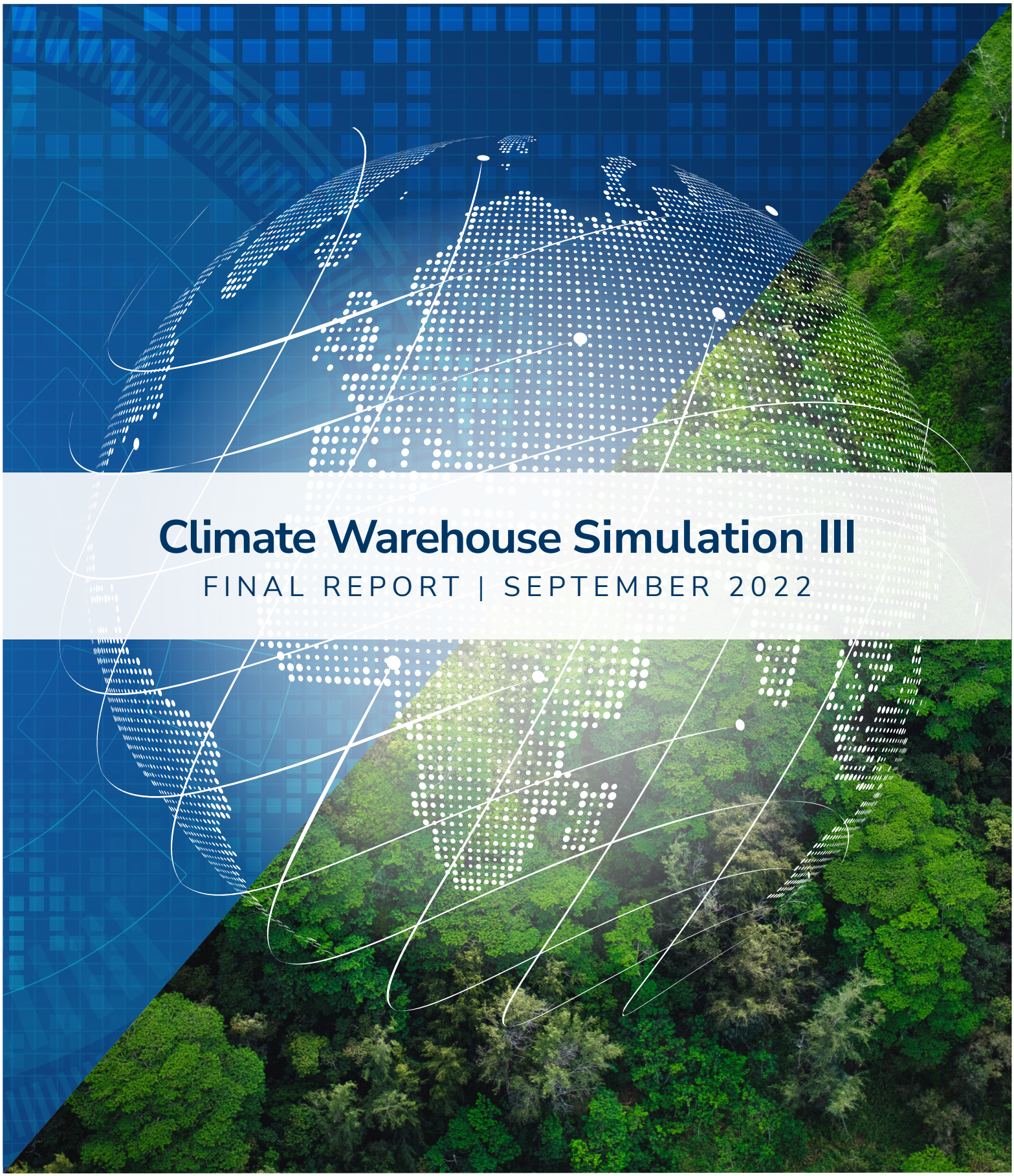

Climate Warehouse Simulation III

FINAL REPORT | SEPTEMBER 2022

PMIF
PARTNERSHIP FOR MARKET IMPLEMENTATION FACILITY

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Climate Warehouse

ACKNOWLEDGEMENTS

This report was prepared by Gen Shiraishi, Gemma Torras Vives, Lucas Belenky, Chandra Shekhar Sinha, Harikumar Gadde, and Seoyi Kim of the World Bank's Carbon Markets and Innovation unit, under the leadership of Wendy Hughes and Venkata Ramana Putti, with support from the Partnership for Market Implementation Facility.

The underlying technology system of the Climate Warehouse Simulation III prototype was developed by the Chia Network. The core team included Neil Cohn, Ken Griggs, Craig Cornick, Lars Kvale, Bram Cohen, Gene Hoffman, and Vishal Kapoor.

In addition, special thanks to the support of the governments of Spain, Sweden, and Switzerland, as well as the government of Singapore and the International Emissions Trading Association (IETA) for their active engagement in moving forward the Climate Warehouse initiative. Further, thank you to Susan David Carevic and the Information and Technology Solutions Technology and Innovation Lab team at the World Bank, including Stela Mocan, Rachel Alexandra Halsema, Emmanuel Ayanfe Crown, Olushola Ibironke Joanne Martins, Mert Ozdag, Yujuan Sun, and Mahesh Chandrahas Karajdi, all of whom supported the Climate Warehouse initiative throughout this and previous simulations.

The following organizations contributed as participants and observers of the Climate Warehouse Simulation III:

- National governments: Chile, Japan, Peru, Rwanda, Senegal, Singapore, Spain, Sweden, Switzerland, Uganda, and United Kingdom.
- Independent standards: American Carbon Registry, Climate Action Reserve, Global Carbon Council, Gold Standard, and Verra.
- Multilateral organizations: European Bank for Reconstruction and Development, International Finance Corporation, United Nations Development Programme, United Nations Framework Convention on Climate Change, World Bank Carbon Assets Tracking System, and World Bank Carbon Markets and Innovation unit.
- Other public and private carbon market stakeholders: Climate Ledger Initiative, ClimateCheck, EcoRegistry Colombia, IHS Markit, IETA, Open Earth Foundation, SK Certification Center, and GenZero.

Editing and design by Clarity Global Strategic Communications (www.clarityglobal.net).

About this report

The purpose of this report is to provide detailed documentation on the context, design, and outcomes of the Climate Warehouse Simulation III, in order to contribute to the Climate Warehouse's ongoing development as a carbon metadata layer and support the new governing body's efforts to launch the operational Climate Warehouse.

Section 1 of the report provides an executive summary of Simulation III's project context, design, and outcomes. Section 2 describes the key elements of Simulation III's project context, including the Paris Agreement framework, findings from previous Climate Warehouse simulations, and the Climate Warehouse's use of blockchain technology. Section 3 details the key features of the Simulation III prototype, which include the technical architecture, technical requirements, and user interface. Section 4 summarizes Simulation III's testing approach, including the testing timeline, list of participants, testing areas, deployment models, testing process, technical support, feedback management strategy, and prototype maintenance and development process.

Section 5 presents summary statistics on Simulation III participants, including the number of participating organizations and testers by group, breakdown of testers by role and selected deployment model, and number of testers who completed each testing area. Section 6 details participants' feedback on the Climate Warehouse by each of Simulation III's 11 feedback categories. Section 7 outlines the lessons learned from each of the same feedback categories, summarizes Simulation III's limitations, and details the testing and simulation team's recommendations for the new governing body. Section 8 provides an outlook on the Climate Warehouse's next steps, summarizing the key elements of the ongoing transition to the operational Climate Warehouse.

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ABBREVIATIONS AND ACRONYMS

API	application programming interface	**ISO**	International Organization for Standardization
AWS	Amazon Web Services	**IT**	information technology
CATS	Carbon Assets Tracking System	**ITMO**	internationally transferred mitigation outcome
CDM	Clean Development Mechanism	**MRV**	monitoring, reporting, and verification
CMI	Carbon Markets and Innovation	**NDC**	nationally determined contribution
EBRD	European Bank for Reconstruction and Development	**SQL**	Structured Query Language
GHG	greenhouse gas	**UNDP**	United Nations Development Programme
IETA	International Emissions Trading Association	**UNFCCC**	United Nations Framework Convention on Climate Change
IFC	International Finance Corporation		

“The Climate Warehouse brings a concrete response to the challenges of Article 6 requirements, using an innovative implementation, and explores new ways of envisaging the new climate regime where more sovereignty and flexibility should be left with the individual parties and cooperative approaches.”

United Nations Framework Convention on Climate Change

“The Climate Warehouse enables users to see what is being done to mitigate climate change around the world and can help to achieve better coordination and access to the available information in carbon markets.”

Ministry of the Environment, Government of Chile

01 Executive Summary

The Climate Warehouse is a public and open-source platform that aims to contribute to the integrity, transparency, and robust accounting of internationally transferred mitigation outcomes (ITMOs), in accordance with article 6.2 of the Paris Agreement. More specifically, the Climate Warehouse is a peer-to-peer metadata layer that uses blockchain technology to harmonize carbon registry data under a common taxonomy and demonstrate interoperability among carbon registries, which is currently complicated by carbon registries' usage of different data management systems and taxonomies.

Starting in 2019, the Climate Warehouse was developed through an iterative process across three phases of testing, which produced and tested developmental prototypes of the Climate Warehouse with a wide range of participants including national governments, independent standards, multilateral organizations, and other public and private carbon market stakeholders. Simulation III was the final testing phase and tested an operational prototype of the Climate Warehouse with 30 participating organizations on a public blockchain network between March and August 2022.

The 30 organizations that participated in Simulation III included 11 national governments, five independent standards, six multilateral organizations, and eight other public and private carbon market stakeholders, representing a wide range of regions including East and West Africa, Europe, the Middle East, North America, Latin America and the Caribbean, and South and East Asia.

In order to collect comprehensive feedback on all dimensions of the operational prototype, Simulation III engaged 75 individual testers in a wide range of relevant roles (e.g. policy setters, registry administrators, and information technology specialists). Depending on their role and expertise, each tester completed at least one of four testing areas that each corresponded to a key feature of the operational prototype (installation, user interface, application programming interface, and Excel import/export).

Throughout Simulation III, the 75 testers collectively completed 58 testing sessions, over 40 weekly office hour sessions, and over 30 kick-off and onboarding meetings and provided 514 individual points of feedback, which were each categorized and logged in the testing and simulation team's feedback management tools. Participants' feedback also helped the testing and simulation team identify 156 development actions, 139 of which were implemented during Simulation III and reflected in the final version of the operational prototype at the end of the simulation.

In addition to the specific development actions that were identified, participants' feedback also provided multiple lessons on key aspects of the Climate Warehouse, including its technical architecture, governance, data model, and user interface. These lessons were shared with the governing body of the operational Climate Warehouse at the end of Simulation III in August 2022, along with a transition package that included a complete log of all participant feedback, a booklet of profiles for each participant, a transition plan, and the Simulation III onboarding package (including an updated technical guide and data model).

The conclusion of Simulation III marked the beginning of the transition to the operational Climate Warehouse, expected to launch in October 2022. The Climate Warehouse is continuing to make progress on its aim to improve the environmental integrity, transparency, and robust accounting of ITMOs, under the leadership of the International Emissions Trading Association as the interim Secretariat, in close collaboration with the World Bank and the government of Singapore.

02 Project Context

THE PARIS AGREEMENT FRAMEWORK

On December 12, 2015, 196 parties adopted the Paris Agreement, committing to a goal of limiting global warming to well below 2°C compared to pre-industrial levels.[1] The underlying mechanism of the Paris Agreement is to reduce greenhouse gas (GHG) emissions through nationally determined contributions (NDCs), which are individual emissions reduction commitments that are set by each party. As such, the Paris Agreement follows a bottom-up and decentralized approach to achieving its climate goals.

To enable parties to reduce GHG emissions in a cost-effective manner and to encourage parties to increase their NDCs over time, Article 6 of the Paris Agreement promotes voluntary international cooperation on mitigation outcomes, which is the Paris Agreement's term for actions to mitigate GHG emissions. Specifically, articles 6.2 and 6.4 enable parties to use internationally transferred mitigation outcomes (ITMOs) to achieve their NDC targets, leading to the introduction of market-based mechanisms. Concurrently, articles 6.2 and 6.3 require parties to "ensure environmental integrity and transparency" and "apply robust accounting to ensure, inter alia, the avoidance of double counting" when they engage in international transfers of mitigation outcomes.[2]

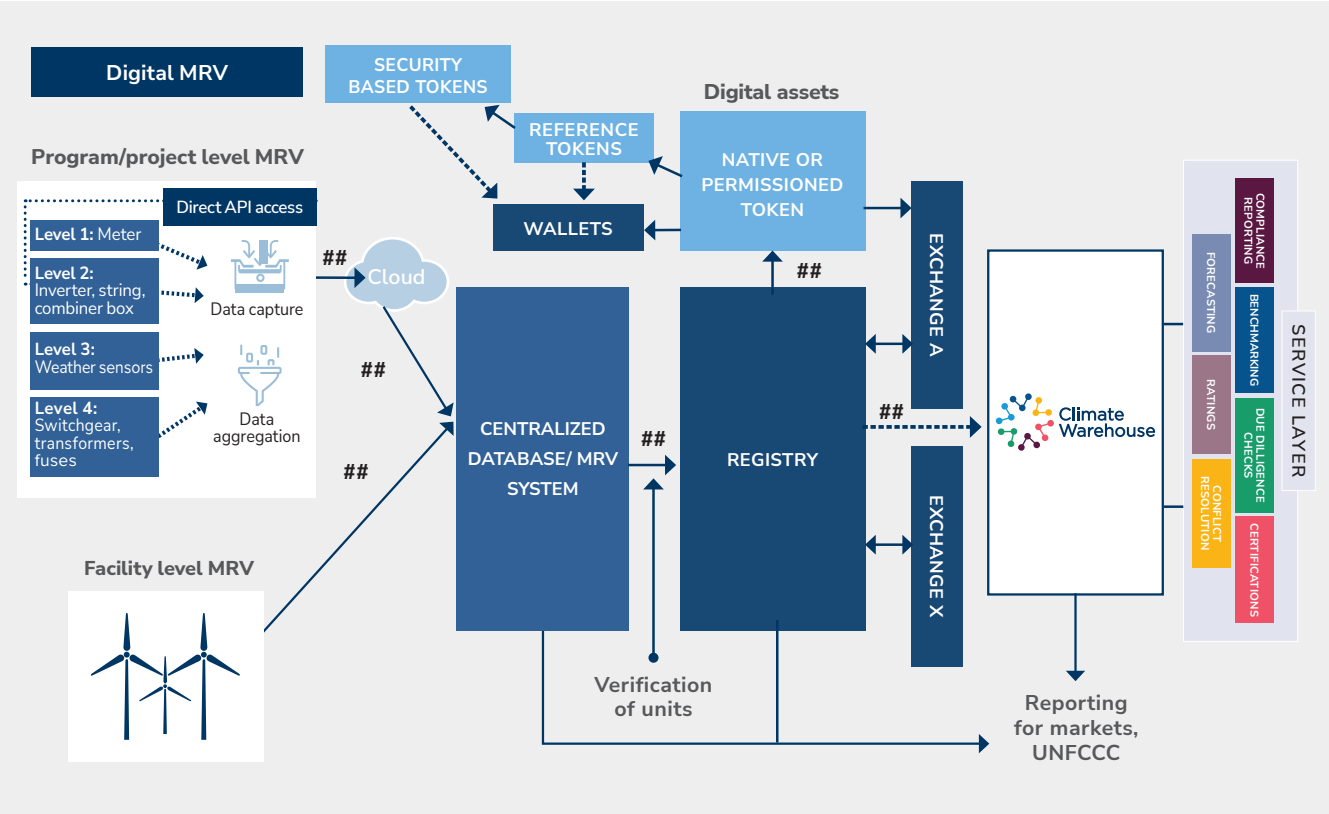
The Paris Agreement's requirements for carbon markets to ensure environmental integrity, transparency, and robust accounting are challenging to implement given the current state of global carbon markets. These markets are characterized by collectively decentralized, disconnected, and heterogeneous registries that each have different governance systems and technological infrastructure. This heterogeneity in the management of mitigation outcome unit information across registries increases the complexity of tracking and recording ITMOs. The Paris Agreement does not provide guidance on how to develop the interoperability among registries.

To address these challenges, the World Bank developed the Climate Warehouse, which is a public metadata layer that uses blockchain technology to facilitate peer-to-peer connections among decentralized registries to link, aggregate, and harmonize underlying data, and enable the transparent accounting of ITMOs. The concept and framework of the Climate Warehouse was developed by the World Bank's Carbon Markets and Innovation (CMI) unit under the Climate Change Group with the support of the governments of Spain, Sweden, and Switzerland.

The Climate Warehouse is a component of the end-to-end digital ecosystem underpinning the development of post-2020 carbon markets under the Paris Agreement by digitizing the generation, reporting, and transfer of carbon assets. Figure 1 shows this ecosystem and how the Climate Warehouse fits in.

1 For more information, see https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.
2 United Nations. 2015. *Paris Agreement*. Paris: United Nations. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

FIGURE 1: Climate Warehouse in the end-to-end digital ecosystem for carbon markets

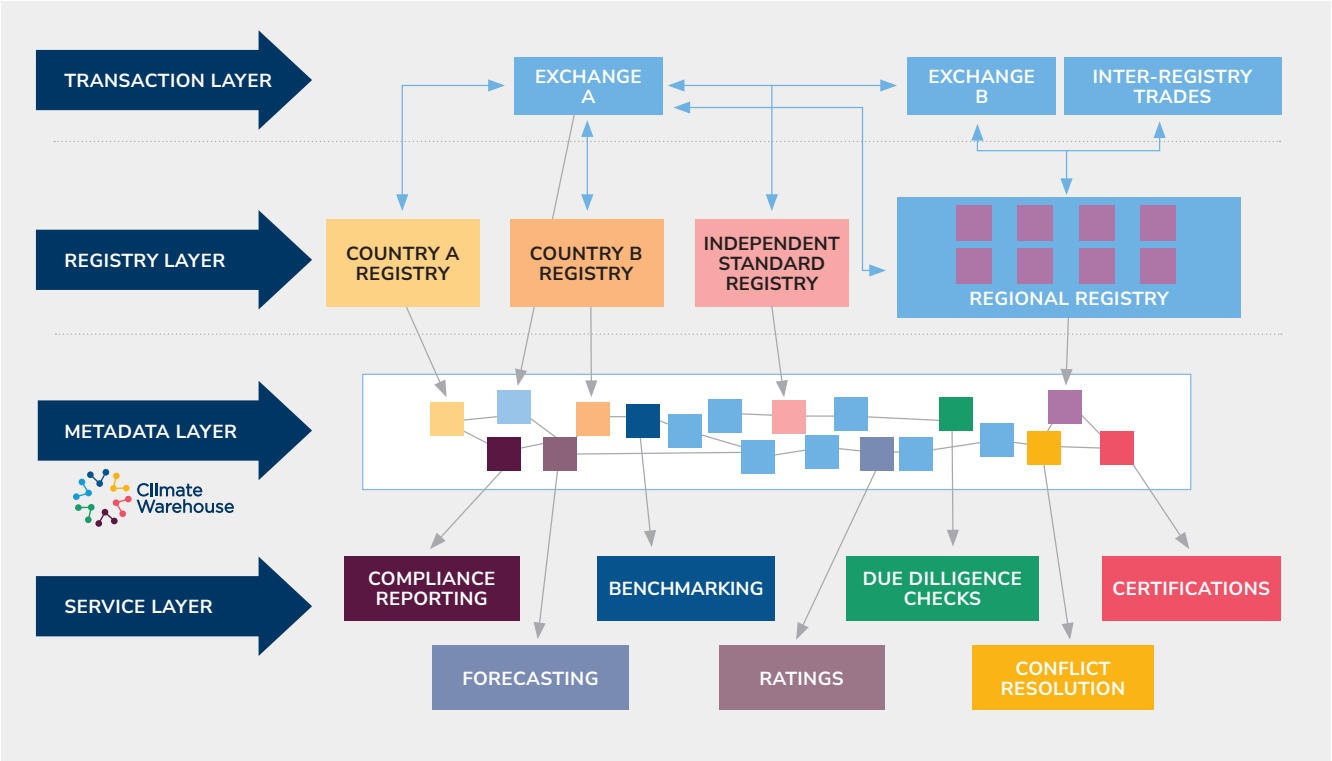


Note: Figure displays the World Bank's latest conceptualization of the end-to-end digital carbon ecosystem for carbon markets as of this report's publish date and is subject to change. ISO = International Organization for Standardization, MRV = monitoring, reporting, and verification.

The Climate Warehouse functions as a metadata layer in the carbon market ecosystem, which can be characterized by four layers (see Figure 2):

- **Transaction layer:** Carbon exchanges and transaction platforms that enable participants to transact carbon units.
- **Registry layer:** Carbon registries that hold records of climate action projects, their generated units (e.g. mitigating outcomes), and transactions under a market mechanism (e.g. country registries, independent standard registries, and regional registries).
- **Metadata layer:** A data layer that uses a common taxonomy to harmonize data across different registries and facilitates carbon data monitoring across registries.
- **Service layer:** Public and private sector entities that use harmonized carbon metadata to offer carbon market services (e.g. auditing, certifications, due diligence, conflict resolution, benchmarking, forecasting, compliance reporting, and ratings).

FIGURE 2: Climate Warehouse as a metadata layer



The World Bank developed and tested the Climate Warehouse through three simulations that successively built on the lessons learned previously.

THE CLIMATE WAREHOUSE SIMULATION I

Simulation I of the Climate Warehouse was conducted in 2019 to examine the prerequisites and requirements of Article 6.2 as well as assess the viability of using blockchain technology to connect heterogeneous registries to track carbon credit units and avoid double counting. Simulation I was led by the World Bank's Carbon Markets and Innovation unit and the World Bank's Information and Technology Solutions Technology and Innovation Lab, and engaged two governments (the government of Chile's Ministry of Energy and the government of Japan's Ministry of the Environment) and two independent certification standards (Gold Standard and Verra).

The key lessons from Simulation I were the following:[3]

- The Climate Warehouse's decentralized metadata layer can provide an inclusive platform to connect different country and institutional registry systems, deliver much-needed visibility for climate activities, and enhance the transparency of overall market activity.
- There was valuable joint learning between the World Bank and participants, which demonstrated the utility of blockchain technology and enhanced understanding of the potential requirements that need to be in place for the Climate Warehouse to operate.
- The Climate Warehouse should support data analysis and different ways of using data.
- The user interface and data visualizations are important to enable users to observe audit and lifecycle information for climate projects and units.
- Enough time needs to be allocated to onboard participants. This includes allowing participants to coordinate internal resources, such as information technology (IT) staff or consultants, who are needed to integrate systems and test functionality.
- All participants indicated interest in participating in possible further development phases, including potentially hosting a blockchain node to connect with the Climate Warehouse in the future, given adequate time and resources.

3 World Bank. 2019. *Summary Report: Simulation on Connecting Climate Market Systems*. Page 8. Washington, DC: World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/128121575306092470/summary-report-simulation-on-connecting-climate-market-systems.

THE CLIMATE WAREHOUSE SIMULATION II

Simulation II of the Climate Warehouse, conducted between November 2019 and December 2021, built on the findings from Simulation I to develop and test an updated Climate Warehouse prototype with more participants. Over 40 stakeholders participated, including country registry operators, independent standards, and multilateral organizations. Concurrently, Simulation II provided participants with practical insights on registry interoperability to inform ongoing Article 6 negotiations.

Specifically, Simulation II was aimed at achieving the following goals:[4]

- Define the minimum technical infrastructure standards that registry systems would need in order to participate in the Climate Warehouse.
- Harmonize various registry data formats into a common data model.
- Test each of the common data model's data fields and assess each field's importance to enable data sharing and harmonization.
- Provide participants with access to the harmonized registry data and enable participants to view and assess project and carbon unit data in real time.
- Test the feasibility of blockchain as an underpinning architecture technology.

The key outcomes of Simulation II were as follows:[5]

- Sufficient participant feedback was received to further refine the data model and inform the development of an updated Climate Warehouse for Simulation III.
- Participant testing demonstrated the minimum technical infrastructure needed to synchronize registry data with the Climate Warehouse.
- The simulation built the capacity of participants on the Climate Warehouse's registry functions and data elements to facilitate the exchange process of ITMOs.
- The Climate Warehouse's ability to use blockchain to trace and audit carbon credit units that are traded between organizations was demonstrated.

THE CLIMATE WAREHOUSE SIMULATION III

Simulation III was the final testing phase of the Climate Warehouse project. Launched in March 2022, Simulation III tested an operational prototype of the Climate Warehouse, which was delivered to the governing entity of the operational Climate Warehouse at the end of the simulation in August 2022. The Simulation III prototype had an updated data model and features that reflected the learnings from simulations I and II, and was open source, interoperable, and hosted on a public blockchain.

Specifically, Simulation III pursued the following goals:

- Simulate how participating registry systems can integrate with the Climate Warehouse and synchronize data updates through application programming interface (API) connections, Excel import/export, or manual data entry.
- Define minimum technical requirements for participation.
- Provide capacity-building support and understand potential barriers to participation that need to be overcome in the operational phase.
- Test and enhance the Climate Warehouse data tables and picklist values that are codified in the data dictionary document.
- Test and enhance the Climate Warehouse user interface, including its core registry function.
- Explore how a public blockchain meets the Climate Warehouse's requirements and allows functions to identify double counting and update information.
- Prepare and test a Climate Warehouse prototype that can be operationalized as a decentralized and peer-to-peer carbon metadata layer leveraging blockchain technology.

4 World Bank. 2022. *Climate Warehouse Simulation 2 Report*. Page 8. Washington, DC: World Bank. https://ik.imagekit.io/mtozw1gojis/world-bank/Climate_Warehouse_Simulation_II_Report_eb939eebe6_ylGMWEArX.pdf.

5 Ibid.

DESIGN AND SIMULATION APPROACH[6]

Throughout simulations I, II, and III, the Climate Warehouse followed a design thinking approach, which focused on identifying stakeholder needs, defining the problems to address, conceptualizing potential solutions, and creating and testing prototypes. In Simulation I, the World Bank conducted a comprehensive literature review and consulted subject matter experts to design a metadata layer that addresses the concerns of stakeholders in the carbon market ecosystem. This process focused on designing the Climate Warehouse architecture in alignment with the Paris Agreement framework. In addition, the World Bank engaged a wide range of stakeholders—including governments, registry providers, carbon credit trading platforms, and the United Nations Framework Convention on Climate Change (UNFCCC)—to understand how emerging technologies, such as blockchain, can address their needs and concerns.

Building on Simulation I's progress, simulations II and III continued the design thinking approach by focusing on testing and improving the Climate Warehouse prototype through an iterative process. Specifically, the testing approaches in simulations II and III were developed and executed in accordance with the following design principles:

- The Climate Warehouse will improve transparency, accuracy, completeness, comparability, and consistency.
- The Climate Warehouse has a specific emphasis on the transfer of mitigating outcomes under Article 6.2.
- The Climate Warehouse data fields will facilitate harmonization, search and filtering, traceability, and audit features.
- Data in the Climate Warehouse mirrors the registry information of partners participating in the warehouse (i.e. data quality is the responsibility of connected registries).
- The Climate Warehouse data can be relied on as a record of registry data for accuracy, auditing, and reporting purposes.
- The Climate Warehouse aims to ensure a flexible architecture and data model in anticipation of changing rules.

STAKEHOLDER ECOSYSTEM[7]

The Climate Warehouse interacts with a wide range of stakeholders in the carbon market ecosystem to enable the interoperability of registry data. This project identified eight core stakeholders, as outlined below:

- **Governments** serve as national aggregators of climate projects and carbon credit units, responsible for the comprehensive and accurate tracking of carbon data within their national jurisdictions. They also participate in the carbon market to track and report their progress against their NDCs. Governments benefit from the Climate Warehouse because it increases the visibility, credibility, and accountability of their climate activities; provides an aggregate view of climate activities that can help identify duplicated projects; and enables them to view carbon credit units outside of their national jurisdiction that they can potentially purchase. Furthermore, synchronizing national registry data with the Climate Warehouse facilitates government partnerships with the private sector (e.g. through the service layer).
- **Independent certification standards** develop and manage project cycle protocols and monitoring methodologies for carbon offset projects. They primarily benefit from the Climate Warehouse because its harmonized and aggregated carbon unit data reduces the burden of monitoring heterogeneous external systems.
- **UNFCCC** induces parties to comply with their NDC targets by providing expertise and direct discussions at United Nations Climate Change Conference meetings, which is a core component of its organizational mandate. The UNFCCC benefits from the Climate Warehouse because it can easily access harmonized and aggregated climate registry data.
- **Exchanges** facilitate trades and transactions and create carbon asset-based financial products. Exchanges benefit from the Climate Warehouse because it decreases market fragmentation, eases integration, promotes standardization and asset integrity, and improves reliable access to the registry data needed to process transactions.

6 Ibid. Pages 9–12.
7 Ibid. Pages 12–13.

- **Project developers** develop and implement emission reduction or removal activities (e.g. renewable energy or land-use projects). They benefit from the Climate Warehouse because it improves the transparency and accountability of their carbon assets.
- **Verification bodies** verify carbon assets issued by emissions reduction projects, in accordance with the standards set by independent certification standards. These bodies benefit from the Climate Warehouse because it eases access to harmonized and aggregated carbon registry data, improving verification bodies' auditing and reporting capabilities.
- **Buyers and traders** transact in carbon assets, driving demand and creating incentives for project developers to develop additional emissions reduction projects and issue more carbon assets. Buyers and traders benefit from the Climate Warehouse because it provides a platform to search through available carbon assets and improves the transparency of carbon asset details (e.g. a transaction history).
- **Public and private market players from the service layer** that offer carbon market services (e.g. auditing, certifications, due diligence, conflict resolution, benchmarking, forecasting, compliance reporting, and ratings) benefit from the Climate Warehouse because its harmonized carbon metadata allows them to develop and expand their service offerings.

TECHNICAL BACKGROUND – BLOCKCHAIN TECHNOLOGY

Blockchain is a data storage and accounting technology that enables the decentralized storage and management of data among network participants (i.e. "nodes") without relying on a central intermediary. It achieves this by using distributed ledger technology, which distributes a ledger of all transactions to each node and validates new transactions through a democratic consensus mechanism (i.e. all nodes validate new transactions). The distributed ledger is designed as a chain of time-stamped "blocks" that each carry a collection of transactions and are cryptographically linked in chronological order. This blockchain is immutable and secure because altering a block retroactively changes all subsequent blocks and does not pass the consensus mechanism, which prevents any node from altering the history of transactions.[8]

In 2018, the World Bank conducted internal testing on the viability of using blockchain to build the Climate Warehouse and demonstrated that blockchain has the capability to simplify data-sharing among different carbon registries.[9] The primary findings were as follows:

- The decentralized and immutable nature of blockchain technology makes it resilient against attacks and ensures data integrity, enabling mitigating outcomes to be reliably traced from their origins to retirement.
- The decentralized and peer-to-peer design guarantees autonomy and accountability to participating registries, each of which retain full control over their own data and can flexibly choose their approaches in line with their own requirements and institutional frameworks.
- The storage and accounting of harmonized registry data on a public, open-source, and permissionless blockchain improves transparency and inclusiveness and can reduce the risks of double counting.
- A blockchain-enabled, peer-to-peer carbon metadata layer follows the decentralized and bottom-up ethos of Article 6 of the Paris Agreement.

To test these findings, simulations I and II prototyped the Climate Warehouse on a private and permissioned platform called Kaleido – a blockchain-as-a-service provider on the Ethereum network. Simulations I and II implemented a private and permissioned blockchain architecture to limit complexity and focus on testing the key features of the prototypes (e.g. the data model).[10] A private and permissioned testing environment also enabled the timely participation of highly regulated carbon market stakeholders.

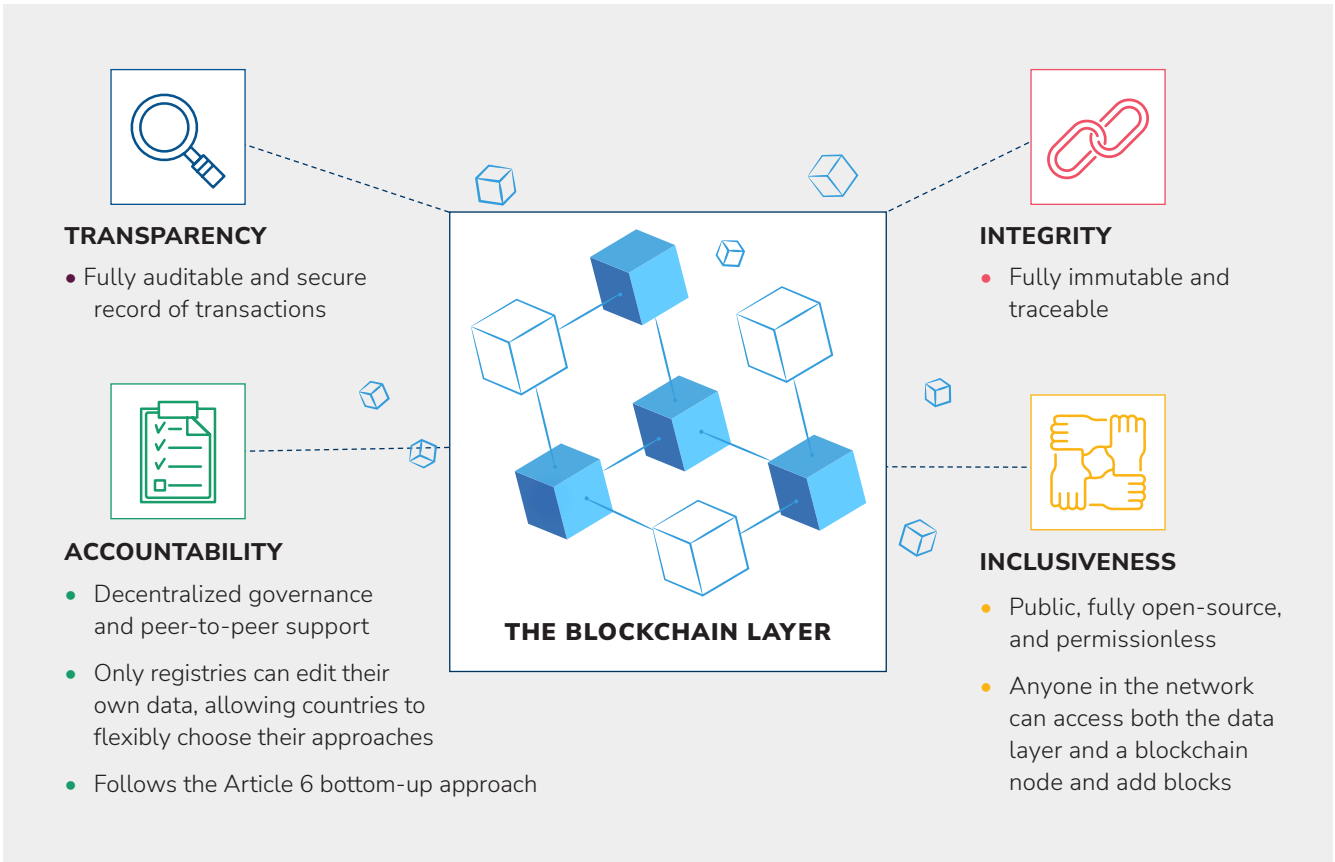
8 Blockchain technology was first implemented by a person (or persons) using the pseudonym "Satoshi Nakamoto" in 2008 to launch Bitcoin, a peer-to-peer electronic currency that enables online payments to be transferred without a financial intermediary. For more information, see https://bitcoin.org/bitcoin.pdf.

9 World Bank. 2018. *Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/29499.

10 World Bank. 2019. *Summary Report: Simulation on Connecting Climate Market Systems*.; World Bank. 2022. Climate Warehouse Simulation 2 Report.

Simulation III subsequently prototyped the Climate Warehouse as a public and open-source platform on the Chia Network's blockchain network. Simulation III's blockchain architecture enabled the Climate Warehouse to be tested in its operational capacity as a decentralized and peer-to-peer carbon metadata layer. The World Bank selected the Chia Network as the blockchain network provider for Simulation III after confirming its suitability through a comprehensive technical assessment that involved a consortium of over 20 carbon experts and technology industry leaders. During the technical assessment, reviewers conducted a detailed examination of the Chia Network's documents and code, and submitted a variety of questions on the Chia Network's technical architecture, economic model, sustainability, functionality, and accessibility. The Chia Network addressed the reviewers' questions and documented the answers in its Climate Warehouse white paper.[11] The collaboration with the Chia Network is based on the principles of non-exclusiveness and open-source public goods, bearing no costs or intellectual property rights from the World Bank, and aims to promote interoperable and inclusive solutions. The World Bank continues to support the effort to provide open-source infrastructure for climate market activities.

FIGURE 3: Benefits of using blockchain technology to build a carbon metadata layer



11 For more information, see https://ik.imagekit.io/mtozw1gojis/world-bank/Chia_as_the_Blockchain_Technology_for_the_Climate_Warehouse_3f553aff80_p_RQYX_le0g_f9da253e1a_n6RklkGfZ.pdf.

03 Simulation III Prototype

TECHNICAL ARCHITECTURE

The technical architecture of the Simulation III Climate Warehouse prototype consists of the metadata layer and the blockchain layer. Registries and observers interact with this technical architecture by publishing or extracting data and hosting blockchain nodes (see Figure 4).

Registries and observers

Registries and observers interact directly with the Climate Warehouse's technical architecture. Registries are databases and ledgers that hold records of climate action projects, their generated units (e.g. mitigating outcomes), and transactions under a market mechanism (e.g. country registries, independent standard registries, and regional registries). Observers are entities that have an interest in the Climate Warehouse's publicly available, harmonized metadata and include auditors, buyers, traders, verification bodies, project developers, exchanges, and regulatory bodies.

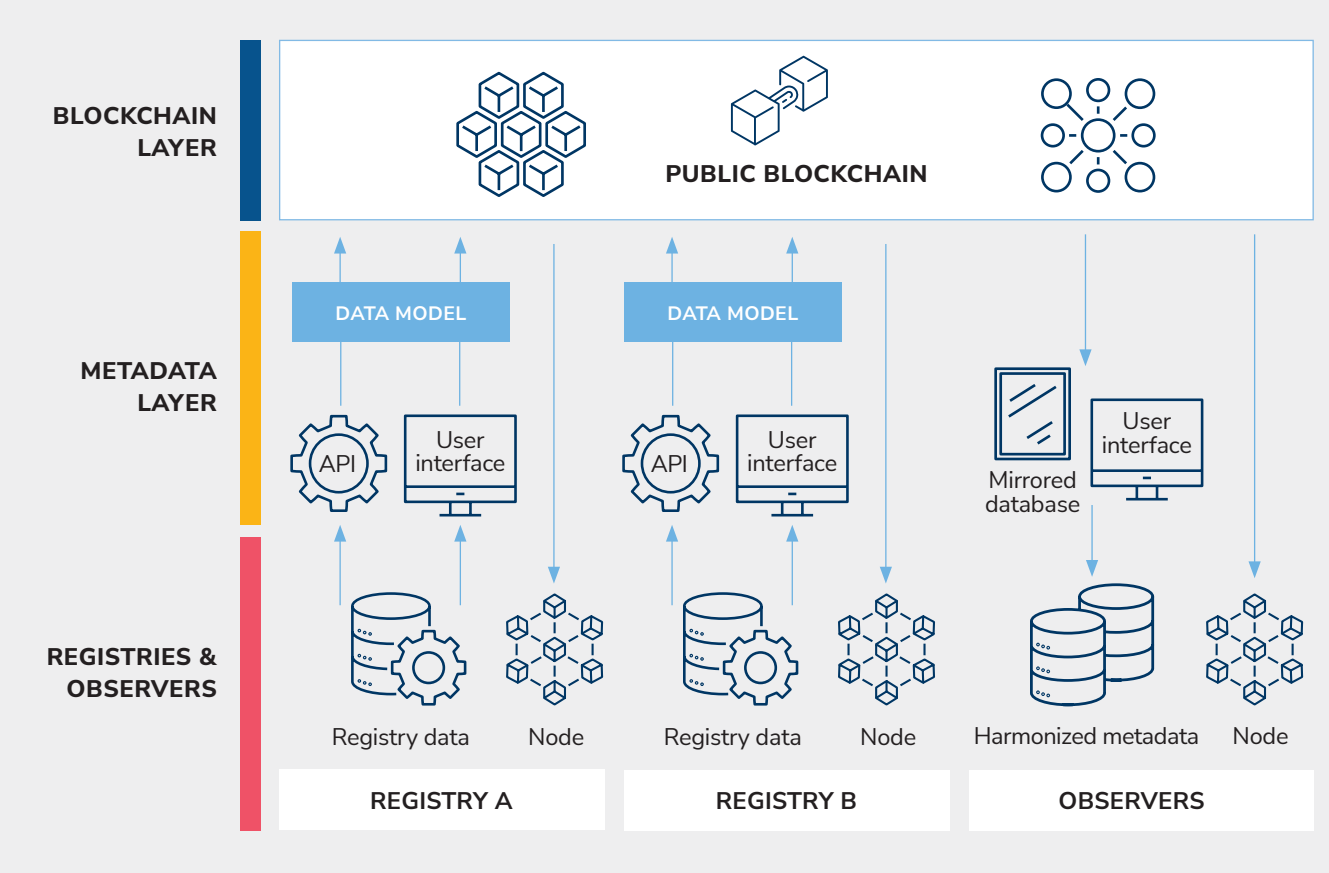
Registries engage with the Climate Warehouse by publishing their registry data and by hosting a Climate Warehouse blockchain node. Registries can integrate their data with the Climate Warehouse in three ways:

- **API:** Dynamic and automated data integration through a direct API connection.
- **Excel import/export:** Bulk registry data imports and exports through the user interface.
- **Manual entry:** Manual registry data input through the user interface.

Registries can select their integration method based on their technical capability (e.g. ability to set up an API connection) and preferred integration model.

Hosting a Climate Warehouse blockchain node involves storing a copy of the Climate Warehouse metadata and the Chia Network blockchain ledger (i.e. history of blockchain transactions). This allows registries to validate and secure updates to the Climate Warehouse's metadata through the blockchain layer's peer-to-peer consensus mechanism, following the bottom-up approach of the Paris Agreement. Registries benefit from hosting a blockchain node because it enables them to ensure that updates to the Climate Warehouse's metadata agree with their local records. In addition, hosting a blockchain node enables registries to control their data integration with the Climate Warehouse and avoid relying on a third party-operated node to extract and publish carbon data.

FIGURE 4: Technical architecture of the Simulation III prototype



Observers engage with the Climate Warehouse by extracting the Warehouse's harmonized metadata and by hosting a Climate Warehouse blockchain node. They can extract the harmonized metadata either by using the mirrored database feature (Climate Warehouse data mirrored into a traditional Structured Query Language (SQL) database) or by downloading a static Excel file in the user interface's Warehouse view. The mirrored database feature is particularly useful for observers interested in using Climate Warehouse data to provide related services (e.g. auditing, market reports, or double counting checks) because it enables dynamic data access and can be linked to "live" dashboards and reports. As with registries, observers host blockchain nodes to participate in the peer-to-peer data validation process, ensure that data updates agree with local records, and control their data integration with the Climate Warehouse.

Metadata layer

The metadata layer is the first layer of the Climate Warehouse's technical architecture and consists of the data model, which harmonizes data fields across different registries using a common taxonomy, and the Climate Warehouse's data integration and extraction features, which include the API feature, user interface, and mirrored database feature. The Simulation III data model is an extended version of the model that was developed during simulations I and II and has two main tables: the projects table and the units table (see Figure 5).

The projects table captures information on GHG mitigation projects and includes data fields such as project name, developer, sector, NDC information, status, and description. The projects table is connected to ancillary tables such as issuances, locations, ratings, co-benefits, estimations, and labels. Each project is tagged with a unique identification number and linked to the unique organization identification number of the registry that submitted the project data. The units table captures information on the carbon credit units that are issued from projects and includes data fields such as unit count, issuance location, vintage year, status, and tags. Each unit is also tagged with a unique identification number and is linked to the project from which it was issued.

The Simulation III data model's data fields and picklist options are specified by the Climate Warehouse governance node, which is managed by the governing body of the Climate Warehouse. The governance node also maintains the organizations list, which is the list of participating registries to which each new node in the Climate Warehouse will automatically subscribe.

FIGURE 5: Simulation III data model

Fields with an * are required form fields

PK denotes primary key for a specific table

FK denotes foreign key which links tables together

Each ID is globally unique, meaning no organizations will generate the same ID for any table

Blockchain layer

This is the second layer of the Simulation III prototype's technical architecture, which secures the data submitted by participants on an immutable blockchain. The blockchain layer is secured by a network of validators in a public and permissionless blockchain through a decentralized and peer-to-peer governance system.

This layer has the following key characteristics:

- **Transaction validation model:** To validate the addition of new blocks to the blockchain, the blockchain layer uses proof of space and time (validators prove that their storage space is allocated to the blockchain and compute a verifiable delay function), which differs from existing validation models including proof of work (validators solve complex and energy-intensive cryptographic puzzles) and proof of stake (validators prove a financial stake in the blockchain).
- **Ledger model:** The blockchain layer uses the unspent transaction outputs ledger model (also used by Bitcoin), in which data records on the blockchain are stored as coins and each transaction involves canceling and creating new coins. In contrast, the account ledger model (used by Ethereum) stores data records on the blockchain in accounts and each transaction involves debiting one account and crediting another.
- **Native data storage:** The blockchain layer offers a native capability to store data on the blockchain, using data tables. Each data table is represented by a unique coin, which is stored on the public blockchain, while the contents of each data table are stored by the nodes that subscribe to the data tables (i.e. Climate Warehouse registries and observers).
- **Transaction fees:** Each data table update incurs a transaction fee to compensate the validators that secure the new data on the blockchain. The transaction fee does not depend on the volume of data updated, since only the coin representing the updated data table is stored on the blockchain.
- **Autonomous:** The blockchain layer is publicly owned by its nodes and runs autonomously.

TECHNICAL REQUIREMENTS

The Climate Warehouse Simulation III prototype's technical requirements include software requirements, device specifications, IT security permissions, and data mapping.

Software requirements

Registries that participate in the Climate Warehouse must install three types of software – the Climate Warehouse back-end software, user interface, and Chia software. The Climate Warehouse back-end software and user interface both run as standard applications in Windows and Mac operating systems and do not require any other software to be installed to run. Installing Chia software enables participants to host a blockchain node by creating a wallet and downloading a copy of the public blockchain and data layer. All required software is publicly available on the Climate Warehouse repository on GitHub.[12]

12 For more information, see https://github.com/Chia-Network/climate-warehouse.

Device specifications

To host a node, participants need to have devices with specifications that are equivalent to or above those of a Raspberry Pi 4 computer, including:

- Processor: Quad core 1.5 gigahertz central processing unit (must be 64-bit)
- Random access memory: 4 gigabytes (GB)
- Programming language: Python 3.7–3.9
- Disk space: 100 GB

IT security permissions

Participants must also have sufficient local IT security permissions to download and run the Climate Warehouse software described above. They specifically need permission to hold and transact cryptocurrencies, since hosting a node and submitting data updates require transactions using a cryptocurrency wallet.

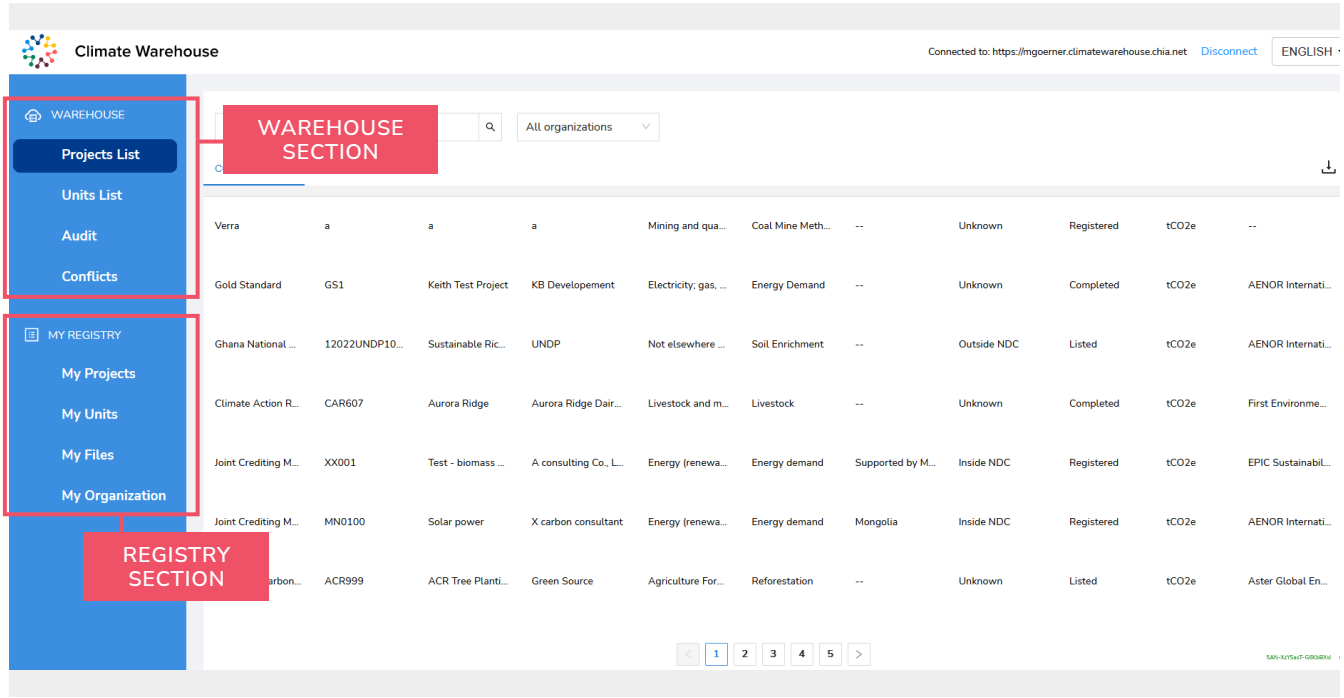
Data mapping

Finally, participants must map their data fields to the fields of the Climate Warehouse data model. The nature of this mapping depends on the participating registry's integration model. If a registry chooses to integrate its data using Climate Warehouse APIs, it will need to create middleware that converts the submitted registry data into the format of the Climate Warehouse data model. If a registry chooses to use the Excel import/export function in the user interface, it will need to map its data fields in the predefined Excel upload template. If a registry chooses to manually enter its data on the user interface, the data field requirements will ensure that submitted registry data fits the Climate Warehouse data model.

USER INTERFACE

The user interface is a tool that helps participants access and update their data in the Climate Warehouse (see Figure 6). In prior simulations, the user interface was also referred to as the "auxiliary application". The primary purpose of the user interface is to enable easy access to the Climate Warehouse for participants that may not have the capacity to create their own integration tools that are tailored to their workflows. As such, participants are not required to use the user interface. The user interface has two sections: the warehouse section and the registry section.

FIGURE 6: User interface



Note: All data displayed is sample data for testing and simulation purposes only.

Warehouse section

The warehouse section visualizes the Climate Warehouse's harmonized metadata and can be accessed by participating registries, observers, and members of the public. The public observer node, available on the Climate Warehouse website, enables members of the public to easily access the warehouse view through an internet browser.[13] The warehouse section includes four subsections: "projects list", "units list", "audit", and "conflicts".

The "projects list" subsection includes a table of all projects submitted by participating registries that are part of the Climate Warehouse governance node. Each row corresponds to a single project and the table columns detail project-specific information such as the project identification number, project name, project developer, sector, project type, and project status. Selecting a specific project leads to the project detailed view, which includes further details on the project, its issuances, location information, and estimations. Project data can be filtered using the full text search feature or by using the organization drop-down bar. Additionally, a static copy of the project data can be downloaded to the local device using the Excel download feature.

The "units list" subsection includes a table of all carbon units that have been submitted by participating registries that are included in the Climate Warehouse governance node. Each row corresponds to a single unit and the table columns detail unit-specific information including unit owner, unit count, unit type, unit status, and corresponding adjustment status. Selecting a specific unit leads to the unit detailed view, which includes further details on the unit, its issuances, and any labels (e.g. eligibility for the Carbon Offsetting and Reduction Scheme for International Aviation). Unit data can also be filtered using the full text search feature or by using the organization drop-down bar, and a static copy of the unit data can be downloaded to the local device using the Excel download feature.

The "audit" subsection displays the full blockchain transaction history of any organization that the user subscribes to if the organization is selected from the drop-down list. Users can select a specific blockchain transaction to view further details regarding the transaction (such as when the data was added or deleted, or what project or unit data was added or deleted).

The "conflicts" subsection lists units in the Climate Warehouse, submitted by participant registries, that were flagged by the user interface's sample double issuance risk detection function. This function was added to the user interface to demonstrate the opportunity for third-party organizations in the service layer to use the data in the Climate Warehouse to develop innovative methods to detect instances of double counting, flag units or projects with higher or lower double counting risks, and increase the overall transparency and efficiency of the market. The function uses a simple algorithm that screens units based on time period, sector, geography, and registry in order to flag units with double issuance risk. The Climate Warehouse Simulation III prototype's double issuance risk detection function was developed for simulation purposes only, in order to demonstrate the potential of service layer double counting mitigation tools, and was not in scope for continued development. This subsection was removed at the end of the Climate Warehouse Simulation III.

Registry section

The registry section mimics simple registry functions (i.e. creating and editing projects and units) and provides a basic data integration capability for registries that do not have the capacity to develop their own integration tools. Participants can use the registry section to add registry data to the Climate Warehouse, either through the Excel import/export function or by manual entry. The registry section comprises four subsections: "my projects", "my units", "my files", and "my organization".

The "my projects" subsection enables users to view and edit the projects they have created and to create new projects. Users can manually create projects using the create project function, which helps users populate each of the project data fields through a step-by-step process. Alternatively, users can add project data to the Climate Warehouse by using the Excel import/export function and uploading a project data Excel file in the specified format.

The "my units" subsection follows a similar format, enabling users to view and edit all created units and add unit data by either manually creating a unit or by uploading a unit data Excel file. Notably, the "my units" tab also enables users to split a single created unit into multiple units using the split unit function.

The "my files" subsection is a repository that enables users to upload, share, and securely download files from other participants. This feature can specifically be used to share geographic information system shapefiles, which track project location details. Users can manage the amount of data that is being stored by selecting the files that they want to receive from other participants.

13 For more information, see https://app.climatewarehouse.chia.net/#/projects?orgUid=all.

The "my organization" subsection displays key details on the user's organization, which include organization name, identification number, public blockchain address, and quick response code. In addition, the organization subscriptions feature enables users to monitor the registries that they choose to follow by subscribing or unsubscribing to other registries' data. This allows participants to flexibly adjust the registry data that they follow based on their preferences (e.g. follow as many registries as possible to minimize double counting risk or only follow the registries listed by the governance body) and is in line with the bottom-up approach of the Paris Agreement.

ITMO TRANSFERS

The Simulation III prototype enables registries to reflect ITMO transfers, which occur outside of the Climate Warehouse, in the Climate Warehouse by updating their unit data. For example, in the case that registry A transfers a carbon unit to registry B outside of the Climate Warehouse and wants to reflect this transaction in the Climate Warehouse, registry A would first change the status of the transferred unit to "exported" by editing the unit record. Registry B would then create a new unit, corresponding to the unit that was transferred from registry A, and mark the status of the unit as "held".

In the future this ITMO transfer process could be consolidated into a single step, in which a blockchain "smart contract" triggers the sending and receiving registries to simultaneously record the ITMO transfer in the Climate Warehouse once they have updated their respective internal registry systems to reflect the transfer.

THREAT MODEL

To provide guidance on the security considerations for participating in the Climate Warehouse, a comprehensive threat model was developed for the Simulation III prototype. The development process included isolating the elements of the Climate Warehouse that are susceptible to attacks, simulating threats to individual blockchain nodes and the overall blockchain network, prioritizing the identified threats by severity, and outlining countermeasures to mitigate each threat. Table 1 summarizes the key potential attacks that were identified in the Climate Warehouse threat model. The final version of the threat model, including a complete list of identified threats and countermeasures, was shared with the governing body of the operational Climate Warehouse at the end of Simulation III.

TABLE 1: Key potential attacks and mitigations identified in threat model

POTENTIAL ATTACK	MITIGATION	DESCRIPTION
Changing data	Blockchain immutability	A threat actor attempts to change Climate Warehouse data without permission
Denial of service	Decentralization	A threat actor attempts to prevent legitimate users from accessing the Climate Warehouse
Malicious code injection	Security-optimized cloud architecture	A threat actor attempts to cause the Climate Warehouse to distribute malicious payloads
Stealing cryptocurrency	Keys secured by multiple layers	A threat actor attempts to steal users' cryptocurrency assets
Blockchain attack	Nakamoto Consensus	A threat actor attempts to change data that was previously confirmed on the blockchain or to stop the blockchain entirely

04 Simulation III Testing Approach

TESTING TIMELINE AND PARTICIPANTS

Simulation III testing was completed in four phases over a six-month period between March and August 2022 and engaged a diverse range of stakeholders, including governments, independent standards, multilateral organizations, and other private and public carbon market stakeholders (see Figure 7). Phases I, II, and III focused on testing and simulation activities with participants, and phase IV focused on consolidating participant feedback and preparing for the Climate Warehouse's transition to the operational governing body.

Simulation III participants broadly fell into two categories:

- **Full participants:** Carbon market stakeholders that were willing and able to simulate publishing registry data to the Climate Warehouse and test key features of the prototype, including installation, the user interface, API, and Excel import/export.
- **Observers:** Carbon market stakeholders that were interested in learning about the Climate Warehouse (e.g. through prototype demonstrations or uploading test data), as part of their role in helping to scale up compliance or voluntary carbon markets.

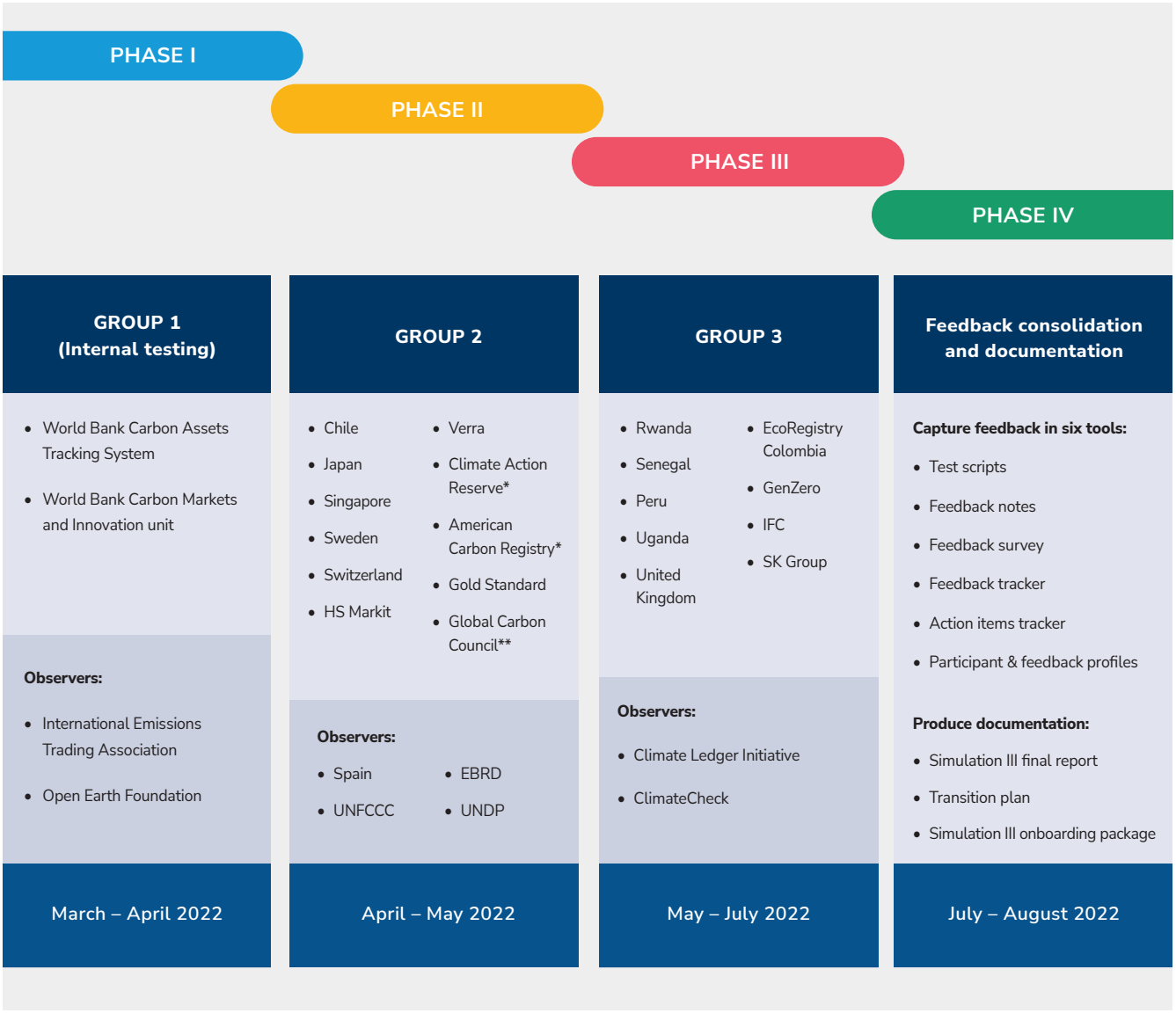
Participating organizations were sorted into three groups, depending on the testing phase that they participated in (see Figure 7). Simulation III testing engaged with 30 participating organizations consisting of 22 full participants and eight observers across the three participant groups:

- **Group 1:** Included two full participants and two observers. Full participants included the World Bank's CMI unit and Carbon Assets Tracking System (CATS). Observers included the International Emissions Trading Association (IETA) and Open Earth Foundation.
- **Group 2:** Included 11 full participants and four observers. Full participants included the governments of Chile, Japan, Singapore, Sweden, and Switzerland, as well as IHS Markit, Verra, the Climate Action Reserve, the American Carbon Registry, Gold Standard, and Global Carbon Council. Observers included the government of Spain, the UNFCCC, the European Bank for Reconstruction and Development (EBRD) and the United Nations Development Programme (UNDP).
- **Group 3:** Included nine full participants and two observers. Full participants included the governments of Peru, Rwanda, Senegal, Uganda, and the United Kingdom, as well as EcoRegistry Colombia, GenZero, International Finance Corporation (IFC), and SK Certification Center. Observers included the Climate Ledger Initiative and ClimateCheck.

Simulation III engaged testers within participating organizations with three types of roles in order to collect comprehensive feedback on all dimensions of the Climate Warehouse:

- **Policy setter:** Sets the participating organization's policies, guidelines, and strategies and can provide high-level feed back on the Climate Warehouse (e.g. value proposition in the carbon market ecosystem and long-term trends that should inform the current design).
- **Registry administrator:** Manages the participating organization's registry and can provide specific feedback on the Climate Warehouse's data model and data fields.
- **IT specialist:** Manages the participating organization's IT systems and can provide specific feedback on the Climate Warehouse's IT requirements.

FIGURE 7: Testing timeline and participants



TESTING AREAS

Simulation III testers completed at least one of four testing areas, based on their role and expertise. The four Simulation III testing areas were installation, user interface, API, and Excel import/export.

Installation

The installation testing area focused on installing and running the software required to participate in the Climate Warehouse. This involved downloading the Climate Warehouse, user interface, and Chia software; setting up a wallet; and syncing a blockchain node. Installation was tested by members of participating organizations who would manage the Climate Warehouse software once the warehouse was operational and had an interest in learning how to install and maintain the Climate Warehouse. This testing area helped participating organizations understand the Climate Warehouse's technical requirements and prepare to manage new releases of the Climate Warehouse software in the future.

User interface

This testing area focused on viewing, entering, and modifying Climate Warehouse data through the user interface. This involved accessing the downloaded user interface application, creating an organization, creating projects, creating units, reviewing other organizations' data, and simulating a unit lifecycle. The user interface was tested by most members of participating organizations since it enabled participants to easily access and review the Climate Warehouse's main functionalities, data model, and data fields. This testing area helped participants simulate the integration of registry data with the Climate Warehouse and identify specific functionalities and data fields that they wanted to modify.

API

The API testing area focused on testing the Climate Warehouse's API endpoints and examining the Climate Warehouse's ability to support API-enabled automatic registry data integration. This involved identifying an optimal configuration to integrate the participating organization's registry data with the Climate Warehouse and considering how middleware could be built to support automatic integration. This testing area was completed by participating organizations that had the technical capabilities to support automatic registry data integration with the Climate Warehouse through an API.

Excel import and export

This testing area focused on using the Excel import/export feature in the user interface to upload registry data to the Climate Warehouse in bulk. This involved populating the Excel upload template with registry data (to ensure alignment with the Climate Warehouse's data model) and uploading the populated template in the user interface. The testing area helped participants understand how they can upload bulk volumes of registry data to the Climate Warehouse without API integration.

DEPLOYMENT MODELS

Simulation III participants were offered a choice between four different deployment models, depending on their needs:

- **Local installation:** Involved directly installing the Climate Warehouse software onto a device owned by the participating organization. This model was used by participants who had sufficient disk space and security permissions to install the Climate Warehouse software onto their own device.
- **Cloud – Amazon Web Services (AWS) workspace:** Involved conducting testing activities in a blank AWS workspace. This model was used by participants who could not meet the requirements for local installation but were still interested in testing the installation and/or API testing areas.
- **Cloud – hosted instance:** Involved conducting testing activities in an AWS workspace with pre-installed Climate Warehouse software. This model was used by participants who focused their efforts on testing the user interface.
- **Cloud – own organizational cloud:** Involved conducting testing activities in a virtual workspace set up by the participating organization. This model was used by participants who preferred to install and test the Climate Warehouse in a virtual workspace, hosted by their own organization.

TESTING PROCESS

Each Simulation III participant completed a series of activities, including:

- **Pre-testing activities:** Complete a kick-off meeting, receive a demo of the Climate Warehouse, select a deployment model, select testing areas, and prepare the local IT environment to enable testing (e.g. confirm IT security protocols).
- **Testing activities:** For each selected testing area, complete the steps included in the corresponding test script, simulating key activities that integrated registries would complete (e.g. creating a project or retiring a unit).
- **Post-testing activities:** Complete the Climate Warehouse feedback survey to provide comprehensive feedback on the testing experience.

FIGURE 8: Testing activities

1 RUN THE CLIMATE WAREHOUSE
- Run through **local install**
- Run through **docker**
- Run through **hosted environment**

2 ORGANIZATION CREATION SCRIPTS
- Create from **API**
- Create from **user interface**

3 PROJECT CREATION SCRIPTS
- Import **XLSX project**
- Create from **API**
- Create from **user interface**

4 UNIT CREATION SCRIPTS
- Import **XLSX project**
- Create from **API**
- Create from **user interface**

5 REVIEW ORGANIZATION AND PROJECTS
- Review own organization and projects scripts
- Subscribe to external organization table
- Unsubscribe from external organization table

6 REPORT ON CW PROJECTS
- Import **XLSX project**
- Create from **API**
- Create from **user interface**

7 UNIT TRANSACTIONS
- Retire units
- List of units on external marketplace
- Transfer units within same country jurisdiction
- Transfer units outside country jurisdiction (internationally transferred mitigation outcomes)
- Apply new label to units
- Add new issuance

Note: Testing activities varied by participant based on selected testing areas.

TECHNICAL SUPPORT

The World Bank and Chia Network team members provided Simulation III participants with comprehensive technical support throughout the testing process to ensure a smooth testing experience. Technical support included kick-off sessions, joint testing sessions, office hours, email support and check-ins, and technical documentation as follows:

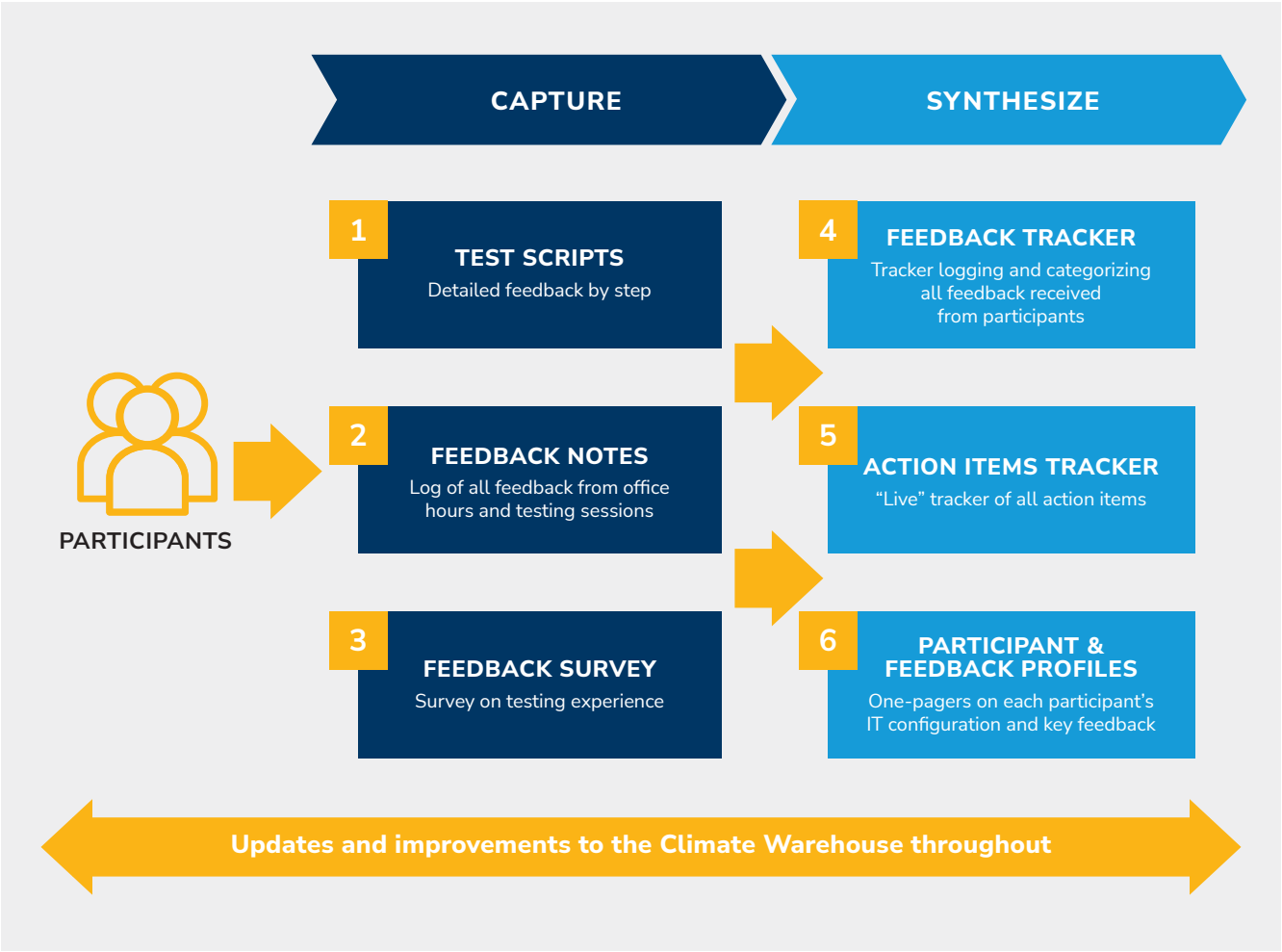
- **Kick-off sessions:** Introduced participants to the Climate Warehouse through a demo and confirmed technical requirements, preferred deployment model, and testing areas.
- **Joint testing sessions:** Guided participants through each testing step, answering questions and documenting any feedback or suggestions.
- **Office hours:** Held open-ended, one-hour office hour sessions twice per week to answer any questions as participants completed testing.
- **Email support/check-ins:** Engaged in regular check-ins and communication over email to track participants' testing progress and ensure sufficient support.
- **Technical documentation:** Provided detailed information on the technical architecture of the Climate Warehouse, testing approach, technical requirements, testing steps, data model, definitions of data fields, and more. Simulation III participants were given technical documentation including an onboarding presentation, a technical guide, test scripts for each testing area, and a data dictionary

FEEDBACK COLLECTION AND DOCUMENTATION

Participant feedback was collected and consolidated systematically throughout Simulation III testing to maintain a comprehensive record of feedback and inform improvements to the Climate Warehouse. Specifically, six feedback management tools were developed and implemented (see Figure 9):

- **Test scripts:** Participants used the feedback column in the step-by-step test scripts to compare the expected and actual outcome of each step and note any comments.
- **Feedback notes:** Detailed notes were taken from joint testing sessions and office hours, capturing participants' questions, suggestions, requests, concerns, errors, and proposed development actions.
- **Feedback survey:** Participants completed the survey after testing to holistically provide qualitative (e.g. views on blockchain technology) and quantitative (e.g. level of satisfaction) feedback on their testing experience.
- **Feedback tracker:** An Excel tracker was used to log and categorize all participant feedback from test scripts, testing sessions, office hours, feedback survey responses, and email exchanges.
- **Action items tracker:** A "live" tracker of all prototype development actions was used to facilitate the development action decision-making process, track completion statuses, and maintain a log of proposed and completed development actions during Simulation III.
- **Participant and feedback profiles:** Participant and feedback profiles were created for each participant, documenting their testing timelines, team member roles, completed testing areas, selected deployment models and IT configurations. The profiles also included a comprehensive log of all feedback received from each participant in testing sessions, completed test scripts, office hours, emails to the testing and simulation team, and feedback survey responses. Participant and feedback profiles were compiled into a testing participant profiles booklet at the end of Simulation III and shared with the new governing body.

FIGURE 9: Feedback management tools



PROTOTYPE MAINTENANCE AND DEVELOPMENT

The Climate Warehouse Simulation III prototype was improved throughout the testing period based on feedback from participants. The prototype was developed through a structured decision-making process, which involved first identifying potential updates to the Climate Warehouse, based on participant feedback. Potential updates were then added to the action items tracker and raised in weekly meetings with the testing and simulation team for a development decision. Confirmed actions were then submitted to the prototype development team for completion through the publicly available Climate Warehouse repository on GitHub, which logged all updates made to the Climate Warehouse during Simulation III.[14]

Table 2 provides a description for each of the key columns in the action items tracker that facilitated this prototype development process.

14 For more information, see https://github.com/Chia-Network/climate-warehouse.

TABLE 2: Key columns in the action items tracker

KEY COLUMN	DESCRIPTION
Action item #	Unique identification number tagging each new potential action that was added to the action items tracker based on participant feedback
Date requested	Date the action item was requested
Organization name	Name of the participating organization that requested the action item
Action category	Category of the action item (user interface, data model, installation, API, documentation, or other)
Action item	Detailed description of the requested action item
Timeline	Timeline within which the action item was to be addressed. Each action was categorized into one of three timelines: – Short-term: Actions with a relatively low burden on the prototype development team's capacity (e.g. fixing an identified bug), which were completed as soon as possible – Before end of Sim III: Actions with a relatively high burden on the prototype development team's capacity, which were in scope for Simulation III (e.g. building a glossary page of key definitions on the user interface) – Suggestion to operational entity: Actions that were out of scope for Simulation III and logged as suggestions for the new governing body of the operational Climate Warehouse (e.g. substantial changes to the data model)
GitHub ticket #	Unique GitHub ticket number, corresponding to the unique issue number on the "issues" tab of the Climate Warehouse GitHub repository[15]
Status	Status of the action item. Each action was tagged as one of five statuses, depending on its completion status: – Not yet confirmed for development: All potential actions were given this tag when they were initially added to the action items tracker – Discuss with operating team: Potential actions that required testing and simulation team input for confirmation were given this tag and raised during weekly meetings – Not started: Potential actions that the testing and simulation team categorized as "suggestions to operational entity" in the "timeline" column or decided not to pursue were given this tag – In progress: Actions that the testing and simulation team confirmed were tagged as "in progress" and submitted to the prototype development team – Completed: Actions that were implemented and reflected as updates to the Climate Warehouse were given this tag. All actions that were categorized as "short-term" or "before end of Sim III" in the "timeline" column were tagged as "completed" in the final version of the action items tracker that was shared with the new governing body of the operational Climate Warehouse at the end of Simulation III

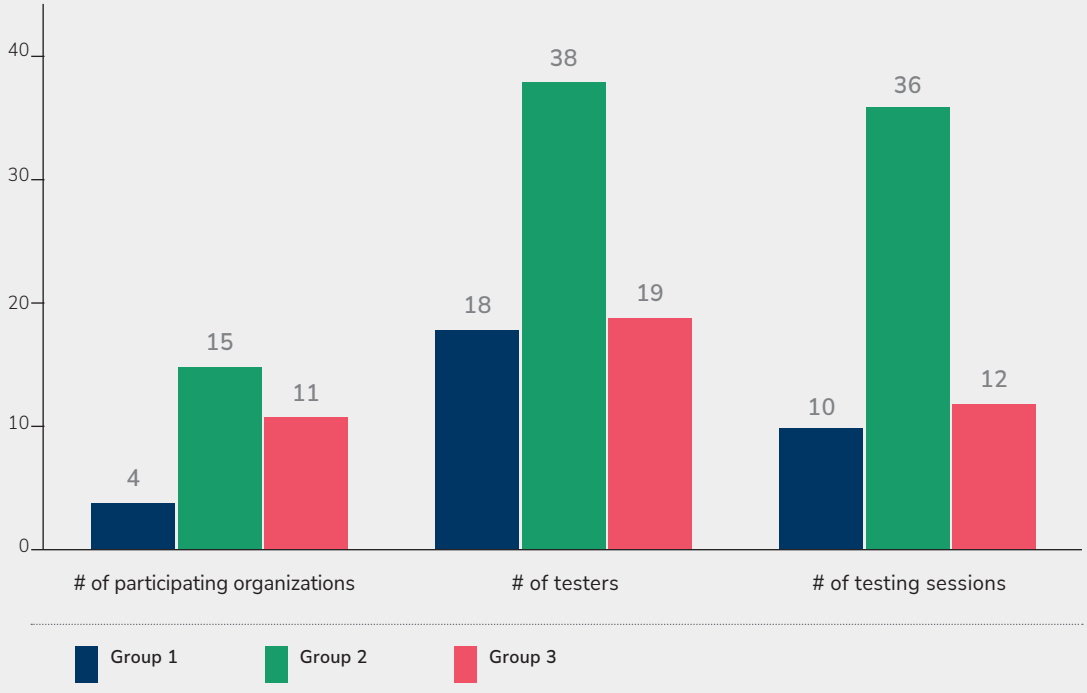
15 For more information, see https://github.com/Chia-Network/climate-warehouse/issues.

05 Overall Testing Statistics

SIMULATION III PARTICIPANTS

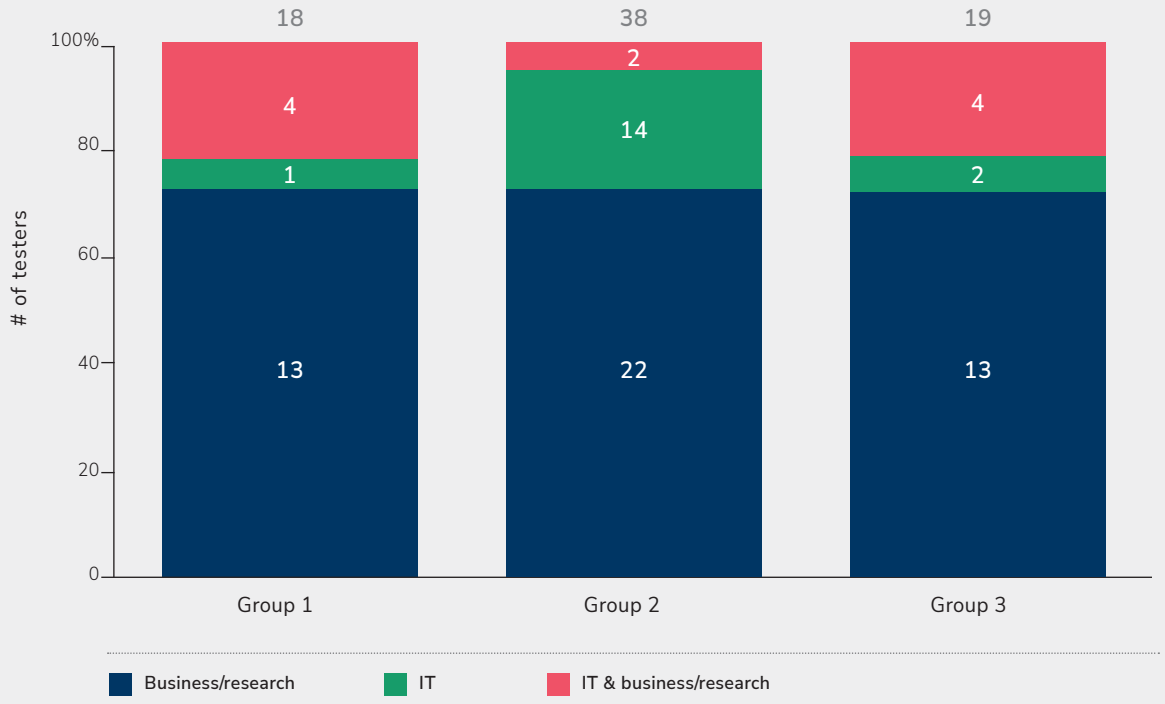
The Climate Warehouse Simulation III prototype was tested with 30 participating organizations and 75 testers across 58 testing sessions (see Figure 10). In addition to the 58 testing sessions, over 40 weekly office hour sessions and over 30 kick-off and onboarding meetings were completed.

FIGURE 10: Participating organizations, testers, and testing sessions



The testers in each of the three groups included members of participating organizations with business or research roles (including policy setters, registry administrators, and professionals with expertise in carbon markets, the environment, and other relevant areas), IT roles (including members of participating organizations who would manage the Climate Warehouse software upon integration), or both roles (see Figure 11). Each participating organization was asked to engage a team of testers that included business or research roles and IT roles to ensure that they could provide comprehensive feedback on the Simulation III prototype from a diverse range of perspectives and expertise.

FIGURE 11: Tester roles

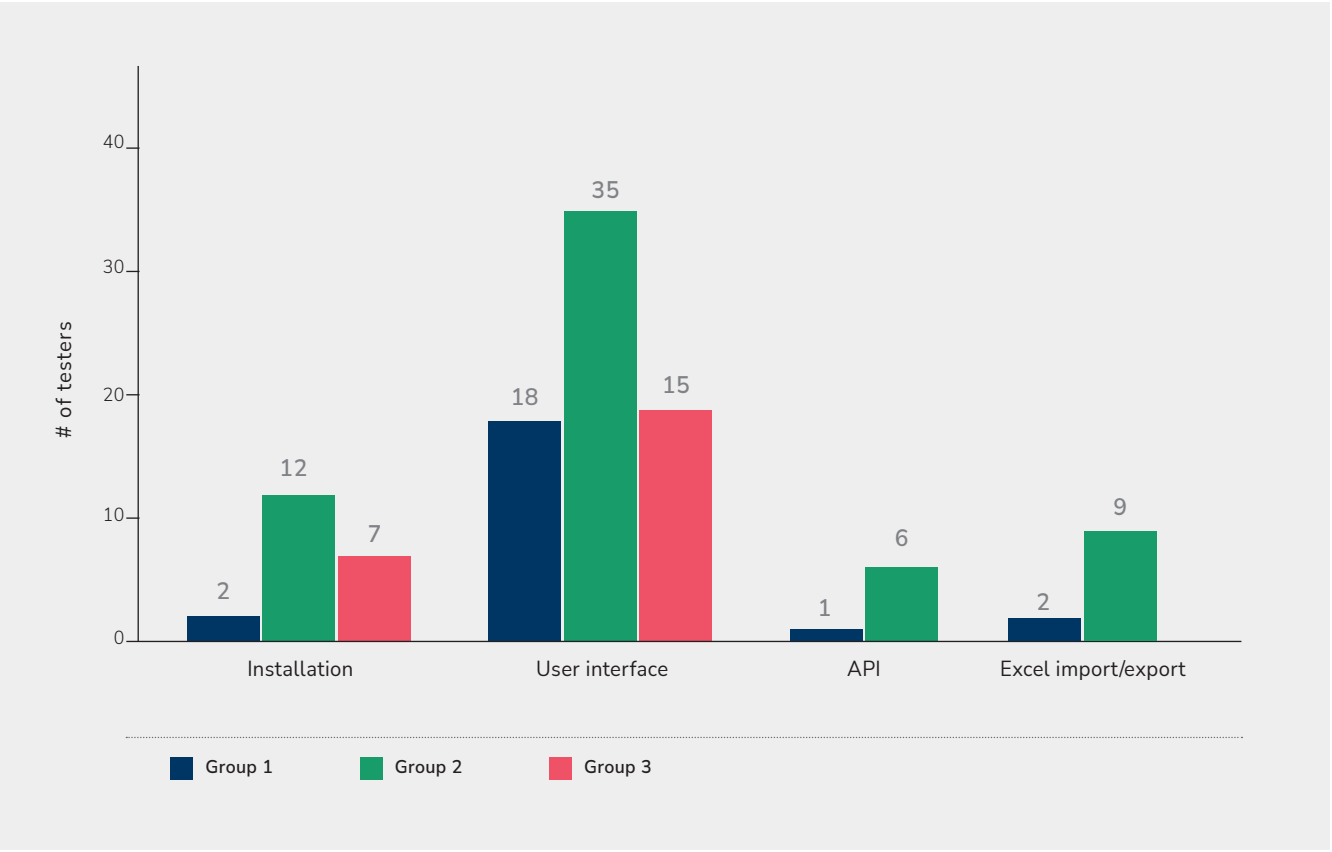


COMPLETED TESTING AREAS

The number of testers who completed each testing area varied by testing area (see Figure 12):

- **Installation:** The installation process was tested by 21 testers who were interested in examining the Climate Warehouse's technical architecture and learning how to install and run the Climate Warehouse software.
- **User interface:** The user interface was tested by 68 testers. Most testers completed this testing area because it enabled them to examine and provide feedback on the Climate Warehouse's data model.
- **API:** The API feature was tested by seven testers. The number of testers was relatively low because testing the API required substantial time and technical expertise to simulate automated integration to the Climate Warehouse.
- **Excel import/export:** The Excel import/export feature was tested by 11 testers who were interested in examining the Climate Warehouse's ability to accept data updates in bulk using the Excel template provided.

FIGURE 12: Completed testing areas



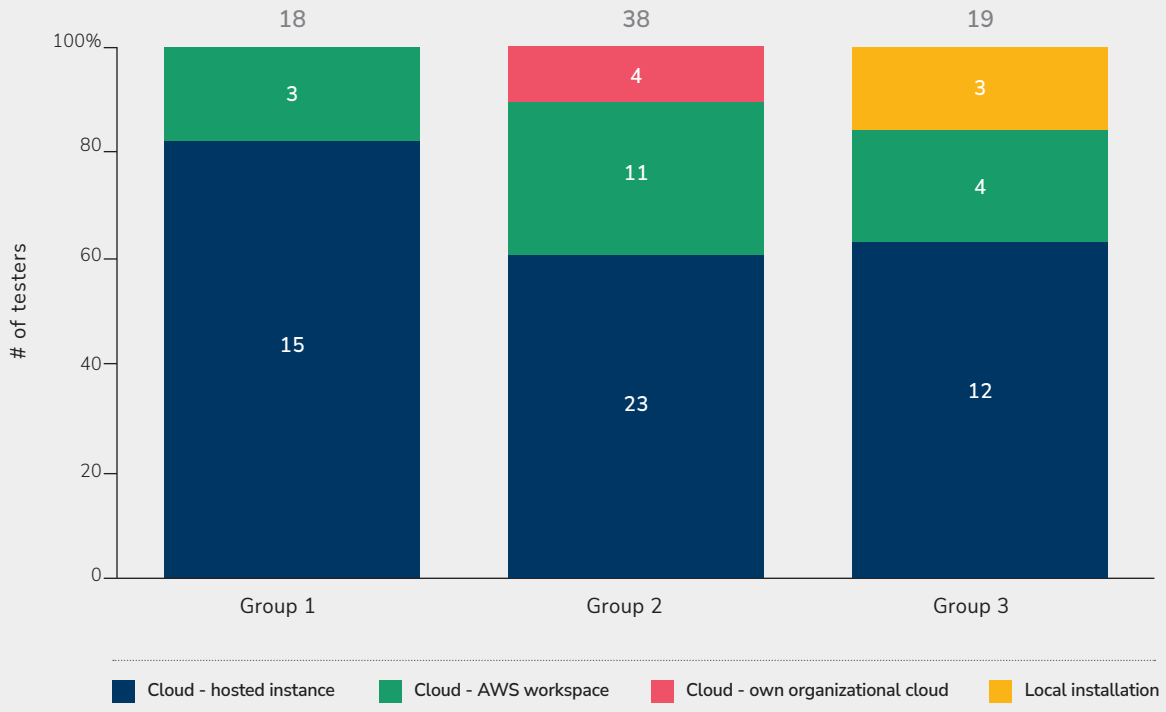
SELECTED DEPLOYMENT MODELS

A majority of Simulation III testers selected the Cloud – hosted instance deployment model because it was the quickest way to test the user interface and the Climate Warehouse data model (see Figure 13). The second most frequently selected was the Cloud – AWS workspace deployment model, which was selected by testers with technical expertise and interest in testing the Climate Warehouse's installation process or the API integration feature. Both deployment models were implemented successfully and smoothly by most testers, demonstrating their viability as options for participants to quickly deploy the Climate Warehouse.

Four group 2 testers selected the Cloud – own organizational cloud deployment model and deployed the Climate Warehouse on cloud computers that were set up by their local organization and hosted by Microsoft Azure Kubernetes Service. After resolving some minor troubleshooting, which involved one of the testers being unable to sync their blockchain node to the blockchain layer on first attempt, these testers were able to successfully demonstrate that the Climate Warehouse can be deployed in cloud computers that are set up by participating organizations and hosted by cloud service providers other than AWS.

Three group 3 testers selected the local installation deployment model and deployed the Climate Warehouse on cloud computers that were set up and hosted by their local organization. Given the need for the testers' organization to deploy the Climate Warehouse in its local IT system in this model, the testers had to attain security and legal approvals to ensure compliance with local requirements (e.g. the testers had to attain specific approval to allow their Climate Warehouse blockchain nodes to transact cryptocurrency). Furthermore, the locally hosted virtual computers' relatively low internet speeds doubled the duration of the blockchain node synchronization process from the standard two-week period to a four-week period. Ultimately, the testers were able to deploy the Climate Warehouse, which successfully demonstrated that participating organizations can deploy the Climate Warehouse in their local IT networks.

FIGURE 13: Selected deployment models



06 Participant Feedback

OVERVIEW

Over the five months of Simulation III testing between March and July 2022, 514 points of feedback were received in completed test scripts, testing sessions, office hours, feedback survey responses, and email exchanges. All participant feedback was recorded in the feedback tracker, participant profiles, and feedback profiles, which were shared with the Climate Warehouse's governing body at the end of Simulation III.

As part of the process to synthesize participant feedback into development actions, each point of feedback was categorized into one of 11 categories: overall highlights and learnings, overall satisfaction, installation, data model, user interface, API, Excel import/export, technical architecture, governance, recommended additional features, and perspectives on blockchain technology. This section details participants' feedback in each of these categories.

OVERALL HIGHLIGHTS AND LEARNINGS

In the feedback survey, participants were asked to share their overall highlights and learnings from participating in Simulation III.

In terms of overall highlights, many participants highlighted the critical value of the Climate Warehouse's fundamental value proposition to integrate the carbon market ecosystem under a common data model. Participants also noted that the Climate Warehouse's open-source design and use of blockchain technology will contribute to greater transparency and security in global carbon markets. Furthermore, participants shared support for the Climate Warehouse's iterative approach to engage and build consensus among a diverse range of carbon market stakeholders.

In terms of learnings, participants noted that simulating integration with the Simulation III prototype helped build operational capacity to integrate with the operational Climate Warehouse and manage data updates. Participants also noted that examining the Climate Warehouse data model clarified their understanding of how carbon registries with different taxonomies could align on a unified data model. Table 3 summarizes participants' overall highlights and learnings.

TABLE 3: Summary of participants' overall highlights and learnings

CATEGORY	PARTICIPANT FEEDBACK
Overall highlights	The proactive engagement of a diverse range of carbon market stakeholders, responsiveness to participant feedback, iterative process to seek buy-in, and willingness to innovate are helping to develop a system with significant potential to contribute to global carbon markets The Climate Warehouse fulfills a very relevant function by aggregating and harmonizing different registry systems and is critical for the successful implementation of Article 6 The Climate Warehouse will help make market systems more transparent and contribute to greater accuracy of information on carbon projects and units The Climate Warehouse's use of blockchain technology brings immutability and security to carbon markets The Climate Warehouse has the potential to fill substantial capacity gaps in registry systems, especially for least developed countries
Overall learnings	Participating in Simulation III provided a clearer understanding of how carbon markets could align on a unified data model Simulating integration with the current prototype helped develop operational capacity to integrate with the operational Climate Warehouse and manage data updates Examining the Climate Warehouse's data model helped identify potential improvements to the taxonomies of existing carbon registries

OVERALL SATISFACTION

The feedback survey solicited respondents' overall satisfaction levels with participating in Simulation III. Specifically, respondents were asked to indicate the extent to which the documentation and technical support that they received met their expectations, and share how likely they are to integrate their registries with the Climate Warehouse based on their testing experience. Figure 14 displays survey respondents' overall satisfaction levels.

FIGURE 14: Overall satisfaction levels

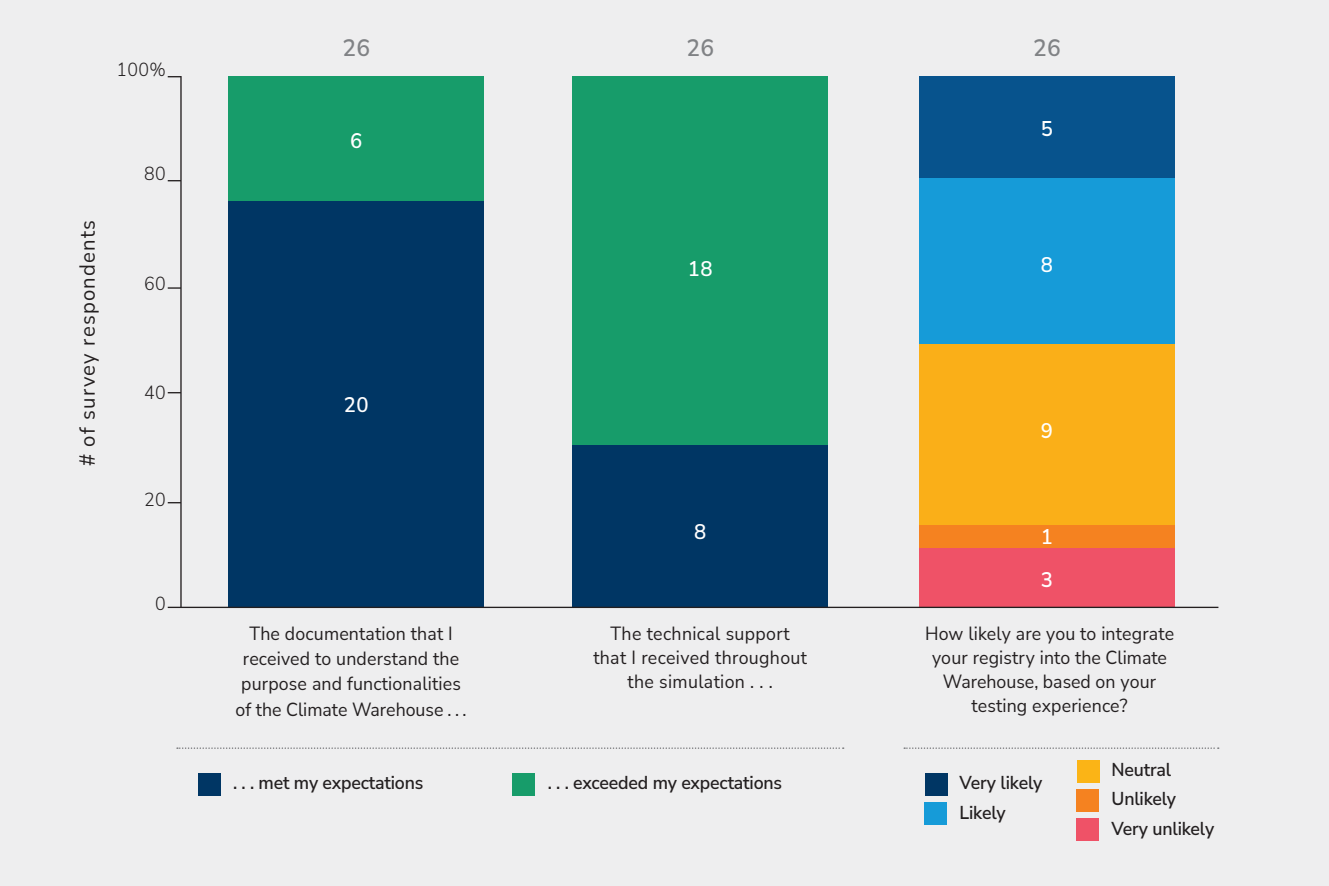


Table 4 summarizes participants' commentary on their overall satisfaction levels with the documentation that they received to understand the purpose and functions of the Climate Warehouse.

TABLE 4: Summarized commentary on participants' overall satisfaction with the documentation received

SATISFACTION LEVEL	PARTICIPANT COMMENTARY
Exceeded my expectations	The modular design of the documentation was easy to navigate and digest The documentation provided clear guidance on each step of the testing process
Met my expectations	The documentation was rich, clear, and complete The presentations and explanatory meetings provided a clear understanding of the information included in the documentation The documentation was self-explanatory and could be followed without additional assistance

Table 5 summarizes participants' commentary on their overall satisfaction levels with the technical support that they received throughout the simulation.

TABLE 5: Summarized commentary on participants' overall satisfaction with the technical support received

SATISFACTION LEVEL	PARTICIPANT COMMENTARY
Exceeded my expectations	The responsiveness, willingness to make changes, and hands-on nature of the technical support was excellent The technical support team was always available When probed on the rationales behind certain features, the team provided very clear supporting information and clarification
Met my expectations	The numerous calls conducted to provide technical assistance were very helpful The team was always very fast in providing assistance The team provided very clear guidance and was always supportive

Table 6 summarizes participants' commentary on their overall likelihood of integrating their registry with the Climate Warehouse based on their testing experience.

TABLE 6: Summarized commentary on participants' overall likelihood of integrating their registry with the Climate Warehouse based on their testing experience

LIKELIHOOD	PARTICIPANT COMMENTARY
Very likely or likely	Integrating with the Climate Warehouse is critical to contribute to the transparency, interoperability, and integrity of the global carbon market Integrating with the Climate Warehouse will generate positive synergies with existing registries' ongoing efforts The Climate Warehouse is the best alternative out there to provide a one-stop platform for all information pertaining to registries
Neutral	Integrating with the Climate Warehouse will depend on additional features to be developed (e.g. smart contract-enabled inter-registry carbon credit transfers) The decision to integrate with the Climate Warehouse depends on multiple other internal stakeholders and requires significant deliberation and consensus building
Unlikely or very unlikely	The decision to integrate with the Climate Warehouse depends on multiple other factors

INSTALLATION

Feedback on the installation process of the Climate Warehouse was primarily collected from the 21 testers who completed the installation testing area. Most testers who completed the Climate Warehouse installation process were able to successfully install the Climate Warehouse, user interface and Chia software; set up a cryptocurrency wallet; and sync their blockchain node. A handful of testers were unable to complete the installation process on devices hosted by their local organizations because some of the steps conflicted with their local IT security or legal requirements (e.g. virtual machine connections were limited to a known list of internet protocol addresses or the AWS desktop application could not be downloaded).

Participants noted that it will be particularly critical for the operational Climate Warehouse to ensure that the required installation steps consider participants' local IT security and legal requirements. Most participants highlighted that the installation process was user-friendly and straightforward given the complexity of the system, while a subset suggested that the process should be further streamlined and simplified (e.g. consolidate steps, provide a virtual machine with pre-installed software, or reduce the time required to sync the blockchain node). Troubleshooting was limited to a few participants who experienced challenges due to the 100GB hard disk space requirement, their local security requirements or were unable to sync their blockchain nodes on first attempt.

Overall, 69 percent of feedback survey respondents who tested the installation process indicated that the installation process met their expectations, 23 percent indicated that it exceeded their expectations, and 8 percent indicated that it did not meet their expectations (see Figure 15). Table 7 summarizes participants' feedback on the installation process.

FIGURE 15: Installation satisfaction levels

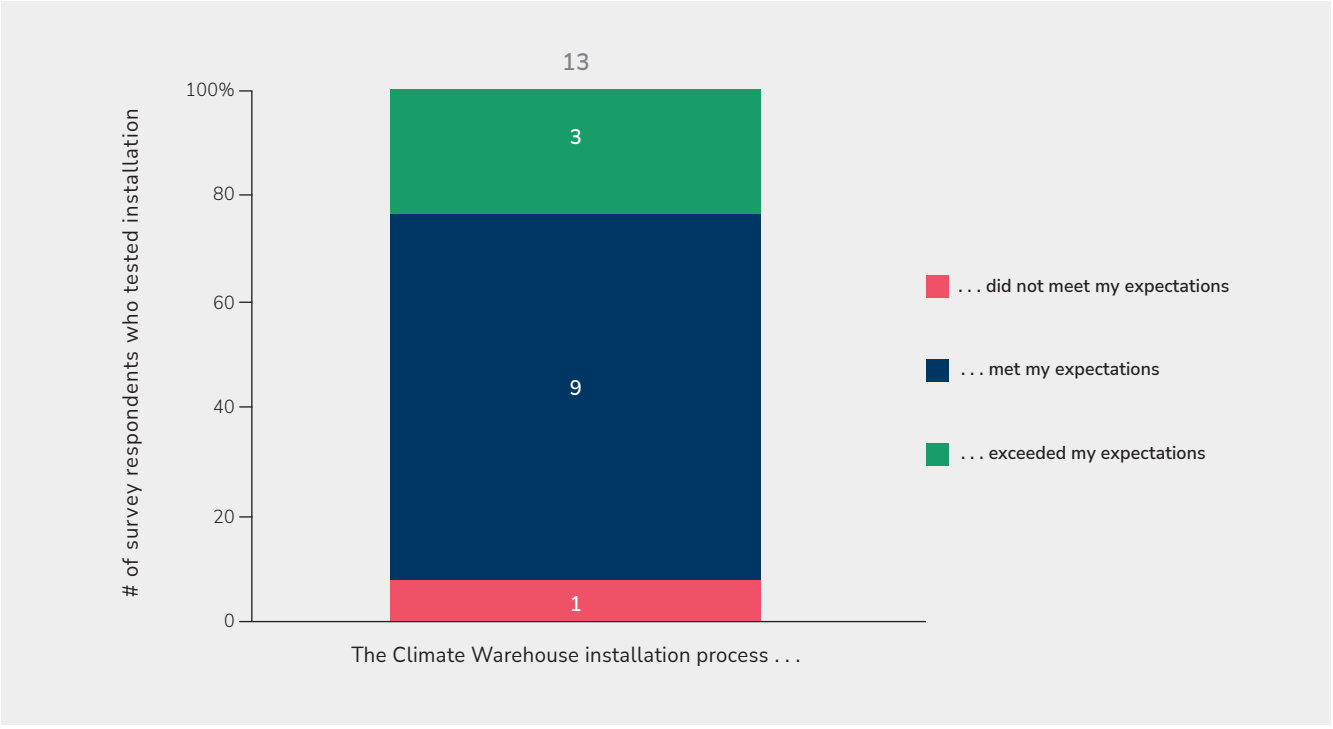


TABLE 7: Summarized feedback on the installation process

CATEGORY	PARTICIPANT FEEDBACK
Technical requirements	For integration to the operational Climate Warehouse, it is critical that the Climate Warehouse can meet participating organizations' security and legal requirements Based on existing security and legal protocols, the Climate Warehouse's requirement for participants to transact cryptocurrencies is particularly challenging to accommodate The governing body should provide participants with a laptop or virtual desktop to facilitate integration with the operational Climate Warehouse due to the 100GB hard disk space requirement The security and threat model of the Climate Warehouse is a crucial document required in the process of installing the software in the local IT system The 100GB hard disk requirement could be challenging to accommodate when installing and maintaining the Climate Warehouse in the local IT system
User experience	The installation process was fast, smooth, and user-friendly Considering the complexity of the system, the installation process was straightforward Installation was not straightforward due to the many components to install, but with the available documentation and support it was manageable It would be great if the back-end and front-end installation steps were consolidated into one installation step It would be great if the Climate Warehouse could provide a virtual machine with pre-installed Climate Warehouse software The Climate Warehouse should make sure that the duration of the blockchain node sync process remains feasible as more organizations and data are added to the Climate Warehouse
Troubleshooting	Some participants could not complete the installation process due to conflicts with their local IT requirements For one tester, the Climate Warehouse application did not sync with the data layer on their first attempt. The tester had to restart the sync process to resolve

DATA MODEL

Feedback on the Climate Warehouse data model was primarily collected from the 68 testers who tested the user interface, which visualizes the data model through interactive steps to create a project and a unit. Participants' feedback on the data model fell into one of seven categories: data field modifications, picklist options, new data fields, data harmonization, data mapping, definitions, and highlights.

The most common data field modification request was to convert specific data fields from required fields to optional fields (e.g. many participants requested that the "unit owner" field should be made optional because this information is frequently confidential). In addition, participants suggested that certain free text data fields should be converted to "select from picklist options or add a new option" data fields, to improve data harmonization (e.g. the "verification body" data field).

With regards to picklist options, multiple participants suggested that users should be able to add new picklist options to certain data fields that require more flexibility, in order to accommodate registries' different taxonomies (e.g. the "project type" and "methodology" data fields). Participants also suggested that the picklist options should be streamlined in certain data fields (e.g. the "project status" and "unit status" data fields). A subset of participants also proposed new data fields that would help enhance the Climate Warehouse data model (e.g. a "cooperative approach" data field).

More broadly, participants suggested that the Climate Warehouse data model could introduce more data validation rules (e.g. reject unrealistic dates) and picklist options to improve data quality and harmonization. While comparing the Climate Warehouse data model with their own taxonomies, multiple participants also noted specific required data fields in which they would have to submit "null" or "N/A" values due to confidentiality, lack of data, or other issues. Finally, multiple participants requested improvements to the Climate Warehouse's definitions of specific data fields and picklist options to help clarify and standardize the use of key terminologies.

Overall, 77 percent of feedback survey respondents who tested the user interface indicated that the Climate Warehouse data model met their expectations, 15 percent indicated that the data model did not meet their expectations, and 8 percent indicated that the data model exceeded their expectations (see Figure 16). Multiple participants highlighted that the Climate Warehouse data model is sufficiently comprehensive and that the data harmonization it enables will contribute significantly to global carbon markets. Table 8 summarizes participants' feedback on the data model.

FIGURE 16: Data model satisfaction levels

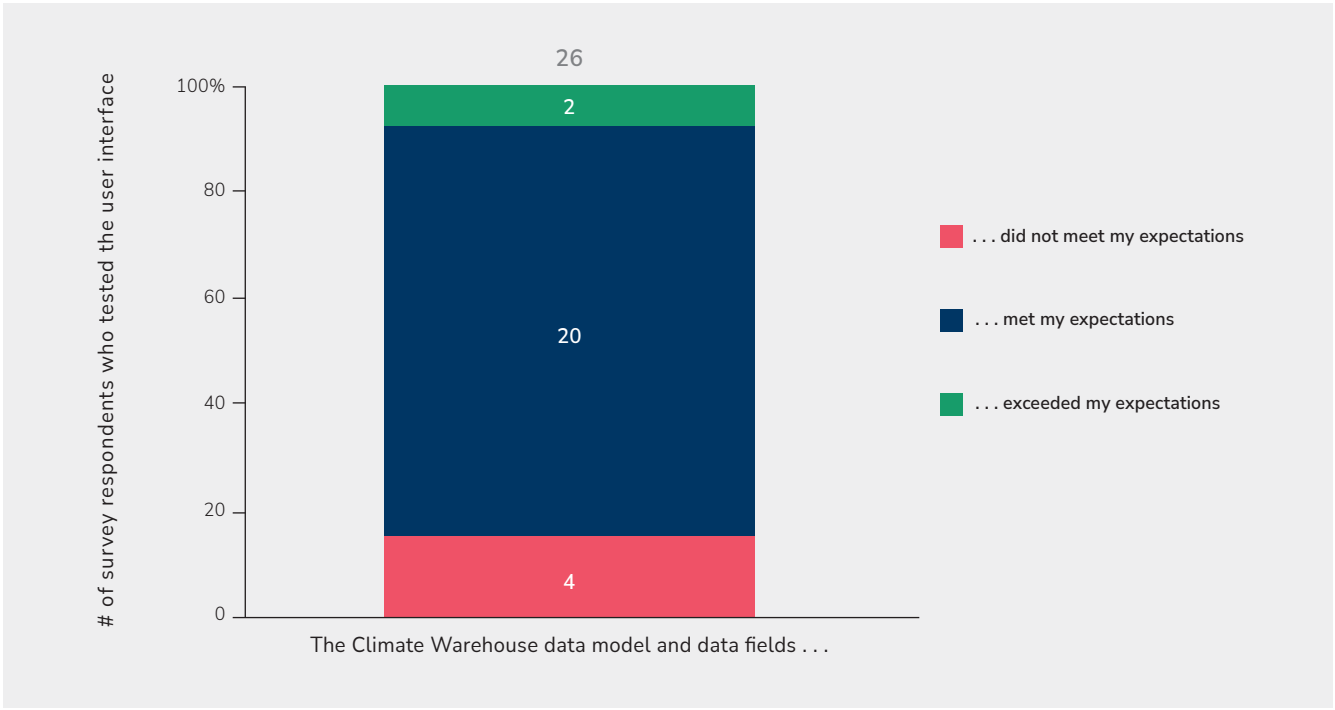


TABLE 8: Summarized feedback on the data model

CATEGORY	PARTICIPANT FEEDBACK
Data field modifications	The "unit owner" data field should be made optional because the unit owner cannot be disclosed in many cases The "country jurisdiction of owner" data field should be made optional because this information cannot be disclosed in many cases Convert the "unit type" data field to an optional field or allow users to input "unknown", since many registries do not currently track this information The "covered by NDC" data field should be converted from a required data field to an optional data field, since Article 6 of the Paris Agreement no longer requires this information to be tracked for carbon units Convert the "verification body" data field and the open-ended tag and label fields to require users to either select from existing picklist options or add new picklist options in order to improve data harmonization The "unit metric" data field should cover non-GHG metrics The Climate Warehouse should allow registries to submit "null" or "N/A" values for a subset of required data fields due to confidentiality, lack of data, or other issues
Picklist options	Users should be able to add new picklist options for the "validation body", "project sector", "project type", "methodology", and "rating type" data fields, as needed The picklist options for the "current registry" data field should include additional placeholders for reporting mechanisms under development The data field "marketplace" should include picklist options such as "tokenized" The "project sector" data field should use the International Standard Industrial Classification of All Economic Activities (ISIC) for its picklist options The picklist options for the "project status" data field should be streamlined (e.g. add options for "de-registered" and "withdrawn") A "partially NDC" picklist option should be added to the "covered by NDC" project data field, since some projects include both units that are covered by an NDC and units that are not covered by an NDC The picklist options "exported" and "pending export" in the "unit status" data field can be misleading in terms of the status or ownership of the carbon credit The "project type" data field should use benchmark databases such as Clean Development Mechanism (CDM) pipeline, Berkeley's Offsets database and Institute for Global Environmental Strategies CDM project database for its picklist options The picklist options of the "unit type" data do not reflect all the types of units. This data category will need to be revisited as the market keeps evolving The picklist options of the "methodology" data field should include the version number of the specific methodology as these are constantly evolving
New data fields	Geographic information system data should be added to the Climate Warehouse data model to enable data to be mapped spatially A new data field should be created for users to note cooperative approaches A new data field should be created for users to note how they plan to use the carbon credit (e.g. offset or contribution claim)
Data harmonization	The Climate Warehouse should introduce more data validation rules and picklist options in data fields to encourage greater data standardization and harmonization (e.g. project locations and project sectors)
Definitions	The Climate Warehouse should provide clearer definitions for certain data fields and picklist options. Participants specifically requested clearer definitions for the "project status", "unit status", "rating type", "rating value", "label", "label type", "unit type", "verification approach", "country jurisdiction of owner", "corresponding adjustment declaration", "project status date", "NDC information", and "unit metric" data fields

TABLE 8: Summarized feedback on the data model (continued)

CATEGORY	PARTICIPANT FEEDBACK
Highlights	The data model is comprehensive and demonstrates the progress from three years of testing
	The data model has a clear taxonomy and is sufficiently comprehensive considering that carbon market rules and consensus are evolving in parallel
	The data harmonization that the Climate Warehouse has the potential to achieve will make a significant contribution to carbon markets
	The Climate Warehouse is well advanced in navigating the complexity of getting to a shared data model

USER INTERFACE

Feedback on the Climate Warehouse user interface was primarily collected from the 68 testers who completed the user interface testing area. These testers received a demonstration of the interface's key features; created an organization, projects, and units; and simulated a unit lifecycle by editing created project and unit data. Participants' feedback on the user interface fell into one of four categories: additional features, user experience, troubleshooting, and highlights.

Based on their experiences with testing the user interface, participants suggested a wide range of additional features that would help enhance its functionalities. These suggestions ranged from very detailed suggestions, such as to add scroll bars to long picklists, to more global suggestions, such as to build a glossary page that includes definitions for all data fields and picklist options.

Similarly, participants shared a wide variety of suggestions to optimize the user experience, ranging from alphabetizing long picklist options to streamlining the steps to create a project and a unit. Extensive testing also helped identify and troubleshoot multiple bugs, such as malfunctioning of the "date selector" feature and users not being able to upload their organization logos.

Overall, 69 percent of feedback survey respondents who tested the user interface indicated that the Climate Warehouse user interface met their expectations, 15 percent indicated that it did not meet their expectations, and 15 percent indicated that it exceeded their expectations (see Figure 17). Multiple participants highlighted that the user interface is user-friendly and seamless, and some indicated that they would like to see improvements to the user experience in the operational version. Table 9 summarizes participants' feedback on the user interface.

FIGURE 17: User interface satisfaction levels

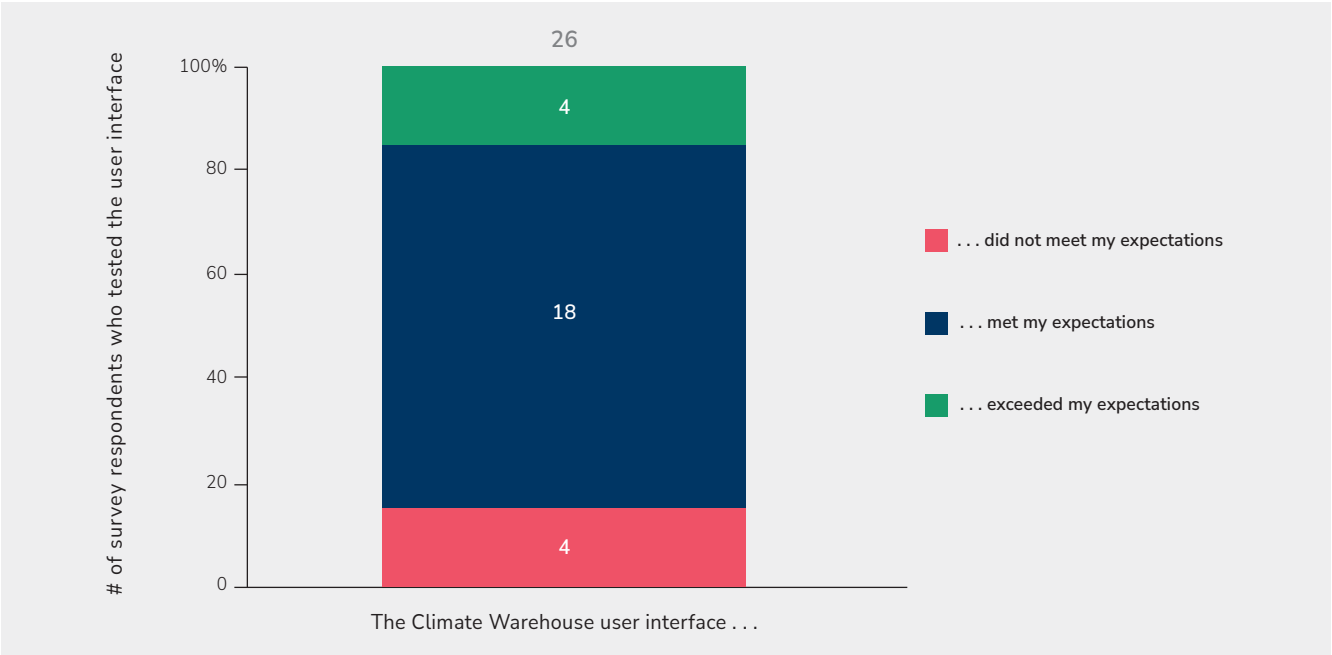


TABLE 9: Summarized feedback on the user interface

CATEGORY	PARTICIPANT FEEDBACK
Additional features	Add a dynamic search function that enables users to filter long picklists by typing
	Add a glossary page to which users can refer for the definitions of data fields and picklist options
	Add a confirmation notification to inform users that their updates have been saved
	Enable users to input more than one location for a single project
	Add a scroll bar feature to help users navigate long picklists
	Enable users to split units into more than two blocks
	Add an ability for users to merge units
	Add more sorting and filtering options to enhance the user experience
	Add a capability to facilitate carbon unit transactions between registries and track each unit's "paper trail"
	Allow users to customize the "projects list" and "units list" tables
	Add a global dashboard that enables users to easily view key metrics (e.g. total quantity of emissions mitigated)
	Enable more than one user to access the same instance of the Climate Warehouse
User experience	Make it optional for users to submit a logo when creating their organization
	Streamline the order of forms when creating a project or a unit and allow users to complete each form in any order
	Introduce an easier way to exit from drop-down lists (e.g. add an "X" to exit)
	Improve the linkages among projects, issuances, and units
	Improve tooltips to help users better navigate the user interface
	Alphabetize picklist options, especially in data fields with long picklists
	Enable users to edit project and unit data directly from the staging tables
	Save inputted data automatically so that users can exit the project and unit creation windows without losing their data
	Convert dates to international date format
Troubleshooting	Multiple users struggled to create their organization logos in scalable vector graphics format
	Some users were only able to create projects after they had cleared their browser caches
	Some users encountered an error when unsubscribing from organizations
	The "date selector" feature did not function properly for multiple users
Highlights	The user interface is easy to use and has basic functionality
	The user interface is user-friendly and reflects a focus on optimizing the user experience
	The user interface allows flexible data entry

API

Feedback on the Climate Warehouse's API feature was primarily collected from the seven testers who completed the API testing area. These testers examined the Climate Warehouse's API feature by calling various API endpoints from API platform tools like Postman and were able to improve their understanding of how to build a middleware integration between their local registry systems and the Climate Warehouse.

Although there was a relatively lower number of testers who had the technical expertise to interact with Climate Warehouse APIs using API tools, it should be noted that the design of the Climate Warehouse is such that the user interface is a static electron application that makes calls to specific APIs. This means that the 68 testers who completed the user interface testing area also indirectly tested the Climate Warehouse's API feature on the back-end, while the seven testers who completed the API testing area specifically tested the ability for the Climate Warehouse's API endpoints to be called by API tools.

TABLE 10: Summarized feedback on the API feature

CATEGORY	PARTICIPANT FEEDBACK
Additional features	Create an option for users to publish only a subset of projects and units When users insert units with issuances that do not yet exist, automatically and instantaneously generate an update to the relevant project to add the necessary issuance Enable users to submit "null" values through the API Add more API endpoints to enable users to access the audit feature and their home organization
User experience	Provide the warehouse project identification number when publishing a new project or new unit Provide a more detailed response for "insert validation" failures indicating the type of failure and the specific fields that failed validation Do not change API keys from the testing phase when the Climate Warehouse is operationalized
Troubleshooting	In some cases, calling API endpoints from participants' local applications led to "503 service not available" errors Participants experienced occasional network errors when back-end services were not running
Documentation	Provide a list of ports that need to be open for incoming and outgoing requests. In addition, provide details on their protocols Update the API-related documentation on the Climate Warehouse's GitHub repository
Highlights	The API is a critical feature since it enables automated integration with the Climate Warehouse The API is a necessary alternative to the user interface for integration with the operational Climate Warehouse, to avoid manual and onerous data input through the user interface

Participants' feedback on the API feature fell into one of five categories: additional features, user experience, troubleshooting, documentation, and highlights.

Participants who tested the Climate Warehouse's API identified multiple additional features that would help enhance participating organizations' automated integration with the Climate Warehouse. Many of these suggestions included requests for the Climate Warehouse to add specific endpoints (e.g. to access the audit feature), which would improve the system's accessibility. Furthermore, testers noted that it would be helpful if they could submit "null" values through the APIs and had an option to publish only a subset of project and unit data.

In terms of the user experience, participants' suggestions included adding further detail to error responses when data uploads fail. Troubleshooting was limited to a few instances when participants were unable to connect to the Climate Warehouse API endpoints and experienced network errors. Finally, participants requested updates to the API-related documentation on the Climate Warehouse's GitHub repository, including further details on the data ports that need to be open for incoming and outgoing requests.

Overall, all five feedback survey respondents who tested the API feature indicated that it met their expectations. Multiple participants highlighted the critical importance of the API feature as an automated alternative to the user interface's relatively manual data input process. Table 10 summarizes participants' feedback on the API feature.

EXCEL IMPORT/EXPORT

Feedback on the Climate Warehouse's Excel import/export feature was primarily collected from the 11 participants who completed the Excel import/export testing area. These testers mapped their own organization's data fields to the Climate Warehouse's data fields, populated the Excel upload template with sample registry data, published the populated sample data using the Excel import feature, edited published data using the Excel upload template, and exported published data in Excel format. Participants' feedback on the Excel import/export feature fell into one of three categories: user experience, troubleshooting, and highlights.

Regarding the user experience, participants suggested that the Excel upload template should be more easily accessible on the user interface and that any displayed error messages should be displayed for longer and logged. Participants also proposed specific improvements to the Excel upload template itself, including a request to add more automatic references to help avoid repetitive user input.

Participants' troubleshooting experiences with the Excel import/export feature helped identify multiple development actions on the feature's initial release. This led to an updated release of the feature, which successfully enabled participants to publish registry data to the Climate Warehouse in bulk. Participants continued to help identify improvements to the back-end system of the updated release (e.g. data inputs should not be required in optional fields).

Overall, 83 percent of feedback survey respondents who tested the Excel import/export feature indicated that the Climate Warehouse user interface met their expectations, while 17 percent indicated that it exceeded their expectations (see Figure 18). Multiple testers highlighted the importance of the Excel import/export feature to enable users to publish data to the Climate Warehouse in bulk. Table 11 summarizes participants' feedback on the Excel import/export feature.

FIGURE 18: Excel import/export satisfaction levels

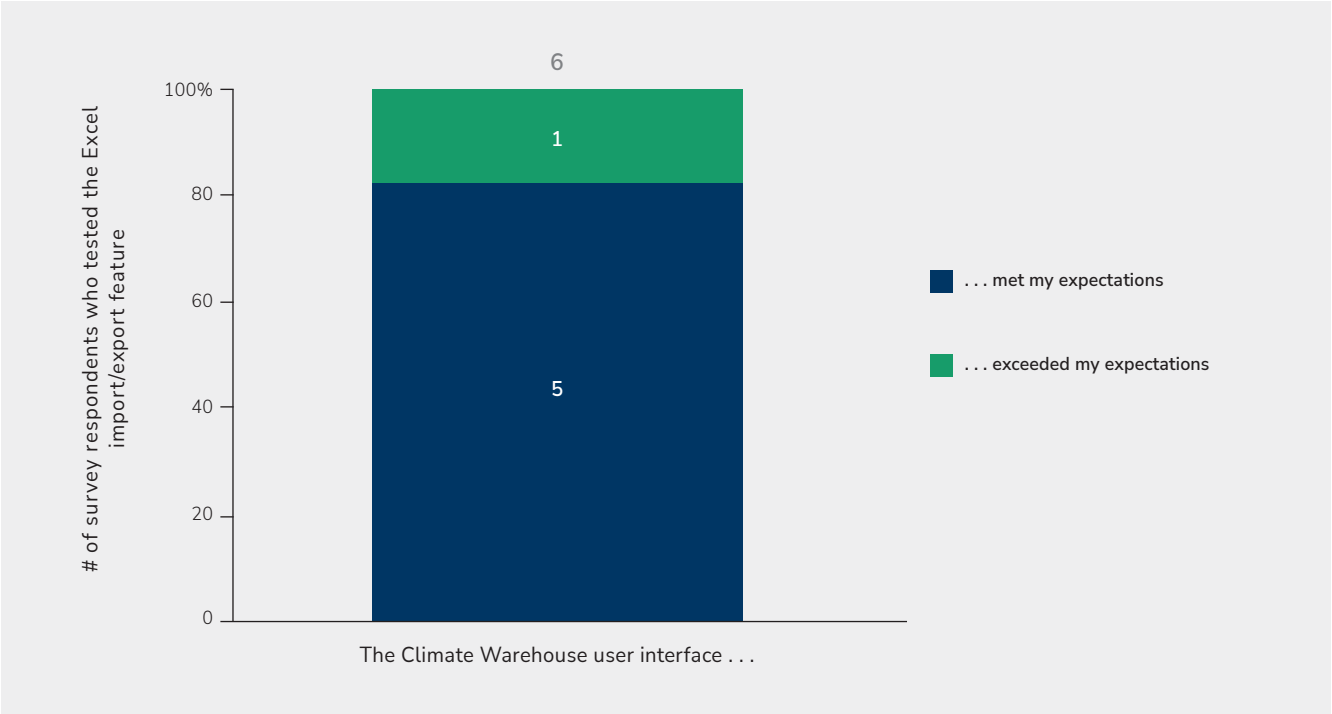


TABLE 11: Summarized feedback on the Excel import/export feature

CATEGORY	PARTICIPANT FEEDBACK
User experience	The Excel template for uploading data should be easier to access on the user interface The error messages that are displayed in the user interface should be displayed for longer Users should be able to access a record of past error messages Add automatic references in the Excel template to avoid repetitive user input
Troubleshooting	Multiple participants were unable to upload data to the Climate Warehouse using the Excel import/export feature in the initial release of the Simulation III prototype Bugs in the back-end system treated the asterisks in the Excel upload template as invalid data inputs and required optional fields to include data inputs In some instances, the Excel export feature did not export the latest data that was previously uploaded by the user
Highlights	The Excel import/export feature was easy to use and useful for publishing and editing a large quantity of data at once

TECHNICAL ARCHITECTURE

Multiple participants provided feedback on the Climate Warehouse's overall technical architecture as they completed their respective testing areas and identified system-level feedback on the Climate Warehouse. Participants' feedback on the technical architecture fell into one of three categories: technical requirements, deployment, and documentation.

Regarding the technical requirements, participants' feedback included requests that the Climate Warehouse's transaction fees remain affordable and that users are able to host blockchain nodes from a wide range of computers. Participants also suggested that the Climate Warehouse should be compatible with a range of cloud service providers and that multiple users should be able to access a single hosted instance.

Most points of feedback on the technical architecture were requests for documentation that further clarifies key elements of the technical architecture (e.g. long-term transaction fee projections, a comprehensive threat model, or a detailed user manual). Table 12 summarizes participants' feedback on the Climate Warehouse's technical architecture.

TABLE 12: Summarized feedback on the Climate Warehouse's technical architecture

CATEGORY	PARTICIPANT FEEDBACK
Technical requirements	Transaction fees to publish data to the Climate Warehouse should remain affordable and not disincentivize data updates Users should be able to host a blockchain node in a Linux box (e.g. Red Hat Linux)
Deployment	The Climate Warehouse should be compatible with other cloud service providers (e.g. Microsoft Azure Kubernetes Service) Enable multiple users to access the same hosted instance of the Climate Warehouse
Documentation	Provide further guidance on how and why participants need to hold and transact in cryptocurrencies to publish data to the Climate Warehouse Provide guidance on the expected long-term trends of the Climate Warehouse transaction fees Provide a comprehensive threat model that shares guidance on the security considerations for participating in the Climate Warehouse Outline the specific technical requirements that participants will need to meet when the operational Climate Warehouse is launched Clarify further how the Climate Warehouse stores data in its blockchain layer Provide further guidance on how the Climate Warehouse's governance node interacts with the blockchain nodes that are hosted by Climate Warehouse participants Provide further guidance on how the Climate Warehouse can help detect instances of double counting and facilitate carbon unit transfers Provide a detailed user manual that participants can refer to

GOVERNANCE

Participants provided feedback on the governance of the Climate Warehouse as they completed their testing areas and identified aspects of the Climate Warehouse that will be particularly critical for the governing body to coordinate. Participants' feedback on governance fell into one of three categories: governance protocols, operational support, and documentation.

Participants identified multiple governance protocols that the governing body of the Climate Warehouse will need to develop and implement to optimize the functionality of the Climate Warehouse. These protocols included standardizing the timelines of participants' data updates, optimizing the Climate Warehouse's data validations, and managing the governance node's list of known organizations.

Participants also provided multiple suggestions for how the governing body can optimize the operational support that it provides to Climate Warehouse participants (e.g. provide online technical support through a live chat feature). Multiple participants that did not have carbon registries also requested additional operational support to help build a carbon registry and enable their integration with the Climate Warehouse. Finally, participants requested documentation that further clarifies how participating organizations are expected to meet the Climate Warehouse's transaction fee requirements. Table 13 summarizes participants' feedback on the governance of the Climate Warehouse.

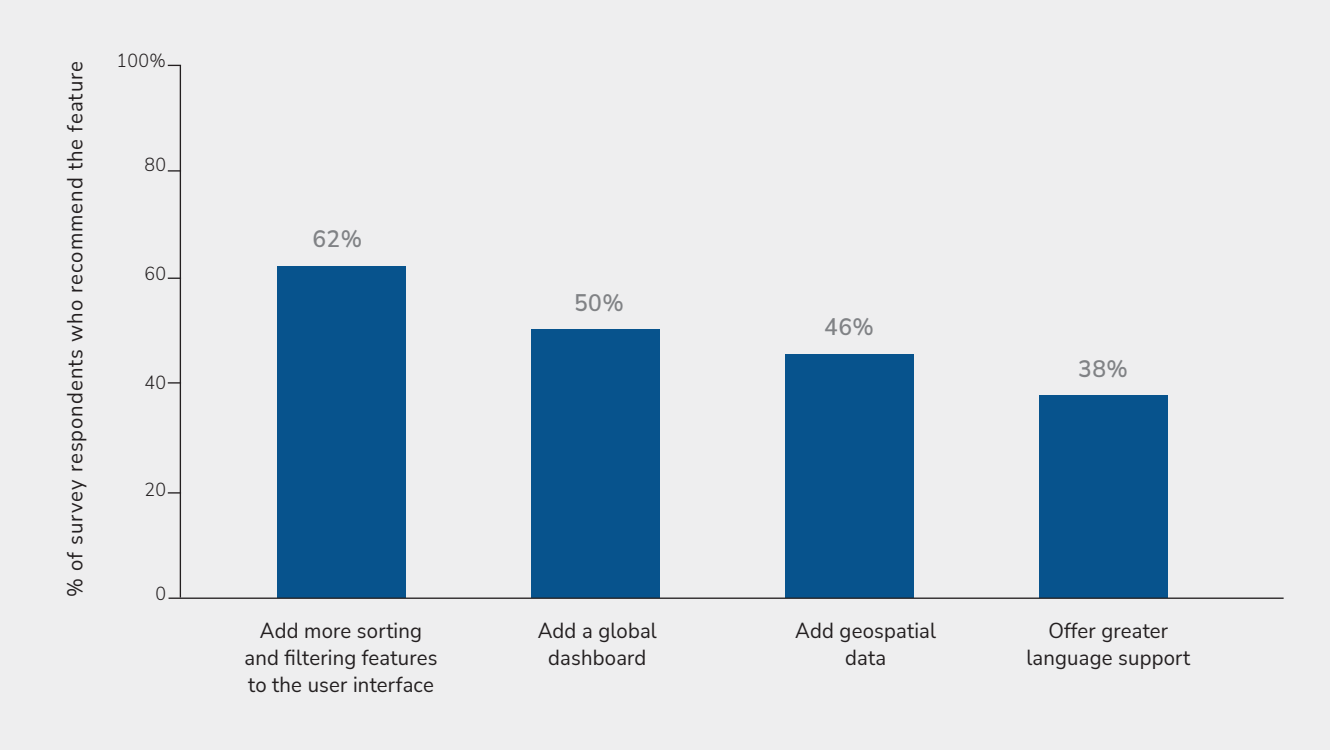
TABLE 13: Summarized feedback on the governance of the Climate Warehouse

CATEGORY	PARTICIPANT FEEDBACK
Governance protocols	Introduce a standard protocol for the timeline and frequency of data updates among participating organizations to mitigate the "staleness" of registry data in the Climate Warehouse Provide guidance on how participants are expected to reflect ITMO transfers in the Climate Warehouse (e.g., coordination between unit-sending and unit-receiving registries) Review and optimize the Climate Warehouse's data validation protocols to maximize data accuracy while ensuring sufficient flexibility and autonomy Develop and implement a protocol for how the governing body will maintain the governance node's public list of known organizations
Operational support	Provide hands-on technical support (e.g., online technical support through a live chat feature) when the Climate Warehouse is operationalized Provide detailed guidance on operational requirements for participating organizations (e.g. the expected operating costs of integrating with the Climate Warehouse) Provide additional operational support to help build a carbon registry and enable integration with the Climate Warehouse Provide new participants with tutorial recordings to facilitate the onboarding process
Documentation	Share guidance on how participants are expected to meet the Climate Warehouse's transaction fee requirements

RECOMMENDED ADDITIONAL FEATURES

In the feedback survey, respondents were asked to select additional features that they would recommend for the operational Climate Warehouse. Respondents were provided with four additional features to consider: add geospatial data, add a global dashboard, add more sorting and filtering features to the user interface, and offer greater language support. Figure 19 displays the percentage of survey respondents who recommended each additional feature.

FIGURE 19: Additional features recommended



PERSPECTIVES ON BLOCKCHAIN TECHNOLOGY

The feedback survey also solicited participants' perspectives on the Climate Warehouse's use of blockchain technology. Specifically, respondents were asked to indicate the extent to which they agree or disagree with three statements regarding the Climate Warehouse's use of blockchain technology:

- **Statement 1:** Blockchain technology improves security and enables registry autonomy while assuring trust for shared climate registry metadata.
- **Statement 2:** Carbon market data layers should be public, with permissionable data edit functionality, and operate under a decentralized governance system.
- **Statement 3:** The specific blockchain technology used for the Climate Warehouse matters a lot.

Figure 20 displays survey respondents' levels of agreement with each statement.

FIGURE 20: Perspectives on blockchain technology

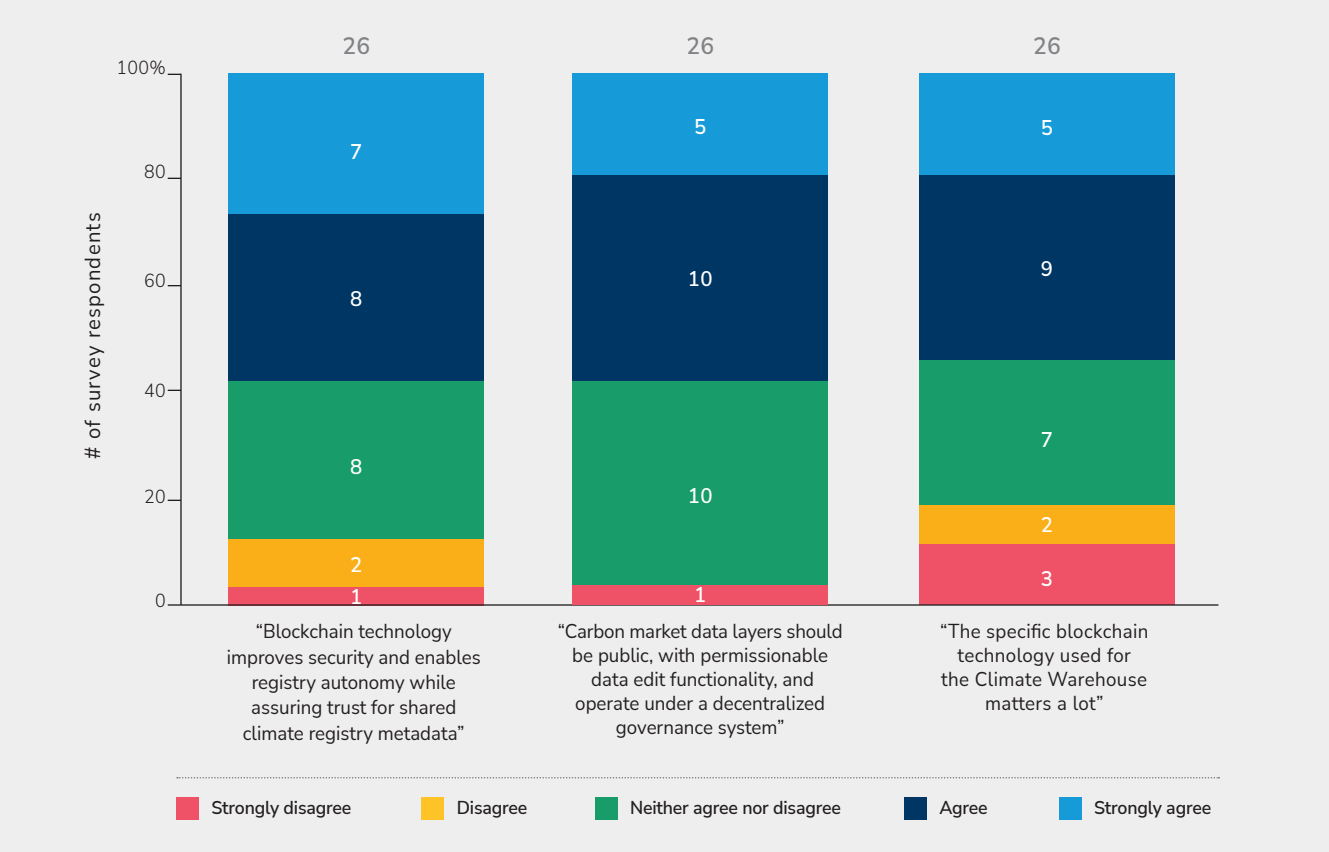


Table 14 summarizes participants' commentary on their levels of agreement with statement 1: Blockchain technology improves security and enables registry autonomy while assuring trust for shared climate registry metadata.

TABLE 14: Summarized commentary on participants' agreement with blockchain statement 1

AGREEMENT LEVEL	PARTICIPANT COMMENTARY
Strongly agree or agree	The Climate Warehouse's use of blockchain technology is an ideal fit for the bottom-up approach of the Paris Agreement Blockchain technology enhances the traceability and transparency of carbon market data To ensure the transparency of carbon credits, blockchain technology must be used to record transactions
Neither agree nor disagree	It is critical for blockchain technology to be used to facilitate transactions between registries It would be helpful to better understand how the use of blockchain technology improves on a centrally managed system Blockchain has multiple applications and can help support security and transparency if designed with a holistic approach
Disagree or strongly disagree	It is better to directly apply blockchain technology to registry systems, rather than to the metadata layer

Table 15 summarizes participants' commentary on their levels of agreement with statement 2: Carbon market data layers should be public, with permissionable data edit functionality, and operate under a decentralized governance system.

TABLE 15: Summarized commentary on participants' agreement with blockchain statement 2

AGREEMENT LEVEL	PARTICIPANT COMMENTARY
Strongly agree or agree	Blockchain technology will help improve transparency and interoperability in carbon markets Publicly auditable data will be critical to enable interoperability among different carbon frameworks The governing body of the Climate Warehouse will need to ensure that the Climate Warehouse complies with existing legal frameworks and produces actionable data for the service layer
Neither agree nor disagree	The Climate Warehouse will need to ensure that it strikes the right balance between efficiency and complexity to maximize adoption Although participants should be able to edit their own data, there should also be a decentralized mechanism for all users to flag data discrepancies, augmented by web-crawling or artificial intelligence, and a centralized team to resolve or confirm any changes. This will be critical to ensure that stakeholders can trust the Climate Warehouse as a credible and accurate source of registry data
Disagree or strongly disagree	Decentralized systems add complexity and are not suitable for a metadata layer that connects climate registries that are not anonymous

Table 16 summarizes participants' commentary on their levels of agreement with statement 3: The specific blockchain technology used for the Climate Warehouse matters a lot.

TABLE 16: Summarized commentary on participants' agreement with blockchain statement 3

AGREEMENT LEVEL	PARTICIPANT COMMENTARY
Strongly agree or agree	The blockchain technology provider must be responsive, reliable, and willing to support the Climate Warehouse on a public good and open-source basis The technology should be future-proof, environmentally sustainable, and secure The environmental impact and security considerations of the blockchain technology matter a lot It is important to adopt a technology that preserves the integrity and utility of the Climate Warehouse's carbon metadata. There should be safeguards in place to ensure that there are no loopholes, caused by the blockchain technology, that undermine the accuracy and transparency of the Climate Warehouse's data management
Neither agree nor disagree	The specific technology is not very important as long as it enables interoperability and is environmentally sustainable The specific technology matters to the extent that it is accessible and can be installed quickly
Disagree or strongly disagree	The differentiation among alternative blockchain technologies is limited The specific technology does not matter as long as it does not introduce any critical risks to the system

07 Lessons Learned

OVERVIEW

Based on internal testing and the 514 points of feedback received from participants during Simulation III, the testing and simulation team identified 156 development actions, which were added to the action items tracker. The team considered each action through its structured prototype development decision-making process, allocated a timeline for completion ("short-term", "before end of Sim III", or "suggestion to operational entity"), and tracked the status of each action to completion, as explained in Section 4.

Among the 156 development actions that were identified in Simulation III, 114 were categorized as "short-term", 25 were categorized as "before end of Sim III", and 17 were categorized as "suggestion to operational entity". All development actions that were categorized as "short-term" or "before end of Sim III" were completed by the end of Simulation III. The development actions that were categorized as "suggestions to operational entity" were logged in the final version of the action items tracker, which was shared with the governing body of the operational Climate Warehouse at the end of Simulation III.

This section first summarizes the lessons and development actions that were identified from participant feedback in each of the 11 feedback categories that were presented in section 6: overall highlights and learnings, overall satisfaction, installation, data model, user interface, API, Excel import/export, technical architecture, governance, recommended additional features, and perspectives on blockchain technology. This section then summarizes Simulation III's limitations and details the testing and simulation team's recommendations for the new governing body.

OVERALL HIGHLIGHTS AND LEARNINGS

Participants' overall highlights and learnings, which they shared in their feedback survey responses, helped identify specific aspects of the Climate Warehouse that are particularly compelling for participants. Participants' overall highlights helped show that participants view the Climate Warehouse's efforts to proactively engage diverse stakeholders, integrate the carbon market ecosystem under a common data model, and contribute to the implementation of Article 6 as the most critical aspects of the Climate Warehouse's value proposition.

Furthermore, participants' overall learnings confirmed the importance of the Climate Warehouse's iterative and multistakeholder approach, based on multiple participants' responses that participating in Simulation III enhanced their understanding of registry data harmonization and capacities to integrate with the Climate Warehouse.

Going forward, it will be critical for the new governing body to ensure that the Climate Warehouse maintains the aspects of its value proposition that are most important to participants and that the Climate Warehouse continues to follow an iterative and multistakeholder approach.

OVERALL SATISFACTION

Participants' overall satisfaction levels on the documentation and technical support that they received during Simulation III and their likelihoods of integrating with the Climate Warehouse based on their experience, which they shared in their feedback survey responses, helped identify key lessons that inform the new governing entity's efforts to provide operational support and expand the number of participants.

All survey respondents indicated that the documentation that they received during Simulation III met or exceeded their expectations, particularly highlighting the documentation's modular and self-explanatory design. This suggests that the current documentation sufficiently meets participants' needs and that the new governing body should continue to design additional documentation in a similar manner.

Participants' satisfaction levels with the technical support that they received during Simulation III were even higher than their satisfaction levels with the documentation, with 69 percent of participants indicating that the technical support exceeded their expectations. Participants' commentary suggests that the new governing body should continue to provide responsive, hands-on, and knowledgeable technical support to maintain participants' levels of satisfaction.

In terms of participants' likelihoods of integrating with the Climate Warehouse, 50 percent of survey respondents indicated that they are likely or very likely to integrate, suggesting that a majority of participants are in favor of integration with the operational Climate Warehouse. On the other hand, 35 percent of respondents indicated that they are neither likely nor unlikely to integrate and 15 percent indicated that they are unlikely or very unlikely, with both groups most commonly noting as their rationale the need to involve more internal stakeholders before making a decision. As such, it will be critical for the new governing body to facilitate consensus building within organizations that are considering integration with the Climate Warehouse in order to successfully expand the number of participating organizations.

INSTALLATION

The 21 testers who completed the installation testing area were able to successfully install the Climate Warehouse software and sync their blockchain nodes with the blockchain layer, confirming that participants who meet the Climate Warehouse's technical requirements can host a blockchain node and participate in the Climate Warehouse. Furthermore, most of the feedback survey respondents who tested the installation process noted that it met or exceeded their expectations, indicating that Simulation III participants were generally satisfied with the Climate Warehouse's installation process.

Most testers were able to complete the installation process within the standard two-to-three-week period, while a subset of testers experienced delays due to a variety of factors including the Climate Warehouse's current 100GB hard disk requirement, restrictive local IT security and legal requirements, and slow internet speeds. As such, a key learning on the installation process was that new Climate Warehouse participants need to be provided with ample time and operational support (e.g. through recorded tutorials and online support) to navigate the installation steps, attain any required security and legal approvals, sync their blockchain nodes, and complete their integration with the Climate Warehouse. In addition, participants will need further information and guidance on how to manage the current 100GB hard disk requirement, which is likely to increase as more data is uploaded in the Climate Warehouse. Furthermore, as a larger number of participants complete the installation process and provide feedback, it will be important for the governing body to regularly revisit the installation process and implement updates that further simplify the process.

Development actions on the installation process that were identified from participant feedback and completed during Simulation III focused primarily on updating and maintaining documentation on the installation process, as well as actions that addressed a handful of troubleshooting cases (e.g. solving a bug in the back-end system that prevented one user from connecting to the Climate Warehouse metadata layer).

DATA MODEL

Most Simulation III participants provided substantial feedback on the Climate Warehouse data model that confirmed the critical importance of the Climate Warehouse's effort to establish a common carbon data taxonomy, especially in the context of continuously evolving carbon market terminologies and definitions. Most participants were satisfied with the Climate Warehouse data model, as shown by the finding that over 80 percent of feedback survey respondents indicated that the data model met or exceeded their expectations.

Most points of feedback on the data model led to incremental improvements (e.g. converting data fields from required to optional fields, streamlining picklist options, clarifying definitions, or converting free text data fields to "select from picklist" fields), rather than fundamental revisions (e.g. adding or removing data fields). This validated the progress that was made on the data model during simulations I and II and demonstrated that the Climate Warehouse is progressing towards an operational data model that meets the needs of carbon market stakeholders.

Going forward, it will be critical for the new governing body to continue refining the Climate Warehouse data model, especially as new participants provide additional feedback and carbon market terminologies evolve. When implementing updates to the data model, it will be important for the governing body to leverage a multistakeholder approach that reconciles any points of disagreement (e.g. the data contained in certain fields may be confidential for some registries and public for others) and ensures that updates reflect consensus among carbon market stakeholders.

Future data model updates will also need to strike an optimal balance between data harmonization and flexibility. This tradeoff was illustrated through requests from multiple participants to convert free text fields to "select from picklist option" fields while also allowing users to add new picklist options if the existing options do not meet their needs. For such "select from picklist option or add a new option" data fields, the governance body will need to implement a standard protocol to regularly review new picklist options that are introduced by participants and decide whether they should be added to the standard list that is supplied by the governance node.

Table 17 summarizes the development actions on the data model that were identified and completed during Simulation III. In addition, Figure 21 visualizes the updates made to the initial data model at the start of Simulation III and Figure 22 visualizes the updated data model at the end of the simulation.

TABLE 17: Summary of completed data model development actions

CATEGORY	COMPLETED DEVELOPMENT ACTION
Data field modifications	Converted the "unit owner" data field from a required to an optional field, based on multiple participants' feedback that the unit owner is often confidential information that cannot be shared publicly Converted the "registry of origin", "current registry", "validation body", "project tags", "unit tags", and "co-benefit" data fields from free text fields to "select from picklist options or add a new option" fields Modified the "methodology" and "project type" data fields to allow users to add new picklist options Converted the "unit count" data field from a system-generated field to a user-input field Modified the "methodology" data field to allow users to add up to two methodologies for a single project
New data fields	Created an optional "project description" data field to enable users to add descriptive details regarding each project (e.g. how the project is differentiated from other projects)
Picklist options	The picklist options of the "project sector" data field were updated to align with the International Standard Industrial Classification of All Economic Activities The "project type" data field was updated with the option "REDD+" as a prefix to the "reduced emissions from deforestation and degradation" picklist option The picklist options of the "current registry" and "registry of origin" data fields were updated with the following changes: Replaced the "Japan national registry" picklist option with "Joint Crediting Mechanism", and added "CDM registry", "Article 6.4 mechanism registry", and "Article 6.2 mechanism registry" as new picklist options The "methodology" data field was updated to include the Joint Crediting Mechanism and Gold Standard methodologies to the picklist options The picklist options of the "unit status" data field were updated with the following changes: Removed "for sale" and "purchased" from picklist options, updated "transferred" to "exported" and "pending transfer" to "pending export", and added "imported" as a new picklist option The "country" data field includes "Chile" and "Saudi Arabia" as new picklist options The "project status" data field includes "validated", "approved", "authorized", "withdrawn", and "de-registered" as new picklist options The "label type" data field includes "letter of authorization" and "letter of approval" as new picklist options
Documentation	Updated the slides visualizing the Climate Warehouse data model and the Excel data dictionary to reflect the latest updates based on participant feedback Revised definitions in the Excel data dictionary for data fields that participants noted were unclear (e.g. the "label" and "verification approach" data fields) Added definitions for each picklist option to the data dictionary

FIGURE 21: Updates to the Simulation III data model

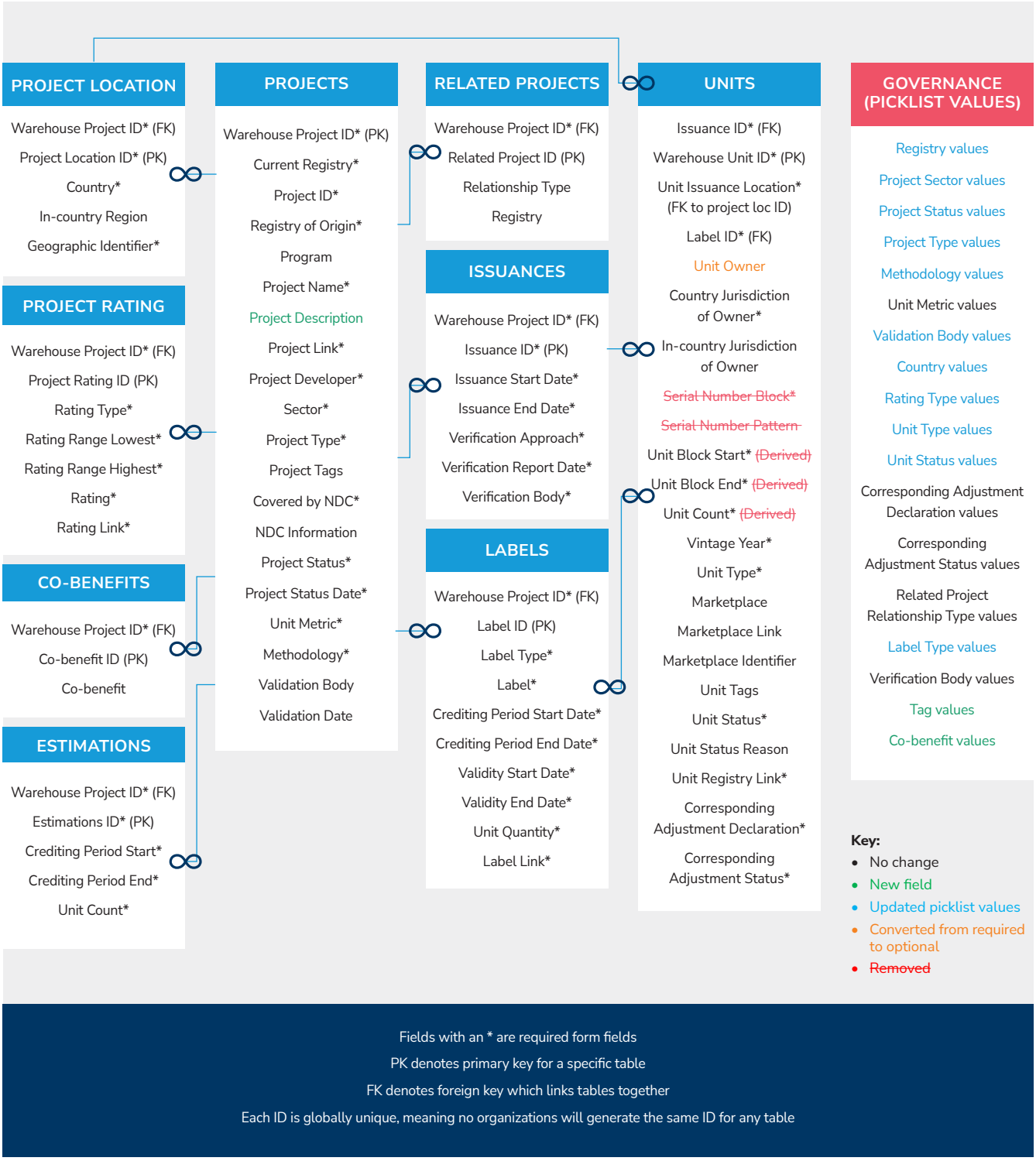
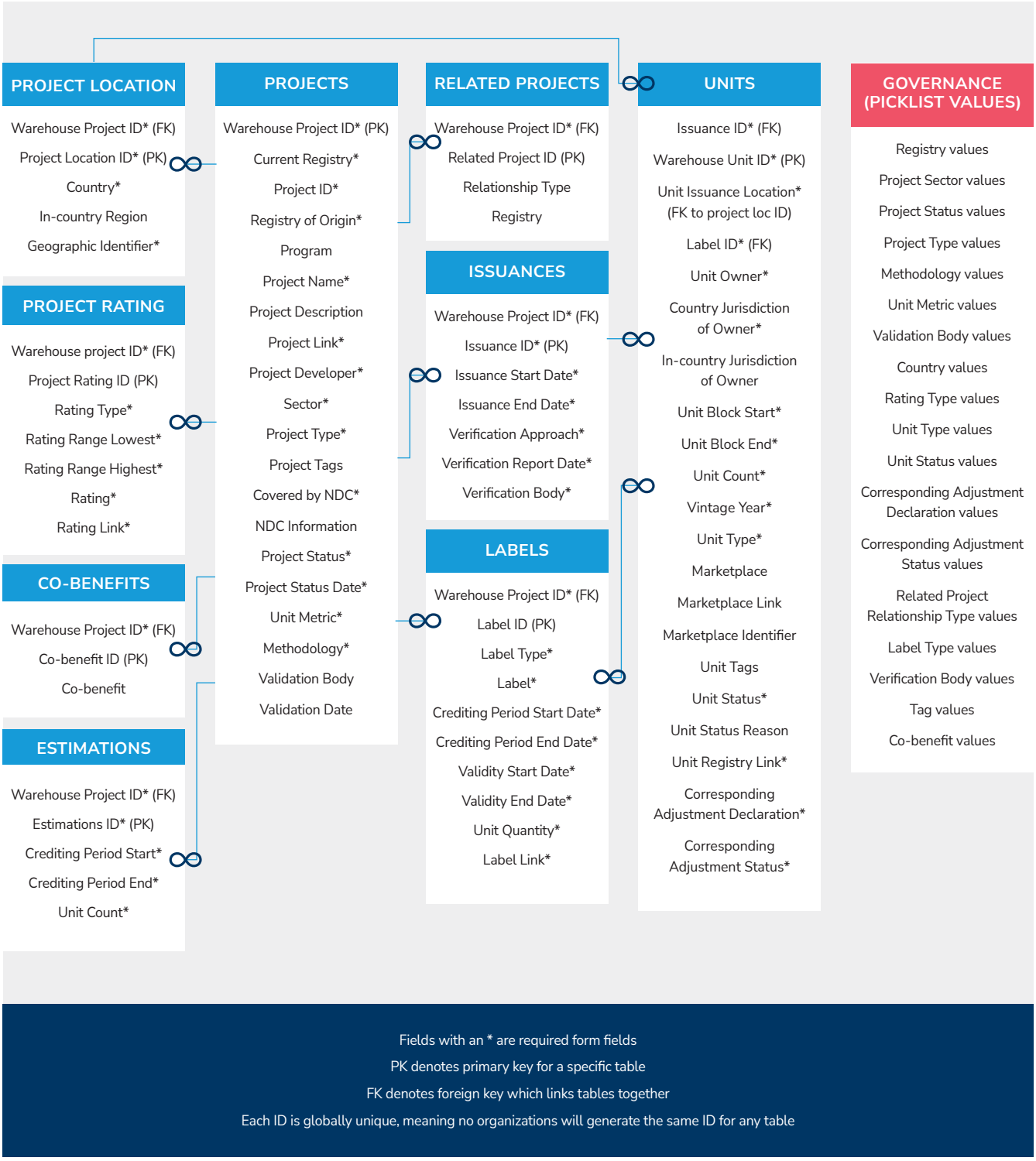


FIGURE 22: Updated Simulation III data model



USER INTERFACE

Most of the 68 testers who completed the user interface testing area created their organization and published data through the user interface, which demonstrated that the user interface successfully enables users to integrate with the Climate Warehouse. Although these testers shared multiple suggestions to further enhance the user interface, most survey respondents noted that the user interface met or exceeded their expectations, indicating that participants were generally satisfied with the user interface.

As explained in Section 6, participants' requests for additional features and improvements to the user experience ranged widely. Nevertheless, most of the feedback points related to making the user interface as self-explanatory as possible (e.g. by adding screenshots to the instructions), clarifying definitions (e.g. by adding a glossary page), making the data entry process as efficient as possible (e.g. by allowing users to search for picklist options rather than scroll through long lists), and adding features that enhance the utility of the user interface (e.g. by adding an audit section). Going forward, any efforts to further enhance the user interface should focus on these four aspects, which were most commonly requested by Simulation III participants.

Table 18 summarizes the development actions on the user interface that were identified and completed during Simulation III.

TABLE 18: Summary of completed user interface development actions

CATEGORY	COMPLETED DEVELOPMENT ACTION
Additional feature	Added a read-only mode to enable observer nodes to view the Climate Warehouse's metadata without being able to edit
	Added an organization subscription feature to enable users to easily select which organizations they subscribe to
	Added a dynamic search function that enables users to filter long picklists by typing
	Added an audit section to the user interface, where users can select an organization and view all updates made by the selected organization
	Added a glossary page including definitions for data fields and picklist options
	Added a function for users to note comments when they publish new data to the Climate Warehouse
User experience	Enabled users to submit organization logos in portable network graphics format and made the logo submission optional to make it easier for users to create their organizations
	Enabled users to edit staged data without having to delete and recreate
	Converted date format data fields from United States date format to international date format
	Updated the workflows in the user interface to directly tie units to their related issuances and projects
	Updated the sorting order of picklist options to alphabetical order, where appropriate
	Consolidated the "my organization" and "registry" sections under a single "my registry" section and added a new "my files" subsection
	Implemented multiple visual updates, which included adding color shading to rows in tables, increasing the space between data fields, and removing infrequently referenced columns from the data tables
Trouble-shooting	Updated the full text search function to search across all relevant pages
	Removed overlaps between long text entries in adjacent data fields
	Fixed the language selector tool and date picker feature
	Corrected the displayed locations of the "country jurisdiction of owner" and "in-country jurisdiction of owner" data fields
	Solved errors experienced by users when unsubscribing from organizations and clicking "create project"
	Added an easier way for users to exit from drop-down lists

API

Each of the participants that completed the API testing area were able to successfully interact with the Climate Warehouse APIs from their API platform tools, demonstrating that the Climate Warehouse's API feature enables automated integration. Furthermore, all five survey respondents who tested the API feature noted that it met their expectations, indicating that testers with sufficient API expertise were generally satisfied with the Climate Warehouse's API feature.

A key overall lesson learned from participants' experiences with testing the API feature is that building a middleware integration will require an IT counterpart within the participating organization to undergo an iterative process of mapping their local system to the Climate Warehouse APIs. As such, it will be critical for the new governing body to ensure that new participants have sufficient time and capacity to build their automated integration with the Climate Warehouse.

In terms of development actions, the testing and simulation team implemented multiple improvements to the API feature based on participant feedback, including adding new features (e.g. added multiple API endpoints to enable a wider range of actions) and optimizing the user experience (e.g. added a more detailed response for "insert validation" failures). Table 19 summarizes the development actions on the API feature that were identified and completed during Simulation III.

TABLE 19: Summary of completed API development actions

CATEGORY	COMPLETED DEVELOPMENT ACTION
Additional features	Added multiple API endpoints to enable a variety of actions, including subscribing to organizations, unsubscribing from organizations, and resetting users' home organizations
	Created an option for users to only publish a subset of projects and units
	Added a function for users to note comments when they commit new data to the Climate Warehouse
	Enabled users to submit "null" values through the API
User experience	Updated the API feature to provide the warehouse project identification number when staging a new project or new unit
	Removed repetitive steps in the project data update process
	Added a more detailed response for "insert validation" failures, indicating the type of failure and the specific fields that failed validation
Troubleshooting	Fixed a bug that was incorrectly allowing users to submit any inputs for the "sector" data field
Documentation	Updated all API-related documentation on the Climate Warehouse's GitHub repository
	Added API examples to the Climate Warehouse's GitHub repository to help guide users on how to format and push data using APIs

EXCEL IMPORT/EXPORT

All 11 testers who completed the Excel import/export testing area were able to successfully publish bulk volumes of registry data to the Climate Warehouse using the Excel import/export feature, demonstrating the feature's ability to enable users to add or edit more than one data record at once. Furthermore, all six survey respondents who tested the Excel import/export feature noted that it met or exceeded their expectations, indicating that participants were generally satisfied with this feature.

A key lesson learned from participants' experiences with testing the Excel import/export feature was that, although the feature enables users to publish data to the Climate Warehouse more efficiently than inputting data manually on the user interface, the process to populate the Excel upload template with registry data can be time-consuming, especially if the data is not readily available in a format that is easily transferrable to the Excel upload template. As such, it will be important for the new governing body to provide participants with specific support to help optimize and automate the ways in which they populate the Excel upload template with local registry data.

Most development actions on the Excel import/export feature that were completed during Simulation III were related to improving the feature's initial release in order to launch an updated version that successfully enabled users to publish bulk volumes of registry data to the Climate Warehouse.

TECHNICAL ARCHITECTURE

In addition to demonstrating that the Climate Warehouse's technical architecture successfully enables carbon data to be stored on a public and decentralized blockchain network, Simulation III participants' testing experiences also helped identify multiple system-level lessons related to the technical architecture.

In terms of the technical requirements to participate in the Climate Warehouse, multiple participants emphasized the importance of the Climate Warehouse's transaction fees and their affordability. As such, it will be critical for the governing body to closely monitor transaction fee trends and implement mechanisms to ensure that they remain affordable (e.g. by establishing a donation-funded resource pool) and do not become a disincentive for participants to publish data.

Although most participants selected the cloud – hosted instance deployment model because it was a convenient way to access the Climate Warehouse for testing and simulation purposes, without having to host the Climate Warehouse in their local IT networks, participants' deployment model preferences for integration with the operational Climate Warehouse varied significantly, based primarily on their IT capabilities and organizational requirements. As such, it will be important for the new governing body to continue to offer a variety of deployment models to ensure that a broad range of carbon market stakeholders can successfully deploy the Climate Warehouse.

Finally, multiple participants requested further documentation on different aspects of the technical architecture, frequently to circulate the documentation internally, build consensus, and attain necessary approvals. As such, the new governing body should continue to develop detailed technical documentation (e.g. a comprehensive user manual) to facilitate participants' consensus-building processes and integration with the Climate Warehouse.

Development actions related to the technical architecture that were identified and completed during Simulation III included improvements to the deployment process (e.g. enabling more than one user to access a single instance of the Climate Warehouse), back-end updates (e.g. increasing the duration of time allowed for a user to create an organization before a failure is recorded), and the preparation of new documentation (e.g. a comprehensive threat model). Table 20 summarizes the development actions related to the technical architecture that were identified and completed during Simulation III.

TABLE 20: Summary of completed technical architecture development actions

CATEGORY	COMPLETED DEVELOPMENT ACTION
Technical requirements	Added an ability for users to use their API key and access the Climate Warehouse through their internet browsers Enabled multiple users to be able to access the same instance of the Climate Warehouse
Back-end updates	Completed various back-end updates to optimize the Climate Warehouse's technical architecture. These back-end updates included adding logic to prevent transactions from being processed without a synced wallet, automating data updates from users' subscribed organizations, and increasing the time allowed for a user to create an organization before a failure is recorded
Documentation	Prepared additional documentation on multiple aspects of the Climate Warehouse's technical architecture, which included the blockchain layer's data storage mechanism, the transaction fee requirements for users to publish data, the threat model, and the deployment models

GOVERNANCE

Participants' feedback on the governance of the Climate Warehouse throughout Simulation III helped identify multiple key lessons regarding the governance protocols and operational support that the new governing body should provide to optimize participants' experiences and the overall functionality of the Climate Warehouse.

In terms of governance protocols, participant feedback helped identify the need for the governing body to coordinate the timeline and frequency of participating organizations' data updates in order to mitigate the potential "staleness" of registry data in the Climate Warehouse. In addition, participant feedback also helped identify the need for the governing body to develop and implement a protocol for maintaining the governance node's public list of known organizations, which would require the governing body to establish transparent criteria for inclusion and a reliable process to validate the identities of new organizations.

In terms of operational support, participant feedback helped to identify that the governing body should consider providing operational and technical support in a variety of formats (e.g. recorded tutorials and online "live chat" support), because the optimal format will vary by participant. Simulation III participants that did not have carbon registries also helped to indicate that the governing body should be able to provide support for the carbon registry development process, in order to enable carbon market stakeholders without registry systems to integrate with the Climate Warehouse.

The development actions related to the governance of the Climate Warehouse that were completed during Simulation III mostly involved adding a governance node feature to the user interface and preparing documentation that improved participants' understanding of the Climate Warehouse's governance model (e.g. preparing an onboarding guide and documentation on the governance node's functionalities).

RECOMMENDED ADDITIONAL FEATURES

Based on participants' recommendations for the operational Climate Warehouse in their feedback survey responses, the new governing body should prioritize adding more sorting and filtering features to the user interface, as this was the most frequently recommended additional feature. Furthermore, the new governing body should consider adding geospatial data and a global dashboard to the Climate Warehouse, since approximately half of the survey respondents recommended that these features be added. Offering greater language support was only recommended by just over a third of respondents, suggesting that most participants were satisfied with the user interface's language capabilities.

PERSPECTIVES ON BLOCKCHAIN TECHNOLOGY

Participants' perspectives on blockchain technology, which they shared in their feedback survey responses, helped identify multiple lessons regarding the Climate Warehouse's use of blockchain technology.

A majority of Climate Warehouse participants appear to support the use of blockchain technology and decentralized governance to improve carbon data systems, based on the feedback survey's finding that more than 50 percent of respondents agreed or strongly agreed that "blockchain technology improves security and enables registry autonomy while assuring trust for shared climate registry metadata" and that "carbon market data layers should be public, with permissionable data edit functionality, and operate under a decentralized governance system".

Concurrently, the finding that 30 to 40 percent of respondents neither agreed nor disagreed with the same statements suggests that many Climate Warehouse participants are indifferent on the use of blockchain technology and decentralized governance. The most common rationales behind these respondents' indifference were either because they believe blockchain technology and decentralization bring tradeoffs (e.g. increased complexity) or because they would like to learn more about the innovations before stating a perspective. As such, it will be critical for the new governing body to continue assessing blockchain technology as it evolves and disseminating the findings among participants to maintain a shared understanding of the Climate Warehouse's underlying technology.

Over 50 percent of survey respondents also agreed or strongly agreed that "the specific blockchain technology used for the Climate Warehouse matters a lot", most commonly mentioning environmental sustainability and security as the two most important characteristics of an optimal blockchain technology. This finding suggests that it will be particularly important for the new governing body to regularly review the blockchain technology that is used for the Climate Warehouse and ensure that it meets participants' environmental sustainability and security criteria, among others.

LIMITATIONS

Although Simulation III successfully tested the latest Climate Warehouse prototype with multiple carbon market stakeholders in preparation for its operationalization as a carbon metadata layer, the lessons that were identified need to be considered in the context of the simulation's limitations. These include Simulation III's limited range of participants and the nascent stage of the Climate Warehouse's underlying blockchain technology.

Simulation III engaged 30 participants in total, including 11 national governments, five independent standards, six multilateral organizations, and eight other public and private carbon market stakeholders. Although this represents a significant range and was an improvement on Simulation II's scope of participants, it does not reflect the full diversity of carbon market stakeholders. As such, it will be critical for the new governing body to continue testing the lessons from Simulation III as it operationalizes the Climate Warehouse and onboards new participating organizations.

Simulation III confirmed the finding from prior simulations that blockchain technology can be used to build a decentralized and peer-to-peer metadata layer that improves the transparency and security of carbon market data. Nevertheless, the blockchain technology that underlies the Climate Warehouse's technical architecture is still in a nascent stage and continues to evolve rapidly, while the availability of empirical data and successful use cases remains limited. As such, it will be critical for the new governing body to interpret Simulation III's lessons on the use of blockchain technology, in the context of the specific time period in which Simulation III testing was executed. Furthermore, the new governing body will need to regularly review the Climate Warehouse's technical architecture to ensure that it optimally leverages the latest blockchain trends and innovations.

RECOMMENDATIONS FOR THE NEW GOVERNING BODY

Table 21 outlines the testing and simulation team's overall recommendations for the new governing body, based on the lessons learned from participant feedback.

TABLE 21: Recommendations for the new governing body

CATEGORY	RECOMMENDATION
Installation	Provide participants with ample time and operational support (e.g. through recorded tutorials and online support) to navigate the installation steps, attain any required security and legal approvals, manage the disk space requirement, sync their blockchain nodes, and complete their integration with the Climate Warehouse Regularly revisit the installation process and implement updates that further simplify the process
Data model	Continue refining the Climate Warehouse data model, especially as new participants provide additional feedback and carbon market terminologies evolve When updating the data model, leverage a multistakeholder approach that reconciles any points of disagreement (e.g. picklist options of "project status" and "unit status" data fields, the data contained in certain fields may be confidential for some registries and public for others) and ensures that updates reflect consensus among carbon market stakeholders, especially among independent standard registries For "select from picklist option or add a new option" data fields, implement a standard protocol to regularly review new picklist options that are introduced by participants and decide whether they should be added to the standard list that is supplied by the governance node
User interface	Focus future development efforts on making the user interface as self-explanatory as possible, clarifying definitions, making the data entry process as efficient as possible, and adding features that enhance the utility of the user interface Add more sorting and filtering features to the user interface and consider adding geospatial data and a global dashboard
API	Ensure that new participants have sufficient time and capacity to build their automated integration with the Climate Warehouse
Excel import/ export	Help participants optimize and automate the ways in which they populate the Excel upload template with local registry data

TABLE 21: Recommendations for the new governing body (continued)

CATEGORY	RECOMMENDATION
Technical architecture	Continue to track the developments related to the UNFCCC infrastructure offering to ensure that the Climate Warehouse evolves to meet the emerging regulatory guidance and reporting requirements Closely monitor transaction fee trends and implement mechanisms to ensure that they remain affordable (e.g. by establishing a donation-funded resource pool) and do not become a disincentive for participants to publish data Revisit how the ITMO transfer process could be consolidated into a single step in the blockchain layer Continue to offer a variety of deployment models to ensure that a wide range of carbon market stakeholders can successfully deploy the Climate Warehouse Continue to develop detailed technical documentation (e.g. a comprehensive user manual) to facilitate participants' internal consensus building processes and integration with the Climate Warehouse Conduct regular assessments of the latest blockchain technology trends and disseminate the findings among participants to maintain a shared understanding of the Climate Warehouse's underlying technology Conduct regular evaluations of the specific blockchain technology that is used for the Climate Warehouse and ensure that it optimally leverages the latest innovations and meets participants' key criteria, which include environmental sustainability and security
Governance	Coordinate the timeline and frequency of participating organizations' data updates, to mitigate the potential "staleness" of registry data in the Climate Warehouse Develop and implement a protocol for maintaining the governance node's public list of known organizations, which requires establishing transparent criteria for inclusion and a reliable process to validate new organization's identities Provide operational and technical support in a variety of formats (e.g. recorded tutorials and online "live chat" support) to meet participants' diverse needs Provide support for the carbon registry development process in order to enable carbon market stakeholders without registry systems to integrate with the Climate Warehouse Continue using modular and self-explanatory designs when developing additional documentation Continue providing responsive, hands-on, and knowledgeable technical support to maintain participants' high levels of satisfaction with the Climate Warehouse's technical support Facilitate consensus building within organizations that are considering integration with the Climate Warehouse in order to successfully expand the number of participating organizations Continue testing the lessons from Simulation III as the Climate Warehouse is operationalized and new participating organizations are onboarded

In addition, Table 22 summarizes the specific development actions that were identified during Simulation III and logged in the action items tracker as suggestions to the governing body of the operational Climate Warehouse.

TABLE 22: Summary of development actions logged as suggestions to the new governing entity

CATEGORY	SUGGESTED DEVELOPMENT ACTION
Data model	Convert the "unit type" data field from a required to an optional field, based on feedback from participants that some registries will find it difficult to map all units to this data field's picklist options Broaden the "unit metric" data field to accommodate non-GHG metrics Add an optional "cooperative approach" data field to enable users to indicate alignment with Article 6.2 cooperative approaches Expand the picklist options for the "label type" data field to ensure that the options are comprehensive Convert the "country jurisdiction of owner" data field from a required to an optional field, based on feedback from participants that this information is often confidential
User interface	Enable users to split units into more than two blocks in a single transaction Add a scroll bar feature to help users navigate long picklist options Add a "merge units" feature to enable users to consolidate multiple units into a single unit Utilize a professional translation service to optimize the user interface's language offerings Remove the Excel import/export icons from pages where they are not relevant (e.g. the staging tab in the "my units" view)
API	Update the API feature to automatically generate the needed issuance from the related project when users insert units that are attached to an issuance that does not yet exist

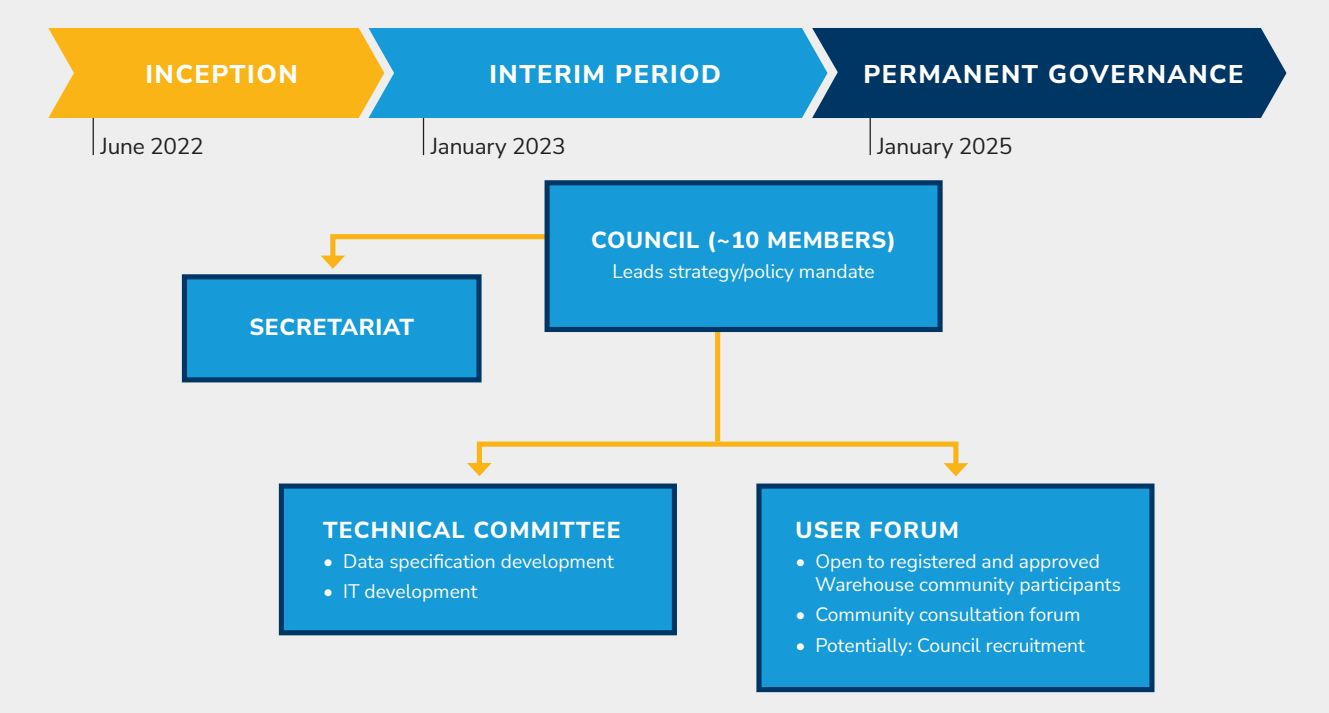
08 Climate Warehouse Outlook

OPERATIONAL CLIMATE WAREHOUSE

The conclusion of Simulation III in August 2022 marked the beginning of the transition to the operational Climate Warehouse, which is expected to launch in mid-October 2022. IETA is leading this transition as the interim secretariat in close collaboration with the World Bank and the government of Singapore based on the recommendations produced in a 70-stakeholder consultation on governance and finance, which was finalized in early 2022. This includes creating an independent legal entity in Singapore and convening an Interim Council of public and private members to serve a two-year term as the main governing body of the operational Climate Warehouse, supported by further advisory bodies and a secretariat. Figure 23 visualizes the interim governance structure of the operational Climate Warehouse.

To facilitate this transition, the testing and simulation team provided the new governing body with the final versions of the feedback tracker (including all 514 points of participant feedback), action items tracker (including all 156 development actions identified), 30 participant profiles and 30 feedback profiles for each Simulation III participant, feedback notes document (including detailed notes from the 58 completed testing sessions and over 40 completed office hour sessions), and the Simulation III onboarding package (including an updated technical guide and data model).

FIGURE 23: Interim governance structure of the operational Climate Warehouse



In addition, the new governing body was provided with a comprehensive transition plan, which included detailed guidance on a sequential and prioritized list of 12 transition recommendations:

1. **Select hosting service:** Select a cloud hosting service for the governance and observer nodes.
2. **Review data model:** Review the Climate Warehouse data model and data dictionary.
3. **Review Simulation III feedback:** Consider the complete log of participant feedback received during Simulation III.
4. **Select administrators:** Select and add administrators to the Climate Warehouse repository on GitHub.
5. **Launch development team:** Build and launch a development team for the operational Climate Warehouse.
6. **Develop website maintenance plan:** Develop a plan to update and maintain the Climate Warehouse's public website.
7. **Develop organization validation process:** Establish and implement a process for validating new participating organizations and adding their details to the governance node's organizations list.
8. **Create onboarding plan:** Create a comprehensive plan and process to onboard new participating organizations to the operational Climate Warehouse.
9. **Develop transaction fee plan:** Develop a plan to ensure that participating organizations can meet the Climate Warehouse's cryptocurrency-based transaction fee requirements.
10. **Determine support structure:** Determine and implement the operational and technical support that needs to be provided to onboarded Climate Warehouse participants.
11. **Create development process:** Create and implement a structured process for how the governing body evaluates and implements new features that are requested by participating organizations.
12. **Create data model update process: Create and implement** a structured process for how the governing body evaluates and implements proposed updates to the data model.

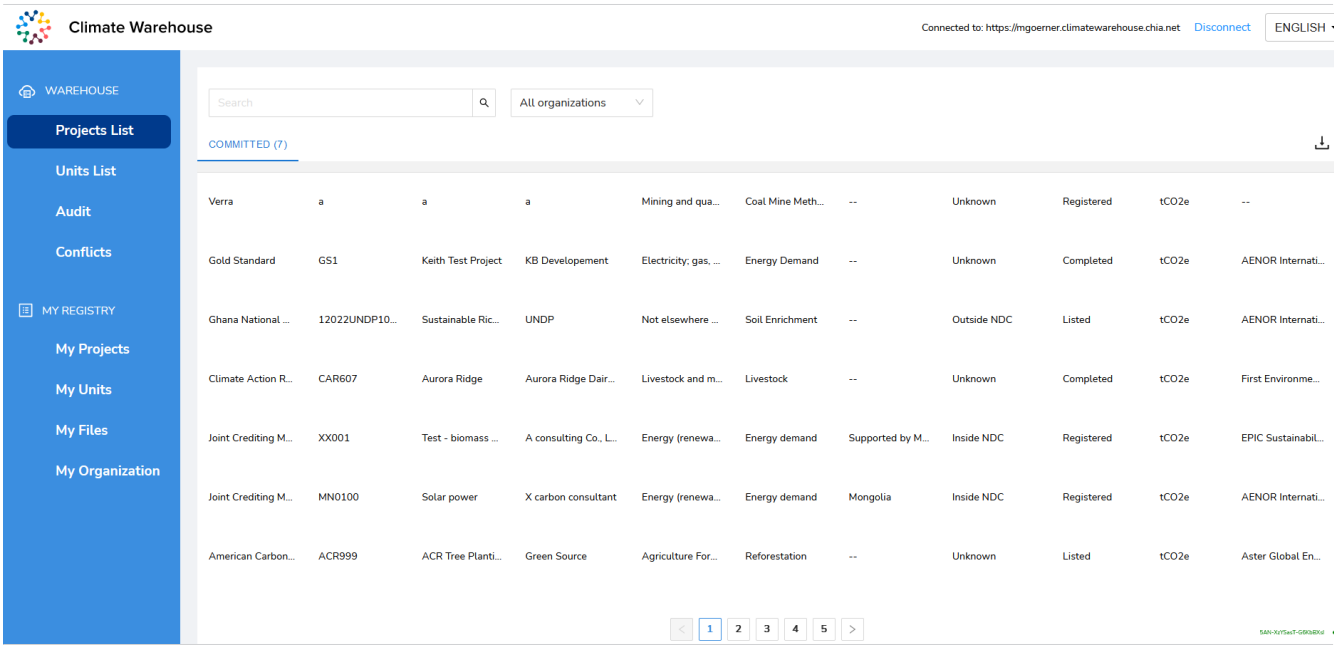
Moving forward, the World Bank will continue to provide technical support with product development as well as onboarding assistance through a capacity-building program with a priority to the Partnership for Market Implementation countries. The capacity-building program will provide support to approximately 15 developing countries for a period of two to three years. In addition, the World Bank may identify service layer functions that could be valuable to market participants and, in particular, to the World Bank client countries. These may include enhanced functionalities for compliance monitoring and reporting and measures to improve transparency and integrity of the carbon markets.

Appendix

USER INTERFACE SCREENSHOTS

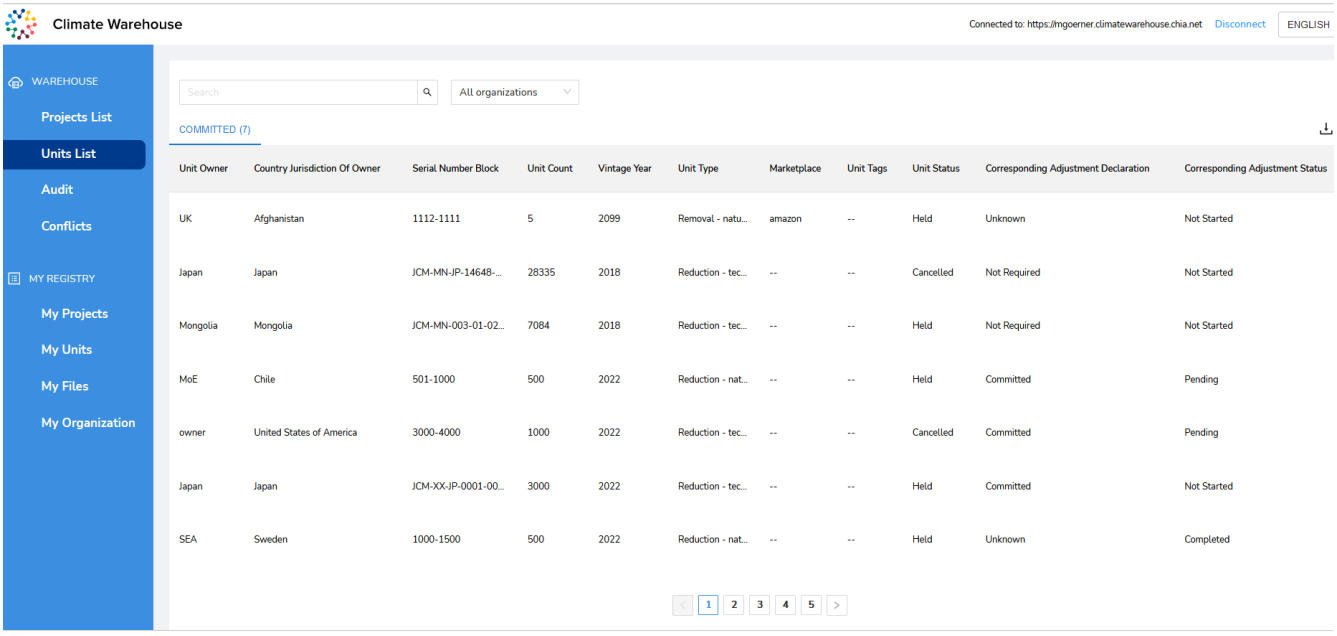
The following figures are screenshots of the Climate Warehouse user interface, as of the end of Simulation III in August 2022. Each screenshot displays a subsection of the user interface. Refer to Section 3 for descriptions of each subsection.

FIGURE 24: User interface – projects list



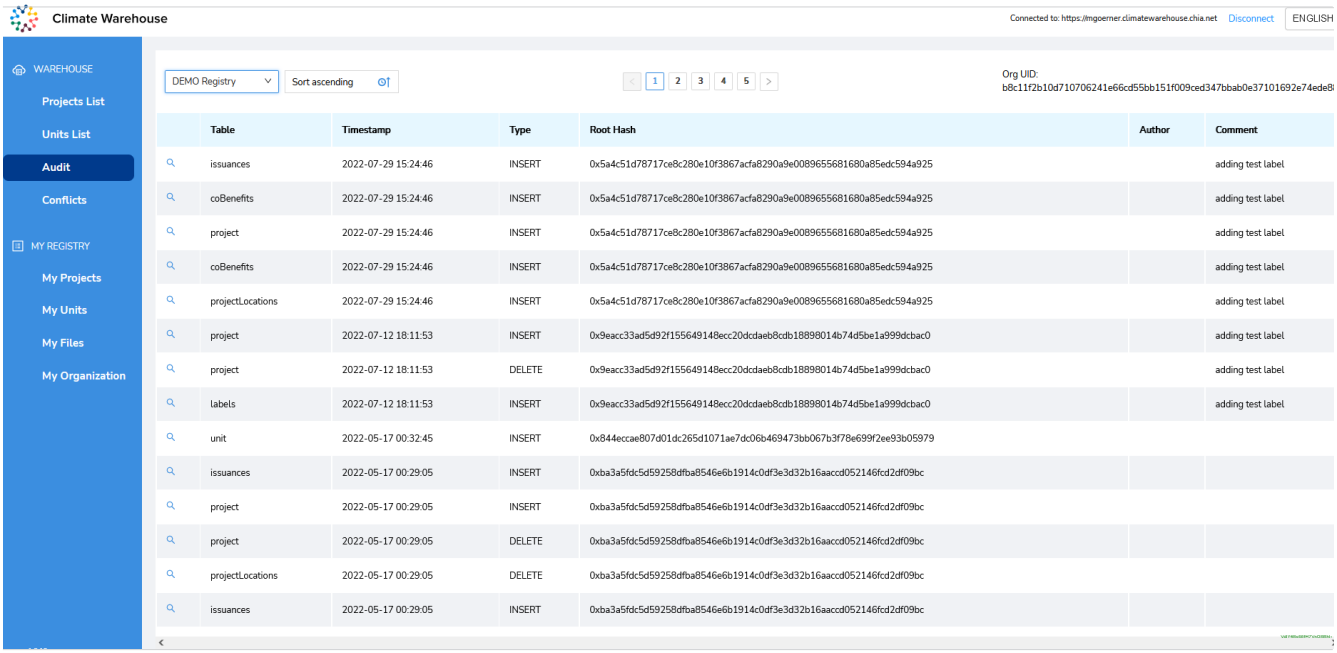
Note: All data displayed is sample data for testing and simulation purposes only.

FIGURE 25: User interface – units list



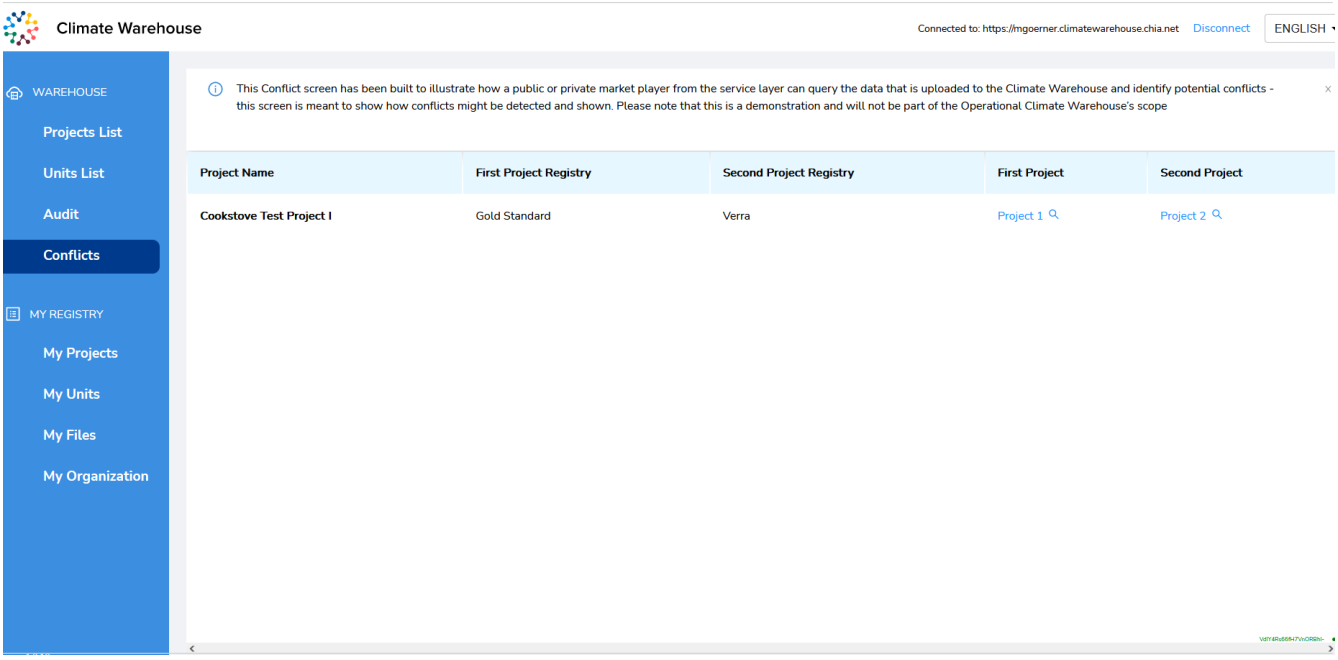
Note: All data displayed is sample data for testing and simulation purposes only.

FIGURE 26: User interface – audit



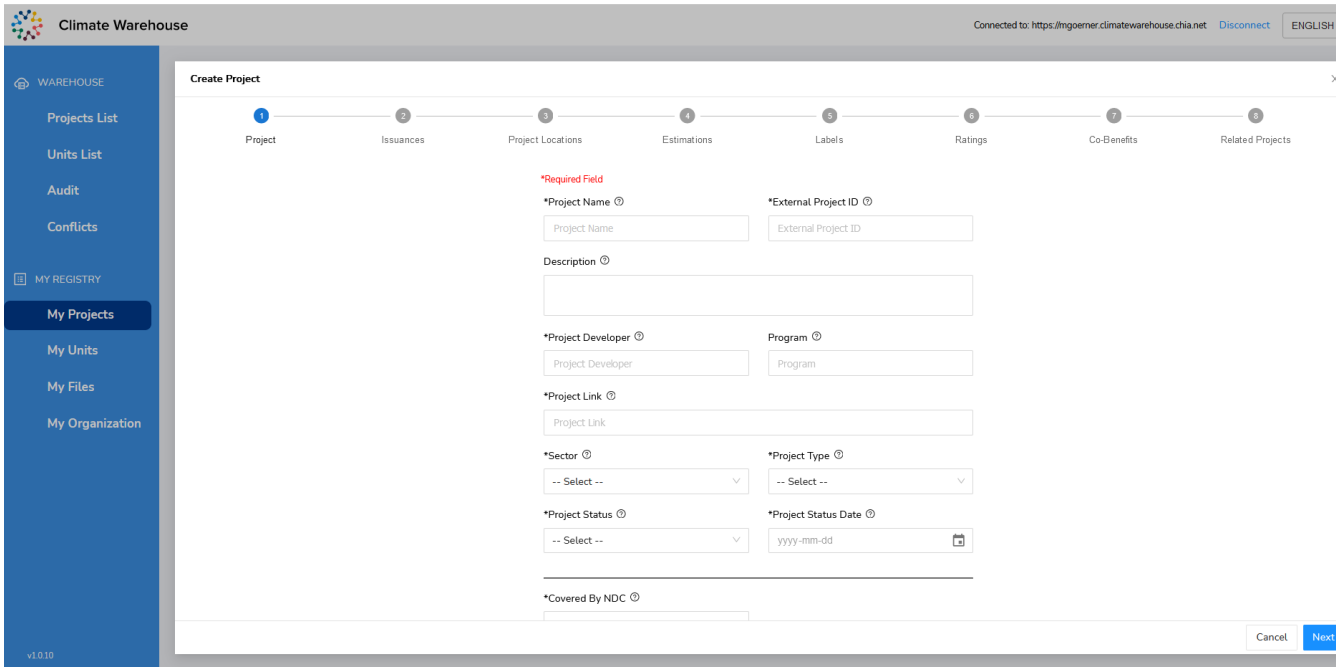
Note: All data displayed is sample data for testing and simulation purposes only.

FIGURE 27: User interface – conflicts



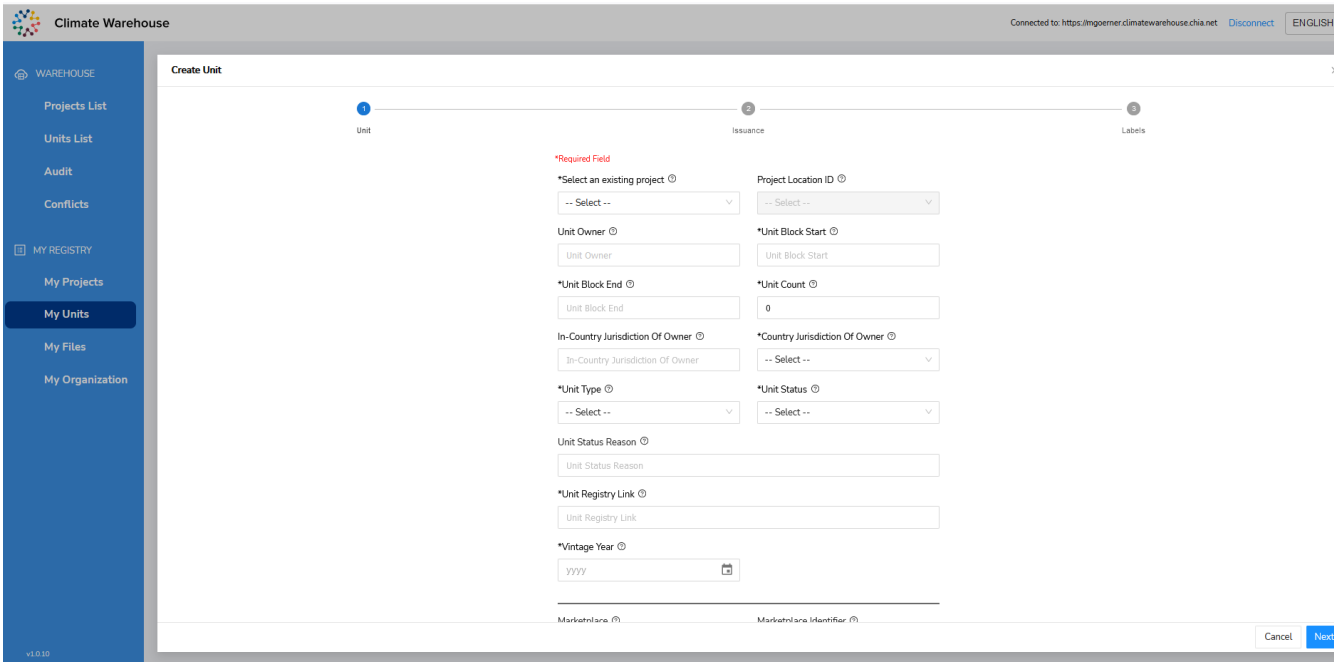
Note: All data displayed is sample data for testing and simulation purposes only.

FIGURE 28: User interface – my projects (create project window)



Note: All data displayed is sample data for testing and simulation purposes only.

FIGURE 29: User interface – my units (create unit window)



Note: All data displayed is sample data for testing and simulation purposes only.

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