Open Collaboration on Next Generation Digital Solutions for Measurement, Reporting and Verification (MRV)

November 2021

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Introduction

ClimateCHECK, Gold Standard, and IOTA Foundation are announcing a white paper and founding of an open collaboration on next generation digital solutions for measurement reporting and verification (MRV) to achieve the ambitious climate goals of the Paris Agreement and the Sustainable Development Goals (SDGs). The envisioned digital solutions will support transformational systems change to scale high-impact climate action that catalyzes sustainable development.

The technical foundation of the next generation digital solutions will ensure cohesiveness, interoperability, and systems access to all through a technical backbone that will be: open source, without user fees, low-energy to support remote users, modular, and with the highest levels of data integrity and security. The system will integrate with other digital platforms, hubs, and infrastructure and will support proprietary applications where applicable to reward market leaders. To ensure credibility, the digital solutions will foster innovative approaches in governance including technical, legal, accounting, and reporting permissions; social engagement and crowdsourcing through online user communities for standards development and assurance; and financial innovations that initiate new business models, digital currency transactions, smart contracts.

The consortium will begin development of core system elements in Q1 2022 including innovative solutions for MRV, data integrity, standards and related governance. The consortium will invite stakeholder participation as an open network and a "big tent" community of practice, to digitally scale climate actions at the magnitude required, to ensure equitable access, to safeguard the credibility of system inputs and outputs, and to respond rapidly to evolving knowledge, data, new technologies, and growing fields such as climate adaptation.

This three-part paper begins with an outline of the ambitious vision, and highlights recent work on the roadmap to realize Next Generation Digital Solutions for MRV. Part 2 provides a deeper definition of Digital MRV and its practical, stepwise engagement and implementation at the project level with a use case example. Part 3 provides an overview of how IOTA's technologies match the needs for a data-driven open-source ecosystem that is low cost, low footprint, decentralized, and scalable.

We hope this paper encourages stakeholders to engage in this call to action.

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Part 1: Next Generation Digital Solutions for MRV

Averting climate breakdown requires the successful implementation of a wide range of policies and financial instruments that drive collective action amongst the competing interests of public and private stakeholders. This brings both opportunities and complexities, paired with an essential need to be sure that policies and actions have real impact.

Balancing these competing interests demands a high degree of sophistication in MRV of climate actions (for example, inventories, mitigation, finance, adaptation) and related sustainability goals. It also requires that such data is accurately and transparently tracked and attributed to relevant stakeholders in a way that enables liabilities and benefits to be correctly identified, valued and managed. Without these elements in place it would be difficult, if not impossible, to ensure that climate actions are effective.

The dual need for *tracking and attribution* of climate-related data and robust MRV is not new. It has however become more urgent given the extremity of climate breakdown and the corresponding requirement to vastly scale up climate actions. The systems in place under the Kyoto Protocol and some project initiatives of that era are often characterized by arbitrary target setting, loose alignment of accounting systems, manual collection and reporting of data and manual, on-site assurance, where it exists at all. That is not to say the underlying understanding of accounting, assurance and disclosure in various instruments is poor, but there have been limitations in implementation that would be greatly exposed by the necessary expansion of effort now required to achieve the 2030 global goals of 50% decarbonization.

In short, the current MRV systems of tracking and attribution cannot prevent the climate breakdown because it would not be possible to be sure of the outcomes, including in aggregate. Even if suitable targets are established and enough momentum and finance are generated to avert climate breakdown in principle, efforts could still ultimately fail due to inefficiency and inaccuracy in the measurement and accounting of what needs to be achieved in practice.

Despite the essential role of MRV, the field faces several challenges. For example, the relatively high costs and long timelines need to be reduced, as well as the lack of confidence in claims relating to products, companies, policies, finance, markets and so on. Other challenges include accurate quantification of greenhouse gas (GHG)

inventories and accurate target setting and tracking, for example, of nationally determined contributions (NDCs). Recent studies (2021) report that:

- Over 90% of organizations do not report accurate and complete GHG inventories, with an average error of 30-40%[1];
- Overall, national inventories have an aggregate error equivalent to 12% of the global GHG inventory (about 5.5 gigatonnes)[2].

With the 2020s "decade of action", there is a clear need to scale finance to accelerate exponential actions and transformational change, such as "deep decarbonization" and low carbon transition pathways, .and a correspondingly clear need for vastly more effective MRV – not least to address concerns about "greenwashing". The July 2021 report by the **Taskforce for Scaling Voluntary Carbon Markets** highlights the value that digitization can provide for carbon markets (Recommendation 11), in particular Digital MRV in order to save time and money and improve market confidence.

In addition, as countries around the world implement their bottom-up **NDCs under the Paris Agreement**, there is a need to improve the cohesiveness and interoperability of MRV systems and activities, to avoid double-counting and double-claiming as well as to support climate change strategies to be more cost-effective and efficient in achieving goals. Investing in better MRV systems for climate change can have a better ROI – financially and for sustainability overall.

The challenges noted above are a combination of many factors, including the need to have the right data and standards, as well as correct application. Examples of specific challenges include:

- Current MRV practices in companies, cities, etc. are mostly (more than 90%) analog and manual processes. This requires in-person visits to audit sites, which is inefficient and costly. Occasional (e.g., annual) visits mean reporters are limited in their ability to monetize climate assets or participate in climate markets.
- Current MRV practices, and even many new efforts to digitize data from climate actions, lack adequate security and trust, thus reducing utility due to a lack of confidence. The existing digital equipment at sites is variable and does not prevent data manipulation. Current MRV practices for data analytics and quality assurance/quality control (QA/QC) are limited: for example, basic visual inspection and spreadsheet calculations.

[1] https://www.bcg.com/press/13october2021-only-nine-percent-of-organizations-measure-emissions-comprehensively
[2] https://www.nature.com/articles/s41558-021-01033-6

- Investors, sellers, buyers and other stakeholders are limited from participating in climate markets and climate finance without secure, immutable, reliable source data, available in near real-time via Distributed Ledger Technology (DLT) to climate registries (NDC registry, carbon credit registry) and in accordance with linked MRV standards.
- There are many different types of climate actions with different data and MRV standards that are not comparable and do not add up with confidence as "one version of the truth". This leads to a lack of cohesiveness and confidence, thus limiting the ability to scale NDC climate actions towards efficient and effective transformational change (for example, 50% decarbonization).

Although the Paris Agreement lays the groundwork for climate policies to stay within the "global carbon budget" (1.5C or 2C), the Nationally Determined Contributions (NDCs) do not have serious penalties and compliance regimes. There are several "moonshot" proposals for exponential transformational climate actions to get to net-zero GHG emissions within 30 years, including interim goals of 50% improvement every 10 years, i.e. half GHG emissions by 2030, then again half of remaining GHG emissions by 2040, and then again by 2050. In parallel, there is significant investment needed to achieve the other Sustainable Development Goals (SDGs). Despite the vastly more ambitious goals than under the Kyoto Protocol, the current state of MRV tools and expertise remain largely unchanged. The world of financial accounting and auditing is investing billions to upgrade to digital solutions to improve value and quality. The world of climate and sustainability can do the same with Digital MRV.

Enter the Next Generation Digital Solutions for MRV. MRV has been using digital tools for many years, including:

- Spreadsheet calculators
- GHG inventory software and data management systems
- Life cycle inventory databases and life cycle assessment software
- Emission factor databases
- Knowledge hubs
- Remote sensing
- CEMS (Continuous Emissions Monitoring Systems)
- Online reporting and registries

However, we are now able to apply rapidly emerging digital innovations (for example, 5G, AI, quantum computing) that disrupt economies and societies. It is imperative that stakeholders can leverage these digital innovations to support climate actions and sustainability, including MRV. This concept of Next Generation Digital Solutions for MRV was presented at COP21 in December 2015 during the official side event "Next Generation Standards Collaboration for Climate Neutrality and Resilience". Several new initiatives have since emerged such as the Climate Ledger Initiative (CLI) and the Climate Chain Coalition (CCC) to establish community collaboratives to advance

shared understanding of the issues and solutions. These efforts have helped to socialize the vision to grow stakeholder engagement, beyond individual activities and towards an open platform.

Image: COP21 Side Event Next Generation Standards Collaboration for Climate Neutrality and Resilience

Next Generation Digital Solutions for MRV is not a substitute for policy or action, but rather the infrastructure needed to enable the scale-up of those instruments to meet the challenge of climate breakdown. It can ensure that finance is efficient, that liability is correctly attributed and not double-counted and that data is accurate, credible and inexpensive to collect, report and verify.

Next Generation Digital Solutions for MRV involves a combination of digital solutions, including: Internet of Things (IoT); digital sensors; remote sensing, edge computing; digital twins, tokenization (for example, security tokens, utility tokens, non-fungible tokens (NFTs)), structured data formats; programmed algorithms; DLT (sometimes called "blockchain"); artificial intelligence (AI), machine learning (ML), smart contracts, online portals with customizable templates for reporting and verification; digital standards and methodologies; interoperability with registries; and digital currency transactions. These digital solutions enable next-generation MRV systems, for example:

- Digital MRV standards (methodologies, protocols) specifying digital requirements and using smart contracts to automate requirements in Digital MRV solutions
- Advanced online platforms and knowledge hubs to engage more stakeholders to develop and harmonize MRV standards in an open and transparent process, as well as transform the natural language standards into Digital MRV standards
- Digital MRV solutions using a combination of digital technologies (for example, digital sensors, DLT, AI, online platforms) to automate Digital MRV standards for climate actions
- Data marketplaces to connect and support data owners/providers and users
- DLT-enabled registries and to provide integrity and systemic cohesiveness

Next Generation Digital Solutions for MRV

- MRV standards transformed into Digital MRV Standards specifying digital requirements and using Smart Contracts to automate application of requirements
- Online platforms to engage more stakeholders to develop and harmonize MRV standards in an open and transparent process, as well as transform the natural language standards into Digital MRV standards
- DLT-enabled registries and tokenized climate units
- Data marketplaces to connect & support data owners/providers & users
- Stacking digital solutions (ex: Digital MRV, Track & Trace in supply chains)

Digital MRV Solution

- Automated application of the MRV Standards, including Quality Standards, Data Standards, Process Standards
- What is automated: measurement, reporting, verification
- What digital technologies are used: IoT sensors, remote sensing, DLT, Digital Twins, AI, Smart Contracts,
- Does the Digital MRV solution use advanced data assurance standards, ex: Data Confidence Fabric
- What type(s) of climate action does the DigitalMRV Solution apply to: Mitigation, Inventory, Finance, Adaptation

Overall Digital Solutions for Climate and Sustainability

- Beyond Next Generation Digital Solutions for MRV use of digital solutions to enable climate action solutions (ex: smart sustainable cities, GeSI) and to help manage the rest of the climate value chain (ex: InterWork Alliance)
- DLT for climate markets (ex: World Bank Climate Warehouse for tracking climate market transactions)
- Climate fintech, DeFi, Tokenization
- Global-level digital ecosystem and digital transformation of socio-economic activities and systems (ex: UNEP, WBGU)

Digital MRV enhances the transparency, accuracy, efficiency, trust and value of climate data through digital solutions for collection, calculation, reporting and assurance. Digital MRV represents a shift from manual collection and assessment of data, for example by survey, on-site sampling or laboratory testing and replacing with automated solutions and robustly applied validated data sets.

Examples of Digital MRV can include how data is collected: for example, switching from household surveys for efficient energy solutions to direct technology-mounted IoT sensors. It can also include how data is captured, stored and analyzed/reported, supported by model-based approaches, AI and Edge Computing; for example, farm data being recorded and uploaded on site for the purposes of calculating Soil Organic Carbon stocks. It may also include how assurance providers assess the data, by enabling automation through tamper-free and highly accurate data collection that does not require specific assessment by a third party. By providing a near real-time creation of tokenized climate units, Digital MRV solutions can add value to these assets; in other words, if you can 'issue' carbon credits or other tradeable units in real-time then your oldest asset is brand new, as opposed to issuing periodically where your oldest asset is as old as the monitoring period (for example, annually) and likely worth less. See Part 2 for more information about Digital MRV.

The Vision of Next Generation Digital Solutions for MRV

The ambition and core principles of Next Generation Digital Solutions for MRV reflect the urgent need and ambition to meet the goals of the Paris Agreement and interface with SDGs, as well as the magnitude of change required for the global economy to be aligned in pace with the goals of the Paris Agreement. Such vision and level of ambition are bold and in the order of a 10-fold decrease in time and cost for standards development and deployment; a 10-fold increase in user efficiency, utility and benefits through automation; a corresponding 10-fold increase in MRV data credibility and impact assurance to eliminate greenwashing; and also supporting a 10-fold increase in resources mobilized into corresponding climate actions. A robust and transparent governance system is part of the DNA of Next Generation Digital Solutions for MRV, as is an inclusive, participatory collaboration process with a view to developing public goods. Furthermore, Next Generation Digital Solutions for MRV includes a strong preference for digital solutions with low energy use and a low environmental footprint.

Next Generation Digital Solutions for MRV is guided by a set of core principles including:

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

The overall design for Next Generation Digital Solutions for MRV includes the ability to:

1. Measure, report, verify, register, certify and transact carbon credits, SDG benefits, and other measurable and verifiable impact units;
2. Scale results in terms of cost and time savings and enhance asset timeliness and value to accelerate climate action and sustainable development solutions;
3. Utilize innovative approaches in governance (technical, legal, accounting, compliance, interoperability, reporting permissions), social engagement (online user communities for standards development and assurance), and financial innovations (digital currency transactions, smart contracts, etc.);
4. Establish a community of practice to scale climate actions and ensure credibility of standards and MRV, as well as their associated inputs and outputs;
5. Link to, integrate and enable other digital platforms, hubs, and infrastructure as a preferred route to scale;
6. Deliver products that are:
    i. modular
    ii. stackable
    iii. cohesive and interoperable
    iv. agile and dynamic, in response to rapidly evolving knowledge and data, new technologies, and new fields such as climate adaptation;

Although Next Generation Digital Solutions for MRV is generally applicable to climate and sustainability, one of our initial areas of focus is to support the digital transformation of the Gold Standard and to catalyze more high-impact climate action in order to:

1. Ensure that Gold Standard for the Global Goals can support the complexity of markets under the Paris Agreement and the increasingly diverse and fragmented market applications
2. Increase access and reduce transaction cost for project developers through an accessible, streamlined, simplified process
3. Improve data quality, transparency, trust and efficiency in monitoring, reporting and verification uh digital methodologies and disruptive technology such as IoT and AI
4. Accommodate new applications of Gold Standard for the Global Goals and seamlessly integrate into existing systems (registry, marketplace)
5. Enhance quality and efficiency of the assurance process, including technical governance engagement
6. Increase efficiency through end-to-end alignment of projects, MRV, crediting, and registries
7. Encompass impact measures beyond carbon, including SDGs, resilience, adaptation, financial co-benefits, etc.

In parallel, the goals of the Next Generation Digital Solutions for MRV include:

8. Collaborating with stakeholders to enable adoption of Next Generation Digital Solutions for MRV across the climate space by other programs – voluntary or compliance; as well as adoption across sustainability for overall cohesiveness support credibility of standards implementation, high data quality and integrity
9. Supporting open and transparent, accessible and participatory online processes for the development of a smart standards system for Digital MRV standards to empower digital MRV, AI for climate and other solutions

10. Enabling unprecedented high-security IoT to DLT data provenance, for example via the Project Alvarium Data Confidence Fabric (see Part 3)
11. Enabling data utility and cohesiveness among digital solutions beyond carbon credits – for example for supply chains, inventories and throughout NDC climate actions
12. Enabling digital MRV relevant beyond 'MRV of impacts', for example to 'MRV of data' and 'MRV of finance' that can be available in data marketplaces to support climate entrepreneurship

The remaining sections of this paper explore in more detail the aspects of Next Generation Digital Solutions for MRV. Part 2 provides a deeper definition of Digital MRV and its practical, stepwise engagement and implementation at the project level with a use case example. Part 3 provides an overview of how IOTA's technologies match the needs for a data-driven open-source ecosystem that is low cost, low footprint, decentralized, and scalable.

Part 2: Digital MRV

The concept of Digital MRV can be summarized as the enhancement and automation of MRV to improve trust, efficiency and value, and implies disruption by different technological solutions to the predominantly manual processes of data collection, emission calculations, reporting and verification. A number of technology-based solutions that aim to improve efficiency, credibility and value are emerging, including:

- The implementation of IoT and remote sensing technology in data collection – for example, the use of smart meters for renewable energy activities, usage sensors for efficient cook stoves or remote sensing and radar for the collection of land-use data.
- Automated model-based approaches for calculating and reporting impacts in combination with remote sensing data collection – for example, the use of validated data and coefficients to convert remote sensing information into carbon stocks – and the use of AI to glean data from other sources for further validation, comparison and calibration in real time.
- Smart verification approaches that can be put in place *ex-ante* and calibrated to allow real-time, remote verification of information as received, enhanced with AI to compare real-time against expected results.

As there are many different digital solutions of varying degrees of sophistication and combinations of these technologies, the fundamental question remains: what exactly is Digital MRV? As described above, the overall MRV system needs to be improved in order to be more cohesive. Therefore, Digital MRV as part of an emerging system involves more than utilizing digital innovations for the implementation of MRV standards and activities. Indeed it is a holistic and systemic approach for next-generation MRV systems and solutions, including the knowledge base and participatory standardization systems to develop MRV "smart standards" and tools that can be more actively integrated with climate change strategies and solutions.

There are many variations of Digital MRV solutions entering the market now and that will evolve individually and collectively for several years. Below, we describe some of the issues and criteria stakeholders could consider to assess Digital MRV solutions.

Digital MRV Solution Criteria and Evaluation

Criteria	Evaluation
Scope of Applications (Climate actions)	What types of use case applications does the Digital MRV solution serve? For example, carbon credit projects, low carbon supply chains, entity inventories, products, technologies, etc. What are the system boundaries and value chain included in those applications? Which sectors does the Digital MRV solution serve?
Scope of MRV Activities	What MRV activities have been digitized and incorporated into the solution? For example, data collection and ingestion using digital technologies from more sources and with bigger volumes of data. Data analytics and calculations are automated to assess data and compute results. Data and information are incorporated into standardized reporting templates. What data QA/QC activities and verification/assurance activities are performed by the Digital MRV solution? Furthermore, to what extent have MRV activities been digitized, and what MRV activities are still performed manually with human involvement? What MRV standards, protocols, guidelines, etc. does the Digital MRV solution enable?
Scope of Digital Technologies	How have MRV activities been digitized and automated? What digital technologies are part of the Digital MRV solution, whether directly part of the solution or integrated with the solution? For example, digital sensors, IoT devices, digital twins, remote sensing, real-time data, DLT/blockchain, smart contracts, AI, ML, data At what level of maturity and sophistication are digital technologies?
Transparency	To what degree is the solution a "black box" (overall and for each component)? How does the Digital MRV solution enable auditors and programs to certify the solution meets or exceeds required MRV performance?
Sustainability	How "green" is the IT, especially the DLT, in the Digital MRV solution? Does the Digital MRV solution provide evidence for the energy it saves relative to conventional MRV (e.g., avoided travel emissions) and also relative to other MRV solutions? If the Digital MRV solution has a worse environmental footprint, how is that compensated to ensure the integrity of the net environmental benefit?
Solution Ecosystem	Who are the partners and stakeholders involved in the design and implementation of the Digital MRV solution? For example, has the solution been developed mainly by "tech experts" with a limited track record on climate change? Is it relatively easy to connect the Digital MRV solution with other solutions to enable both end-to-end and broad participation throughout the value chain?
Professional Services and Resources	Does the Digital MRV solution provider also offer professional services to deliver a complete package of deliverables and results? For example, perform initial Digital MRV readiness assessments, methodological development (e.g., transform conventional standards into "smart standards"), project design as well as conventional MRV activities? What resources – such as expertise (technical, climate and sustainability), IP, financial, infrastructural – does the Digital MRV solution provider have to expand and mature applications in cooperation with customers and stakeholders?

	How well do the Digital MRV solution provider's vision and values align with market and stakeholder needs and expectations?
Vision and Values	How does the Digital MRV solution provider's vision, and action plan, of the climate and SDG space differ from others? For example, considering both technical (e.g., hardware, software, content, open data, open source) and non-technical issues (e.g., governance, markets, equity, empowerment) are digital innovations aligned with governance innovations, social innovations, financial innovations, etc.?

It is helpful to acknowledge that activities to digitize MRV will be a gradual process. Currently, perhaps 10% of MRV activities are utilizing advanced digital tools. That percentage will gradually increase, but is unlikely to achieve 100% over the next 5 to 10 years, as some stakeholders may need more time until they are able to support total digitization. In general, non-technical issues such as governance and social matters are among the major challenges to design and realize a fully mature Digital MRV system, as well more generally for digital climate solutions. That is why we, along with thousands more, are involved in multi-stakeholder initiatives like the **Climate Chain Coalition** and **Climate Ledger Initiative**, as well as the **InterWork Alliance** within the **Global Blockchain Business Council**.

Another perspective on defining Digital MRV is to consider a scale of 1 to 10 for a frame of reference. 1 represents MRV using common digital tools (e.g., emission factor databases, emission quantification software) and 10 represents the nearly full implementation and global realization of Next Generation Digital Solutions for MRV and the digital future as envisioned in the UNEP's publication **The Case for a Digital Ecosystem for the Environment: Bring together data, algorithms and insights for sustainable development** and WBGU's **Towards Our Common Digital Future**. In general, the current level of maturity of Digital MRV for climate is low and in the range of 2/10 or 3/10: these are overall averages that recognize there are some exceptions in certain sectors. There is growing expectation to advance Digital MRV maturity to 4/10 or 5/10 over the next year.

An example of Digital MRV use case is the aptly named **DigitalMRV**, which was launched in 2020 by ClimateCHECK and IOTA as an MVP and during 2021 has expanded collaboration to include new partners, including Dell Technologies and the **Project Alvarium Data Confidence Factor**.

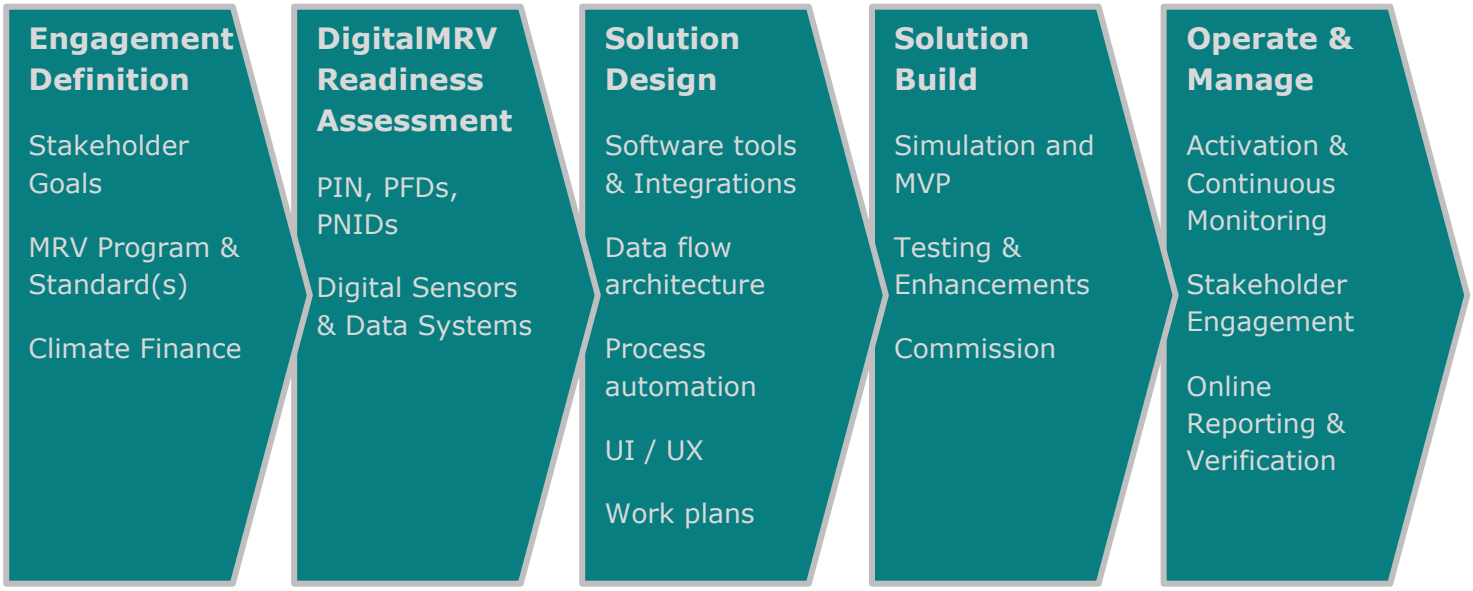
DigitalMRV Use Case Process and Lessons Learned

The process for the DigitalMRV use case has five phases:

1. Engagement definition
2. Assess the readiness of the site for the DigitalMRV solution
3. Design the DigitalMRV solution

4. Build the DigitalMRV solution and iterate enhancements
5. Deploy and manage the DigitalMRV solution

DigitalMRV Implementation Process



Next Generation Digital Solutions for MRV Processes

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 regards 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 and data systems (eg, dedicated PC, VPN)

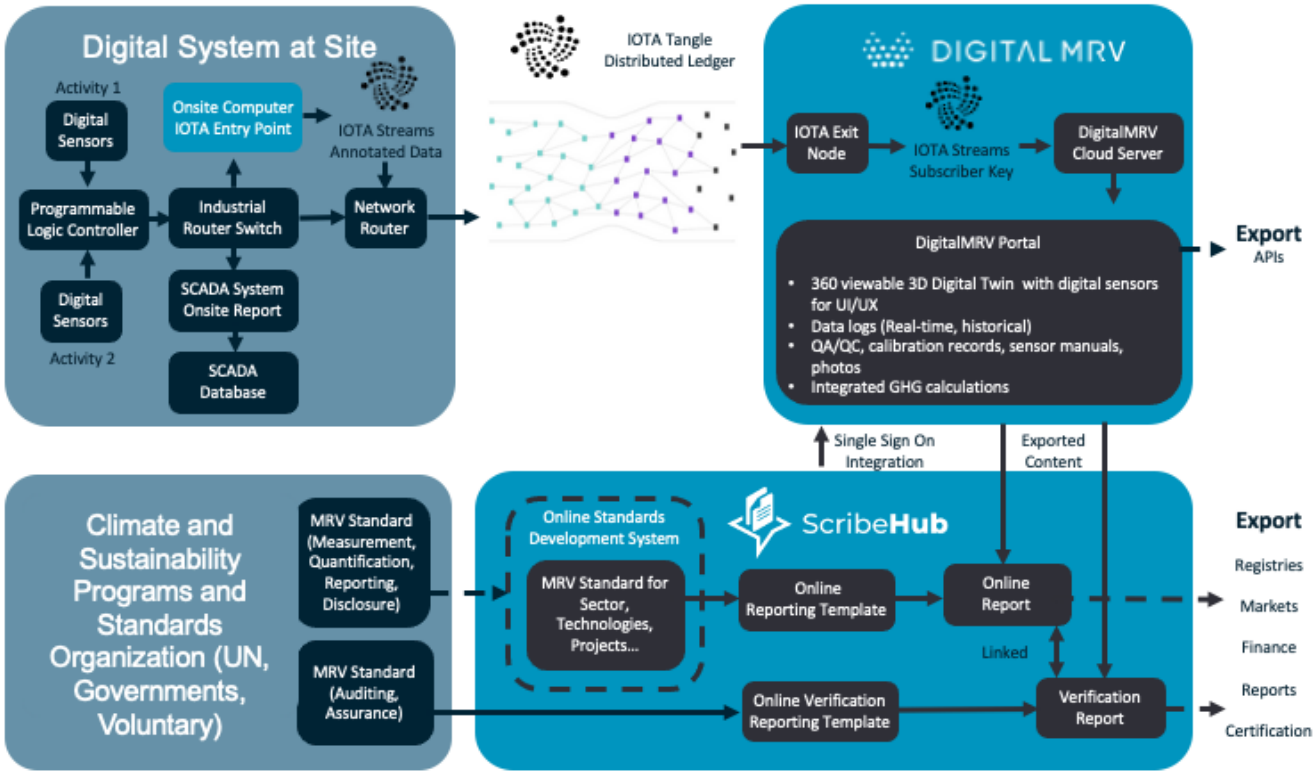
A dedicated data room for sharing files and web-meetings are conducted to clarify and share information. After approximately one month including interim drafts, the readiness assessment report (approximately 10 pages) is provided to the project developers and partners.

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

After approximately two months the design plan is shared to project developers and partners.



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.

Lessons Learned from the Copiulemu Landfill DigitalMRV Use Case

While the Chile waste project is the first demonstration of the DigitalMRV solution, there are some notable lessons learned from the implementation at the Copiulemu landfill. At the conceptualization stage of the DigitalMRV, there was concern that the DLT in the DigitalMRV system might increase the overall complexity, but in fact the development and implementation of the DLT was simpler than expected, as IOTA's DLT is specifically designed for these types of DigitalMRV solutions. The Chilean government also had little difficulty in endorsing IOTA's DLT and understanding how the DLT encryption ensures the integrity of the collected data for the purpose of verification and verification.

Prior to the start of the DigitalMRV use case, a new MRV methodology was developed using the **ScribeHub** platform to manage an online multi-stakeholder methodology development process, involving six steps:

1. Establish working groups/task teams for the review, adaptation or development of the MRV methodology, which includes technical subject matter experts and external peer review stakeholders (academia, private sector, consultants, government experts).
2. Develop specific work plans for the adaptation and development of the MRV methodology.
3. Identify existing MRV methodologies relevant for the Chile situation and stakeholders
4. Adapt the selected MRV methodologies with the assistance of the technical working group, documenting the rationale for approaches and key elements selected, modified or developed.
5. Coordinate internal reviews and comments on the MRV methodology and revise the MRV methodology accordingly, documenting justifications for each modification made to the MRV methodology. This review process was conducted during in-person meetings and also using ScribeHub for online development.
6. Coordinate public stakeholder and peer review process via 30-day public comment period. Incorporate feedback into a final version of the MRV methodology, and maintain transparent records of the overall MRV methodology development process.

The DigitalMRV solution for tracking and reporting emission reductions at Copiulemu was built on top of the landfill facility's newly-commissioned state-of-the-art digital measurement and management systems. Therefore, no specialized equipment was needed and only minor costs were incurred. The DigitalMRV solution tracks gas flow rates, gas composition, and combustion efficiency, among other things.

The DigitalMRV solution is supported by various digital technologies. Onsite, digital sensors report data in accordance with the new MRV methodology. In landfill projects, the collected data 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 10 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 25 times that of carbon dioxide).

The digital sensors recording gas flow and composition report the data to a dedicated computer at the landfill from which it is uploaded to the cloud. 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 solution. 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 portal is integrated with ScribeHub to enable

customizable online project reporting and verification reporting according to the MRV methodology and international standards.

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 solution include using digital solutions to:

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

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

The DRI is responsible for the "last mile" on site, for example ensuring connectivity works as designed. It is ideal to maintain open communications (for example, email) to facilitate automatic monitoring in case of an alert on any outage. The DRI's task is to document (for example, 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.

Although DigitalMRV solutions incur upfront costs, DigitalMRV can be cost-effective compared with current MRV practices when considering the entire period of the climate action. DigitalMRV enhances the quality and value of the MRV, as well as near real-time availability that can increase the financial valuation of the climate action (for example, price of carbon credits, financing terms).

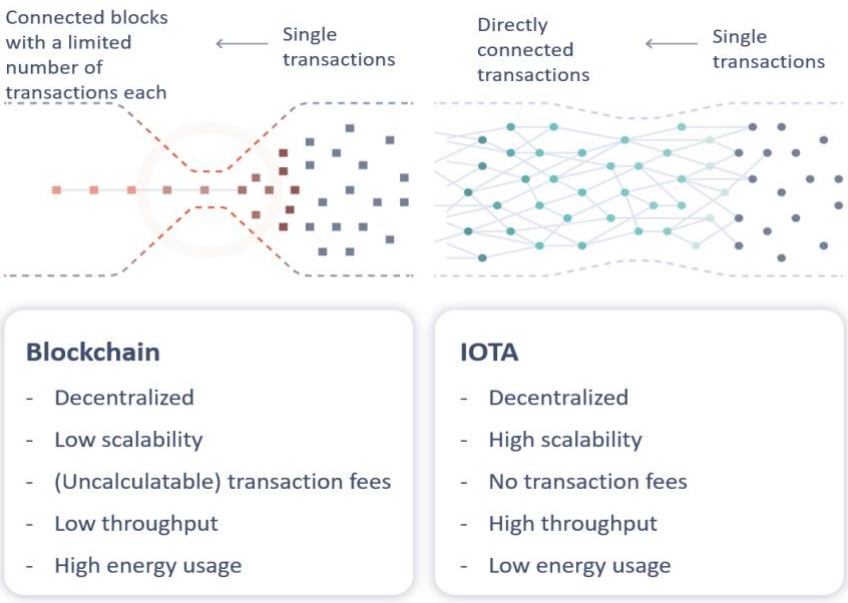
Part 3: Next Generation Digital Solutions for MRV Collaboration with IOTA

As described in Part 1, the vision for Next Generation Digital Solutions for MRV is guided by a set of core principles:

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

With the above in mind, initial work on Next Generation Digital Solutions for MRV has been undertaken in close collaboration with the IOTA Foundation, producer of the IOTA DLT (known as "The Tangle"). DLT plays a central role in Digital MRV. DLTs such as IOTA eliminate the need for intermediaries to verify data and create a reliable, immutable, and traceable energy monitoring system. Promoting Digital MRV 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 certification, trading, and accounting.

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-manipulatable way creates trust in a process which translates to insights or products. The choice of IOTA as a DLT for Next Generation Digital Solutions for MRV rests on properties and frameworks that differentiates the IOTA network (known as The Tangle) from other DLTs and traditional blockchains, as seen in the figure below.



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. This t distinguishes IOTA from other blockchains or DLT protocols and is a great advantage for companies that want to take advantage of DLT but cannot buy or hold a 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. For example, IOTA can implement a hardware wallet on a chip (such as the ESP32), which enables applications to connect to Wi-Fi and Bluetooth while keeping power consumption to a minimum.

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.[3] 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 second, respectively. Adding more connected devices does not automatically incur additional costs for having to scale the related decentralized server infrastructure.

[3]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.

IOTA also offers several frameworks that makes it the ideal partner.

Framework 1: IOTA Streams

The IOTA Streams framework 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 Digital MRV 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 '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 n 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 application 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 LFG sites and other sites 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.

Framework 2: IOTA Digital Identity

Individuals are forced to rely on big tech for online identification; we pay for this service with our data. Privacy-centric regulation like GDPR is a complicated patchwork against data abuse, creating difficulties for organizations to comply. Connecting devices to the internet is not secure and increases privacy risks, which makes device data untrustworthy and our networks and infrastructure vulnerable.

Decentralized identities solve these problems and enable data sharing and independent auditing, thus building trust online.

IOTA Digital Identity provides a high-quality and secure decentralized identity framework that enables the creation and verification of the identity of people, organizations, devices, and objects. The decentralization of the Identity framework on the IOTA Tangle enables trusted sharing of identity-related information across loosely related parties with potentially conflicting areas of interest. For example, a single

identity can be used to prove vaccination status for one person across many applications, organizations and borders.

The Digital Identity framework is also in full compliance with the new W3C standards on Decentralized Identities, Verifiable Credentials, and more, providing the base functionality necessary for future interoperability with other DID solutions. The goal of enabling Self-Sovereign Identities for any thing, person, organization, or even process requires a flexible, scalable, efficient and fee less core to grow for the eight billion people and 800 billion devices that will be present in the future. To make this possible, interoperability and building on existing standards are critical, and the IOTA Foundation is committed to doing this openly and transparently in order to accelerate innovation and standard developments in the space.

IOTA Streams and Identity use case: Dig_it Project – Bringing transparency and sustainability to the mining industry

The mining industry leverages complex supply chains while still relying on centralized systems, with low trust across stakeholders and the public. There is an urgent need within the mining industry for a trust infrastructure that allows the sharing of data, the provenance of which is verifiable, both between stakeholders and with the public. This is especially clear in three major industry innovations:

1. Increasing mining efficiency and reducing costs through connected machines and predictive maintenance
2. Increasing safety of workers using wearable technologies
3. Improving mining sustainability, using environmental sensor monitoring technologies

IOTA provides the stakeholders of Dig_it (an EU-funded project to establish a sustainable digital mine) with Oracles that implement industry protocols (like OPC UA) to connect centralized industrial IoT platforms and allow them to securely exchange trusted data across stakeholders and share it with the public. IOTA Streams are used to manage and guarantee access to immutable data to specific beneficiaries, including public authorities, the general public, and others. IOTA Identities, meanwhile, allow stakeholders to verify the authenticity of the data. This allows the industry to report autonomously on mining practices and their impact and enables a holistic step forward to more sustainable mining practices. This can also give a direct method for verifying compliance for governments and enable businesses to build trust directly in their process, fostering transparency and bringing more business opportunities as they showcase their efforts.

Framework 3: IOTA Digital Assets & Smart Contracts

Tokenization allows real-world assets to be managed, traded, bought and sold on DL). The ramifications of this technological breakthrough cannot be overstated: tokenization will transform the concept and the exchange of value as we know it. Tokenization breaks down barriers, allowing for a greater democratization of finance and investment while simultaneously providing a more secure, transparent and easily manageable environment for assets.

IOTA Digital Assets are tokens that can be used to represent assets from the real world or traditional finance like company stocks, derivatives, precious metals or even carbon credits, Smart contracts enable most traditional finance concepts to be used with cryptocurrencies, retaining all the benefits of a decentralized currency.

One key aspect to understand is that these capabilities can all be actioned and enabled without the necessity of smart contracts. However, smart contracts further accelerate the level of innovation, asset creation, interoperability, oversight, transparency and scale of investment available for advancing these solutions towards global measurable impact. Through IOTA's newly released Smart Contract Protocol (ISCP), it is possible to create an open data commons for measuring, reporting and verifying impact data, providing transparency into the solutions through measurable data confidence, and connecting these solutions under jurisdictional requirements while directly incentivizing their growth and enabling large scale investment from retail investors and ESG investors alike.

Common assets can be created using ISCP to have a highly granular yet measurable understanding of the amount of carbon being offset, how much is left to be offset, how much oxygen is being created through offsetting methodologies, how much carbon is being captured through Direct Air Capture solutions, how much carbon is being mitigated through carbon mitigation implementations, and much more, while tying them all to relevant and connected smart digital assets to incentivize climate impact and innovations.

However, it is important to ensure that efforts are synchronized across the industry. Striving for interoperability and ease of use, IOTA Smart Contracts now supports the Ethereum Virtual Machine (EVM) and any smart contract written in Solidity. While this is an early implementation, it already provides extensive compatibility, bridging the biggest smart contract ecosystem onto IOTA's feeless base layer. This means that Solidity contracts can easily be ported to IOTA, reducing implementation time and benefitting from the vast ecosystem of Solidity tooling and products available on the market today. As IOT Smart Contract protocol advances, this interoperability will continue to expand to other chains and other solutions, allowing a heterogeneous

ecosystem of smart assets that can interact and be traded autonomously with the benefit of the base IOTA protocol’s scalability, efficiency and feeless structure.

This can lead to the creation of a true single source of truth for a global understanding of humankind’s impact on the planet and what is yet to be achieved in order to meet the goals of the Paris Agreement. All while ensuring that the infrastructure enabling this insight is not owned or controlled by any single party, but actually ensuring that it can be a permissionless and open network supplying such an insight for all stakeholders and service providers to cooperate through and own mutually. This can be seen as the future of true digital public infrastructure.