Protocol for Digitalised Monitoring, Reporting and Verification (D-MRV Protocol)

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Acronyms and abbreviations

D-MRV	Digitalized (automated) Monitoring, Reporting and Verification
API	Application Programming Interface
CDM	Clean Development Mechanism
CME	Coordinating / managing entity
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DOE	Designated operational entity
GHG	Greenhouse gases
GSM	Global System for Mobile Communications
MWh	Megawatt hour
PD	Project developer
PDD	Project Design Document
PO	Project owner
POA	Programme of activities
PV	Photovoltaic (type of solar power system)
t	tonne
UNFCCC	United Nations Framework Convention on Climate Change
VVB	Validation and verification body

Part A: Introduction

1.1 Objective

The generation of certified environmental attributes, such as emission reductions, through the deployment of mitigation activities is required to comply with monitoring, reporting, and verification (MRV) requirements. However, past experience with the Clean Development Mechanism (CDM) and voluntary carbon offset standards shows that transaction costs related to conventional approaches towards MRV and issuance of emission reduction certificates has been a prohibitive factor for the financial feasibility of emission reduction projects, especially in the context of low carbon prices. Further, manual processing of required data and information throughout the different MRV stages has often led to errors and misstatements, impacting issuance of certified credits and associated carbon finance flows, thereby compromising efficiency of the carbon markets.

With the advent of new technologies and systems, it is possible to significantly reduce MRV-related transaction time and costs, while improving accuracy, transparency and reliability of MRV, and keeping the robustness of data acquisition and processing at the required level. A main limiting factor for a more efficient MRV system are the rules of the emission reductions standards that establish certain requirements for data measurement, data collection and on-site inspections by the verification and validation bodies (VVB)[1] for validation and verification. Existing carbon standards would have to be adapted in order to unleash the cost and time efficiency potential of digital technologies that can not only reduce or eliminate the need for on-site inspections but also to minimize the need for manual checks of data integrity, completeness and accuracy, which can be easily performed by advanced digitalised MRV, and eventually enable close to rea-time issuance of certified credits and associated payments for their delivery.

The purpose of this Protocol is to define an improved automated digitalised MRV system (hereafter referred to as "Digitalised MRV system", or D-MRV) enabling the performance of all MRV functions in an streamlined fashion with maximum degree of digitalisation and no/limited manual data handling[2], without compromising the environmental integrity of carbon markets. This Protocol aims at establishing *basic requirements* and *principles of operation* of a D-MRV system, with the objective of ensuring accuracy, consistency, traceability and integrity of mitigation outcome data from on-site raw data measurement through to output of mitigation results calculation, ultimately enabling more efficient verification and issuance of respective mitigation outcome units, cutting down time and cost for bringing these mitigation assets to the market.

The minimum requirements outlined in this Protocol related to data *acquisition*, *handling*, *processing* and *storage* across various phases of the MRV process shall enable greater degree of standardisation and digitization.

The procedures to be followed by the project developer (PD), coordinating and managing entity (CME) and validation and verification body (VVB) are presented in this Protocol, in the context of generation of emission reductions from the underlying mitigation project(s).

By presenting the minimum requirements in a technology-neutral way, this Protocol is addressed principally to any type of project whose performance can be measured in an automated and digital

[1] Throughout the Protocol, VVB is used to also include Designated Operational Entities (DOE) under CDM

[2] Such manual data handling should be limited to instances when, for example, automated cross-checking identifies discrepancy in the digitally measured value and manual upload of records is needed in order to substantiate a particular value.

way. In the interest of clarity, the relevant elements are exemplified[3] based on the use case of a solar photovoltaic (PV) project, displacing fossil-based electricity generation.

1.2 Principles

The application of the following guiding principles helps build the confidence and trust in the MRV system. The guiding principles that underpin this D-MRV Protocol are the same as those that have been cited in the international standards: ISO-14064, IPCC Guidelines, CDM Project Standard, Gold Standard and Verified Carbon Standard (VCS), and could be summarised as per the following characteristics:

- **Relevance**: to select the greenhouse gas (GHG) sources, GHG sinks, GHG reservoirs, data, methodologies and all other information that is appropriate to the needs of the intended user.
- **Completeness**: to include all relevant GHG sources and sinks, and information to support compliance with all requirements.
- **Consistency**: to enable meaningful comparisons in project activity-related information.
- **Accuracy and conservativeness**: to reduce bias and uncertainties as far as it is practical/cost-effective, or otherwise use conservative assumptions, values and procedures to ensure that GHG emission reductions or net anthropogenic GHG removals are not overestimated.
- **Transparency**: Disclose sufficient and appropriate project activity-related information in a truthful manner to allow intended users to make decisions with reasonable confidence. However, proprietary or confidential information should not be disclosed without the written consent of the provider of the information, except as required by national law.

The application of the aforesaid guiding principles is incorporated and explicitly presented in the respective procedures.

[3] Once the D-MRV is deployed and demonstrated in other project types (e.g. energy efficiency, transport etc.) this Protocol will be expanded with additional use case examples accordingly.

Part B: Digitalised MRV system

This section assesses the three parts of the MRV process (i.e. monitoring, reporting and verification) separately and outlines the automatisation and digitalisation of each part.

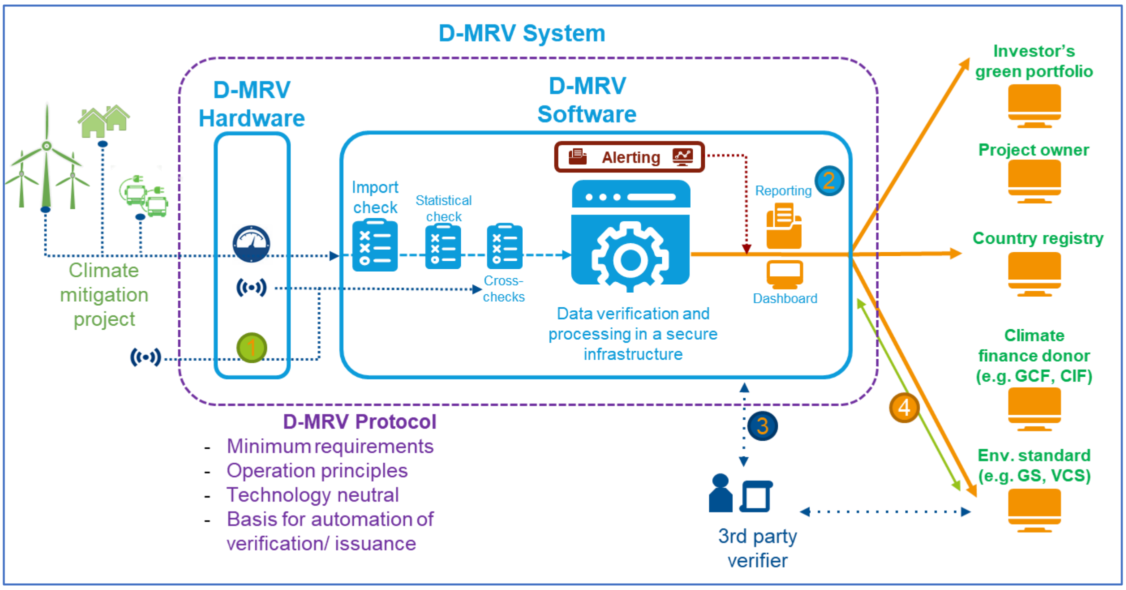

Figure 1: D-MRV process chain from Monitoring (1), Reporting & processing (2) to Verification (3) and issuance (4)

(Source: South Pole)

By drawing on the applicable functionality of the hardware and the software components, the D-MRV system aims to (1) directly capture, communicate, store and process actual project performance data and automate quantification of resultant environmental (climate) outcomes; (2) automate reporting on environmental results achieved through pre-defined templates; (3) enable streamlined verification of reported environmental results based on prior certification of the system; and (4) enable more efficient and frequent issuance of certified environmental attributes.

Throughout this section, the general guidance is exemplified by the concrete case of an emission reduction project in the form of a solar PV plant, displacing fossil-based electricity from the grid. It shall be clear however that the purpose of this Protocol is to promote D-MRV across a broad variety of project types and technologies, so this guidance will be expanded with relevant examples and additional details in subsequent updates of the Protocol as practical experience of D-MRV application in other sectors emerges and gets codified.

2 Automated monitoring

A clear understanding of the key data that is required to be measured and monitored and the associated methodology for calculating the environmental impact to be adopted are essential to perform consistent and accurate reporting that could be compared and transparently verified.
The monitoring requirements in the methodologies provided by the standards (such as the CDM or the Gold Standard) could involve measurements through meters, installed at the project site (for e.g., electrical energy generated or fuel consumed) and/or collecting information manually through surveys or sampling (for e.g., number of operational devices - cookstoves). As mentioned in the introduction, it shall be noted that this Protocol is focussed on the monitoring procedures

that can be automated and digitised to a very high degree. Monitoring procedures that depend mainly on 'manual' information collection are outside the scope of this Protocol[4].

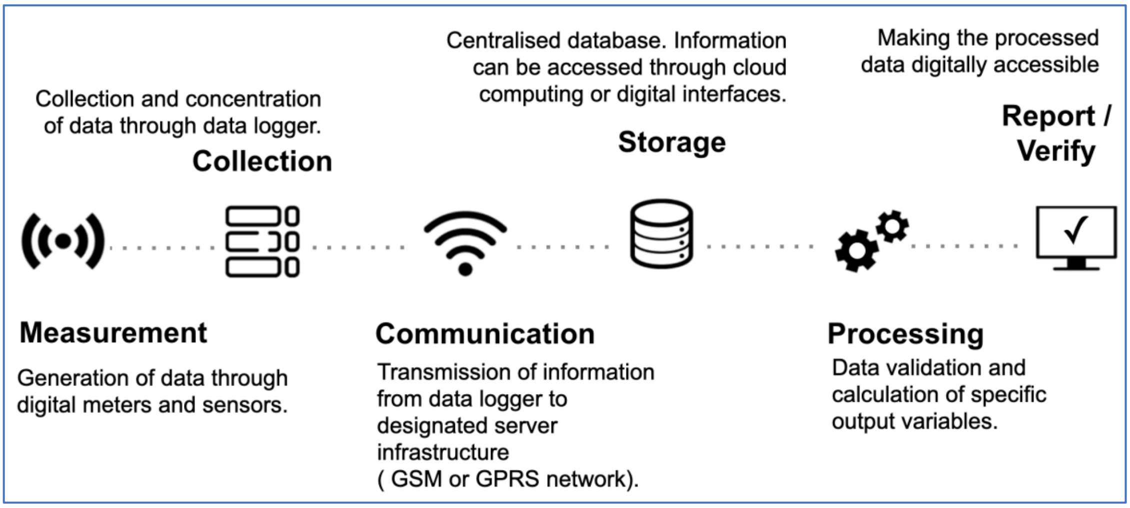

Figure 2: Key building blocks of automated monitoring

(Source: South Pole)

These monitored parameters form the basis for the estimation of environmental impact, such as emission reductions, that a project would achieve in any period.

The arrangements needed for an existing site or an upcoming greenfield project to be ready for remote monitoring are summarised in the following table.

Table 1: Arrangements for automated monitoring

Scenario	On-site metering arrangement at renewable energy site	Automated monitoring arrangement needed
Scenario 1	Main meter used for accounting and billing of electricity without automatic remote meter reading facility	Option 1a: Existing meter along with data-logger Option 1b: Replacement of existing meter with additional meter to be installed along with data-logger Option 2: Automatic Remote Meter Reading facility / Advanced Metering Infrastructure (AMI) including smart meter
Scenario 2	Main meter used for accounting and billing of electricity controlled by other party (e.g., sealed by grid authorities) and restricted access to remote communication	Option 1b: Installation of additional meter along with data-logger Option 2: Installation of additional smart meter
Scenario 3	Main meter used for accounting and billing of electricity under control by the project developer and with remote communication	Option 3: Application Programming Interface (API) needed to access the data already available remotely

(Source: South Pole)

[4] Surveys, counts through observations and other in-field information collection methods are increasingly being digitised by the utilisation of IT equipment (e.g. smartphones, teleconference etc.). As such, these monitoring procedures should, and thus can, continuously be integrated into D-MRV systems as their digitisation matures reliably.

2.1 Measurement

Measurement enables the quantification of the underlying parameter at a certain point in time. Tracking the parameter over time helps in arriving at the monitored value.

2.1.1 Project performance metering

Measurements for the relevant parameter shall be performed using a calibrated device - meter conforming to certain accuracy class, (installed) at a location where the complete data gets monitored transparently.

The following requirements shall be observed while performing the monitoring:

Table 2: Monitoring requirements aspects

Aspect	Details	Example
Data / Parameter	As defined by the methodology	Quantity of net electricity generated by the RE system (EG_y)
Data unit	As defined by the methodology	kWh
Metering arrangement	Measurements are undertaken at the point where the entire value (Completeness) under consideration gets measured transparently without interference	Measurements are undertaken a) using electricity meters installed at the grid interface for electricity export to grid and b) using electricity meters installed at the entrance of the electricity consuming facility for supply to captive consumers
Accuracy class	The accuracy class of the meters should be in accordance with the local standards and regulatory requirements or as stipulated in the applicable national requirements	The minimum suggested accuracy with reference to the installed capacity of the renewable energy plant is as follows: ● < 100 kW should have an accuracy class of +/- 1.0% ● 100 kW - 1 MW should have an accuracy class of +/- 0.5% ● 1 MW should have an accuracy class of +/- 0.2%
Measurement procedure	The measurement procedure shall ensure accurate capture of the measured value in line with the methodology requirements.	This parameter should be either monitored using bi-directional energy meter or calculated as the difference between the measured values of: (a) the quantity of electricity supplied by the project plant/unit **to** the grid (energy export); and (b) the quantity of electricity consumed by the project plant/unit **from** the grid (energy import).
Monitoring frequency	Regularly and at least monthly recording	Continuous monitoring, hourly measurement and at least monthly recording
Meter calibration	The meter(s) shall be subject to regular maintenance and testing in accordance with the stipulation of the meter supplier or national requirements.	The calibration of electricity meter(s), including the frequency of calibration, should be done in accordance with national standards or requirements set by the meter supplier. If these standards are not available, calibrate the meters every 3 years. In the event, meters are found faulty they will be

Aspect	Details	Example
		replaced with immediate effect by new calibrated meters
Cross-check	Apart from plausibility check (see section 3.2.1), the measurement results shall be cross-checked with other available records.	The measurement results of the electricity delivered to a third party / grid, shall be cross-checked with records of sold/purchased electricity (e.g. invoices/receipts)
Event of meter failure	The procedure for handling uncertainty in the metering system or eventually a metering system failure shall be as follows: • In the event when meters are found faulty or not working, these shall be replaced immediately with new calibrated meters. • In the event when meters fail to communicate for a certain period (silence period) the data recorded at the project site shall be used for emission estimation purposes. • In case of missing data due to meter failure or other reasons, conservative approach shall be applied.	In case of missing data due to meter failure or other reasons, one of the following options to estimate electricity generation may be applied: (i) the conservative value as zero; (ii) the lowest daily value among the daily monitored values from the current crediting period multiplied by the number of days with missing data. However, estimation of electricity generation can only be applied if it is demonstrated that the renewable energy project is operational during the missing data period. Missing data period shall not exceed 30 consecutive days within six consecutive months.

(Source: South Pole, based on UNFCCC)

With a view on hardware requirement, further to the aforementioned aspects for automated monitoring, the recommended basic features of such (smart) meters should be as follows:

- The smart meter should have an **integrated communication module** to enable remote communication with a device over a standardised protocol.
- Ability to **provide time-stamped data** to the remote meter data acquisition system at periodic intervals or on-demand, on a standardised protocol. This data can be instantaneous data parameters as well as logged data (like cumulative energy etc., profile parameters like power/voltage/current recorded at predefined periodic time instants, and events that notify occurrence of predefined conditions, etc.).

Tamper event detection, recording and reporting

- The meter(s)/data logger(s) shall have appropriate security measures to prevent and detect tampering and ensure that unauthorised systems cannot access it remotely nor locally for acquiring data or modifying its configurations.
- Local display: the meter shall have a small visual display (GUI based) for displaying data locally and to run system diagnostics.
- Remote firmware upgrade: the meter shall support on the field as well as remote firmware upgrading, after passing due authorisation and authentication.

2.1.2 Data measurement for cross-check

After measuring the project performance via appropriate metering, it is vital to assess whether the data reflects the normal operation of the project and hasn't been manipulated with[5].

[5] System manipulation such as the notoriously famous case of solar farms producing electricity throughout the night (because diesel aggregate generators have been installed in front of the production meters) can easily be detected if for example solar irradiation data is used for cross-checking.

To do so, the accuracy of the data obtained through the main meter reading shall be assessed for correlation with alternative measurements performed simultaneously and/or associated records. The aim of cross-checking is to find proof or plausibility of the correctness of the monitored project performance.

Therefore, for automated monitoring, the minimum basic features for performing cross-checks are as follows:

- Parameters shall be identified (as well as appropriate ways to measure them) that allow for correlation analysis between them and the project performance data.
- Cross-check information shall be collected/metered under comparable aspects and requirements as the project performance data.
- If the cross-check information can be metered, the meter shall have either an integrated communication module to enable remote communication with a device over a standardised protocol or allow communication through a data logger.
- Option for manual upload of records / invoices (in digitally readable format) should be provided to substantiate the measured value (e.g. in case discrepancies are identified during automated cross-checks against other parameters) or to submit other relevant information not otherwise available digitally (e.g. meter calibration certificate).

The actual cross-checking is done during the automated verification procedure as part of the data processing (see section 3.2).

Cross-check measurement for the example of a solar PV project

Inverter
In the context of a solar PV project, in general every inverter already measures the AC yield in kWh of the PV system so an additional meter does not need to be specifically installed for the D-MRV system. It is useful to reduce the risk of upfront tampering (e.g. use of diesel generators), since this secondary measurement cannot be easily manipulated. Further, each inverter has an ID that can be linked to the solar PV plant as an identifier for the D-MRV system.

Pyranometer
These devices can be installed directly on the solar panel or next to them to measure the solar irradiance. In the D-MRV system it could be used to determine the theoretical maximum energy output of the PV system, i.e. as an automated plausibility check on the data provided by the electricity meter. For small solar PV systems, it is deemed that the costs of such a device would outweigh the benefit of this additional data source. In such cases, publicly accessible weather information (including solar irradiance) from the region where the solar PV plant is located, can be used as an alternative data source for the same kind of plausibility check on the data provided by the electricity meter.

2.2 Data collection

2.2.1 Data logger

In case of multiple datasets (main meter, other sensors, etc.), a data logger will be needed. The data logger shall be compatible with the measurement instruments installed upfront. The frequency for recording and exporting the data shall be chosen so that a reasonable resolution results. This of course depends on the nature of the project type and can vary across parameters and technologies. However, the frequency shall always satisfy the requirements set out in the applicable methodology and ensure that there is no relevant information lost between any two data points. For renewable energy projects, for example, a sufficient recording frequency is one hour, which is a typical recording frequency in regulated power markets - recordings every half or quarter hours are also common but do not add significant value for emission reductions determinations.

Table 3: Data to be read by the logger

Data type	Purpose	Solar PV project example
Time & date stamp	To allow data from multiple meters to be assigned to a unique point in time	Time & date
Project performance	As described in Section 2.1.1 above	Quantity of net electricity generated by the RE system (EG_y) [kWh]
Cross checking data	As described in Section 2.1.2 above	Solar irradiance (W/m^2) Settlement documents

(Source: South Pole)

The data logger shall have sufficient storage capability to store acquired data from the various devices.

2.2.2 Information upload

Apart from the automated remote data collection, certain manual data entry and associated physical records might also be needed to be furnished, such as the project licence, commissioning certificate, monthly settlement documents, meter calibration certificates, etc. D-MRV system shall provide an upload function that facilitates storing such external data in the database in structured and categorised way, relational to the data of a certain operation period (e.g. documents such as calibration reports or electricity invoices (in electronically readable format) or other datasets like geo-references photographs, grid emission factors or certificate market prices).

2.3 Communication

The data capture could happen through collation of multiple data parameters locally at site through a data logger and possibly also involving acquisition through API access, whereby software systems hand over data through dedicated process connections.

For data parameters captured locally, proper configuration of the local equipment to communicate to each other accounting for interoperability aspects is essential.

As an example, in the case of a solar PV installation, table below shows an appropriate configuration:

Table 4: Example configuration of a solar PV installation

Equipment	Connection mode
Energy meter	RS232 to a MODBUS meter
Sensors	RS232/RS485
Inverter	RS485

(Source: South Pole)

The data collected at various time intervals (by the data logger) is required to be pushed onto the communication network as per the following:

Push acquired data instantaneously: A set of data parameters acquired at predefined periodic time intervals and pushed immediately to the D-MRV system.

Provide locally processed data: Acquired data parameters are processed locally at the data logger (for e.g., daily minimum/maximum/average) which is then pushed to the D-MRV system.

The transmission of information from the metering system or the data logger to the designated server infrastructure for storage and further processing shall be done in a reliable and secure way. Established data transmission technologies such as mobile telecommunication networks (GSM, GPRS, LTE etc.) or wide area networks (WAN) for computer data networking lend themselves to the task.

Table 5: Communication modes per equipment

Equipment	Communication network	Communication mode
Data logger to D-MRV system	GPRS (wireless connection)	GSM module
Data logger to D-MRV system	Internet router (wired connection)	Ethernet
D-MRV system	Internet	Ethernet

(Source: South Pole)

Data transfers shall include standard safety features such as encryption, time stamping, logging etc. Data transfer between the data logger and the D-MRV system shall use non-proprietary formats such as XML or JSON[6].

In cases where the communication network link is intermittent or gets disrupted (e.g., due to failure for some time), data shall be stored in the data logger and pushed to the D-MRV system as soon as the link is restored.

[6] Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable; JSON (JavaScript Object Notation) is a lightweight data-interchange format and it completely language independent. It is based on the JavaScript programming language and easy to understand and generate.

3 Automated Reporting & Processing

This section describes the central automatisation processes which take part in the D-MRV system. Whether such a system is operated by the project owner, the CME or an entirely independent party shall not be relevant, as long as the immutability of data, access restrictions and general principles elaborated in Part A of this Protocol are adhered to.

3.1 Data storage

The raw data received from the logger or smart meter shall be stored after transmission in a centralised database on a server or cloud (e.g. amazon web services). The information can then be accessed through cloud computing or other digital interfaces. All data transfers to and from the database shall include standard safety features (encryption, time stamping etc.) to avoid data tampering.

The data warehousing shall adhere to high security standards such as password protection, encryption and redundancy both in transit and rest. The database or file system shall be structured in a way that limits the raw data manipulation to ‘append only’ operations (tagging, labelling, new data derivations and calculations) but never to allow to alter the original data itself. It should further allow for ‘status’ labelling, such as “passed statistical check”, “approved by VVB”, “rejected” etc. Each event, operation or status change shall be logged and, as applicable, ascribed to the user responsible for the event.

3.1.1 Data accessibility

Accessibility to detailed (raw) data shall be restricted by customisable access rights and functions for different users (e.g. project owner, CME, VVB, standards bodies); restrictions on the execution of specific (non-automated) audits and access to the available information and reports apply accordingly.

3.2 Data processing

3.2.1 Quality assurance & quality control

The D-MRV software shall run automated data checks to assess the data for completeness, consistency, integrity and accuracy as well as statistical plausibility, outliers and data gaps.

The three main groups of automated data checking are:

A) Import checks

Only data that matches the expected format, file size, file type and originating server address (and other measurement hardware identifiers, such as meter ID) shall be allowed to ‘enter’ the D-MRV system and be written into database/file system. This is an important safety measure to avoid faulty or malicious data to potentially damage the stored data or the processing infrastructure.

B) Numeric / statistical checks

Using mathematical and statistical methods, irregularities or inconsistencies in the performance levels of the project can be detected and assessed. Such operations shall identify whether there are data gaps or other irregularities in the input data. The science of Artificial Intelligence / machine learning might provide useful means to improve such assessments in the future.

C) Plausibility cross-checks

As described in Section 2.1.2 above, apart from the project performance data itself, peripheral information shall be collected to allow cross-checks for plausibility.

The most important one is the calculation of the theoretical maximum output, based on parameters that influence (and thus should correlate with) the project's performance.

As an example, in the case of renewable energy projects, the following should be adequate cross checks to determine the maximum potential performance and thus compare the actual performance for plausibility:

Table 6: Example plausibility calculations for renewable energy projects

RE-project type	Calculation of plausible maximum
Solar PV	Calculation of theoretical maximum using solar irradiance data from onsite irradiation measurement and/or online irradiation databases
Wind Farm	Calculation of theoretical maximum using wind speed data from on-site wind speed measurements and/or publicly available wind data
Hydro Power Plant	Calculation of theoretical maximum using the run-off from the power house

(Source: South Pole)

In cases of discrepancies when performing these cross-checks, the D-MRV system shall flag such instances and provide for additional evidence and explanations to be added, ensuring that the more conservative value (i.e. lower than the theoretical maximum) is always used in the calculation of environmental benefits (which would lead to lesser emission reduction value).

Alarms/alerts shall be automatically sent by message via different communication channels (e.g. email, SMS) to the project participant, coordinating & managing entity or auditing agency in case of major data gaps, malfunction of the system or non-compliance with integrity checks (sensitivity for the alerts needs to be defined). Further, the triggers and alarms for regular maintenance and testing of the meters in accordance with the stipulation of the meter supplier or national requirements shall be set. The check for the calibration of meters linked to the uploaded details and any associated delay would be addressed conservatively.

In case of errors, data gaps or unpassed automatic checks of the automated remote collected data, the plant operator should be informed and be offered the possibility to complete / correct the faulty dataset by manually submitting commented information to the D-MRV platform, where it undergoes the same cross-checks again.

3.2.2 Emission reduction calculation

After the automated checks and balances, the data shall be processed with a calculation engine that determines the overall emission reduction based on the raw activity data and the respective emission factor. To ensure traceability and auditing capability, the processed data shall be stored in a separate column/part of the D-MRV database. This allows that all calculation steps can be verified and checked comprehensively at any time.

3.3 Display

The processed data shall be displayed on a graphical user interface (GUI) accessible also from a remote location. The user interface allows different user groups' access to the dataset in the form of a monitoring dashboard. Such user groups will be defined and equipped with special access rights. This function shall allow different user groups to easily see, interpret and, as relevant, audit the datasets at any time.

Requirements:

- **Login feature**
  - prevents access to data to unauthorised individuals;
  - ensures identification of the user and access with the corresponding rights; and
  - allows traceability and auditability;
- **Search function** enables users to search for specific projects;
- **Data upload** is possible for each project site; all uploaded documents and external data are presented in a user-friendly way;
- **Dashboard** allows users in an easy-to-use way the access to the datasets from the project sites, as well as additional data like grid emission factors, calibration reports etc.;
- **Report creation** in terms of the certification process must be simple and easy to start; this includes the selection of existing report templates as well as a preview functionality.

The following 4 user roles are considered to cover relevant stakeholders and should be envisaged in the D-MRV system design. Additional roles can be considered that are limited to (extended) read access, such as impact finance donors (providing funding for projects and thus required performance information).

Table 7: User roles and their acces rights to the data

/ User role Data point	PO	CME/ Consultant/ Portfolio Manager[7]	VVB	Standard
Emission factor	Read	Create / read	Read	Read
Generation data	Read	Read	Read	Read
Emission reductions	Read	Read	Read / approve	Read
Data for cross-checks and notifications	Read	Read	Read	Read
Calibration certificates	Read / update (via upload)	Read	Read / approve	Read
Issuance request forms	Create / read / update (automated preparation of issuance request forms)	Create / read / update (automated preparation of issuance request forms)	Read	Read
Issuance confirmation (status information fed back from issuing body)	Read	Read	Read	Create/ read / update

(Source: South Pole)

[7] The role of Portfolio Manager is intended to include organisations who manage a portfolio of projects (or investments therein), and use the D-MRV capabilities for the purpose of impact reporting and climate disclosure.

3.4 Reporting

The reporting function enables the automatic generation and export of reports in different file formats (e.g. CSV, excel, word, PDF) and in line with monitoring report forms of the UNFCCC or any other relevant template.

Specifically, the D-MRV system should as a minimum enable the following data and information to be readily visualised and printed as required (e.g. aggregated for all plants, individual plants, etc.):

- Project title
- Project location
- GPS coordinates
- Capacity of plant (kW)
- Monitoring date and time range (per minute)
- Meter serial number
- Meter installation date
- Meter last calibration date and calibration due date
- Monitored data (e.g. net electricity generated)
- Unit of parameters
- Last maintenance date
- Next maintenance date
- Sensor details (active and inactive sensors)
- Baseline situation (e.g. supply to grid, consumption from captive power plant)
- Baseline emission factor (off-grid and on-grid)
- Emission reductions (tCO2e)
- Comparison with ex-ante estimation along with reasoning for deviation

4 Automated & Remote Verification

The validation and verification of the project will be undertaken by an independent auditor having relevant experience and accreditation (e.g. a VVB accredited under a voluntary standard, or a DOE accredited under CDM) in line with the respective standards' regulations.

The verification process in the D-MRV system, which shall form an integral part of the monitoring plan of the project or programme, is envisaged as a single audit/certification of the D-MRV system and associated calculation engine initially and thereafter periodic remote verifications for the respective project performance.

4.1 Certification of the D-MRV system

The initial audit or certification of the D-MRV system is additional to the overall validation of the project or programme and will take place once at the start to ascertain that the system has been set up correctly in accordance with the present Protocol and the applicable methodology and following the relevant standards and correct application of the guidelines (e.g. calibration guidelines), in the design.

The subsequent periodic verification could only start once the D-MRV system has been certified by the VVB and all the relevant data and records (e.g., invoices, calibration records etc.) for the defined period are in place in the D-MRV system.

4.1.1 On site visit

If the D-MRV system and the project are operational at the point of validation, then an on-site inspection by VVB will validate the project and certify the D-MRV system, then the next on-site verification will be required only after 5 years, with automatic issuances allowed during this period.

If the project and the D-MRV system are not operational at the time of the validation, the validation of the project will occur remotely and the certification of the D-MRV system will occur during an on-site verification inspection prior to the first issuance.

4.2 Periodic verification

Conventionally, the verification process involves performing desk-review, on-site visit by the verifier, issuance of findings (corrective action requests, clarification requests), resolution of findings and thereafter issuance of the verification/certification report. The D-MRV system will address these process steps in a digital, remote and no/minimum paper-based manner as elaborated in the following sections.

4.2.1 Remote assessment

The D-MRV system addresses the on-site inspection requirements through remote verification as follows:

Table 8: On-site verification requirements

No.	Requirement[8]	D-MRV system / Remote verification	PV project specific example
(i)	An assessment of the implementation and operation of the registered CDM project activity as per the registered PDD or any approved revised PDD	These could be ascertained based on uploaded supporting documents on the D-MRV database such as purchase orders, name plate specifications, commissioning certificates, among others.	As these projects are out in the open sun, these can be checked based on the latitude, longitude and place of the project site with complete physical address complemented by the google map image of the site.
(ii)	A review of information flows for generating, aggregating and reporting the monitoring parameters	In the D-MRV system, there is minimal manual intervention. Rather, the monitoring parameters are automatically fetched and stored in the database. The remote access to the monitoring database shall be provided to the VVB.	Only the net electricity generation is to be monitored and the same is remotely done.

[8] As presented in CDM validation and verification standard for project activities, paragraphs 339−341.

No.	Requirement[8]	D-MRV system / Remote verification	PV project specific example
(iii)	Interviews with relevant personnel to determine whether the operational and data collection procedures are implemented in accordance with the registered monitoring plan	A fact-finding mission in the form of an internet audit with participants located in multiple locations simultaneously can take place. The audit could be linked by simultaneous telephone conference between all participating offices at various locations along with simultaneous access to the monitoring database.	The remote monitoring capabilities are built on top of an underlying on-site monitoring system adhering to the methodological requirements.
(iv)	Cross checks between information provided in the monitoring report and data from other sources such as plant logbooks, inventories, purchase records or similar data sources	The upload of external data to the database in structured and categorised way for e.g. documents such as electricity invoices, calibration reports (in digitally readable format) can be accessed and checked by the VVB apart from the current real-time meter reading comparison with the closing meter reading presented for the monitoring period (taking into account meter reset).	The generation data on the one hand can be directly cross-checked with said inverter meter and on the other hand with a maximal theoretically feasible production determined by taking into account the measured irradiance or wind speed data in the case of wind projects and the technical specification of the plant.
(v)	A check of the monitoring equipment including calibration performance and observations of monitoring practices against the requirements of the PDD, the applied methodologies, the applied standardized baselines and the other applied methodological regulatory documents	The upload of calibration records to the database can be accessed and checked by the VVB.	Same
(vi)	A review of calculations and assumptions made in determining the GHG data and GHG emission reductions or net anthropogenic GHG removals	The D-MRV software and associated calculation engine shall be made remotely accessible to the VVB for audit (as performed during the initial certification of the system).	Same
(vii)	An identification of quality control and quality assurance procedures in place to prevent, or identify and correct, any errors or omissions in the reported monitoring parameters	The D-MRV software and associated calculation engine shall be made remotely accessible to the VVB for audit (as performed during the initial certification of the system).	Same

(Source: South Pole)

4.2.2 Resolution of findings

As part of the on-site verification process once every 5 years, the issuance of findings are expected to be negligible owing to initial certification of the D-MRV system and minimal human intervention[9].

Table 9: Issuance of findings

No.	Finding type	Description	D-MRV system certification
(i)	Corrective Action Request (CAR)	A CAR is raised when: - non-conformities with the monitoring plan or methodology are found in the monitoring and reporting, or if the evidence provided to prove conformity is insufficient; - Mistakes have been made in applying assumptions, data or calculations of emission reductions that will impair the estimate of emission reductions. Usually, a CAR results in changes to the monitoring report.	The initial certification of the D-MRV system would ensure that: - the monitoring and reporting is conforming with the monitoring plan and methodology; - The automated application of data and assumptions aligned with the methodological requirements for calculations of emission reductions without manual intervention will avoid mistakes to happen. Thus, the issuance of CAR gets avoided.
(ii)	Clarification Request (CL)	A CL is raised, if the information is insufficient or not transparent not clear enough to determine whether the applicable requirements as set by the Standard have been met. Usually, a CL results in providing additional evidence(s) and explanation by the PO.	The initial certification of the D-MRV system would ensure that sufficient information is transparently provided to confirm the Standard's requirements. Thus, the issuance of CL gets avoided.
(iii)	Forward Action Request (FAR)	A FAR is raised during verification for actions if the monitoring and reporting require attention and/or adjustment for the next verification period. Usually, a FAR is for future action to be taken by the PO.	The initial certification of the D-MRV system would ensure that with avoidance for the need to issue CAR/CL, there is no need for any future action required. Thereby, the issuance of FAR gets avoided.

(Source: South Pole)

4.2.3 Issuance of verification/certification report

Verification ends when the verifying body provides a written confirmation report to the PO/CME/Standard with reasonable assurance, wherein, based on sufficient appropriate evidence it is concluded that the reporting conforms in all material respects with identified suitable criteria, and is in the form of a positive assurance[10].

[9] Guidelines on integrating potential verification findings (CARs, CLs, FARs) into the D-MRV system design will be addressed in subsequent updates of this Protocol on the basis of experience gained.

[10] On the contrary, for limited assurance or reviews, the practitioner gathers sufficient appropriate evidence to conclude that the subject matter is plausible in the circumstances, and gives a report in the form of a negative assurance

A positive verification report shall have no pending or open corrective action requests in the opinion of the verifying body. As part of the verification process, based on the desk review and remote auditing of the D-MRV software (once), the VVB confirms on the following aspects:

- Compliance of the project implementation and operation with the registered PDD
- Compliance of the registered monitoring plan with the methodologies including applicable tools and standardized baselines
- Compliance of monitoring activities with the registered monitoring plan
- Assurance that all data passing the checks and processing (without triggering errors or alerts) has the status of “approved”
- Further, as part of the periodic verification process, based on the desk review and remote access of the MRV database the certification report from the VVB confirms on the following aspects:
    - Post-registration changes (if any)
    - Compliance with the calibration frequency requirements for measuring instruments
    - Assessment of data and calculation of emission reductions.

Once the set-up of the D-MRV system and its components have been certified by the VVB, the data transmitted to and processed by the system shall receive the status of being ”approved”, if during the processing no errors occurred, or no alerts were triggered. Data which was approved, be it automatically by the platform or manually by the VVB, can be passed on to an issuing body for issuance of certified environmental attributes (see Part C of this Protocol).

The D-MRV system shall have a functionality enabling the 3rd party verifier to audit the monitored data on a sample basis by comparing it to manually uploaded information and manually approve performance data where necessary. It shall also have the possibility to review any triggered errors/alerts (statistical check / plausibility check), and communicate back to the project owner or CME via comment / feedback functions.

PART C: Considerations for automated issuance

5 Automated issuance of environmental attributes

This section gives general suggestions how the data flow could continue after conclusively being processed by the D-MRV system and being passed on to any downstream services. Main focus lies on issuing bodies who issue certified environmental attributes (e.g. Verified Emission Reductions or Renewable Energy Attributes / Guarantees of Origin). The automatisation of their process steps lies entirely in the authority of their organisation. The compatibility and seamless connection/interaction with D-MRV system such as described in this Protocol is the logic consequence and thus central to the entire concept of MRV automatisation.

After the processing of the data through the D-MRV system, the data represents verified truth of environmental impact (e.g. in the form of ERs [tCO_2e] or renewable energy generated [MWh]). For this data to be issued as a tradable environmental attribute, it needs to go through the issuing process of a designated issuing body (e.g. VERRA, The Gold Standard, I-RECs or TIGRs), respectively their registries.

5.1 System connection

For this purpose, the IT systems of the D-MRV system and the applicable issuing registry should be connected in a way that allows all information required for the issuance process to be transmitted in an appropriate way.

The connection of the D-MRV system and the issuing systems have to address the account ownership structure of each system, so that the project in the D-MRV system corresponds with project owners account on the registry, into which the certified attributes are then issued.

5.1.1 Data transfer

The registries shall accept data “Submitted for Issuance” by the PO (only possible to submit if passed verification) as a valid request for issuance. This request could be automated as well, either triggered directly on successful verification or periodically in a pre-defined schedule.

Upon the submission of issuance request, the processed data will be sent to the issuing registry structured in a way as per requirements of the specific standard (i.e. with the connected meta-data: data status tag, error log, VVB verification statement, manually uploaded information etc.).

5.1.2 Two-way communication

The issuing bodies’ systems should be capable of communicating back to the D-MRV system to reflect status changes (data received, rejected, issued etc.) and mark/label the relevant data accordingly. This closes the information loop back to, concluding the processing sequence from origination (monitoring) to redemption (issuance) for each data point. Status changes feedback from the issuing system should be visible to the involved stakeholders as described in Section 3.3 above.

Issuing bodies should design their automated issuing processes in a way that the different D-MRV systems can be connected to their systems[11].

[11] Common communication formats (protocols) for connecting D-MRV systems with issuing bodies’ infrastructures will be considered future updates of the present D-MRV Protocol.