3. Brief Review of Technologies and Practices in Existing Climate Markets

Current Data Collection

In spite of their differences, carbon pricing mechanisms around the world share common elements (e.g., data-driven emission caps and allowances, offset provisions, defined sectors),[4, 5, 6] and there are a multitude of MRV practices and technologies encompassing data collection, data processing, and data analysis that underpin these mechanisms. Since the 1990s, new technologies have enabled expanded MRV practices, from simplified organizational and subnational inventories and project-specific calculations to more accurate and comprehensive accounting, including, for example, continuous emission monitoring systems (CEMS), integrated life cycle assessment (LCA) databases, and cloud-based, tracking software systems for supply chains and programs of activities (POA).

More recently, innovative MRV practices and technologies utilizing information and communication technologies (ICT),[7] such as mobile and remote monitoring, are being advanced for transportation, distribution of household appliances and land use mitigation activities.

At a time when climate markets are gaining interest,[8] and advances in technological adoption and automation of MRV is occurring, nevertheless most climate change related MRV practices still involve manual processes that rely on disconnected data trails, spreadsheets, and static PDFs to achieve market and environmental integrity. These processes stand in contrast to the increasingly interconnected, highly transparent digital paradigm that is emerging globally,[9] constraining market integration and scalability.

Current Market Schemes

The Kyoto Protocol took a homogeneous approach to tradable units, which by definition were all equal to one tonne CO_2-equivalent GHG emission. The two most common types of tradable units in climate markets have been allowances and credits and following the Kyoto approach, these are generally set at a value of one tonne as well, although what it is a tonne of (e.g., CO_2, or CO_2–equivalent, or another GHG) will depend on the nature of the particular scheme.

The next generation of bottom-up climate markets must include mechanisms to address these differences so as to not inhibit reaching the scale, heterogeneity, and functional complexity that will be required.

4 World Bank, 2016, "Emissions Trading Registries: Guidance on Regulation, Development, and Administration," October 1, http://documents.worldbank.org/curated/en/780741476303872666/pdf/109027-WP-PUBLIC-12-10-2016-15-54-42-PMRFCPFRegistriesPosting.pdf.

5 Kossoy, Alexandre et al., 2016, "State and Trends of Carbon Pricing," World Bank, October 14, http://documents.worldbank.org/curated/en/598811476464765822/pdf/109157-REVISED-PUBLIC-wb-report-2016-complete-161214-cc2015-screen.pdf.

6 World Bank, 2016, "Emissions Trading in Practice: A Handbook on Design and Implementation," January 1, http://documents.worldbank.org/curated/en/353821475849138788/pdf/108879-WP-P153285-PUBLIC-ABSTRACT-SENT-PMRICAPETSHandbookENG.pdf.

7 Smarter2030, accessed September 30, 2017, http://smarter2030.gesi.org.

8 World Bank, 2015, "State and Trends of Carbon Pricing," September 20, http://documents.worldbank.org/curated/en/636161467995665933/State-and-trends-of-carbon-pricing-2015.

9 World Economic Forum, 2016, "Introducing the Digital Transformation Initiative," accessed September 30, 2017, http://reports.weforum.org/digital-transformation/introducing-the-digital-transformation-initiative/.

Allowances are issued under cap-and-trade programs where emissions within a defined boundary (e.g., country, industry sector) are capped. The allowances are issued to entities that are regulated within the boundary of the cap, to be surrendered by them against their emissions. Thus, the face value of an allowance reflects a unit of the amount the regulated entity can emit, rather than the amount of GHG emission mitigation brought about by a unit of that scheme.

Credits can encompass a variety of instruments, most notably GHG offset credits, renewable energy certificates,[10] and renewable fuel certificates (RINs).[11] As opposed to an allowance, a credit can reflect a unit of the amount of GHG emission reduction achieved, although depending on the type of credit, it may need to be converted into a base unit such as tonnes CO_2-equivalent: for example, renewable energy certificates may be expressed in KWh and need to be converted in order to be comparable with other units.

In any case where diverse pricing mechanisms are connected so as to allow transactions between them, in other words to provide for "fungibility" (or the mutual interchangeability) of their respective tradable units, there will need to be a mechanism to enable comparability. This is discussed further below.

Existing Technological Architecture

A functioning climate market requires rules, institutions, and infrastructure to enable proper market operation, transparent accounting and to ensure environmental integrity. A fundamental building block for market infrastructure is the accounting system(s) in which tradable units are held, transferred, retired, and recorded.

The World Bank has defined three types of emissions accounting systems (illustrated in Figure 1.)

Figure 1. Different Types of Emissions Accounting Systems Compared

GHG Inventory	Register/ Transaction Registry	Data Management System
Records physical GHG emissions and removals	Records carbon units for market mechanism/ results-based climate finance programs	Records information on carbon unit and policy/program/ project

Source: Emissions Trading Registries – Guidance on Regulation, Development, and Administration. World Bank, 2016.

The term registry can refer to a GHG emissions inventory, a list of project and program information, or databases with varying levels of functionality. While there are multiple considerations in the development, administration and regulation of GHG registries, there is a commonality in the underlying technological architecture of existing registries. Regardless of structure or level of complexity, existing transactional registries utilize a technological architecture based on a centralized ledger (or database) to support the transaction of units. There are good reasons for this design around central ledgers. Centralized ledgers are reliable and provide a system of record for transactions within a given scheme with clearly defined, tradable units.

Due to legal constraints, confidentiality concerns, institutional barriers, or other factors, there may be multiple registries or multiple centralized ledgers used within a single jurisdiction. Integrating multiple centralized ledgers requires not only new architecture (see Figure 2), but also overcoming constraints so as to facilitate the integration and transfer of relevant data.

For example, under California's Cap-and-Trade Program, details associated with an approved project may be stored across multiple websites each referencing serialized numbers and reports held in various places. The California Air Resources Board (ARB) summary for a project will be a set of serialized numbers held in the ARB central ledger, but these same numbers might initially have been held as a separate serialized set of numbers in a centralized register operated by another registry, such as the American Carbon Registry (ACR) and backed by a separate, PDF verification report.[12] In order for the original set of serialized numbers representing offsets issued under the ACR and held on the ACR registry to be transferred to ARB's centralized ledger, ACR must (a) "retire" the serialized numbers in its central ledger, (b) manually transfer the same numbers to ARB via spreadsheet or CSV to ARB, and (c) have ARB reissue a new, equivalent set of serialized numbers in ARB's central ledger.

An approach, such as in this example, may be sufficient within a given jurisdiction with appropriate governance and oversight. However, when the centralized ledgers are in different jurisdictions, standardized rules and oversight to enable transfers of units between those ledgers may not be available.

Figure 2 illustrates the systems supporting GHG data collection, aggregation, accounting, and reporting in jurisdictions usually organized around centralized databases. The databases have varying degrees of integration, depending on the jurisdiction and/or program considered. This is indicative of the system architecture in many jurisdictions with a market program in operation, each of which operates with its transaction registries at the core of its design. Each transaction registry will reflect the particular

10 United States Environmental Protection Agency, "Renewable Energy Certificates," accessed September 30, 2017, https://www.epa.gov/greenpower/renewable-energy-certificates-recs.

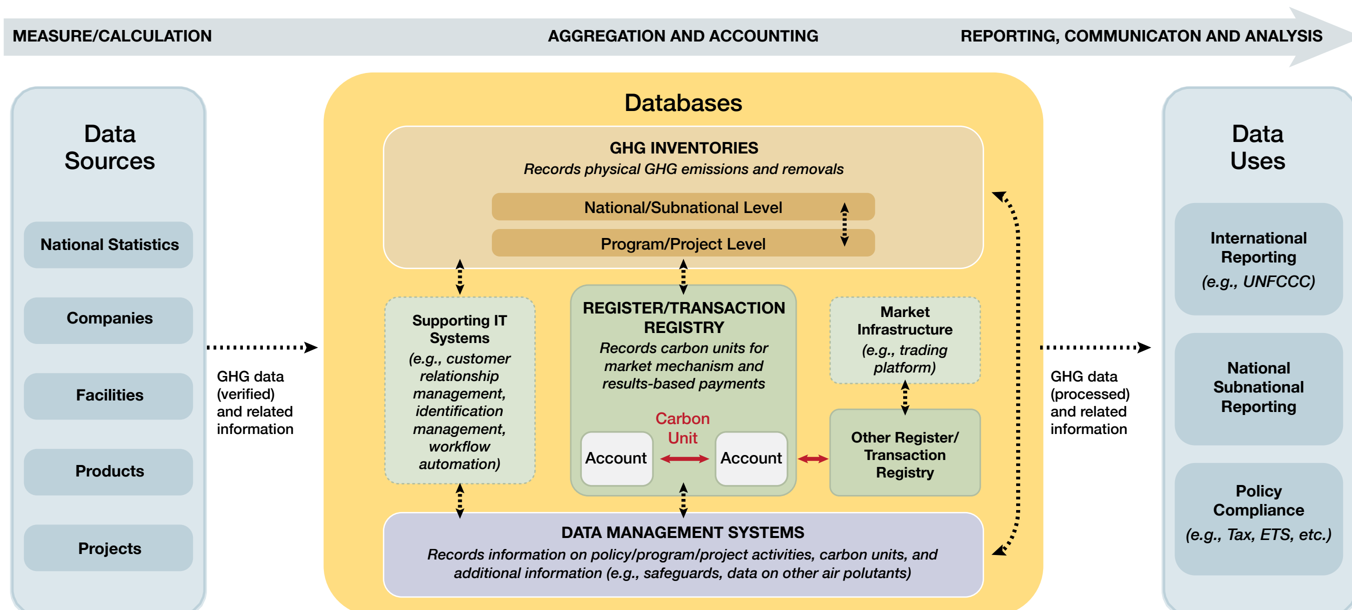
11 United States Environmental Protection Agency, "Renewable Identification Numbers (RINs) under the Renewable Fuel Standard Program," accessed September 30, 2017, www.epa.gov/renewable-fuel-standard-program/renewable-identification-numbers-rins-under-renewable-fuel-standard.

12 California Air Resources Board, "ARB Offset Credits Issued," accessed September 30, 2017, https://www.arb.ca.gov/cc/capandtrade/offsets/issuance/arb_offset_credit_issuance_table.pdf.

design and type of scheme of which it forms part, and thus will be technologically separate from those in other jurisdictions with different schemes, as will be the units, transactions in which are recorded in that ledger.

To address these differences, specific bilateral or multilateral agreements are required for any cross-jurisdictional transactions to occur. When the climate actions in the different jurisdictions are both emissions trading schemes, agreement as to the relative respective value of the units (and as to what those units/that value is a measure of) is necessary. The complexity of conducting transactions between heterogeneous climate actions across jurisdictions increases when additional instrument types (e.g., not just emission allowances, but also renewable energy certificates, RINs, offsets) are introduced. Thus, the next generation of bottom-up climate markets must include mechanisms to address these differences so that the technological limits of an infrastructure based on centralized registries does not inhibit reaching the scale, heterogeneity, and functional complexity that will be required.

Figure 2. The Transaction Registry in its Environment: Potential Connections and Interfaces



Source: Emissions Trading Registries – Guidance on Regulation, Development, and Administration. World Bank, 2016.

4. Architecture for New Market Design

As noted above, different climate markets trade different units (assets), have differences in structure and governance, and rely on separate, centralized registries. The result is a multitude of schemes trading instruments within closed technological systems (central-ledger-based registries) and differing rules—for example, those associated with MRV. There are examples of linked programs (e.g., the California-Quebec-Ontario cap-and-trade program) that aim to facilitate larger, more liquid markets by providing for cross-jurisdictional transactions, but the advent of more advanced technological approaches and designs that could provide more secure, efficient transactions of assets (carbon allowances, credits, or other carbon units) is changing the paradigm.

To facilitate larger, more liquid and resilient trading across heterogeneous climate markets, a new architecture is needed. There is a corresponding need, also, for the capability to generate, manage, and harmonize information representing the outcomes of GHG mitigation actions across multiple industry sectors and governmental jurisdictions. Advances in technology and standards, discussed in subsequent sections, allow conceptualization and design of systems in which information pertaining to different qualities of assets can be identified and tracked separately, but in connection with, other information concerning those assets, as they are transacted in the markets.

This delineation and tracking of separate value elements in the units is the key idea behind this new architecture.

Enhancing the Comparability and Potential Fungibility of Mitigation Outcomes Across Bottom-up, Heterogeneous Markets: Tracking Environmental Attributes of Various Commodities

Physical commodities such as oil, coal, palm oil, or soybeans can vary in value according to grade or quality or source location. Assets in climate markets (emission allowances, credits, renewable energy certificates or other units), although they are not natural commodities but a function of the policies and legislative schemes by which they are created, similarly may vary in value, in terms of the GHG mitigation in which they result. The variations will be a function of many factors, such as scope of the scheme, coverage, specific rules and scheme boundaries; the suite of policies and measures within which the scheme operates; or the jurisdiction's particular circumstances, capacity and ambition.

For different physical commodities, a digital asset can be created to represent and provide title to the commodity asset, as well as the multiple outputs (e.g., energy content) and outcomes (e.g., GHG emissions, energy access enhancement, poverty reduction impact) associated with its production and/or lifecycle.[13] The digital asset can be registered at the point of initial production to create a single, immutable record of the embedded attributes for that unit of the particular physical commodity.

Similarly, for tradable units in climate markets, information concerning value in terms of mitigation, or in relation to co-benefits such as energy access enhancement, or poverty reduction impact, can be identified as separate elements and tracked independently, while at the same time maintaining information concerning their source or identity. Blockchain technology can provide a digital mechanism for recording and tracking these separate streams of information associated with units, including when they are transacted across jurisdictional boundaries.

13 World Bank, 2017, "Results-Based Climate Finance in Practice: Delivering Climate Finance for Low-Carbon Development," May 1, http://documents.worldbank.org/curated/en/410371494873772578/Results-based-climate-finance-in-practice-delivering-climate-finance-for-low-carbon-development.

This delineation and tracking of separate value elements in the units is the key idea behind this new architecture. As long as firstly, the integrity of the recording of the information is maintained, secondly, the information is aggregated in an accepted form of a climate information asset (or "climate asset"), and thirdly, the necessary mechanism is in place to convert climate assets to a common metric for comparability, such as their mitigation value, then transactions can take place across jurisdictions. Further, any type of market instrument (e.g., allowances, credits, RINs, renewable energy certificates), can be so transacted, provided such a metric (as, for example, mitigation value) can be applied. Furthermore, irrespective of how markets bundle and transact, the underlying information for the climate asset remains the same. This approach ensures market and environmental integrity by precluding double counting in relation to climate assets.

In this paradigm, ideally, new and existing markets (commodity markets, environmental and climate markets) might incorporate, or be configured in relation to, a universal ledger and trade the underlying attributes. Physically measurable events, represented by production and operational data, could be certified against new standards and aggregated into universally accepted assets. In the case of electricity, for instance, each MWh of power (derived from coal, natural gas, solar, hydro, or wind) could be accurately associated with its embedded impact within a given electricity market or, as in the case of renewable energy certificates, transacted separately.

This approach is dependent on the integration of production data (supported by appropriate technology, e.g., the IoT), the next generation of governance that supports digital approaches to MRV, larger scale data analysis to support MRV processes (e.g., big data analytics), and the broad application of blockchain functionalities in a dynamic market context at (or close to) real time. Such an integrated approach is unlikely to be possible through the combination of manual audit processes and multiple, disaggregated databases at the producer, auditor and/or market level. Further analysis of these emerging technologies and practices is included in Section 5.

The combination of blockchain technology, IoT, and the governance of the next generation of climate markets (discussed below), enables the creation of digital representations of commodities that can be used for existing markets and for transacting across climate markets (see Figure 3). The function of each layer illustrated in this vision of the new architecture in Figure 3 is outlined in Table 1.

Figure 3. Architectural Vision for the Networked Climate Markets

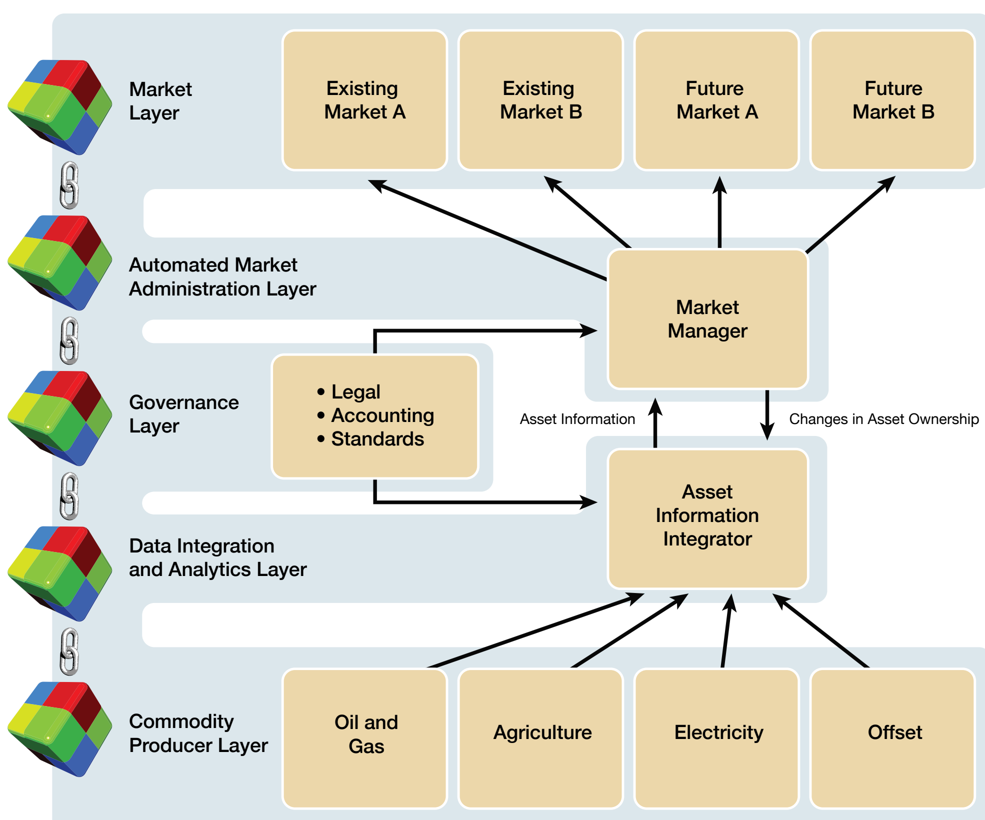


Table 1. Implementation Responsibilities for the New Generation of Climate Markets

Functional Layer	Role	Function	Examples
Commodity Producer	Event Data Provider	Foundational role in the ecosystem. The entities are primarily commodity producers and other sources of GHG emissions or emission reductions, subject to governance.	▪ Oil and gas producers, growers, refiners, power generators ▪ Capped emitters ▪ Offset project developers
Asset Information Integrator	Data Integration, Analysis, and Attribution Assignment	Gathers event data from event data providers. Data analytics and assignment of quantified and verified climate asset using consensus and peer-to-peer communication protocols (that is, blockchain). The role of "information provider" is also key to transparency. Increasingly, information asset providers will leverage IoT to obtain access to production data and Big Data as a secondary source of information for automated verification.	▪ Data platform operator ▪ Independent monitoring and verification body (although this role could be automated, depending on design)
Governance Layer	Legal, Accounting, and Standards	Governance will also be increasingly automated and can be administered through embedded logic derived from a combination of consensus-based, internationally-recognized standards, market rules, regulation, and auditing.	Standards organizations
Automated Market Administration Layer	Market Manager	Aggregates and structures climate assets using blockchain and makes them available to the market. This layer also records the provenance of the assets as they are bought, sold, and eventually retired.	Blockchain platform
Market Layer	Transactions	All manner of markets	▪ GHG allowances, RINs, renewable energy certificates, offsets ▪ Existing commodity markets (e.g., oil and gas, agricultural, electricity)

This simple "information service provider" architecture is the key to transacting across climate markets from the bottom-up. If deployed across multiple jurisdictions over time, the technological link between jurisdictions together with appropriate mechanisms to allow comparability of tradable units would enable direct transfers of mitigation outcomes and decrease the need for complex trading agreements across separate, centralized registries housing non-fungible assets. Over time, the foundational approach of generating climate assets could encourage standardization of MRV processes, enhancing the reliability of the mitigation outcomes of different instruments.