CHAPTER 19

Networked Carbon Markets: Permissionless Innovation With Distributed Ledgers?

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The purpose of this chapter is to outline the most important questions identified in relation to the connecting of carbon markets through the application of distributed ledger (DL) technologies, and share the authors' current thoughts on those questions.

19.1 Connecting Carbon Markets

Carbon markets[2] are highly regulated and vary in scope, design, implementation, and rules and standards across the globe. Therefore, any approach to link them should be able to connect diverse and heterogeneous carbon markets, not by equalizing them, but rather by recognizing the differences between them and placing a value on those differences. This is important for enabling a sustainable carbon price across various carbon markets; incentivizing investment in carbon mitigation projects and carbon-efficient manufacturing; and encouraging more transparent auditing and accountability for carbon emission mitigation in global carbon markets, thereby meeting the ambitions of the Paris Agreement.

Regulators in each carbon market control supply of tradable emission units and set requirements for carbon accounting. Therefore, any system to link such markets should be able to address these variations in policy and approaches while still enable trading between participants.

1 https://www.epcc.ed.ac.uk/blog/2017/08/10/distributed-ledgers-carbon-markets

2 In this chapter, the authors are focusing in the first instance on connecting government-instigated emission trading schemes (ETSs), as a first step toward the ultimate objective of being able to connect more generally a broader range of mitigation actions/carbon pricing measures (e.g., including carbon taxes, renewable energy certificate schemes and so on). Also, note that the expressions "market," "carbon market," and "ETS" or "ETS market" are used interchangeably throughout the chapter to mean the same.

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Furthermore, given that carbon emissions and climate change are global issues, we need a global solution accessible to developing and developed nations without barriers to adoption such as heavy investment in bespoke software or hardware for nations with limited resources, but still allowing participation on an equal footing for all.

19.2 What Types/Levels of Market Should We Support?

Although the overall goal is to connect numerous individual carbon markets to enable international transfers of mitigation outcomes, it is necessary to recognize the multiple levels where carbon trading or carbon accounting and tracking may occur.

19.2.1 Corporate Level

Firstly, individual corporations may need systems to allow them to undertake carbon accounting across various jurisdictions, locations, and suborganizations in which they have operations. Many businesses currently do this in some form to track data, be it with spreadsheets that are e-mailed among participants; or bespoke applications/data infrastructures. Different jurisdictions may require different accounting/tracking procedures, meaning a single spreadsheet or application may not be fit for purpose across all those jurisdictions. There may also be oversight and auditing requirements within a corporation.

19.2.2 Single Emissions Trading System (ETS) Level

Secondly, individual carbon markets (or ETSs), be they subnational, national, or regional, require credible systems to organize and administer their operations. These operations include assigning and distributing emission allowances to companies; allowing for trading of emission units among organizations (subject to the rules of the ETS); and allowing companies to surrender/report emission units for obligations when required (recorded through ETS) administrator-maintained registries A carbon market should be an open level-playing field in which various organizations should be able to participate. Traditionally, this right to participate has been mainly the remit of large, multinational corporations. But for climate mitigation movement to be a real success, the market should be able to account for organizations of all sizes,[3] including those without the funds to purchase and operate costly computing infrastructure.

19.2.3 Connecting Carbon Markets

Finally, the aim is to connect these individual ETSs to enable trading among different jurisdictions' markets. Individual ETSs are differentiated by varying timescales, rules of

[3] Or even for individuals to trade, if such is approved by the relevant jurisdiction.

auditing and accountability, as well as environmental performance standards. Given the diversified attributes of existing ETSs, at present, direct, unrestricted, trading of carbon credits among all markets is not possible.

An international agreement for the ETSs in all jurisdictions to be linked is unlikely to be feasible. Thus, we need a mechanism which recognizes the individuality of carbon markets provides for their interactions. The system will need to support different approaches of interactions among markets by governing how/when/whether they interact with each other. Essential for this mechanism is flexible membership. Individual jurisdictions should be allowed to connect or disconnect, as they deem appropriate. Voluntary participation is crucial in fostering ever-growing emissions trading systems and achieving the intent of the Paris Agreement of engaging the Parties in cooperative approaches voluntarily.

Ideally, the Parties can agree to create a single system, or at least a single set of tools (a *software infrastructure*) that can accommodate the demands at all three levels described above. These range from providing the functionality of carbon assets/exposure management for a single organization to availing a platform that can network multiple carbon markets. Although there is no necessity to have a single software infrastructure for cross-level use, uniform emissions trading infrastructure would provide the potential for multi-jurisdictional benefits, from enabling simple adoption and sharing of data to full-system carbon auditing and tracking, which is to ensure transaction parties' accountability and prevent fraud in the system. Further, as will be discussed in greater details, the technical issues that need to be addressed for such a single system inside a major/partitioned organization are applicable at the networked market level and vice versa. Therefore, a feasible technical solution must have the capacity to support multilateral participation in a network of carbon markets comprising various organization users.

19.2.3.1 A Single Software Infrastructure

Despite this discussion being about a single software *infrastructure*, it does not necessitate a single software *solution*. What is proposed is a data infrastructure that enables all of the functionalities outlined above; and creates a reference implementation that is usable without precluding others from implementing their own solutions and participating in the networked markets.

Some may question if it would be possible to create a solution which satisfies the requirements outlined without using distributed ledger technologies (DLTs). Yes, it would. Nonetheless, the core benefit that DLTs offer is the unique functionality to ensure that access to the data in the network is distributed and available to all participants (subject to any access restrictions deemed necessary in carbon markets/carbon trading[4]) and, hence,

[4] As we will discuss later in the chapter, we are not necessarily advocating fully visible, fully unpermissioned ledgers. There may be good reasons to restrict the access or permissions to changing some data in the system.

equal participation in the market. Other functionalities such as auditability and visibility of transactions can easily be enabled and extended/augmented as required, ensuring that carbon market(s) can be made as transparent, trusted, and liquid as possible.

19.3 What Is Distributed Ledger Technology (DLT)?

DLT covers a wide range of potential functionalities, from completely decentralized, permissionless systems in which anyone can participate, to permissioned and controlled systems which are very similar to current data networks controlled by a single or small number of entities. As such, it is necessary to understand different types of DLT for available options with which to design a DLT-based system to connect carbon markets; and the impacts these options would have on the functionality of carbon market linkages.

The following features (Table 19.1) are recognized as key for any system to be considered a DLT:

The following features (Table 19.2) are recognized as configurable[5] for a DLT depending on the application it is being used for and the environment in which it exists:

19.3.1 Designing for Use Cases

The distinction between functionalities that define a DLT versus those features that are configurable provides scope for designing DLTs which are quite specific to targeted Use Cases and User Groups.

Permissionless systems, for example, are open to all participants. Anyone may become a ledger node (i.e., hold a copy of the ledger) and add valid entries. The converse of this is a **permissioned system**, where only authorized entities can hold a copy of the ledger or participate in transactions. However, it may also be possible for a range of permissions to be applied to the system, i.e., permission may be required to become a ledger node but individuals may interact with ledger nodes without permissions; or anyone may be able to become a ledger node but may require permissions to add entries to the ledger; or there may be different permissions for adding entries compared to viewing entries; and so on.

To give this more structure from a design perspective, there are two different types of permissions that determine a participant's scope of interactions with the ledger:

- Hosting the DLT (i.e., having a copy of the ledger, being a node in the system)
- Interacting with the ledger (i.e., viewing, or adding to, the ledger)

[5] Configurable: Potentially present or not in the system; also, potentially different levels or types of this functionality present in the system.

Table 19.1: Design features defining a distributed ledger.

Feature	Description
Distributed infrastructure	The system must be composed of multiple entities, or nodes, that each have a full copy of the ledger. This implies that nodes can be added and removed from the system without affecting the overall operation of the system or the integrity of the data stored in the ledger.
Encrypted transactions	The ability of participants to use public/private key encryption to authorize/assign/interact with transactions in the system.
Global consensus	The nodes in the system must have a mechanism for coming to agreement about what is a valid addition to the ledger and what is the current state of the ledger. This means that entries to the ledger can be added by different nodes and the ledgers held by the nodes in the system will be updated to reflect the changes made at individual nodes. This also implies that there is a system for deciding whether an entry, or set of entries, that has been added to one or more of the copies of the ledger is valid and reject entries that are not valid.
Immutability	The ledger is accumulative: once entries have been accepted into the ledger it should not be possible to go back and amend them. This is achievable by including some type of *hashing*[a] in the ledger, generating a key from the data in an entry in the ledger, and incorporating that key in the subsequent entries. This process makes it extremely hard to alter entries in the ledger without that alteration being noticed as any change to the data in the ledger will change the key (or hash) generated from that data. An audit of the ledger (passing back through the ledger, calculating the hashes for each entry and comparing them with the hash stored in the subsequent entries) will quickly highlight if entries have been changed.
	Immutability becomes more problematic in the distributed infrastructure as it is possible for different versions of the ledger to exist (remembering that each node has a version of the ledger and they may be in different states of being up-to-date). This is overcome by the global consensus model of the system, but this does need careful consideration to ensure that immutability is not compromised. There are mechanisms for addressing these issues which must be considered when designing the immutability and consensus models of the DLT.

[a]A "hash" is a one-way mathematical function that summarizes a piece of data as a piece of unique, fixed-size, short data. The hash function turns data into a key of random characters called a "hash."

Although it may seem strange to separate out these two types of permissions (after all does it make sense to be a node in the system if one cannot add or view transactions?), there may be use cases when entries can only be added to a ledger following external approval (e.g., in a regulated environment); or where visibility of entries in the ledger is restricted (e.g., if commercially sensitive data are present).

19.3.1.1 Using a Single Ledger for Carbon Markets?

One option would be to create a single distributed ledger that contains the emission units to be assigned, traded, and surrendered in all the ETS markets that will be involved in the network. This yields the benefit of providing a single ledger for all carbon trades, meaning

Table 19.2: Design features of DLTs that are configurable.

Feature	Description
Permissioning	DLT systems have traditionally been viewed as permissionless systems, in which anyone can participate and be part of the system. No one entity, organization, or system participant is in charge or has any more authority than any other participant. However, this is not necessarily a fundamental property of distributed ledgers.
Proof of work	One of the key features of permissionless cryptocurrency systems, such as Bitcoin, is the ability to decide when a transaction (addition to the ledger) is valid or not. With no permissions in the system there is no authority to consult on validity; therefore, a computational system for ensuring validity is required. This is tied up with the global consensus feature, which *proof of work* (also known as *mining*) schemes use to both control the availability of entries in the ledger (coins in the cryptocurrency) and ensure that the selection of which node can add an entry next is random in the system.
Smart contracts	When entries are added to the ledger it is also possible to automatically perform some actions associated with that entry or ledger. A *smart contract* is simply a set of operations to be performed automatically once the contract has been fulfiled.[a] In the context of DLTs, fulfiling the contract is likely to be the same as adding an entry into the ledger, although smart contracts could rely upon multiple ledger entries to be fulfiled.
Settlement, exchanges, or payment systems	Although DLTs can be used as cryptocurrencies and can also support many business processes, the actual transferral of money between parties, or settlement for physical assets, need not be part of the DLT. Indeed, there are numerous Bitcoin exchanges that operate to allow transfer between Bitcoin and Fiat currencies.

[a]Or in a more legalistic sense, it might be seen as the transactional terms and conditions embedded in computer code which allow automatic execution of the relevant transaction once precise conformity with those terms and conditions has been established.

that emission units traded between markets can easily be tracked and audited. However, the requirements to support different operational modes and timescales for individual ETS markets (and their respective emission units) make such a system unwieldy.

A single-level system would require multiple regulator (or administrator) nodes in the system, with all being able to issue and accept surrender of emission units. They would also potentially be entitled to authorize or block transactions of emission units issued by them or traded with organizations being regulated by them. Such entitlement would either potentially significantly reduce the responsiveness of such a DLT/market, or make the system very complex.

More critically, how different administrator nodes allocate emission units to entities, account for the differences in the respective markets; and the fact that each jurisdiction would need to continue maintaining and operating its own domestic registry (i.e., its part of the ledger), make a single market solution very hard to conceive. The translation of value between emission units issued by different administrator nodes on the same ledger would require sophisticated functionality in the systems surrounding the DLTs.

Finally, having a single-level DLT would make it difficult for carbon markets to connect or disconnect. It would require full migration of operations into the DLT for a market prior to joining, and full withdrawal of operations from the DLT into something different if a jurisdiction wished to disconnect.

Therefore, while a single-level DLT provides the requisite functionality for a market to operate, it is not compatible with the foreseen evolution of that market and its linkages with other markets. Hence, a broader view of the relationship between design and user adoption is required.

19.3.2 Designing for Diffusion

To have meaningful impact on emissions trading practices, any new solution has to be adopted by user groups that extract value, share knowledge about system use, invest in support, and thereby help to accelerate adoption by others. This enables the solution to diffuse across its intended markets, grow in scale and add value for users. Having designed a DLT for a specific set of Use Cases, it should be recognized that new users will bring new contexts and modalities that might not be predicted, but do need to be anticipated if the system is to achieve its design objectives.

The study of the diffusion of technology is a well-established field and relevant to the design of a DLT-based network infrastructure. The configurable design criteria discussed above offer justification for rejecting a single-level DLT design, including: complexity, responsiveness, and flexibility. These qualities are known to affect the rate of adoption and diffusion of any new technology. They were among the five characteristics for speedy adoption, first suggested by Everett (Rogers 1962), including: *relative advantage* over existing technologies; *observability* of those benefits; *compatibility* with existing needs and use patterns; relative *complexity* of the innovation and the degree to which it has *trialability*, where availability for experimentation is positively correlated with adoption speed.

Considering the configurable design criteria of *Permission*, it is reasonable to posit that each of the qualities associated with adoption and diffusion above may be somewhat dependent on the degree of permission (Table 19.3).

The associations above highlight the importance of the link between design decisions and the potential for an innovative technology to diffuse via adoption amongst its intended users. These associations also suggest that we can learn from earlier studies of the diffusion of information and communications technologies, including: (i) Open Systems development

Table 19.3: Potential relationships between DLT design and diffusion: Focus on permission.

Diffusion Characteristics	Potential Relationship with Degree of Permission
Relative advantage	Unpermissioned DLTs have applications, such as cryptocurrencies that have no fiat currency analog, and hence a significant relative advantage in that application area. Fully permissioned DLTs may operate with a central authority and offer an alternative to traditional systems where the locus of relative advantage is more constrained. *Relative advantage might therefore be seen as inversely correlated with degree of permission, but highly market specific.*
Observability and trialability	Unpermissioned DLTs may be used by anyone without restriction while fully permissioned DLTs require user identification and authentication that defines the type of access that is available to the user. To this extent, a potential user may experiment with the unpermissioned DLT and hence directly observe the purported advantages. Fully permissioned DLTs, however, require user engagement before full experimentation can occur. *Observability and trialabilty might therefore be seen as inversely correlated with degree of permission.*
Complexity	Complexity: the complexity that is "observable and trialable" by the user can be constrained by the degree of permission: strongly permissioned systems define the user access rights and, hence, constrain the range of features available to a user. Unpermissioned systems in contrast, not only require technical expertise, but also significant computing resources to engage with fully, representing the difference between using a cryptocurrency versus cryptocurrency ("bitcoin") mining. *Complexity might therefore be seen as inversely correlated with degree of permission.*
Compatibility	Compatibility: in markets where applications for DLTs are seen as improvements over legacy applications, the match between existing user needs and DLTs is easier to establish for fully permissioned systems.
	In terms of impact on diffusion, compatibility will be strongly market specific—while it is possible that an unpermissioned DLT will diffuse quickly across a global user base, so too will a fully permissioned system that is a clear upgrade path from existing systems for an established user base. *Compatibility might therefore be seen as positively correlated with degree of permission but highly market specific.*

and Open Innovation where, for example, as we adjust the degree of Permission we make the solution more "open" or "closed," impacting the potential for others to innovate at the "edge" of these technologies and generate new markets that accelerate diffusion. This is why diffusion is generally modeled as a nonlinear process, with the potential for exponential market growth. If it is assumed that an initial market demand exists then "Diffusion Potential" is highly sensitive to changes in "Degree of Permission" and must be carefully considered at the earliest design stage. This is illustrated in Fig. 19.1, along with the relationship between Degree of Permission and Openness discussed above.

Although it is clear from the design considerations applying to a single DLT for carbon markets that design needs to support the evolution of a market infrastructure, "designing for diffusion" illustrates just how nonlinear the diffusion process is, and hence the importance

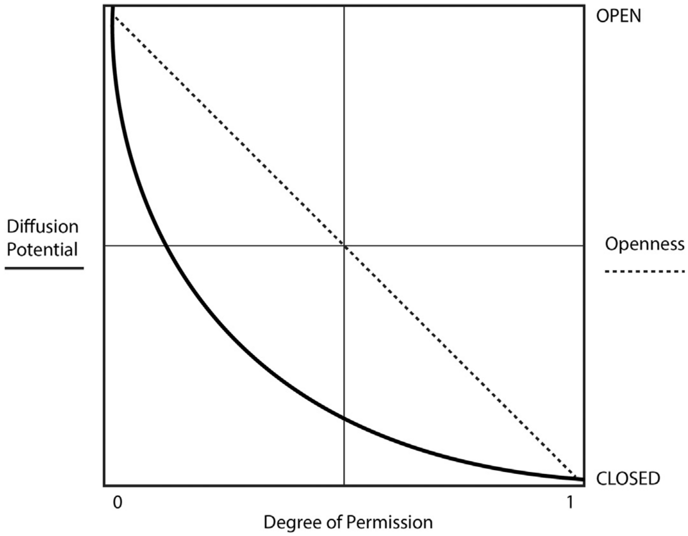

Figure 19.1
Diffusion potential as a function of Degree of Permission (see Table 19.3).

of incorporating this rationale into the design of any potential solution that will reduce emissions in accordance with the timetable defined in the Paris Agreement.

To better understand the barriers to diffusion, a more granular examination of the market structure and, in particular, User and Stakeholder groups is required.

19.4 DLT/Carbon-Matrix

The DLT/Carbon Matrix (Table 19.4) incorporates the linear and nonlinear elements of design. Applications at the level of corporate accounting and internal transactions over different ETSs will form the basic use case for any implementation scaling at the next level. The first level already carries the essential components for the following levels and diffusion requirement. If the functional requirements of each use case are not met then there is effectively no solution to diffuse; but as design decisions move from the left to the right, the network effects and diffusion impacts become stronger. These decisions are explored in the following text.

Table 19.4: DLT/Carbon matrix.

DLT/Carbon-Matrix	Ledger Use Case	Transaction Mechanism	Permissioning
Corporate level	1.	2.	3.
Single ETS	1.	2.	3.
NCM	1.	2.	3.

19.5 Ledgers (Matrix 1.)

19.5.1 What System Can We Have if We Don't Have a Single Ledger?

The alternative to a single-level structure is to have **multiple different ledgers for different carbon markets**. This would enable jurisdictions to run their own ledgers, manage their internal carbon market operations as required by local laws and regulations, but still connect to other markets for trades.

The challenge with multiple different ledgers is to create a distributed ledger: (i) within a single organization to manage its own carbon trading data; (ii) operate a single carbon market; and (iii) create a network among carbon markets. The same technology is used to operate different markets with different requirements, but can interoperate and allow movement of data between different levels.

Connection of ledgers is not a new concept. Indeed, mechanisms for connecting ledgers together such as, side chains,[6] inter-ledger protocol, as well as connection technology, such as that used by Ripple,[7] are actively currently being developed, tested, and used. We are proposing employing an approach broadly similar to the *side-chain* model. A side-chain model for linked carbon markets would allow different local carbon markets to connect to the global carbon market, without jeopardizing the core code of the global carbon market and putting potentially billions of dollars of emissions units at risk. Side chains, also known as intermediate ledgers, can join the federation of our primary market ledgers, enabling many primary ledgers (or *parent chains*) to trade/transfer resources.

A Carbon Market Ledger is the connection (*side chain*) between Single Market Ledgers for trading among these separate markets. Likewise, at the next level, the Single Organization Ledger is the connection (*side chain*) between Single Market Ledgers for accounting and tracking of assets across the markets an organization is involved in. However, we need to enable such functionality without lengthy waiting periods or delays between operations.

These intermediate ledgers provide a place to both undertake conversion of emission units between ETS markets, and ensure resources can be securely traded with both parties having visibilities of the resources to be traded and their availability. This can be achieved using two-way-peg-like mechanisms through the intermediate ledgers; although research is required in the safest way to integrate such mechanisms into DLTs without significantly

[6] This chapter has a good explanation of side chains and the two-way peg mechanism: https://blockstream.com/sidechains.pdf

[7] https://ripple.com/technology/

impacting ledger update rates while ensuring secure integration with ledger divergence reconciliation mechanisms.[8]

Also, our concept requires different types of participants in the overall ledgers, with administrator nodes able to interoperate with ledgers at levels higher or lower in the hierarchy. In keeping with the general requirements, required is the capacity to have different types of participants in the ledger for different operations (e.g., the regulator or administrator who can create and allocate emission units).

The attractiveness of this multilevel approach is that the DLT functionality can be used independently of other operations; for instance, a company can adopt the solution to manage its carbon assets even if the local market is not using such a solution. A local market can be created using this solution without requiring organizations participating in the market to use the solution for local accounting—and can use this approach without networking with other markets, or even before other markets are available. As different levels are separated, organizations or markets can change their approach or technology without impacting other markets or other involvement in these systems, allowing the system to diffuse easily.

The goal is to create a set of software tools that are sufficiently configurable to create and participate in any of the levels outlined, but do not mandate any particular level for their use. However, as the figure is illustrative it does not fully represent the required distributed infrastructure. With an operational solution, each of the nodes holds a full copy of the ledger and communicates, in a peer-to-peer fashion, with other nodes in the system.

19.6 Transaction Mechanism (Matrix 2.)

19.6.1 Are Smart Contracts Fit for Purpose?

Any system designed for carbon market trading and administration must be flexible enough to enable a range of metadata to be stored with emission units, and enable transactions through smart contracts. This is necessary to ensure emission units can be identified as being from a particular ETS, as part of a particular market cycle, for instance, and then not used in future market cycles (unless for instance, the jurisdiction allows banking, in which case this would be built into the metadata), or it may be required to ensure emission unit conversion rates and prices can be decided and applied automatically in trades.

8 Because of the distributed nature of the ledger, different nodes in the system can have different versions of the ledger, which need to be reconciled at some point using the consensus mechanism. The use of interconnected ledgers may complicate this reconciliation, some further work is required to ensure it can be achieved without rolling back resources committed to remote ledgers or received from remote ledgers.

Having fully functional smart contacts requires the code implementing those contracts to be correct and secure; so, there is no way to change the contract once it has been added to the ledger. Part of the work that needs to be done to link carbon markets with DLT will be to design a safe way of executing contracts on the ledger. Indeed, to ensure emission units can be transferred between ledgers, automatic locking, and releasing of emission units would be desirable; so, participants from other markets can have confidence that double spending of emission units is not occurring.

19.6.2 How to Enable Consensus without Mining?[9]

Technologies like Bitcoin or Ethereum use “mining” to ensure that no entity is in control of the network and subvert the ledger. However, it has a significant computational overhead and, hence, energy and cost requirements that make it unsuitable as a technology that needs to scale globally.

To address this, this chapter has proposed **a permissioned distributed ledger that does not require mining to add emission units to the ledger**. However, there would still need to be a mechanism for ensuring consensus across the copies of the distributed ledger. Mining is used to enforce some level of randomness over the choice of which node in the system (which copy of the distributed ledger) gets to add its update to the ledger at any given point in the operation of the ledger. Without mining, there needs to be a method to ensure that no one node can hijack the ledger and alter it.

19.7 Permissions (Matrix 3.)

19.7.1 How Can Permissions Be Distributed?

The authors advocate a **permissioned ledger**. Indeed, one of the strengths of the system design proposed is the ability to have different functionality, different roles, for individual nodes, or participants, in the system, not through different software, but **purely through different permission levels assigned in the ledger**. To implement a permissioned ledger system and assign different roles to different participants, this chapter is proposing **the combination of two ledgers in our infrastructure at each level: one ledger for recording emission unit transactions; whereas, the other ledger for storing permission**

[9] Mining: The process of undertaking arbitrary work to decide which network participants can add an entry at a given point in time. Bitcoin uses proof of work, where every node wanting to add an entry to the ledger undertakes to solve a mathematical problem, the node that solves it first gets to add their entry to the ledger next. The random and variable nature of the mathematic problem randomizes which nodes can add entries to the ledger at any one point, distributing update rights and aiming to avoid the ledger being hijacked by any given node.

transactions, using an Authorization Unit (AU) to record permissions of organizations or individuals in the system.

Each node participating in the DLT will have a full copy of both ledgers, but what they can do with the ledgers, and how much data they can see, will depend on their entries in the permission ledger, their AU. Without an AU, they will only have basic access to the ledger. This may be "read only" access to all the emission unit transactions, or may be simply being a passive node on the network, depending on how the DLT is configured.

19.8 Conclusion

This chapter has considered some technological options for connecting carbon markets and argued that, although there are many options, the capabilities of distributed ledger technologies are well suited for doing so in a way that will help deliver the emissions reduction targets of the Paris Agreement.

Exploring use cases and DLT design flexibility indicates that design not only needs to be functionally capable to address the requirements of a viable market infrastructure, but also needs to address a complex and dynamic range of stakeholder requirements. By so doing, the solutions can diffuse quickly to build the required scale on a timescale that is compatible with the deadlines for the Paris Agreement targets.

To achieve this, the authors propose a solution based on a concept of **multiple levels of Distributed Ledgers** (what we describe as "**federated distributed ledgers**"), but with dual ledgers at each level (encompassing both permissioning data and market data) that can be deployed to enable markets. Hence, at each level, there is a set of ledgers encompassing permissioning, then a second set of ledgers that facilitate inter-market trading, or connecting of the markets. This approach offers a number of advantages including reduced transaction costs through: (a) making the transactions faster; and (b) eliminating intermediaries that both slow the transaction and charge fees.

In addition, the intended design emphasizes ease of adoption by participants, with the objective of making the software (and, if applicable, hardware) as accessible as possible, leveling the playing field and, hence, helping the solution diffuse quickly. Other types of engagement are also anticipated and need to be supported, with participants other than compliance entities likely to engage with the market also if there are opportunities for delivery of value-added services or direct arbitrage.

Consequently, it follows that to meet the functionality anticipated by the Paris Agreement, the technology platform needs to be designed to accommodate carbon markets that are different in their design, implementation, and ambition. Experience with DLT suggests that the technology is mature enough to deliver a robust functioning system, but specific design options to address potential barriers to adoption and diffusion require additional research.

Reference

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Further Reading

<https://blockstream.com/sidechains.pdf>
<https://ripple.com/technology/>