool[19] allows remote sensing to be used to determine input parameters such as the agricultural practices in the project area before project implementa-tion.

To sum up, with A/R the market is already in the middle of a digitalization process and various products are already available. ♦

[13] There are several other types of forestry-related project types. According to the Berkeley Carbon Trading Project's Voluntary Registry Offsets Database (v5), REDD+ projects are the most prevalent ones covering 25.8% of the total voluntary market by credit issuance. Second are Improved Forest Management projects covering 14.1% of the market (mainly in the U.S.). Third are A/R projects covering 3.3% of the market.

[14] Reforestation projects can also be seen as a reduction of emissions due to deforestation, in which case they would rather fit the definition of technical projects.

[15] A crucial difference is, however, that changes in stock face the risk of non-permanence: A/R may be reversed at any point in time by e.g. subsequent deforestation or forest fires.

[16] A/R projects may also comprise components such as herbaceous biomass, harvested wood products, dead wood, litter, soil organic carbon or N2O emissions from fertilizers. The challenges of quantifying these components are usually higher in compari-son with woody biomass.

[17] "Methodology for afforestation, reforestation and revegetation projects" (v0.1), page 56. This methodology is at the time of writing not yet active, but publication is expected in late 2022.

[18] "Methodology for afforestation, reforestation and revegetation projects" (v0.1), page 78 et seq.

[19] "Module for estimating leakage from ARR activities" (Version 0.2)

TREE PATTERN PHOTOGRAPHY, JACOB OWENS.

3. TWO BLUEPRINTS FOR DIGITAL VERIFICATION

3.1. GENERIC DESCRIPTION OF THE BLUEPRINTS

In this White Paper, two blueprints for digital verification are presented. They differ regarding the role of the project participant and the verifier:

- Digitalized reporting and verification (D-VER, see Figure 5): Here, the roles of stakeholders basically remain the same as in current (non-digitalized) project cycles. The project participant develops a project-specific digital verification (D-VER) platform[20] that reduces their transaction costs and allows the verifier to verify projects digitally. Project participants may also hire a third-party service provider to build and operate the D-VER platform.

- Digitalized integrated quantification and verification platform (I-Q&V, see Figure 6): Here, the project participant merely captures the data. All other tasks are shifted to an independent I-Q&V entity that maintains a digital I-Q&V platform providing both quantification and verification services (and not verification only as with a D-VER platform).[21]

For both blueprints, there will be a pool of verifiers or I-Q&V entities respectively from which the project participant can choose.

[20] The project participant would probably develop a comprehensive digital measurement, reporting, and verification platform (D-MRV platform). However, the focus of this paper is on verification. Thus, the term D-VER platform is used throughout.
[21] It is also possible that the I-Q&V entity controls the meters and captures the data. In this case, data capture would be part of the I-Q&V platform.

FIGURE 5 I
VERIFICATION UNDER THE DIGITALIZED D-VER BLUEPRINT

In the D-VER blueprint, the roles of stakeholders in a typical project cycle basically remain the same as with the current approaches. However, the project participant (blue) develops a project specific digital verification platform (D-VER). The verifier (orange) has comprehensive access to the platform to assess all relevant project data and calculations (magnifying glass). Data quality is checked automatically. Quantification is based on the requirements of the standard (green) and the applicable methodology. After a spot-check review by the standard (approval stamp), credits are issued.

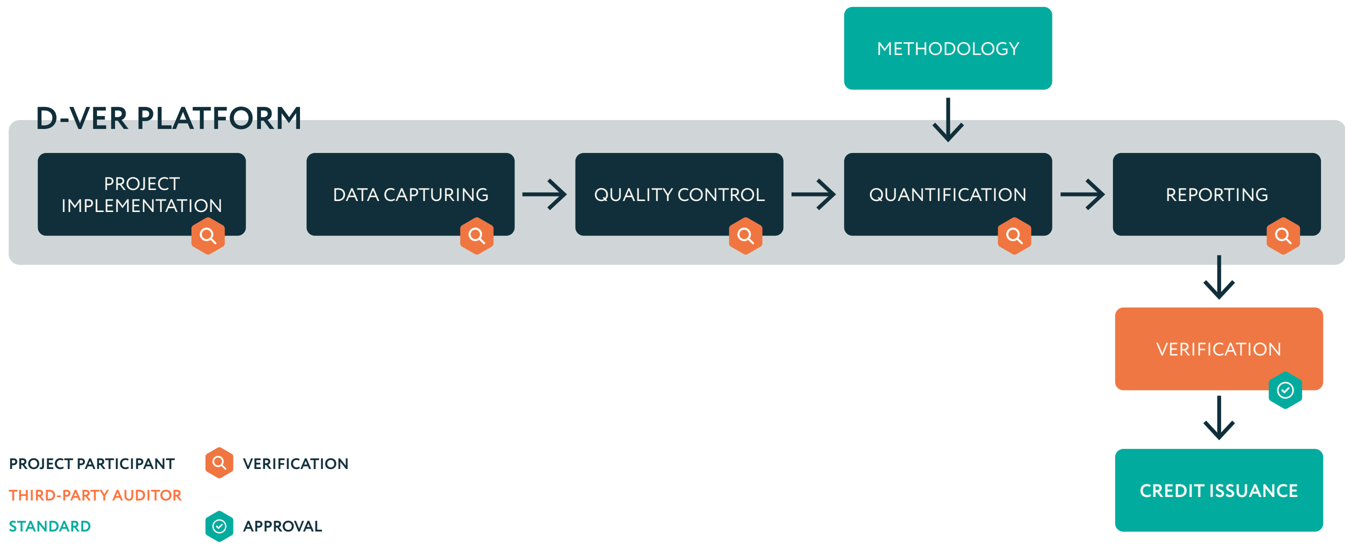
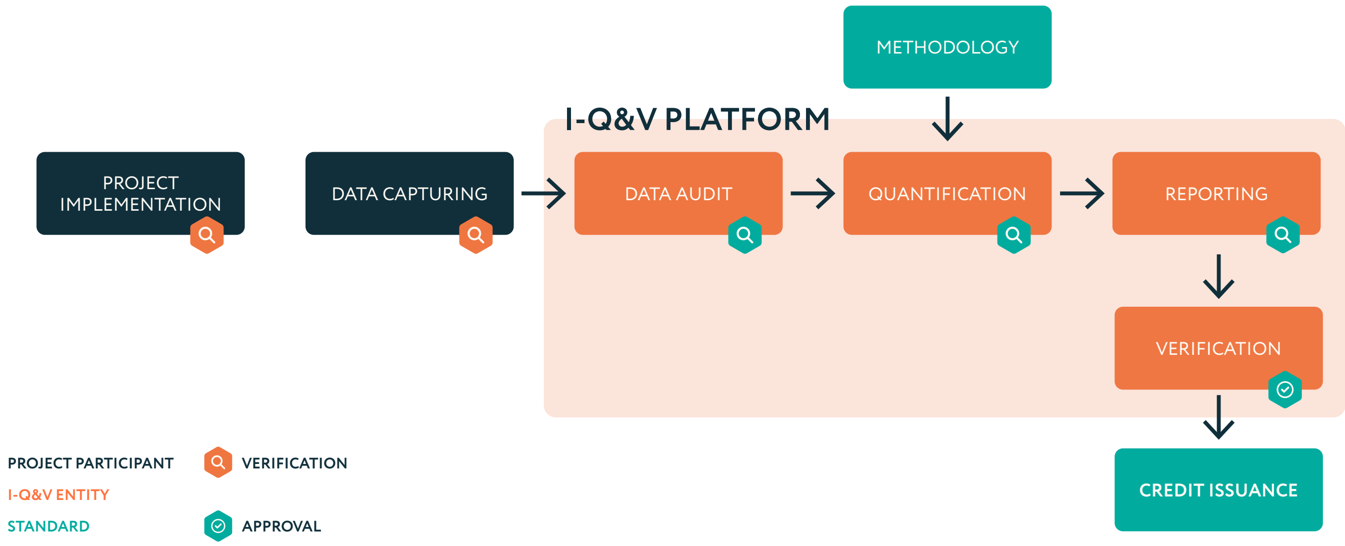


FIGURE 6 I
VERIFICATION UNDER THE DIGITALIZED I-Q&V BLUEPRINT

The I-Q&V blueprint represents a paradigm shift. The project participant (blue) merely captures data. All other tasks are shifted to an independent integrated quantification and verification (I-Q&V) entity (orange) that maintains a digital platform providing both quantification and verification services. Standards (green) still need to make spot checks of reported and claimed emission reductions (green magnifying glass and approval stamp).



The degree of digitalization of the verification process can vary:

- At a lower degree of digitalization, there is digital support for some elements of the current verification process. Digital tools are used wherever useful (data checking, information management, reporting, etc.). Already today, there are digital solutions to MRV services[22] that can digitally support certain verification steps.

- At a higher degree of digitalization, the complete verification process is fully digitalized, including automated quantification and checks. An unbroken chain of automated verification allows credits to be issued in real time.[23] A prerequisite for real-time issuance would be the possibility to fully automate measurement, reporting, and verification of so-called sustainable development co-benefits, as certified by certain standards.

The White Paper describes the two blueprints at an advanced state of digitalization. However, D-VER can start with the current non-digitalized or only partially digitalized processes and could, over a transitional period, increase the level of digitalization in all components of the project cycle step-by-step. For instance, digitalization might start with automated data quality control, checking for outliers and consistency with comparable projects, and supporting a (still mostly manual) conventional verification process. For I-Q&V, such a transitional period is less meaningful, as a high level of digitalization is an inherent feature of the I-Q&V platform.[24] I-Q&V changes the verification process fundamentally and thus demands an abrupt paradigm shift in processes, responsibilities, and governance. SustainCERT considers itself as an I-Q&V entity. The remainder of this section briefly showcases the digitalization potential of the two use cases which could be harnessed under both blueprints. A more detailed and systematic assessment of specific topics, broken down by blueprint, is carried out in Section 4.

3.2. USE CASES: DIGITALIZATION POTENTIAL FOR GRID-CONNECTED RENEWABLE ELECTRICITY GENERATION PROJECTS

The crucial monitoring parameter is electricity generation, which is already measured in digital form by design. However, currently measurement results are often not processed digitally, but transferred manually into Excel for quality checks, emission reduction calculations, and verification.

A digitalized platform could perform digital data quality control (see box) and quantify emission reductions automatically. Credits could then be issued in real time, which requires all digital tools to be certified prior to use.

Currently, the grid emission factor (GEF) is usually fixed during the registration phase for the total crediting period. It is best practice to provide a yearly update, which could be fostered by digitalization. The respective calculations could be automated on the platform and data input could either be automated or follow strict requirements, so that only spot checks by a third-party would be required.[25] The platform would also allow for a comparison of the outcomes of different options (if possible) or GEF values from similar projects, especially in those case where ex-post values are calculated regularly. Another possibility is that GEF calculations for the same region are not repeated across all affected projects, but instead done only once and then synchronized and shared across projects within the platform.

3.3. USE CASES: DIGITALIZATION POTENTIAL FOR A/R PROJECTS

Digitalization can strengthen the existing trend towards using remote sensing techniques for quantification. The following remote sensing technologies exist:[26]

[22] See Soini, Kohli, and Fuessler 2022 and references therein
[23] To be precise it is more near-real time. There will/should be some processing time in the various stages (e.g. data upload frequency of 15 minutes to one hour. In this sense, anything less than, say, 48 hours would still qualify as real time.
[24] Without digitalization, processes cannot be automated, which would pose a problem for the governance structure of the I-Q&V blueprint, as it requires automated processes to be certified prior to use (see also Section 4.2). In addition, a less automated system requires more human resources. An I-Q&V entity could, in principle, provide these recources, but the idea is to make best use of digitalization and keep the entity reasonably small and flexible.

DIGITAL DATA QUALITY CONTROL FOR GRID-CONNECTED RENEWABLE ELECTRICITY GENERATION

DIGITAL DATA QUALITY CONTROL INCLUDES A SERIES OF SEQUENTIAL CHECKS:

- **Onboarding checks:** sensors, data format, data transfer test (connection failure, outages,missing values), etc.
- **Non-technical checks:** plausible range (negative values, maximum capacity), missing/null values, frequency, etc.
- **Basic-statistical checks:** distribution (mean, standard deviation, etc.)
- **Technical checks**: pattern (daily, seasonal, etc.), load factor, dynamic checks (e.g. implausible jumps in consecutive data points)
- **Cross checks:** historical data, portfolio of peer projects with similar features, deviation from simulation data, correlation with internal data (e.g. plant journal/logbooks, inventories, purchase receipts), or correlation with external data (e.g. weather or temperature data; see also Table 2)
- **Possibly in the future:** machine learning checks using more complex pattern recognition to detect anomalies.

[25] The same ought to be true if the GEF is determined ex-ante during the registration phase.
[26] See Soini, Kohli and Fuessler 2022 for a more detailed description of these technologies and their respective strengths and weaknesses.

- Passive optical measurements rely on satellite images and aerial pictures (openly accessible or commercial) at various resolutions. Higher-resolution imagery can improve accuracy but is more costly and faces more problems owing to cloud obstruction.

- Light Detection and Ranging (LiDAR) uses reflections from actively emitting lasers operated from dedicated aircrafts (or satellites) to measure distances. For dense canopies, this method yields more accurate results. As data collection is costly, LiDAR is usually used to cal-ibrate passive optical methods. Satellite-borne LiDAR could decrease costs but is not yet available at scale.[27]

- Microwave sensors use a wavelength that is different from that for optical measurements. It is not obstructed by clouds. The appropriate wavelength depends on the use case (e.g. longer wavelengths are better suited to penetrate to lower forest levels). Both aircraft-borne and satellite-borne solutions exist.

Using remote sensing data, A/R models follow roughly a two-step process:

- Remote sensing data is fed into suitable algorithms to derive the geometric properties of trees – such as canopy height or stem dimensions. The uncertainty is usually smaller for larger trees, thus making results for areas with high biomass density more robust. One challenge is to remotely determine the distribution of species, however.

- Allometric models convert the geometric information into biomass volume. As remote sensing provides different input data that field measurements (see Section 2.2.2), models have to be re-calibrated.

Digital quantification approaches are thus always a combination of remote sensing techniques and models that process the data. Digitalization allows for the optimum integration of existing approaches and those currently in development. Verification and MRV more broadly could thus both be less costly and more accurate. It is, however, important to test each approach's accu-racy in accordance with a set of stringent criteria.[28]

3.4. ASSESSMENT OF D-VER AND I-Q&V COMPARED WITH CURRENT VERIFICATION PROCESSES

This section compares today's verification process and the two blueprints based on costs, credibility and scalability. Table 3 in the Annex presents current non-digital verification processes and their characteristics. The information serves as a basis for the assessment in this section. The following table reflects the authors' approximate, indicative estimates for an average case. ♦

TABLE 1 I APPROXIMATE, INDICATIVE QUALITATIVE COMPARISON

CHARACTERISTICS	ASSESSMENT		
	Verification costs	Credibility	Scalability
Grid-connected renewable electricity generation			
Today	Medium	Low-medium	Medium
D-VER	Low-medium	Low-medium	Medium-high
I-Q&V	Low	High	High
A/R			
Today	High	Low-medium	Low
D-VER	Medium	Medium	Medium
I-Q&V	Medium	Medium-high	Medium

Table: INFRAS. Source: Authors' estimates based on an assessment of selected blueprints for D-VER.

[27] Alternatively, see the GEDI project (https://gedi.umd.edu/; retrieved at 05.07.2022)
[28] For example, Verra provides procedures for the calibration, validation, and verification of empirical process-based models ("VMD0053 Model Calibration, Validation, and Uncertainty Guidance for the Methodology for Improved Agricultural Land Man-agement"). CAR provides requirements and guidance for model calibration, validation, uncertainty, and verification for soil en-richment projects

4. DISCUSSION OF BLUE-PRINTS AND PROPOSAL OF PRINCIPLES

4.1. DIGITAL VERIFICATION (D-VER)

The following analysis considers the main steps in project verification and discusses the potential role of digital approaches, options for their implementation, and the benefits and challenges that arise.

4.1.1. VERIFICATION OF COMPLIANCE OF PROJECT IMPLEMENTATION WITH DOCUMENTATION AND STANDARD REQUIREMENTS

The assessment of the compliance of a project's implementation and operation with the project documents and the standard's requirements forms part of the initial verification. This checks if the project has been implemented according to the requirements of the documenta-tion of the registered project and all relevant rules of the standard. It may cover the location, type of technology, equipment, devices, installed capacity or project perimeter. This step also includes a site visit by an independent third party to check that the project has been actually implemented. While approaches are emerging to carry out these checks remotely (e.g. by vide-oconference) experience with such processes indicates that this step cannot be fully replaced by digital means. It may be assumed that a certain level of manual verification work by experts is required in most cases, including site visits at the beginning of and during the project. This work can, however, be made more efficient and robust with digital support. For example, it could be mandatory to upload relevant data (e.g. photos, protocols, descriptions, independently audited financial data) that may replace certain onsite verification processes. Or the verifier could be guided through the process based on an online form that already contains some of the digitally uploaded data.

PRINCIPLE FOR ASSESSING COMPLIANCE

Apply digital approaches to support and streamline the process of checking the compliance of project implementation with documentation and standard requirements. How-ever, these are unlikely to fully replace site visits.

4.1.2. VERIFICATION OF DATA CAPTURE, SAMPLING APPROACHES, SURVEYS AND QUALITY CONTROL

The assessment of raw data capture, sampling approaches, surveys, default values and quality control is key to ensure robust quantification and permits the uncertainty surrounding inputs to be evaluated and reduced. Currently, the verification of input data occurs through document transfer, during site visits and through desk research. It is mostly based on Excel, Word and pdf files. Cross checks (also known as plausibility checks) are not usually part of the monitoring plan, and thus not a major part of verification.

Under D-VER, raw data capture is automated as much as economically and technically possible.[29] The project participant performs a digital data quality control (see box in Section 3.2 for examples). The monitoring plan is intended to provide ranges and predefine the mechanisms to deal with erroneous or implausible raw data. The extent to which data quality is checked should depend on its relevance to emission reduction and removal quantification, as well as digitalization potential. If raw data transfer is continuous, where technically meaningful the set-up may include automated real-time alarms when out-of-range submissions occur for a prolonged period. This would also decrease the credits lost due to preventable data gaps. Tools for digital data quality control need to be checked by an independent third party against the standards or methodological requirements.

PRINCIPLES FOR ASSESSING DATA

Use numerical algorithms and machine learning for automated checks on the quality and robustness of data, to increase data accuracy and reliability, and simplify data quality audit as part of verification.

Make peer data on performance from similar projects available as a key basis for automated data checking, comparison with similar projects, and verification.

Build and use cross-institutional open data platforms providing access to peer data, e.g. IGES project database or the WRI's NDC30 tracker, to perform efficient algorithms and feed into machine learning.

Have all tools for digital data quality control checked by an independent third party.

For programs that contain many small units (e.g. biodigesters, cookstoves, solar water systems), monitoring cannot usually cover all units, as this would be time-consuming and costly. It is thus common to gather information on a representative sample. Digitalization can help in two ways. First, it can improve sampling accuracy by prescribing "smart sampling," where sampling probability depends on the estimated emission reductions or removals – if differences are to be expected. Initially, the sampling rate would be rather high, but decrease for later samples towards a minimum rate if no problems are detected. Second, if digital meters are cheap, they may even allow all units to be covered, thus eliminating the need for sampling altogether. In addition, the surveys themselves can benefit from digital approaches, e.g. with smartphone applications that guide surveyors through the data collection process and make automated data quality checks on survey data.

Raw data that serves as an input to quantify emission reductions or removals (primary data) must be cross-checked as much as possible with secondary data. Secondary data is not directly used for quantification, but ins-tead is information based on known correlations with primary data. It comprises historical data for the same project, portfolio data from peer projects with similar features, simulation data, correlations with other internal data (such as plant journals/logbooks, inventories, and purchase receipts) or weather data such as irradiance, wind, and/or temperature. Requirements to collect appropriate secondary data should be part of the monitoring plan, including frequency and responsibilities. Examples of secondary data for specific project types are provided in the following table.

TABLE 2 I EXAMPLES OF SECONDARY DATA USED FOR CROSS CHECKS

PROJECT TYPE	PRIMARY DATA TO CALCULATE EMIS-SION REDUCTION OR REMOVALS SECONDARY DATA USED TO CROSS CHECK		DATA SOURCE FOR SECONDARY DATA
Mini grid PV	Electricity generation	Solar irradiance Electricity generation of plants nearby	Meteo station Nearby plants
Wind power plants	Electricity generation	Wind speed Electricity generation of plants nearby	Meteo station Nearby plants
Cook stoves	Baseline and project wood con-sumption, stoves in operation	Data from other household surveys in similar communities	Other project de-velopers, NGOs, research
Wood district heating Heat	Heat	• Utilized wood (accounting for species and moisture) • Heated space in conjunction with heating degree days	Project

Table: INFRAS. Source: Authors

[29] See Soini, Kohli, and Fuessler 2022 for a snapshot of digital MRV in decentralized energy, forestry, and agriculture.

4.1.3. VERIFICATION OF QUANTIFICATION: DEFAULT VALUES, ASSUMPTIONS, MODELS AND CALCULATIONS

The assessment of the quantification approach that determines reporting and claims of emission reductions or removals is part of the validation step during the registration phase. Verification, meanwhile, concerns the correct application of that quantification approach. Automated processes improve verification of the quantification. The timeframe in which automation will be implemented depends on the project type and data availability:

- Automation will be implemented more rapidly for simpler quantification methodologies such as grid-connected renewable electricity generation, which rely on fewer parameters that can be measured with well-established equipment such as digital power meters. Here, digital platforms are already fully operational on a commercial basis, e.g. in the context of large-scale wind generation.

- Automation may take longer for more complex quantification methodologies such as for soil organic carbon, where checking model calibration, validation, and use, etc. requires expert human knowledge to consider site-specific circumstances. However, much research

into automation is already underway. The ability to scale digital approaches for A/R activities may be greater, in particular in more homogenous land areas (e.g. with regard to tree species in A/R approaches), where the use of remote sensing may allow for rapid upscaling.

All automated processes need to be certified prior to use. In addition, proprietary "black box" models (such as those relying primarily on machine learning algorithms for quantifications) should only be certified if the model is calibrated and carefully assessed so that it is eligible for use under the specific conditions at the site, and for the specific activity in question.[31] Certification must remain valid for a pre-defined period that may be less than the crediting period.[32]

During verification, the automated processes should only be checked for tampering and unforeseen errors. For project types where data capture is continuous and full automation possible, credits could be issued in real time (e.g. for grid-connected renewable electricity gen-eration).[33]

This helps to improve the project developer's cash flow and real-time issuance. The conditions of real-time issuance include regular ex-post audits involving human expertise, and buffer credits to account for potential errors. Thus, credits for only a certain percentage of the quantified emission reductions or removals are issued in real time.

Whereas automating verification is more challenging for complex methodologies and will take more time to develop, the potential to improve the quality of quantification is high. This is because of the increased amount of (high-quality) data that is captured digitally by projects, or that becomes available from the literature or open data repositories. The following box provides more information on why digitalization is an important tool to improve quantification methods.

A digital platform would allow changes in default values or methods over time to be applied simply to quantification algorithms. Changes within the crediting period would usually improve environmental integrity (as new data can be used more rapidly) but mean lower investment security. An alternative is to shorten the crediting period for project types that feature complex and uncertain methodologies. Here, digital approaches can help to simplify the process, as renewals of crediting periods could be partially automated as well. As an extreme case, crediting periods could be disposed with altogether and replaced with a project-type-specific maximum length of credit issuance in which all parameters that potentially alter the baseline (or affect additionality) are monitored such that baseline corrections occur continuously and not only at renewal.

Digital approaches that replace at times very generous default factors can improve quantification. This may lead to lower volumes of credits being issued per project. However, the greater accuracy and quality of credits can increase trust in carbon markets. Greater trust may in turn be rewarded by higher prices on the market for such credits, which potentially compensates for the lower number of credits issued per project.

Taking into account country specific NDCs and competing incentive systems (such as emis-sion trading schemes) is increasingly important to determine baselines, facilitate the corresponding adjustments and prevent overlapping claims. Digitalization can help to align quantification (e.g. baseline setting) dynamically with host country-specific NDCs so that emission reductions are not over-estimated.[42]

DIGITALIZATION AS AN IMPORTANT TOOL TO IMPROVE QUANTIFICATION METHODS

To achieve high environmental integrity, quantification should be carried out in a conservative way such that there is a low likelihood of overestimating emission reductions or removals. It is thus best practice to have an expert panel periodically scrutinize the uncertainty of the quantification approach prescribed by the methodologies, and make adjustments if needed. Improving the quantification approach is not directly part of an individual verification, as the approach and its default values are usually fixed during validation based on the methodologies.[34] However, digitalizing monitoring and verification will support these improvements as it may encourage the project in question or its peers to make more data available.[35]

To generate more data, the prevailing incentive structure has to be changed. In many cases, methodologies currently allow default values to be used instead of measurements. Usually, project participants use the default options, as measurements are costly and outcomes uncertain. Therefore, little data is generated, and the applied default values remain unchallenged over long periods. In fact, many current methodologies use default values from the IPCC's NIR guidance from 2006, which in turn uses data from the 1990s or simply "expert judgement".[36] Correspondingly, default values are uncertain and often outdated. Digitalization is a chance to improve this situation, as the cost of measurement and data processing decreases. To provide an incentive to generate data, current default values should

be subject to a discount factor to make them sufficiently conservative.[37] Measured data should be stored centrally on a project proponent's platform or ideally a shared on a third-party platform and be used for periodic expert panel scrutiny of existing default values.[38] The platform should not only provide information about uncertainty, but also about data quality (e.g. estimate vs. measurements).

Using data to scrutinize quantification works best if the data:

Is from independent sources, validated and from peer reviewed research,[39]

Covers a wide range of different applications, different practices, technologies and species, and conditions (locations, soil, weather etc.), and

Stems from studies that apply more than one approach in a given location.[40]

Note that IPCC's NIR guidance performs a similar function. Updates are, however, rare. In fact, the version from 2006 has been updated only once, in 2019, when certain parameters were re-assessed and uncertainty ranges have been provided. Furthermore, uptake by CDM methods – which still serve as a blueprint for many project types in the voluntary market – has been slow.[41] Thus, it is recommended that the voluntary carbon markets pick up the pace, even though it is acknowledged that alignment with the IPCC guidelines is sensible. One of the important contributions of the carbon market is in fact that it results in data being generated in data poor jurisdictions or areas that can be used for other purposes such as national inventories.

[30] Nationally Determined Contributions (NDCs) from each country under the Paris Agreement.
[31] For example, VERRA has guideline VMD0053, which specifies a standardized approach to test model performance as an ele-ment in quantifying credits for improved agricultural land management.
[32] An example along these lines is CAR's "Soil Enrichment Protocol Development Version 1.0". During validation, applicable models must be assessed by experts or published in one of approx. 30 pre-approved scientific journals. Verification need only confirm the proper use of the models, e.g. appropriate coverage of crop types, practices, and climate zones.
[33] This would require that sustainable development co-benefits are assessed in real time as well.
[34] A project must usually apply updated methods at the start of a new crediting period. There may be instances in which adjust-ments within the crediting period are required (see discussion in Section 4.2).
[35] New data also helps to determine the uncertainty attached to non-adjusted methods/projects and allows the quality of their issued credits to be graded. These ratings serve as assurance of a conservative approach and therefore the quality of the result-ing credits.
[36] There is a new version from 2019, which provides updates on some default values.
[37] If a range is known it should be at the low end of the range. If the range is unknown, discounts could be in the order of 50%.
[38] Ideally, data from similar project-types would be shared across all standards. In turn, quantification approaches oughtto be standardized across standards.
[39] This is not directly related to digitalized verification. It is nevertheless important and can be leveraged by meta platforms that come along with digitalization.
[40] For example, above-ground biomass may be independently determined from (i) on-site measurement and (ii) different re-mote sensing data and modelling approaches.
[41] For example, NIR 2019 provides new default values for baseline methane emissions from rice paddies. However, as at June 2022 the corresponding up-to-date CDM method, AMS-III-AU, still dates from 2014 and thus uses the old defaults, which are higher.
[42] See Schneider et al. 2017a and Schneider et al. 2017b on the importance of taking into account NDC targets for setting base-lines and demonstrating additionality.

4.1.4. PLATFORM: INFORMATION TRANSFER AND INTEROPERABILITY WITH PROJECT DEVELOPER, STANDARD, AUDITOR, REGISTRY, DOCUMENTATION, ARCHIVING OF VERIFICATION

The D-VER platform is developed and hosted by the project participant themselves or by a third-party platform operator.[43] Designing and implementing such a platform requires considerable resources, including interaction with the standard. It has to be ensured that the platform allows the verifier access to all relevant information. The verifier also needs access to confidential data. Furthermore, the platform must allow information to be shared in a structured way throughout the project cycle between the project participant, the verifier and other actors. Currently, verifiers receive individual documents from the project participant, which is a time-consuming and error-prone process. Once in place, a platform increases the efficiency and quality of verification.

As D-VER platforms are decentralized, it would be useful to transfer reports and aggregated information to a meta-platform that serves as an information hub for existing projects. This might be hosted by an international institution, and must be publicly accessible (open data). Currently, the publicly available project documentation and archives in the voluntary carbon market often appear to be rather inconsistent and unstructured. CDM documentation is better in this respect. A digital meta-platform would improve this situation, thus increasing the transparency and consistency of verification as well as the credibility of the issued units. As all project-related documents would be on the D-VER platform already, certain (automatically generated) documents could be made directly available to the public on the meta-platform (e.g. project design documents, validation report, calculation tools, monitoring and verification reports). It should be possible to redact data, as confidentiality provides an incentive to generate further data. However, there should be strict rules on the cases in which this is justified. For example, to receive feedback from NGOs, it is necessary to have relevant data publicly available.

Finally, a standard may also provide a platform that serves as an online repository for all the documents that the project participants need for project documentation, i.e. digital methodologies code, tools, guidelines, and templates.[44] Currently there is a multitude of documents and guidelines, sometimes in different formats and difficult to find. Methodologies include several options as well as references to tools or other methodologies (that may yet again include references).

A platform of digitalized methodologies would allow a streamlined approach and display all relevant and up-to-date methodological information and options on a single webpage, which could be exported as single file for further use on the project proponents' D-VER platforms.

PRINCIPLES FOR ASSESSING QUANTIFICATION

sensing, to measure key parameters at low cost, leading to higher levels of accuracy and credibility.

Adapt processes and guidelines to profit from the fact that automated quantification can be implemented relatively fast for projects of low complexity (such as grid-connected renewable electricity generation, but to a certain degree also A/R).

Be ready to adapt processes and guidelines as soon as possible to profit from the potential to considerably improve quality for more complex model-based quantification methodologies (e.g. those applied in agriculture), even if more time is required to develop the necessary tools for automation.

As a general rule, use open models that build on peer-reviewed research and only use proprietary models if thoroughly checked.

Have all digital quantification and modelling tools certified by an independent third party.

"Lock in" all automated digital processes and do not change code of certified elements (e.g. by hashing the code onto a blockchain).

Make use of digital NDC data to align quantification (e.g. baseline setting) dynamically with host country-specific NDC targets.

[43] Having many different digital platforms hosted by individual project participants implies greater verification effort, as they differ in structure and approach. In this respect it helps to have a single or only a few third-party applications with uniform structures and processes. On the other hand, it may be difficult to design a one-size-fits-all platform. The number of different platforms would thus be a market decision that balances costs and flexibility requirements.

[44] Verra is currently developing a "Digital Projects and Methodology" platform along these lines.

4.1.5. GOVERNANCE FOR DIGITALIZED VERIFICATION

In digitalized verification systems, stringent governance is important to ensure the high credibility of credits. Digitalization and the related automation may provide fewer points of intervention along the project cycle at which (human) experts can intervene when encountering issues. Standards must thus provide rules for all of the important steps that decentralized D-VER platforms have to meet. These requirements must be in accordance with the needs and possibilities of digitalization. For example, digital verification would start with the one-time certification of all automated MRV systems to ensure that it is digitalization-ready, including checks on data transfer procedures and implemented algorithms. Certification by a third party would be part of the implementation phase and partly replace validation of the monitoring plan.

Standards must allow for remote site visits, but there should be clear guidance about when mandatory onsite visits are necessary and when digital tools suffice (e.g. mandatory site visit for the initial verification or when there have been substantial changes).[45]

All data, except confidential information, must be made public and presented in an easily accessible way to facilitate comparison and analysis within and across projects (see Section 4.1.4). Digitalization may allow the performance of different auditors to be compared more easily.

Project developers inherently benefit from the issuance of credits. Of paramount importance to the high credibility of these credits is an adequate incentive structure that provides actors with as little reason as possible to inflate credit issuance. One example is flat fees for standards or verifiers. Along the same lines, standards must not compete in a race to the bottom regarding credibility, but agree on a minimum common threshold for conservative assumptions. Ideally, this would mean that default values and methods would be synchronized across standards as much as possible. This is currently the case to some extent, as CDM approaches are building the de-facto standard for many project types (albeit not for land use, for example, where CDM is outdated). While this issue is not per se related to digitalization, digitalization may help because it facilitates synchronization.

It is important to make sure that no one is left behind because of digitalization. There is a need for solutions that function even if no internet connection is available owing to the remoteness of a project, for example, or that also function with less sophisticated tools such as simple cell phones instead of smart phones.

PRINCIPLES FOR PLATFORM

Provide verifiers with comprehensive access to the digital platform to assess all relevant project data.

Ensure collaboration between standards, auditors, project participants, institutions, and academia in sharing and providing open access to data e.g. on a meta-platform to make best use of automation, foster consistency and interoperability, and allow digital data verification to be scaled up.

Ensure and verify the security and integrity of all data transfers.

[45] Gold Standard recently published such guidance (see https://globalgoals.goldstandard.org/112_par_site-visit-and-remote-audit-requirements-and-procedures; accessed on 31.05.2022)

4.2. INTEGRATED QUANTIFICATION AND VERIFICATION (I-Q&V)

The integrated quantification and verification (I-Q&V) blueprint (Figure 6 in Section 3.1) aims to harness the full potential of digitalization. On the I-Q&V platform, the digital tools are largely similar to those of the D-VER platform. However, the platform is developed and hosted by an independent I-Q&V entity that conducts both the quantification and verification of data capture and the quality audit simultaneously. It provides the standard with the information to issue a partly automated issuance report that combines the results. With this approach, the project participant merely transfers the data to the entity and there is no dedicated third-party verification. Compared with today's situation, this is a paradigm shift that requires a new governance set-up.

The following focuses on additional considerations compared with the D-VER blueprint at the general level. The I-Q&V entity essentially fulfills all tasks downstream of the raw data capture and as many tasks as possible are carried out by the digital platform. The project participant pushes raw data in a predefined and standardized electronic form through an interface to the I-Q&V platform. The I-Q&V entity would verify the raw data received by the project participant, albeit in a mostly automated way (see box in Section 3.2, for example). Quantification for individual projects is not independently verified. Because the I-Q&V entity is now conducting many tasks that it used to verify, it is important to apply additional safeguards such as the standard (or a dedicated meta-verifier) conducting more comprehensive checks. This includes checking the I-Q&V digital platform, its algorithms for data auditing, and the implementation and operation of the quantification methodology. All code that is used for automation may have to be certified by a third party prior to use. The standard would publish a list of requirements that all platforms have to fulfil. Where manual input is allowed, this may be earmarked for potential spot checks by the standard.[46]

Having an independent entity providing I-Q&V services has the potential to provide more accurate and conservative quantification. It may help to overcome the problem of information asymmetry.[47] Project participants usually have the highest level of information about their specific project and have an incentive to maximize the number of credits. This is possible by navigating the gray area almost every method exhibits (options, assumptions, samples, control groups, modeling approach, etc.). The I-Q&V approach may mitigate this problem if the entity is independent. The independence of the I-Q&V entity can be supported by having the I-Q&V platform certified, as outlined in the previous paragraph. Additionally, the I-Q&V entity may in no way depend on the number of credits it processes and prepares for issuance. This could be accomplished as follows:

- The I-Q&V entity receives a flat fee depending on the project type and size (technical capacity in MW, area of activity, etc.).
- I-Q&V entities operate on a not-for-profit basis.
- Over time, I-Q&V entities that are known to quantify credits rather generously may be much more in demand than entities that pursue more conservative approaches. To mitigate this selection bias, standards could randomly assign projects to any one of a pool of accredited I-Q&V entities.[48] ♦

PRINCIPLE FOR GOVERNANCE

Have entire digital platforms checked by independent third parties (probably as part of the validation step).

Make sure to leave no one behind using novel digital systems, and foster access to high-quality carbon markets rather than being a barrier to access.

[46] A major pillar of independent third-party verification is the separation between the entity that quantifies and reports and claims emission reduction or removals and the entity that verifies this information. The I-Q&V blueprint blurs this distinction to a certain extent for individual projects. It is thus essential that the governance structure still ensures that the level of third-party scrutiny is not lower than with the traditional model. Furthermore, it must be assessed whether and under what circumstances the blueprint fulfils official guidance such as ISO14064-3.
[47] Fuessler, Herren, and Kollmuss 2014.
[48] For further information on managing conflicts between auditors and project developers see Section 9.2 in World Bank Group 2021.

USGS - SATELLITE IMAGE OF THE SIERRA MADRE ORIENTAL MOUNTAIN RANGE. Original figure caption: "This desolate landscape is part of the Sierra Madre Oriental mountain range, on the border between the Coahuila and Nuevo Leon provinces of Mexico."

5. CONCLUSIONS

This White Paper looked at the implications that digitalization has for the verification of GHG emission reductions or removals. There are different levels of digitalization, from digital tools supporting the current verification process wherever useful, to having the complete verification process fully digitalized. If done correctly, digitalization provides an opportunity to strengthen environmental integrity, increase the accuracy and quality of credits, and increase trust in carbon markets. Greater trust may in turn be rewarded by higher prices on the market for such credits. This potentially compensates for the lower number of credits issued per project due to more accurate approaches that replace at times very generous default factors. Because of greater efficiency, digital approaches also hold the key to scaling the voluntary carbon markets. Where real-time credit issuance is possible, they facilitate earlier cash flows, reducing the financial risks for project proponents.

The White Paper presented two blueprints for digitalizing the verification process for carbon market project activities. Both blueprints feature a high level of digitalization, assuming that the best available and financially viable technology is applied for each project type. The blueprints differ in the roles of the stakeholders.

For the D-VER blueprint (see Figure 5), the role of stakeholders in a typical project cycle basically remains the same as in the conventional (non-digitalized) approaches of today. The project participant conducts the complete monitoring and reporting chain up to the point at which the emission reductions or removals are reported and claimed. The new element here is that this is done on a digital platform (D-VER) run by the project participant. The verifier has comprehensive access to the platform to assess all relevant project data and calculations. Certain tasks like site visits will still be required, but may be made more efficient and less frequent by digital means. The automated checking of the quality and robustness of data can increase data accuracy and reliability, as well as simplify the data quality audit. In this context, access to peer data and open data platforms can help improve automated data checking. Digital tools for data quality control, quantification, and modelling need to be checked by an independent third party. Ideally, open models that build on peer-reviewed research should be used because they are easier to verify than proprietary models. For project types where full automation is feasible, there is the option that credits are issued in real time. This would require the facility for fully automated measurement, reporting, and verification of sustainable development co-benefits that are certified by certain standards.

The second blueprint proposes an integrated quantification and verification (I-Q&V) plat-form (see Figure 6). It is hosted by an independent third-party (the I-Q&V entity) that provides for integrated services that combine the previous verification tasks with quantification as well as reduction reports and claims. The role of the project participant is limited to providing the necessary raw monitoring data through digital interfaces to an I-Q&V platform in a fully automated way. Integrated quantification and verification from a single source represents a paradigm shift. Currently, project participants are responsible for monitoring, quantification, and reporting, and there is a third-party audit for all those steps. Under the I-Q&V blueprint, data handling and quantification would be automated and handled by the I-Q&V entity as much as possible. The quantification and modelling tools used by the digital I-Q&V platform must be certified by an independent third-party. Additionally, spot checks on reported and claimed emission reductions will still be necessary. Real-time issuance would be possible under the same conditions as explained above.

A crucial difference between the two blueprints is the involvement of the project participant. With the D-VER blueprint, the project participant has to set up a digital D-VER platform, which entails considerable know-how and up-front costs. This represents a barrier to entering carbon markets, especially for smaller and local project participants with little experience and limited financial means. Since they are an important target group for carbon money, this is a considerable disadvantage. The I-Q&V blueprint, has lower barriers to entry, as the project participant's task would be reduced to implementing the project and providing raw monitoring data, which is usually their main field of expertise. However, the barriers for entrance could also be eased in case of the D-VER blueprint by the emergence of third-party D-VER platform service providers supporting project participants for a fee.

The report assesses the use of digital verification in the context of use cases representing project technologies of different levels of complexity. Digitalization is easier to implement for project types where digital measurement systems are already available or used and where methodologies are less complex. For the grid-connected renewable electricity generation use case, electricity production is often already metered continuously, such that few technical barriers exist to implementing both types of blueprint (D-VER and I-Q&V). For the A/R use case, digitalization is more complex, but various solutions are already applied in practice. There are, however, project types like soil organic carbon where automation is challenging. The measurement devices and accompanying models for quantification are still under development and require significant project-related expertise and manual interventions. This is particularly a challenge for the I-Q&V blueprint, as quantification would be done by the I-Q&V entity – which would need to have relevant expertise. If modelling approaches require considerable amounts of "manual" work, this is a problem or both human resources and governance (as it is not possible to certify as much manual work up front).

The White Paper presents a set of principles as a contribution to the discussion on digital verification to generate accurate and high-quality carbon credits. Major standards have started working groups on digital approaches. In addition, standards, certification bodies, project developers, industry associations, multilateral institutions and tech entrepreneurs are involved in a flurry of activity to enable D-MRV, including digital verification. Although this proliferation of different projects may be a fruitful approach, it will be crucial going forward to increasingly link and coordinate the digital initiatives to enable cheaper, better, and faster digital verification.

Standards want to ensure that their guidelines and processes are adapted to the new technologies. Verifiers want to understand their new role and might require more IT know-how while still requiring specialist human expertise in the related carbon reduction or removal projects in the future. The ongoing work of various actors will help to further refine the blueprints and principles presented in this White Paper in order to gain a common understanding of how to make best use of digital verification.♦

ANNEX

CHARACTERISTICS OF CURRENT NON-DIGITAL VERIFICATION PROCESSES

The following table assesses the characteristics of current verification processes. It includes several categories with further specific questions. The categories serve as a basis for the as-sessment of the blueprints in this study (see Section 3.4).

TABLE 3: ANALYSIS OF CHARACTERISTICS OF CURRENT NON-DIGITAL VERIFICATION PROCESSES

RELEVANT CHARACTERISITCS	CDM	VERRA	GOLD STANDARD
Governance			
How are the verifiers selected for a specific project?	Project participant chooses from among accredited auditors[49]		
Is the performance of verifiers checked?	Yes[50]	No[51]	Yes[52]
Is it possible to do the validation together with the first verification?	No	Yes	Yes
Who issues credits?	Standard	Verifier	Standard
Verification of the compliance of project implementation with documention and standard requirements			
How often are site inspections required?	At initial verification and every three years (or every 300 ktCO2)[53]	No specific requirements[54]	Physical site visits are required within 2 years of the project start date and thereafter every 3 years.[55]
Verification of implementation and operation (technology, facilities, equipment & devices, QA/QC)?	Physical site visit and desk review		
Procedures to detect material deviations (technical, economic or emission reductions or removals compared with ex-ante estimate)	No specific procedures		
Verification of data capture, sampling approaches, surveys and QA/QC			
What is the usual frequency of monitoring reports?	1 - 3 years		
How is data presented to the verifier?	Mainly Excel, Word documents, shape-files	Mainly Excel, Word documents, shapefiles. Satellite images and aerial pictures provided digitally	
Checks of QA/QC systems and procedures to prevent or detect & correct errors or omis-sions in the monitoring parameters (raw data or calculated/aggregated data)?	Yes, mainly desk reviews of Excel files provided by the project developer. Depth and breadth of reviews also depends on auditors.[56]		
Are there any plausibility checks required (e.g. correlations with a secondary data source or comparison with past results)?	No such requirements. Thus, not a relevant part of verification		

[49] For CDM, verification and validation cannot be conducted by the same auditor.
[50] See CDM procedure "Performance monitoring of designated operational entities."
[51] VCS Program Guide v4.0, p. 8 states that Verra "may provide feedback and require the validation/verification body to address non-conformities." However, there do not seem to be systematic procedures, regular spot checks and/or sanctions in place.
[52] See inter alia Gold Standard Validation & Verification Body Requirements, Section 7.8.8.1
[53] CDM validation and verification standard for project activities v3.0, para 339
[54] In VCS Validation and Verification Manual v3.2 or VCS Standard v4.2
[55] GS: Site Visit and Remote Audit Requirements and Procedures – V1.0-> 3.1.1
[56] For the Gold Standard, first RE projects using remote site visits and audits started in 2022, based on Site Visit and Remote Audit Requirements and Procedures.

RELEVANT CHARACTERISITCS	CDM	VERRA	GOLD STANDARD
Verification of quantification: Default values, assumptions, models and calculations			
Calculations of emission reductions or re-movals according to monitoring plan?	Manually, comparing monitoring plan and monitoring report.		
Platform: Information transfer and interoperability with PPs, Standard, VVB, registry, documentation, archiving of verification			
How do project developers, verifiers and other relevant actors share documents (platform, file formats)?	No platform. Free exchange of Word, Excel and pdf documents		
Does the standard provide templates for project proposals, monitoring reports and verification reports?	Yes	Yes	Yes
Are there requirements to document the verification process (e.g. a published list of clarification requests and corrective action requests)?	Yes	Yes	Mainly Excel, Word documents, shapefiles. Yes Satellite images and aerial pictures provided digitally
How extensive is a usual verification report?	Rather extensive (20-100 pages)		
Is all information publicly available?	Systematic and complete filing of documents with clear reference on the CDM web page. Information may be redacted.	Information is, in principle, available. How-ever, documents are usually missing (e.g. calculation Excels, monitoring reports for certain years) and documents are presented unsystematically.	

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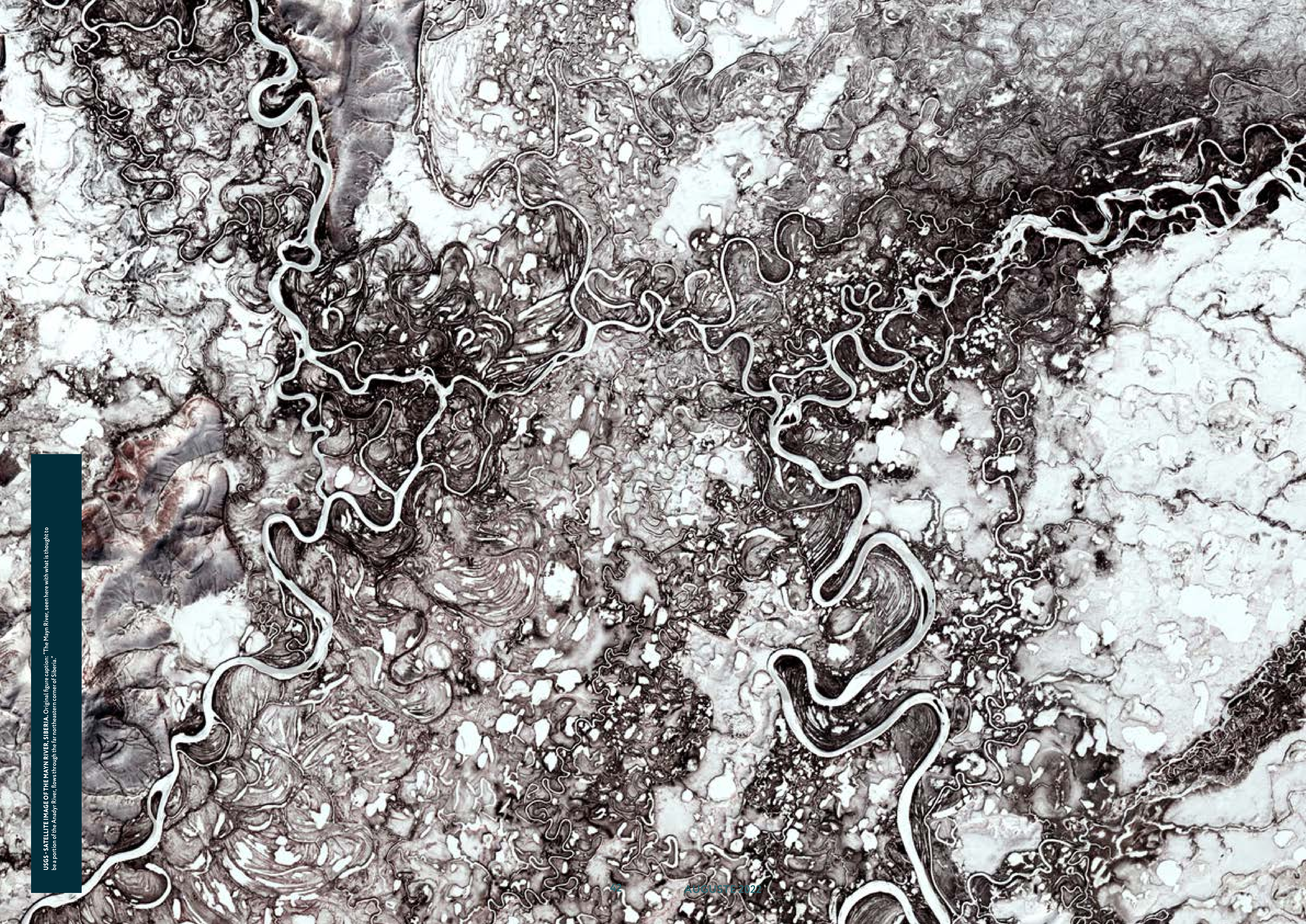

USGS - SATELLITE IMAGE OF THE MAYN RIVER, SIBERIA. Original figure caption: "The Mayn River, seen here with what is thought to be a portion of the Anadyr River, flows through the far northeastern corner of Siberia."

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