DIGITAL MRV

Digital Measurement, Reporting and Verification (MRV) Report on Pilot Projects, Roadmap and Resources
March 2022

ClimateCHECK

IOTA FOUNDATION

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Executive Summary

This report summarizes the digital measurement, reporting and verification (aka "blockchain") pilot projects within the Reciclo Organicos program. The digital pilots include the demonstration of "DigitalMRV" software for the Copiulemu landfill gas project and the Molina biodigester project located in Chile. The objectives of the digital pilots include determining the feasibility to develop and road test digital technologies to enhance and/or substitute for conventional MRV services at waste projects. Furthermore, the pilots compared the DigitalMRV versus conventional MRV to determine the pros and cons.

The Reciclo Organicos program (2017-2022) is associated with the Chile-Canada Bilateral Agreement on Environmental Cooperation, part of the Chile-Canada Free Trade Agreement. The Government of Canada provided $7M CAD in financial support for the implementation of Chile's NDC, including the Reciclo Organicos program to focus on the waste sector and involves activities for:

- landfill gas capture and utilization
- composing
- anaerobic digestion (biodigester)
- MRV Innovations

The DigitalMRV pilots used digital technologies and tools including:

- an online portal to manage collaboration and consultation to develop MRV methodologies for the waste projects, and integrated with the DigitalMRV software
- an online portal for online reporting of the waste projects, and also online verification based on leading standards (e.g., ISO 14064) and GHG programs (e.g., WCI)
- an online portal with customized 3D "digital twin" of the project sites and customized UI/UX (user interface and user experience) to display the project data and supporting evidence (photos, images, electronic manuals)
- connection to onsite digital sensors (aka "IoT" devices) sending real-time data via dedicated computer edge server and internet connection
- distributed ledger technology (DLT, aka "blockchain") and cryptography to secure the data

The key results include:

- development and deployment of DigitalMRV software at the Copiulemu landfill, and also DigitalMRV software at the Molina biodigester
- Chile is hosting two world leading DigitalMRV implementations, which have been highlighted publicly in reports by UNEP and World Bank
- capacity building of project participants in the implementation of DigitalMRV software onsite, as well as stakeholder webinars and a spotlight paper as part of the South-South exchange between Chile and the Pacific Alliance with countries in West Africa

- involvement of Dell Technologies to provide an industrial server and engineering expertise to implement the leading edge “data confidence fabric” (value $25,000 contribution)
- a summary “how to guide” to plan a DigitalMRV pilot and to perform the initial DigitalMRV readiness assessment for future projects
- compilation of resources and prospective partners to facilitate future DigitalMRV projects

DigitalMRV has been developed to be more effective than conventional MRV, for example in terms of credibility, verification quality and time availability of reporting results.

The economic efficiency of DigitalMRV compared to conventional MRV depends on the specific circumstances. Two scenarios were assessed to compare DigitalMRV vs conventional MRV. The assessment considers current costs for DigitalMRV, which are expected to decrease as the digital technologies and supporting systems mature. In contrast, as carbon markets rapidly increase and there is increasing demand for MRV services, the supply of conventional MRV will not keep pace and therefore demand will increase conventional MRV costs over the next several years.

The more DigitalMRV is replicated to projects, the more savings DigitalMRV can achieve – it is not cost effective to develop DigitalMRV to deploy at just one project site due to the large upfront investment. Assuming replication of DigitalMRV to 10 project sites, estimated costs savings range from $1.29M to $2.69M over a 10-year period.

There are more and more companies developing DigitalMRV solutions and the outlook is very positive. Examples of interest in digital MRV and digital for climate (markets, finance, actions) includes:

Table 1: Organizations active in DigitalMRV

IT Sector	Financial Institutions	Carbon Markets	Governments	Others
Dell Technologies Microsoft Google IBM HP Samsung InterWork Alliance Global Blockchain Business Council	World Bank EBRD ADB Citibank Temasek DBS Bank Barclays Macquarie HSBC	Gold Standard Verra AirCarbon Exchange IETA Taskforce for Scaling Voluntary Carbon Markets EU ETS	Canada Chile EU Japan Netherlands Spain Sweden Switzerland	UNFCCC UNEP ClimateKIC GeSI ITU ISO SBT CCC CLI

As countries and subnational actors address growing demand for climate actions and resources, there will be increasing efforts to advance MRV systems (governance, data, methodologies, experts…) including use of digital solutions to provide cost-effective, high-quality MRV.

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1. About Us

ClimateCHECK has an establish track record for Setting the Standard and a world class partner ecosystem to support best in class digital innovations and 3rd generation distributed ledger technology ("DLT") solutions to enable the tokenization and monetization of standardized sustainability benefits. For example, ClimateCHECK's ScribeHub online platform is used by the Government of Canada (ECCC) for both domestic and international GHG Quantification Methodology development. As well, the Government of France in partnership with CDP uses ScribeHub to support the development of sectoral methodologies for Assessing the low-Carbon Transition (ACT) of companies. ScribeHub is also integrated with DigitalMRV that is built on IOTA technologies and leading standards for the data economy (see below). These digital solutions encompass the end-to-end value chain for standardization, certification, tokenization, and subsequent monetization of sustainability benefits.

ClimateCHECK collaborates and partners with several leading organizations to deliver industry leading solutions for MRV of climate and sustainability:

- IOTA Foundation – a 3rd generation distributed ledger technology (DLT) ecosystem encompassing a suite of technologies for the data economy (e.g., Digital Identity, Track and Trace, International Trade, Industrial IoT) that enables DigitalMRV to be stacked with the foundational digital infrastructure of next generation sustainability markets; IOTA is collaborating with the European Commission's European Blockchain Services Infrastructure
- Gold Standard Foundation – the leading non-profit organization advancing high integrity methodologies and next generation MRV systems for climate and sustainability; ClimateCHECK and IOTA partnered with Gold Standard to launch the Open Collaboration for Next Generation Digital Solutions for MRV with the support of Google.org
- Dell Technologies – Dell collaborates with IOTA and other industry leaders on Project Alvarium (now managed by the Linux Foundation) to establish an industry standard specifying a methodological framework for Data Confidence Fabrics (DCF – link to report). Dell is collaborating with IOTA and ClimateCHECK, providing edge servers and engineering time, to integrate the DCF with DigitalMRV at the Molina, Chile biodigester facility.

Furthermore, international organizations supporting the global movement to advance digital solutions for climate, including the World Bank and UNEP recognize (in publications and events) the DigitalMRV solution is a market-leading solution.

2. Background Context and Rationale

Stakeholders around the world are facing a climate crisis that is getting worse and achieving climate targets is becoming more challenging. Global GHG emissions are going up, not down – and time is running out to achieve government climate goals. Clearly we are all facing an increasingly challenging "crunch period" to achieve as quickly as possible the most economically efficient, deep decarbonization and GHG emissions reductions that also enables a long term low-carbon transition. Recognizing this wicked challenge to achieve 2030 climate goals, to make matters worse, there is a proliferation of recent reports highlighting the epidemic of "greenwashing" that is creating a crisis of credibility. For example,

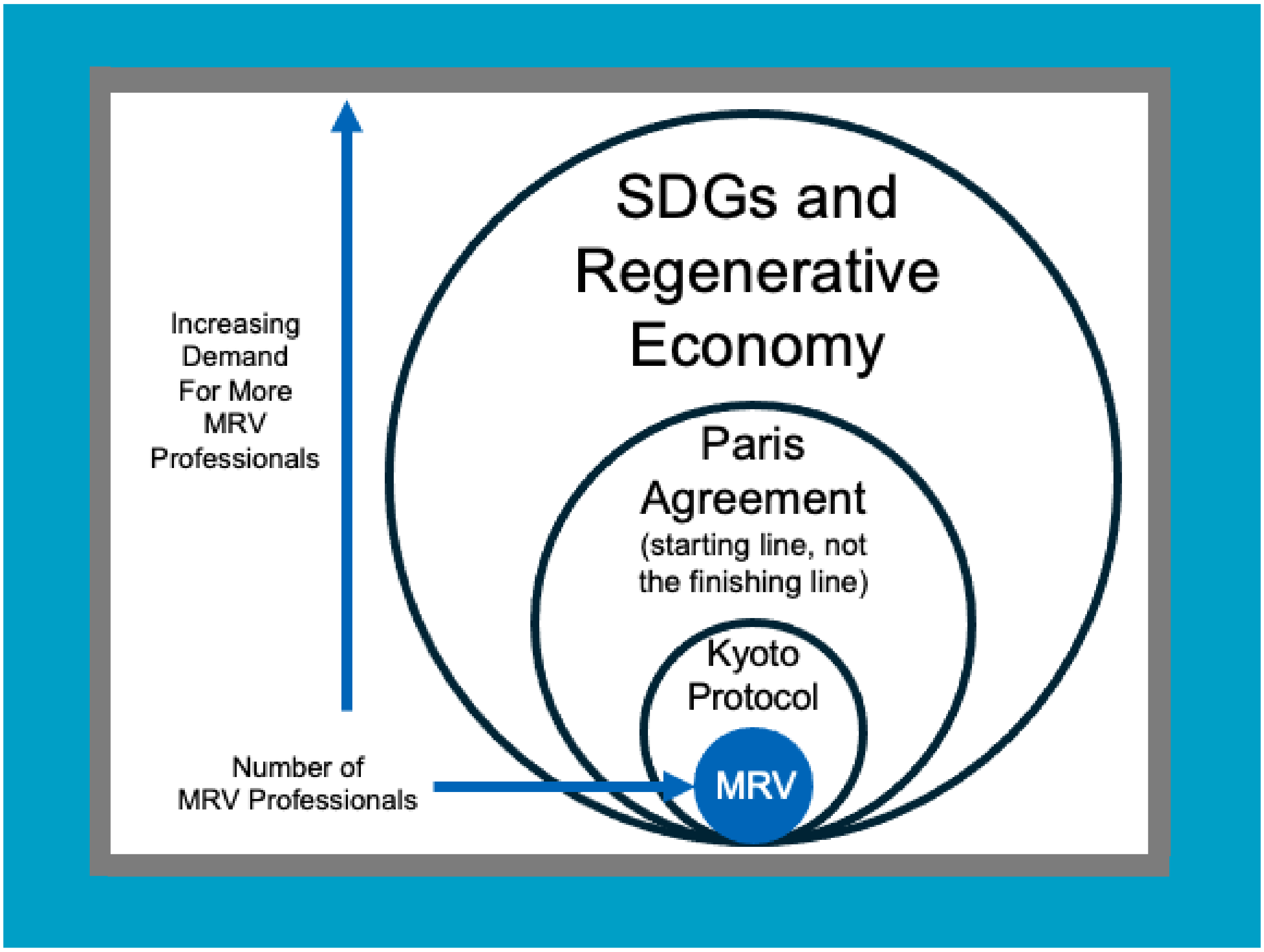
- Bloomberg: 'False climate solutions' (2022) and 'ESG greenwashing explodes' – $2 trillion erased from European markets (2021)
- Boston Consulting Group: AI-powered study reveals 91% of companies do not measure emissions comprehensively and report average errors of 30% to 40% (2021)
- Nature Magazine: global GHG emissions are misreported by 5.5 billion tonnes of CO_2e; other estimates range from a low-end error of 8.5 billion tonnes to a high-end of 13.3 billion tonnes across all sources of GHG emissions (waste, energy, land use, industry) of the current global total annual GHG emissions of about 40 billion tonnes of CO_2e. For comparison, the US annual GHG emissions are 6.6 billion tonnes.

Notwithstanding these crisis of increasing GHG emissions and lack of credibility from greenwashing, Carbon markets and carbon prices are rapidly increasing. For example, Reuters reported the EU ETS carbon allowance price neared 100 Euros per tonne of CO_2e in December 2021. The IMF recommends a minimum carbon price of $75 be established by 2030. Voluntary carbon markets exceeded $1 billion in 2021, and the Taskforce for Scaling Voluntary Carbon Markets, led by Mark Carney, estimates voluntary carbon markets are expected to be $100 billion by 2030. Reuters reported the global carbon markets (voluntary and compliance) grew 164% during 2021 to a new record of $851 billion.

Over the last several years, Chile has been cooperating with its partners in the Pacific Alliance within the Technical Subgroup on MRV (SGT-MRV). The SGT-MRV has developed a Coordinating Framework to determine priorities and activities to advance the maturity and effectiveness of their MRV systems. The main objective is to improve the condition of MRV systems, for example, shared definitions and taxonomies as well as interoperability, in order to accelerate climate investments and reduce climate finance risks.

However, there are many different approaches, as well as gaps, among national and subnational actors. Furthermore, there is insufficient MRV capacity (i.e., not enough MRV professionals). As NDC implementation and carbon markets rapidly increase and there is a demand for MRV services, the supply of Conventional MRV will not keep pace and therefore demand will increase Conventional MRV costs over the next several years. The following figure illustrates the scale of the challenge for MRV today to meet growing demand over the coming years and decades.

Figure 1: Scale of the challenges for MRV



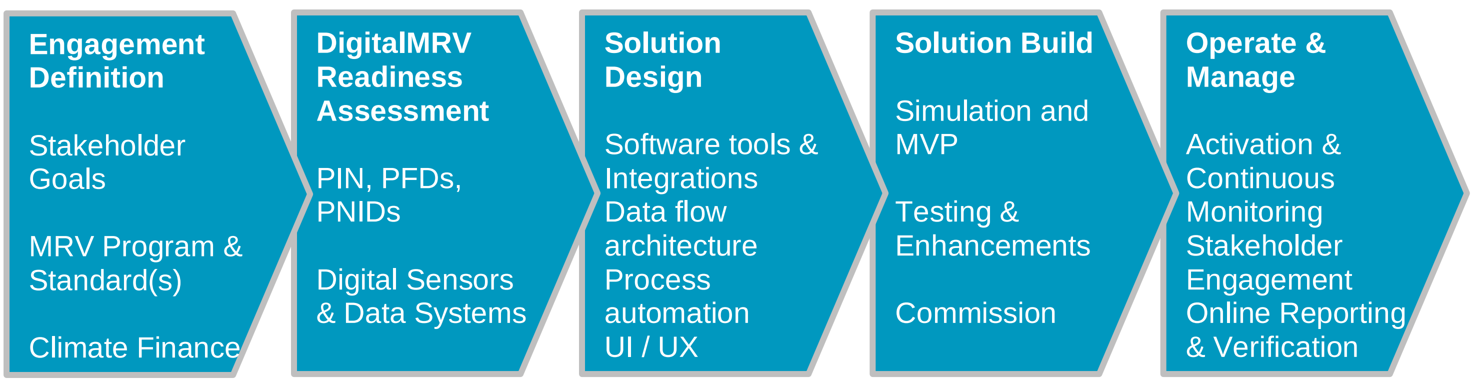
3. Overview

This section summarizes the DigitalMRV pilot projects within the Reciclo Organicos program. The DigitalMRV software for tracking and reporting emission reductions at Copiulemu and Molina was built on top of the facility's existing data measurement and management systems. The DigitalMRV software was developed according to the requirements of the GHG Quantification Protocols developed within the Reciclo Organicos program. The DigitalMRV software was jointly developed by ClimateCHECK and IOTA.

The process for the DigitalMRV pilot projects has five phases:

- Engagement definition (concept note and proposal)
- Assess the readiness of the site for the DigitalMRV solution
- Design the DigitalMRV solution
- Build the DigitalMRV solution and iterate enhancements
- Deploy and manage the DigitalMRV solution

Figure 2: Phases of the DigitalMRV pilot projects



Assessing the readiness of the site for the DigitalMRV solution

In consultation with the project developers and stakeholders (for example, government, project partners), the parties establish the scope of work, objectives, et cetera for the DigitalMRV process and solution. The main activities in this phase include collecting and assessing project information in regard to the MRV methodology requirements, for example:

- PFDs, PNIDs, equipment, related primary value chain activities
- Data acquisition (meters and sensors, calibration, data availability, data systems, SCADA, databases, site connectivity, data structure, etc.)
- Data treatment (security, processing, missing data, etc.)
- Data reporting (format, programs, etc.)
- Data verification (QA/QC, reasonableness checks, etc.)
- GHG calculations based on the MRV methodology

- Feasibility to procure hardware, data systems and reliable internet connectivity (for example, dedicated PC, VPN)

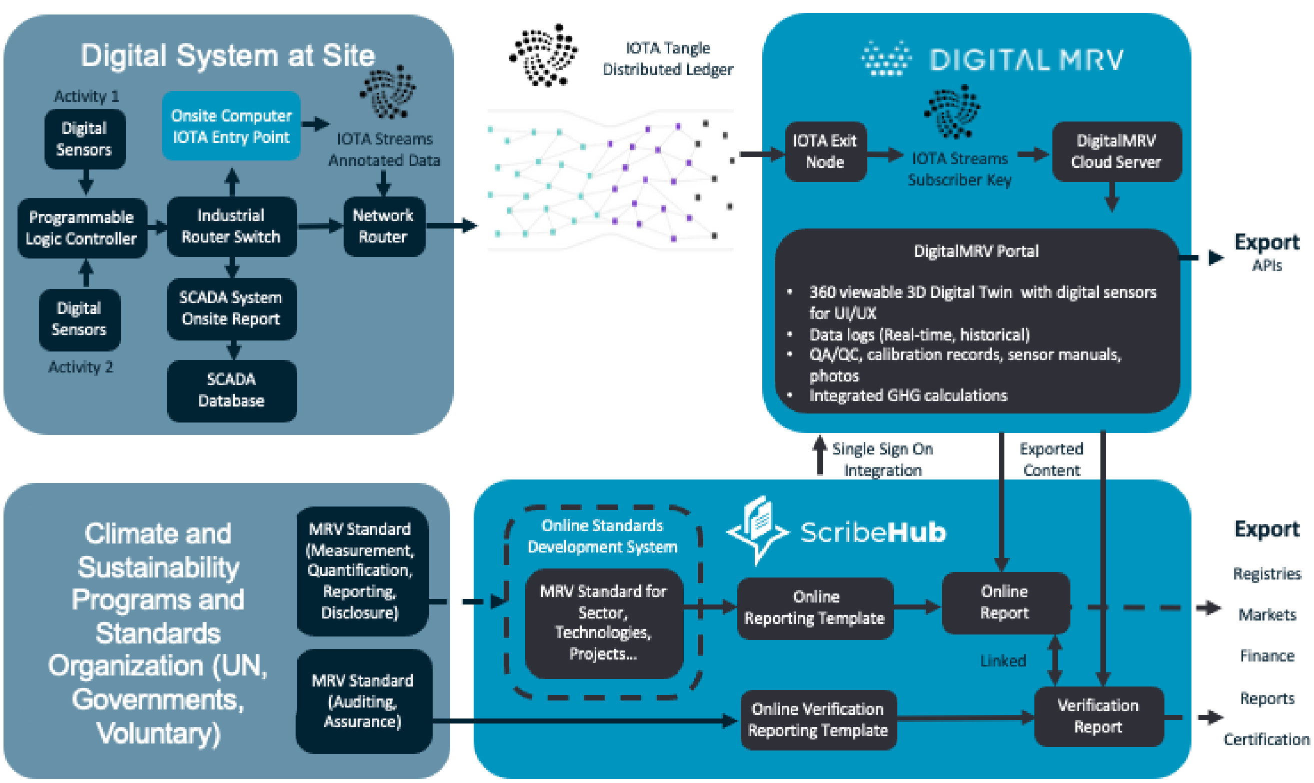
A dedicated data room for sharing files and web-meetings are conducted to clarify and share information. After approximately one month including interim drafts, the readiness assessment report (approximately 10 pages) is provided to the project developers and partners.

Designing the DigitalMRV solution

Based on the readiness assessment report, a design plan is developed to guide the development of the DigitalMRV solution. The DigitalMRV solution is developed based on the underlying digital technologies (for example, IoT, DLT), and for this use case it is based on existing IOTA open source solutions and software; for example, IOTA Identity, IOTA Streams and the IOTA Tangle. Additional solutions can be integrated; for example, the Project Alvarium Data Confidence Fabric (DCF) methodological framework. The main activities include:

- Define solution objectives, scope, system requirements, etc.
- Define solution data-flow architecture, software integrations, real-time and live data transmission, automation and processing requirements
- Define user interface and user experience (UI/UX), mock-ups for webpage layouts and functionality, user personas…
- Define development and implementation roadmap and timelines

Figure 3: Dataflow process diagram



Building the DigitalMRV solution

Based on the design plan, detailed instructions are developed for engineers, software developers, and other stakeholders. The main activities include:

- Build an initial internal minimum viable prototype for the site based on the MRV methodology
- Conduct internal testing, interact with the project developers as onsite data systems are commissioned, and identify areas for improvement
- Finalize the build and prepare for deployment

The ScribeHub online platform is used to create the online project report and online verification report in accordance with the MRV methodology requirements and relevant standards. A single sign on (SSO) Integration is implemented between DigitalMRV and ScribeHub within a dedicated workspace for the site.

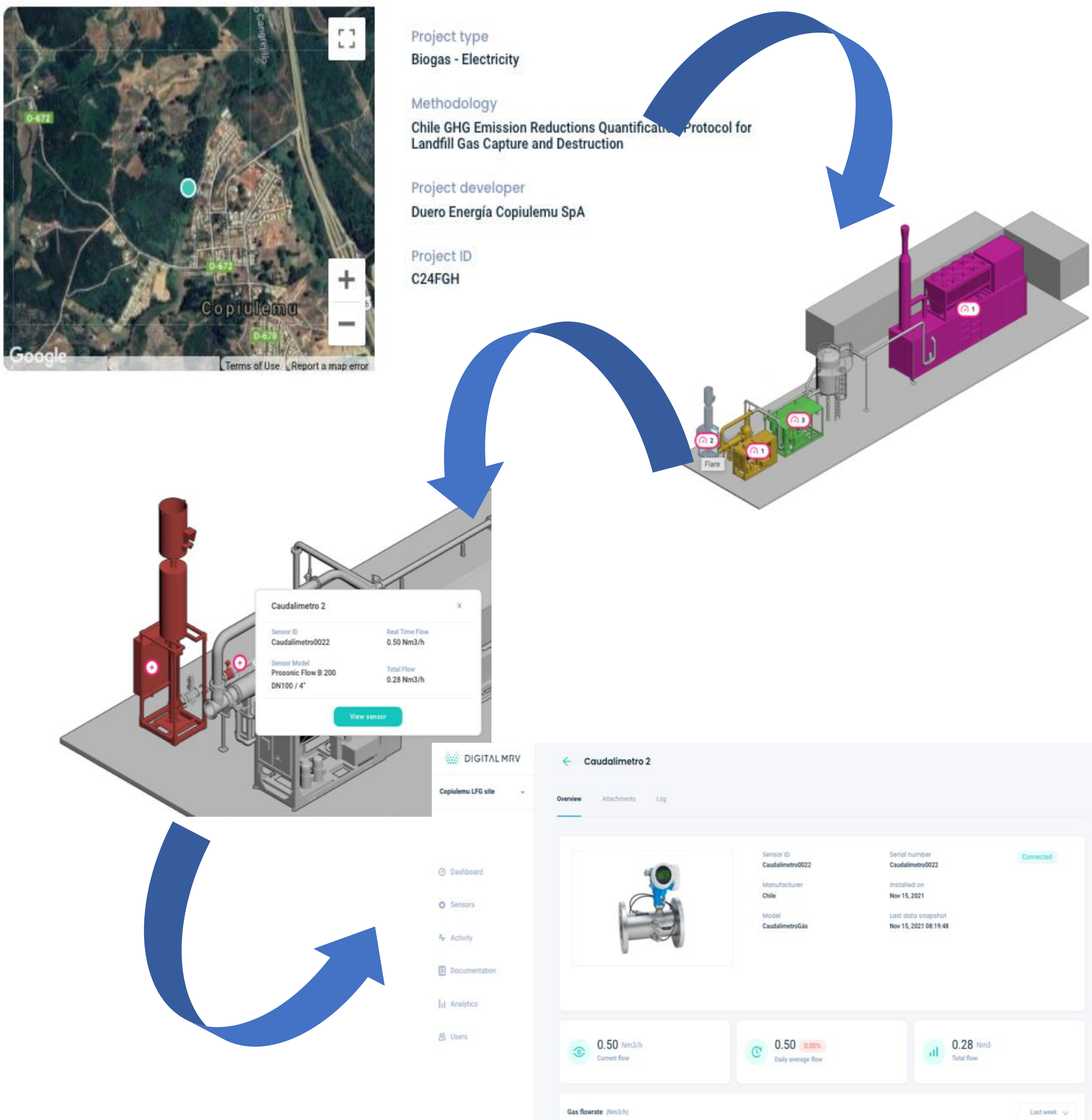
Deploying and Managing the DigitalMRV Solution

The main activities include:

- Confirm connections and integration with onsite sensors and data systems with the DigitalMRV solution (in close cooperation with the project developers)
- Commission the initial activation of the DigitalMRV software, and continuously monitor performance for the first two weeks,
- Detect any issues and perform system fixes and resolve errors/disruptions, and develop improvements
- Write up the online project report and perform internal reviews
- Write up the online verification report
- Continuous supervision and coordination among stakeholders
- Engage stakeholders on an as-needed basis with web meetings, web tutorials, progress reports, etc.

Figure 4 shows examples of DigitalMRV online software webpages to illustrate the “drill down” from the 3D digital twin of the landfill gas facility, down into the operational unit equipment, down into the digital sensor on the equipment measuring gas flow, and to the level of data and information.

Figure 4: Examples from DigitalMRV online software webpages



The DigitalMRV software is supported by various digital technologies. Onsite, digital sensors report data in accordance with the GHG Quantification Protocol. For landfill projects, the data collected concerns the volume and composition of biogas produced at the landfill. The volume of biogas is recorded in units of cubic meters and monitored every 15 minutes. By measuring the composition of the gas, it is possible to record the percentage of methane in the biogas; the destruction of methane results in the project's emission reductions, due to the high global warming factor of the gas (approximately 28 times that of carbon dioxide).

The digital sensors recording gas flow and composition report the data to a dedicated server at the landfill from which it is uploaded to the "cloud". A dedicated onsite computer for the DigitalMRV software was used in order to avoid the complexity (including security and compatibility issues) of installing the DigitalMRV software on the landfill operator's computer system. Monitoring and data records that act as supporting evidence - for example photos of sensors and equipment, calibration records, sensor manuals and monitoring plans - are incorporated into the DigitalMRV software. A 3D digital twin of the project site and sensors is incorporated into the portal's user interface (UI) to enable a virtual audit user experience (UX). The DigitalMRV software is integrated with ScribeHub to enable customizable online project reporting and verification reporting according to the GHG Quantification Protocol and international standards.

4. Benefits

The DigitalMRV software uses IOTA's permissionless DLT (Distributed Ledger Technology), which uses a Directed Acyclic Graph rather than a traditional blockchain. Unlike blockchains, IOTA's DLT enables unparalleled energy efficient performance with security, scalability, decentralization and with no fees for transferring data. These attributes of IOTA's technology have the ability to revolutionize MRV. DLT plays a central role in DigitalMRV. DLTs such as IOTA, in combination with digital sensors, eliminate the need for intermediaries to verify data and create a reliable, immutable, and traceable energy monitoring system. Promoting DigitalMRV with DLT could be one of the biggest drivers of climate change mitigation and new sustainable business models, as it opens opportunities for a new carbon market with better emissions accounting, assurance, certification, trading, and monetization.

To verify data sources, documents, contracts, identities, or official certificates, DLT automatically provides the security and trust that would otherwise be generated by third parties. As a DLT, IOTA also offers transparency in the origin of objects, materials, and processes. The fact that every step can be documented in a non-manipulable way creates trust in a process which that can yield new insights or products. IOTA is the only DLT protocol that enables data transactions without tokens. IOTA can be used for secure data transactions without having to buy or hold cryptocurrency.

Due to its ability to integrate data transactions, it also enables a high level of utility to hardware-based integrations. The hardware/processor requirements for IOTA are very low, which enables a broad range of device types to connect to the Tangle. The energy consumption on each device is also very low, which enables the protocol to run on battery-powered devices.

The absence of miners (a feature of most other blockchains) and the lightweight nature of the IOTA technology guarantee a significantly lower overall energy consumption.
Bitcoin uses ~926.23 kilowatt-hours per transaction whereas IOTA needs only ~0,0000000000003% of the energy required by Bitcoin. It also requires less energy for processing a transaction compared to other platforms such as Ethereum, Tezos, and Mastercard.[1] This highlights the fact that IOTA is designed to minimize energy consumption.

There is virtually no upper limit to the number of devices communicating on the Tangle. Contrary to other architectures where transactions must be processed one after the other in packages called blocks, IOTA's tangle technology provides parallel processing where various transactions can be processed simultaneously. This enables IOTA to process over 1000 transactions per second, while Bitcoin and Ethereum are currently able to process seven and 25 transactions per

[1] Source on comparison IOTA Bitcoin and Ethereum: Overcoming the dual crises of climate change and greenwashing; Calculations based of Tezos based on the reported numbers of Tezos Proof of Work vs. Proof of Stake: the Ecological Footprint; Mastercards energy consumption per transaction has been retrieved from Mastercard Corporate Sustainability Report 2017.

second, respectively. Adding more connected devices does not automatically incur additional costs for having to scale the related decentralized server infrastructure. The IOTA Streams framework, which is used in DigitalMRV, enables secure, structured capturing of data on the device it is created on (e.g., environmental sensor array) and tamper-proof, efficient transport over the Tangle, guaranteeing the authenticity of the data for all involved parties.

All IOTA frameworks are built to be used without the need of transferring value tokens with each transaction. For example, an Oracle can capture and transmit data to a subscriber over the IOTA protocol without the need for neither publisher nor subscriber to possess IOTA cryptocurrency tokens.

The IOTA protocol distinguishes between data and value. Indeed, information is communicated in the Tangle in generic envelopes we call transactions. Transactions can contain value or data stored in a particular payload. This approach separates the communication of information with the applications running on top of the Tangle, allowing the core protocol to be largely agnostic to the information it stores, making development easier and more flexible.

As DigitalMRV integrations continue to advance through pilots such as mentioned in this paper, new capabilities under development by other entities in the open-source ecosystems surrounding data integrity, security, compliance, privacy and analysis will continue to bolster the existing capabilities that are being tested and developed. One such use case is:
Use case: Project Alvarium - Increasing high reliability in data for business-critical decision making through the Data Confidence Fabric

Modern industries rely on automated algorithms to make business-critical decisions. These algorithms can improve the speed and quality of decision-making, but only if the underlying data is trustworthy, which becomes more difficult to ascertain as data sets grow. Together with Dell Technologies and Intel, the IOTA Foundation is working on Project Alvarium, which develops new methods for evaluating and guaranteeing the reliability of ever-growing data sets, collected from various sources including intercompany data transactions. This will increase reliability and efficiency in decision-making processes and can reduce costs.

The work being done in Project Alvarium has established the core capabilities to monitor data as it is transferred from its point of creation to the point of consumption, or from the sensor to the local network, through the edge infrastructure and into the cloud where it is integrated into an application. The capability to have granular oversight and transparency in data across the complete IT infrastructure enables an unparalleled ability for trust and compliance in the data to be established and, more importantly, quantified. The quantification of this trust is established in a metric known as a confidence score. This confidence score is based on pre-established criteria and variables set by stakeholders to be able to trust the data. These criteria and variables are verified and traced through the IT infrastructure that facilitates the creation, delivery and consumption of the data and allows the data to be autonomously valued. This will be critical for the growth of trusted data marketplaces and for applications to autonomously utilize data for various applications in near real-time.

In the climate space, this becomes critical because the ability to measure the trust in the data can be explicitly tied to the value of the emissions reductions. If the data utilized in the DigitalMRV software has a very high data confidence measurement, then the carbon credits it enables would also be more valuable. This variable can be used to offset the cost of enhancing traditional climate actions attempting to make a positive climate impact and get integrated into carbon markets. It allows for a more readily measurable return on investment, incentivizing ESG investment in new impact creation mechanisms and facilities, and accelerating industry-standard development, methodology creation and adoption. As it scales into adoption, it provides global insight into the rate of impact that the industry is creating as a whole.

In addition to expanding the geographic and sectoral scope of the DigitalMRV system, further functionalities can be incorporated. From the IT side, future improvements of the DigitalMRV software include using digital solutions to:

- Report data from the DigitalMRV software directly to a national GHG inventory and for climate finance;
- Verify emission reductions in real-time as data is collected;
- Link to carbon credit registries and or marketplaces; and,
- Link to climate finance MRV.

5. Economic comparison of DigitalMRV vs Conventional MRV

DigitalMRV has been developed to be:

- more efficient than conventional MRV to save time and money on quantification and verification
- more effective than conventional MRV, for example in terms of credibility, verification quality and time availability of reporting results.

The economic efficiency of DigitalMRV compared to conventional MRV depends on the specific circumstances. Two scenarios were assessed to compare DigitalMRV vs conventional MRV.

- Scenario 1 for DigitalMRV still requires full independent third-party verification; this is because there is not a consensus for an international standard for automating digital verification. Although DigitalMRV can reduce the level of effort to do an independent third-party verification, the economic assessment does not consider those potential cost savings.
- Scenario 2 for DigitalMRV automates the verification however a new type of independent third-party verification must still be involved just for the first year to validate DigitalMRV is performing the verification, and also to perform periodic spot audits (e.g. every 3 years).

The assessment considers current costs for DigitalMRV, which are expected to decrease as the digital technologies and supporting systems mature. In contrast, as carbon markets rapidly increase and there is a demand for MRV services, the supply of conventional MRV will not keep pace and therefore demand will increase conventional MRV costs over the next several years.

The key points of the economic assessment include:

- If DigitalMRV does not already exist and is therefore a “new build”, then DigitalMRV requires significant upfront investment to develop and commission the software at the first site
- A high-end conventional MRV engagement is estimated to cost on average $65,000 per year; this cost is much easier to finance year-to-year.
- If DigitalMRV is deployed to 10 sites, and assuming a 10 year timeline, then Scenario 1 results in a 28% reduction in total MRV costs ($1.29M) compared to conventional MRV
- If DigitalMRV is deployed to 10 sites, and assuming a 10 year timeline, then Scenario 1 results in a 56% reduction in total MRV costs ($2.69M) compared to conventional MRV

The following tables present the year-by-year assessment for Conventional MRV vs DigitalMRV Scenario 1 and Scenario 2 (values in $1000s CAD).

Table 2: Conventional MRV ($1000s)

Conventional MRV costs at first site	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Collect data and supporting evidence	$ 10.0	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 7.5	$ 77.5
Quantify GHG calculations	$ 5.0	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 2.5	$ 27.5
Develop GHG report	$ 15.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 105.0
Prepare and participate in verification	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 10.0	$ 100.0
Conventional MRV costs at first site	$ 40.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 30.0	$ 310.0
Independent third-party verification	$ 25.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 160.0
Total costs at first site	$ 65.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 45.0	$ 470.0
Cost for ten sites	$ 650.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 4,700.0

Table 3: Scenario 1: DigitalMRV cost at first site (plus additional independent third-party

DMRV cost at first site	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Concept proposal	$ 5.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5.0
Readiness assessment	$ 25.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 25.0
Design	$ 50.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 50.0
Development (tech and reports)	$ 250.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 250.0
Deployment (integrations)	$ 60.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 60.0
One year support	$ 20.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 65.0
DMRV costs at first site	$ 410.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 455.0
Independent third-party verification	$ 25.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 160.0
Total costs at first site	$ 435.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 615.0

Table 4a and 4b: Scenario 1: DigitalMRV cost at additional sites (near identical conditions, $1000s)

DMRV cost at an additional site (near identical conditions)	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Concept proposal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Readiness assessment	$ 5.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5.0
Design	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Development (tech and reports)	$ 65.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 65.0
Deployment (integrations)	$ 15.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15.0
One year support	$ 20.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 65.0
First site total	$ 105.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 150.0
Independent third-party verification	$ 25.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 15.0	$ 160.0
Total costs at first site	$ 130.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 310.0

DMRV cost at first and nine additional sites	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Total cost	$ 1,605.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 3,405.0
Cost per site (across ten sites)	$ 160.5	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 20.0	$ 340.5

Table 5: Scenario 2: DigitalMRV cost at first site (verification is automated and an independent third-party verifier must still be involved just for the first year and spot audits, $1000s)

DMRV cost at first site	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Concept proposal	$ 5.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5.0
Readiness assessment	$ 25.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 25.0
Design	$ 50.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 50.0
Development (tech and reports)	$ 250.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 250.0
Deployment (integrations)	$ 60.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 60.0
One year support	$ 20.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 65.0
DMRV costs at first site	$ 410.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 455.0
Independent third-party verification	$ 10.0	$ -	$ -	$ 5.0	$ -	$ -	$ 5.0	$ -	$ -	$ 5.0	$ 25.0
Total costs at first site	$ 420.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 480.0

Table 6a and 6b: Scenario 2: DigitalMRV cost at first site (verification is automated and an independent third-party verifier must still be involved just for the first year and spot audits, $1000s)

DMRV cost at additional sites (near identical conditions)	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Concept proposal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Readiness assessment	$ 5.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5.0
Design	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Development (tech and reports)	$ 65.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 65.0
Deployment (integrations)	$ 15.0	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15.0
One year support	$ 20.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 65.0
First site total	$ 105.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 5.0	$ 150.0
Independent third-party verification	$ 5.0	$ -	$ -	$ 5.0	$ -	$ -	$ 5.0	$ -	$ -	$ 5.0	$ 20.0
Total costs at first site	$ 110.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 170.0

DMRV cost at first and nine additional sites	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Total cost	$1,410.0	$ 50.0	$ 50.0	$ 100.0	$ 50.0	$ 50.0	$ 100.0	$ 50.0	$ 50.0	$ 100.0	$2,010.0
Cost per site (across ten sites)	$ 141.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 5.0	$ 5.0	$ 10.0	$ 201.0

Table 7: Comparison of Conventional MRV vs DigitalMRV scenario 1 and scenario 2, ($1000s)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Conventional MRV cost	$ 650.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 450.0	$ 4,700.0
DMRV Scenario 1 cost	$ 1,605.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 200.0	$ 3,405.0
Cost difference vs Scenario 1	$ (955.0)	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 250.0	$ 1,295.0
DMRV Scenario 2 cost	$ 1,410.0	$ 50.0	$ 50.0	$ 100.0	$ 50.0	$ 50.0	$ 100.0	$ 50.0	$ 50.0	$ 100.0	$ 2,010.0
Cost difference vs Scenario 2	$ (760.0)	$ 400.0	$ 400.0	$ 350.0	$ 400.0	$ 400.0	$ 350.0	$ 400.0	$ 400.0	$ 350.0	$ 2,690.0

6. Key Results and Lessons Learned

The first pilot project at the Copiulemu landfill started January 2020. As COVID started to become a global pandemic, it was necessary to revise the original project work plan because travel and onsite workshops were not possible. Unfortunately, COVID travel restrictions continue to remain in place through to the end of both pilot projects in March 2022. It was difficult to arrange for personnel to access the sites to set up the DigitalMRV software and the new computers. However, the challenges of COVID motivated developers working on the DigitalMRV software as it became more evident that new ways would be required to do MRV (without onsite MRV professionals).

The key results include:

- development and deployment of DigitalMRV software at the Copiulemu landfill, and also DigitalMRV software at the Molina biodigester
- therefore, Chile is hosting two world leading DigitalMRV implementations, which have been highlighted publicly in reports by UNEP and World Bank
- capacity building of project participants in the implementation of DigitalMRV software onsite, as well as stakeholder webinars and a spotlight paper as part of the South-South exchange between Chile and the Pacific Alliance with countries in West Africa
- involvement of Dell Technologies to provide an industrial server and engineering expertise to implement the leading edge “data confidence fabric” (value $25,000 contribution)
- a summary “how to guide” to plan a DigitalMRV pilot and to perform the initial DigitalMRV readiness assessment for future projects
- compilation of resources and prospective partners to facilitate future DigitalMRV projects

DigitalMRV has been developed to be more effective than conventional MRV, for example in terms of credibility, verification quality and time availability of reporting results.

The pilot projects provided many lessons learned for implementing DigitalMRV in different circumstances. For example, the Copiulemu landfill had digital sensors installed throughout the site, however, internet connectivity was not reliable. In contrast, the Molina biodigester had only a few digital sensors and much of the evidence was entered manually into the database.

To facilitate operation of the DigitalMRV solution, it helps if there is a person onsite designated as the direct responsible individual (DRI), whose first activity is to document the activities with photos (e.g., check if this cable is connected here..., do this, click here), and then compile these activities into a manual, which is available in a shared drive or printed and placed next to the IT hardware (ex: dedicated computer).

The DRI is responsible for the "last mile" onsite, for example to ensure connectivity works as designed. It is ideal to maintain open communications (e.g., email) to facilitate automatic monitoring in case of an alert on any outage. The DRI's task is to "document" (e.g., screenshot, etc.) how to fix these outages and add them to the manual. This ensures that the whole operation is documented, has an owner and that the know-how can easily be transferred (in case the person leaves or is on vacation).

Furthermore, for an initial project or the initial phase, it is important for a technically competent partner to be available in the vicinity of the site to be able to respond in the event of critical faults. As well there needs to be a level of redundancy implemented into the design of the local integrations, so that if connectivity fails, there are backup systems to ensure that data is still being made available to the DigitalMRV solution.

DigitalMRV solutions can be crucial for the cost-effective and transparent reporting of greenhouse gas emission reductions in sectors covered under a country's NDC with industrial processes where smart sensors can record data in real-time. The innovative use of DLT to ensure the integrity of data collected is equally important for future carbon credit markets to function.

7. Next Steps

The pilot projects at the Copiulemu landfill and at the Molina biodigester ("projects") may continue to run the DigitalMRV software at no charge. There are many potential options for next steps.

The projects can contact potential partners across the digital carbon value chain, for example:
- Energy Lab Chile on digital MRV services
- Climate Chain Coalition (co-chaired by the UNFCC Secretariat) global multistakeholder network to identify partners
- EcoRegistry to register mitigation outcomes and carbon credits in an online registry
- ClimateTrade to trade carbon credits on an online climate trading platforms

The Government of Chile can engage with several initiatives on digital MRV and related digital for climate topics to advocate new policies and frameworks), for example:
- World Bank's Climate Warehouse (Chile's Ministry of Energy is already active) for both an international mitigation outcomes online registry and digital MRV
- Verra for its new digital MRV working group
- IETA for its new digital climate committee
- Open Collaboration hosted by Gold Standard for next generation digital solutions for MRV

Examples of the types of activities of the above initiatives include:
- Working groups and committees (Gold Standard, Verra)
- Research and case studies (UNEP, World Bank)
- Develop frameworks, terminology, processes (Gold Standard, Verra, IWA/GBBC)
- Pilot projects (land use, waste, renewable power)
- Capacity building and events (World Bank Innovate4Climate)

Over the last several years, Chile has been cooperating with its partners in the Pacific Alliance within the Technical Subgroup on MRV (SGT-MRV). The SGT-MRV has developed a Coordinating Framework to determine priorities and activities to advance the maturity and effectiveness of their MRV systems. The main objective is to improve the condition of MRV systems, for example, shared definitions and taxonomies as well as interoperability, in order to accelerate climate investments and reduce climate finance risks.

As Chile develops a strategy to guide development of its MRV systems, it is worthwhile to continue pilots, capacity building, and collaboration to determine which combination of digital solutions match with the needs and goals of MRV stakeholders in Chile, for example:
- IT Infrastructure
- Online reporting portals
- Information management systems
- Data management systems
- Knowledge management systems
- Digital sensors ("IoT") as well as remote sensing and mobile sensors

- Distributed Ledger Technology ("DLT", aka blockchain) for activity data, financial data, environmental data (e.g., GHG emissions tracking)
- Artificial Intelligence ("AI"), Machine Learning ("ML") and big data analytics
- Emissions modeling software and emission factor databases

The following sections provide examples of resources, training and potential partners.

8. Resources

Recommended Reading (reports and websites) on Digital MRV and Digital for Climate (Markets, Finance, Actions…)

What is Digital MRV? – ClimateCHECK, 2020

Open Collaboration White Paper on Next Generation Digital Solutions for MRV – ClimateCHECK, IOTA, Gold Standard, 2021

Navigating Blockchain and Climate Action 2020 State and Trends – Climate Ledger Initiative, 2020

Climate Ledger Initiative (website)

Climate Chain Coalition (website)

Distributed Ledger Technology for Climate Action Assessment – ClimateKIC, 2018

Blockchain for Sustainable Energy and Climate in the Global South – UNEP, 2022

Using the Disruptive Force of Distributed Ledger Technology to Fight Climate Disruption – Blockchain Research Institute, 2018

Climate Fintech: Mapping an Emerging Ecosystem of Climate Capital Catalysts – New Energy Nexus, 2021

Climate Fintech Alliance (website)

Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets –World Bank, 2018

The National Climate Change Metrics System (SINAMECC) – World Bank, 2020

World Bank Climate Warehouse (website)

Protocol for Digitised MRV – EBRD, 2020

Taskforce for Scaling Voluntary Carbon Markets – TSVCM, 2021

Climate Fintech Rise Report – Barclays, 2021

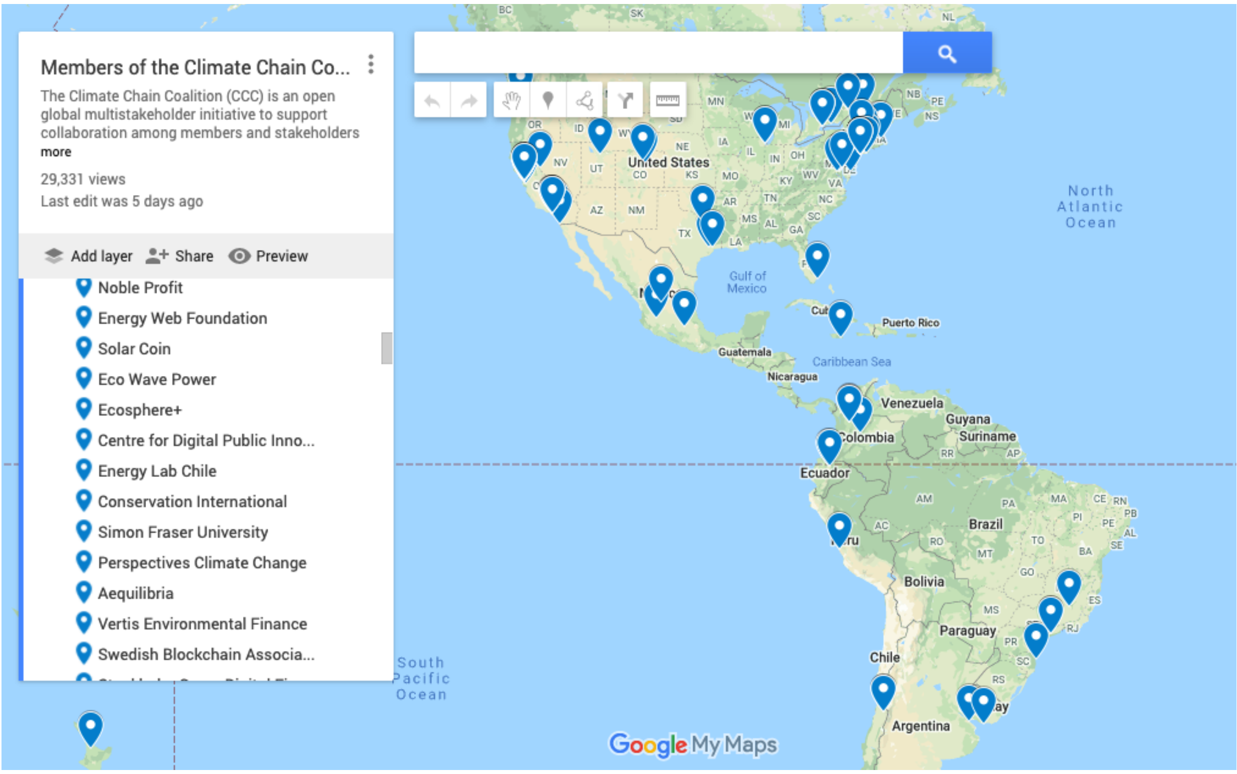
Digital MRV Framework – InterWork Alliance, 2021

Turning digital technology innovation into climate action – ITU, 2019

9. Partnering and Training Opportunities

There is a global community of digital and DLT solution providers that are prospective partners. For example, the Climate Chain Coalition includes over 300 members in over 50 countries.

Figure 5: Linked map listing members of Climate Chain Coalition



Examples of blockchain solution providers for climate that are active in Chile include:

- ClimateTrade
- EcoRegistry and Santiago Climate Exchange
- Energy Lab Chile
- OpenSurface REDD Chain Project (RCP Chile)

There are many different types of blockchains/DLTs, and there are even more training courses available – including many online options. Here are some examples:

- IOTA
- Hyperledger
- Udemy
- Coursera
- LAC Chain Academy

10. How to Develop a DigitalMRV Pilot and Perform a DigitalMRV Readiness Assessment

Digital MRV Pilot Project Activities

[My Organization] proposes the following activities to develop a Digital MRV solution [Customer Organization].

1. Draft a Concept Note for and interact with stakeholders to guide the process for Digital MRV customization and implementation with [Customer Organization] and relevant partner situation (e.g., pilot host facility) to validate functionality and obtain stakeholder approval

2. Perform a Readiness Assessment of the [Customer Organization] and relevant partner situation in regard to design and develop the Digital MRV solution for [Customer Organization].
    a. Scope Digital MRV solution
    b. Obtain and assess project information, e.g., overall information about the project (based on MRV methodology) such as PFDs, PNIDs, equipment, org charts, and related activities such as sources of feedstock
    c. Assess project data systems, e.g., mesh network, direct-to-cloud communication, GPS, SCADA, meters/sensors (temperature, humidity, shock), site-connectivity, system accessibility, monitoring plan, data availability, databases, switches, routers, PCs, chain of custody, analysis and reporting, AI/ML, track and trace software, pooling interface, third party integrations, data management systems and other relevant information systems; as well as defining data system boundaries
    d. Consult with [Customer Organization] to determine need for new sensors and data systems onsite
    e. Document the readiness assessment, e.g., overall results, key findings such as gaps and possible solutions to enable Digital MRV; as well as action items

3. Design Digital MRV solution
    a. Define solution objectives, scope, system requirements, considering relevant stakeholders ([Customer Organization], partners, customers, stakeholders)
    b. Define solution data-flow architecture, software integrations, real-time and live data transmission, automation and processing requirements
    c. Define user interface and user experience (UI / UX), mock-ups for webpage layouts and functionality, personas

   d. Define development and implementation roadmap and timelines

4. Customize Digital MRV solution
   a. Develop detailed instructions for engineers, software developers, etc.
   b. Build online project report and online verification report with online software platform
   c. Build initial internal version
   d. Internal testing, interacting with the project developers as onsite data systems are commissioned, and identifying areas for improvement
   e. Final build and preparation for deployment

5. Integrate, Operationalize and Deploy Digital MRV solution
   a. Connect and integrate onsite sensors and data systems with the Digital MRV solution (in close cooperation with the project developers)
   b. Commission and initial activation of the Digital MRV solution
   c. Continuous performance monitoring, system fixes and resolving errors/disruptions, developing improvements
   d. Complete online project report and online verification report on online software platform
   e. Continuous supervision and coordination among participants, web-meetings, reporting
   f. Interact with stakeholders to obtain their approval of the operation and results of the Digital MRV solution for [Customer Organization]
   g. Implement links to stakeholders for carbon credits or other solution provider

Schedule

The proposed schedule is presented in the following table.

Table 8: Project schedule

Activities	**Month to Month Schedule**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Interact with Stakeholders												

Activities	Month to Month Schedule											
	1	2	3	4	5	6	7	8	9	10	11	12
2. Develop Concept Note for Stakeholders												
3. Develop GHG Quantification Methodology												
4. Develop Concept Note for DigitalMRV												
5. Perform Readiness Assessment for DigitalMRV												
6. Design DigitalMRV												
7. Customize and Build DigitalMRV												
8. Integrate, Operationalize and Deploy DigitalMRV												

The proposed timeline/schedule represents work that will be performed by [My Organization] and its partners. The schedule does not reflect the time necessary for stakeholders to respond to requests and perform reviews required in their methodology approval process.

Budget

The proposed budget for the proposed activities is:

1. Concept Note for Digital MRV (e.g., $2,000 to $5,000)
2. Perform Readiness Assessment (e.g., $10,000 to $30,000)

3. Design DigitalMRV solution (e.g., $20,000 to $70,000)

4. Customize and Build Digital MRV solution (e.g., $100,000 to $350,000)

5. Integrate, Operationalize and Deploy Digital MRV solution (e.g., $40,000 to $80,000)

Overall budget estimate [$$$,$$$ to $$$,$$$].

The prices for activities 3, 4, and 5 are highly variable due to the uncertainty of the full concept and the dependency on stakeholder approval.

The proposed budget excludes any fees charged stakeholders, e.g., registration fees and certification fees.

Digital MRV Readiness Assessment

Assessment Process Fundamentals

The following outlines the fundamental scope for the purpose of this assessment.

Objectives

1. Define an overarching assessment of the existing information systems in place with regard to both digital and analog integrations.
2. Assess and recommend any improvements for the existing system to ensure adequate information availability is being appropriately gathered and disseminated.
3. Define key integrations areas where Distributed Ledger Technology (DLT) will be able to provide value to the methods data is gathered and transferred in the monitoring, reporting and verification process.

Scope

1. Overall GHG MRV informational needs as per the [specific project type] MRV Methodology and related MRV standards
2. Physical SCADA systems active at the [Customer Organization] facility
3. Data acquisition and sensor integrations whether digital or analog
4. Data gathering mechanisms, to include near-real time data solutions such as digital sensors, manually checked analog sensors, and manual reporting and documentation processes and their timeframes
5. Sensor data formats and automated reports
6. Data storage systems, monitoring dashboards, and transfer systems and protocols

Information Request

This section outlines the information requested by [My Organization] to assess what is available from the project, for example, data sources (e.g., measurement devices, paper and electronic records), data management systems, etc. The information and assessment are used to define the development plan for the Digital MRV solution. It is acknowledged that some of the information requested below may be in various formats or combinations depending on the practices of the project manager. The following table provides a high-level summary - the following sections go into detailed assessments.

Table 9: Information being requested for assessment purposes

Information Requested	Comments (explanation, source of information)	Status
PNID, Data Map	PNID = process and instrumentation diagram across the site, e.g., equipment and meters for collection, treatment, combustion, generation - data process map showing the step by step "data trail".	Date and extent of the information provided
Site information	- Facility site plan / schematics / technical drawings - fuel and electricity consumption and supplement use, and monitoring equipment - organization chart – who is the site manager, technicians... - project info such as start date, ownership, contact persons, address/coordinates… - photos of site, equipment, meters - information about the main equipment	
Feedstocks	Types and quantities of feedstocks (on most frequent time of receiving); Name and location of feedstock sources - how are feedstocks produced - how are feedstocks collected and processed at source - how are feedstocks transported to the site - what meters/method are used for feedstock quantity (mass, volume) measured - what used to happen to the feedstocks before the facility was built?	
Meter information	Measurement equipment (e.g., flow meters, flow composition, pressure, temperature, electricity); digital sensors; Meter description and operational manuals	
Meter calibration and maintenance records	Service dates of calibration and maintenance, meter ID/location, who performed services.	
IT and Data Management System	Electronic Manuals, description of and access to software system, onsite hardware system - software used (e.g., to analyze/utilize the data) - data and record keeping	

Information Requested	Comments (explanation, source of information)	Status
Data Monitoring and Data QA/QC procedures and systems	- data acquisition/logging, collection, frequency... - procedures performed on the data (e.g., QA/QC such as completeness check, data timestamp, etc.) - data transmission, data storage, data security, etc. (use of service providers such as Amazon Web Services...) - data access - procedures for missing data - SCADA system, internet access	

Review and Results of Information Provided

[Customer Organization] operator/manager provided information which was compiled into a confidential access-controlled online data room (e.g., Google Workspace).

The overarching diagram outlining the essential data systems that manage the data reporting and verification process in the facility are outlined throughout this document. It outlines where the field equipment, or more precisely the sensors are situated in the data management workflow at the plant.

The major components include the following which perform the described tasks.

1. **Field Equipment -** Field equipment includes all digital and analog sensors located throughout the facility for the purpose of monitoring existing processes, gathering data on those processes, and making it available to external parties for verification. These devices are then listed in more detail in the document [ID, filename…] in which all devices are listed by model number and their location in the system.
    a. A comprehensive list of measuring devices is outlined in the document [ID, filename…]
    b. The data process map showing the step by step “data trail” is illustrated in the document [ID, filename…]
    c. Based on the data network diagram provided in document [ID, filename…], and the equipment listed in the file, there are a number of data producing sensors and gauges that already have their data structured. The values from these devices are structured in JSON formats at the PLC and sent to the onsite SCADA DB for local storage and tracking.

Table 10: List of measurement devices

List of measurement devices					
Facility Operation	**Quantity**	**Signal Type**			**Remarks**
		Analog	*Digital*	*Undefined*	
Operation 1	20	1	6	13	
Operation 2	10	0	0	10	
Operation 3	25	12	4	9	

Operation 4	3	0	0	4	
Operation 5	15	0	3	12	
Operation 6	20	6	6	8	
Operation 7	8	2	0	6	
Operation 8	5	0	0	5	

2. **Programmable Logic Controller (PLC) -** It is assumed that the sensors are directly connected to the existing PLC. It is not known how many PLCs currently are in use. For designing the Digital MRV device integrations, an understanding of the number of PLCs needs to be known, so that a defined number of Digital MRV host devices can be planned prior to the project development process. Ideally the Digital MRV host machine will direct connect to the PLC to consume data from as close to the sensors as possible. These dedicated Digital MRV host machines would structure the sensor data into the implementation, then connect to the industrial routing switch to push the data onto the DLT for integration into the Digital MRV portal.

3. **Industrial Routing Switch -** It is understood that this device is used to manage the routing of the data from the PLC. This includes routing the data internally to the SCADA PC Desktop and encompassing SCADA DB based on [specific software]. For a full assessment of any necessary changes to the industrial routing switch more information on the device make and model, as well as the existing Access Control Mechanisms and/or firewall integrations will need to be ascertained. Based on specifications in the document [ID, filename…], it appears there are [##} switches present. One in the location #1, and another in location #2 at the facility. If this is correct, then at least two Digital MRV host machines would be developed in order to have a local device in each facility for structuring and capturing the data independently of the overall facility and SCADA systems to give a proper level of data provenance.

4. **SCADA PC Desktop -** The make and model of this device is currently unknown and not necessarily relevant for this assessment. It is best to not integrate directly with the existing SCADA PC due to potential conflict with existing applications, and the potential for the PC to not be consistently connected to the network. It is advised that a dedicated unit be integrated into the existing systems for Digital MRV utilization to avoid any issues that integration with other compute devices may cause.

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