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Taking the Guesswork Out of Climate Action

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> *"We need transformational change at the speed that science demands, and in a manner consistent with democracy."*[1]
>
> *- Christina Figueres*

If climate destabilization is the existential challenge of this era, then humanity is compelled to do whatever is necessary in order to address it. While many strategies to address climate change have emerged,[2] there remains a need for innovators, policymakers, and the public to develop tools that perform at the scale required to address the challenge.

This article looks at the relevance of blockchain and distributed ledger technologies ("DLT")[3] as a mechanism by which data-based climate strategies can be deployed to reduce pollution and improve climate outcomes.

Blockchain for Social Good

The promise of blockchain technology to drive socially beneficial outcomes is frequently extolled by developers and supporters of DLT. However, examples of viable real-world use cases that rely on the technology are relatively few in number and nascent in development.[4] This disparity between the purported abilities of the technology and the actual impact being realized invites questions about the viability of addressing the climate challenge through the use of blockchain to solve environmental, sustainability, and governance ("ESG") challenges.[5]

Policymakers, innovators, and entrepreneurs are starting to consider the role of public blockchain technology alongside other emerging data-based technologies like machine learning (AI), edge sensor (IoT), and satellite observatory (EO) technology as they seek to build an effective global climate enforcement regime.[6] This article argues that there are important ways that blockchain could be utilized as a tool to address climate challenges and that the specific considerations of the challenge faced will inform the best role for deploying technology.

The Climate Data Challenge and Blockchain

Because greenhouse gas ("GHG") emissions are invisible to the human eye, efforts to craft appropriate climate policies and responses are limited by an inability to see emissions in real-time and in detail. In order to develop an appropriate response to the damage being done, there needs to be a full and accurate set of emissions data. Such information would enable decision-makers to incorporate technologies that enable real-time measurement, tracking, and monitoring at a global and granular level.

In the United States, the climate policy landscape at the federal, state, provincial, regional, and local levels remains fragmented with major gaps in coverage and a lack of coordination. The result is an inability to map and analyze important changes in the carbon pollution and emissions landscape. Additionally, changes in political administrations, the potential for cyber attacks, and the cost to maintain digital infrastructure all pose foreseeable risks to any long term efforts to centralize climate data, learnings, and insights. In order to overcome these challenges, there is a need for a new type of infrastructure that is public, accessible, trustworthy, and permanent.

Against the backdrop of the global climate landscape, it is increasingly likely that digital technology will play a critical role in addressing these challenges. The unique demands of a coordinated, disintermediated, and trustworthy resource for storing numerous, global sets of information, supports an argument for the use of blockchain technology. Such a solution could enable governments, corporations, consumers, and others to share and access information transparently, without creating a risk of a single point of failure.

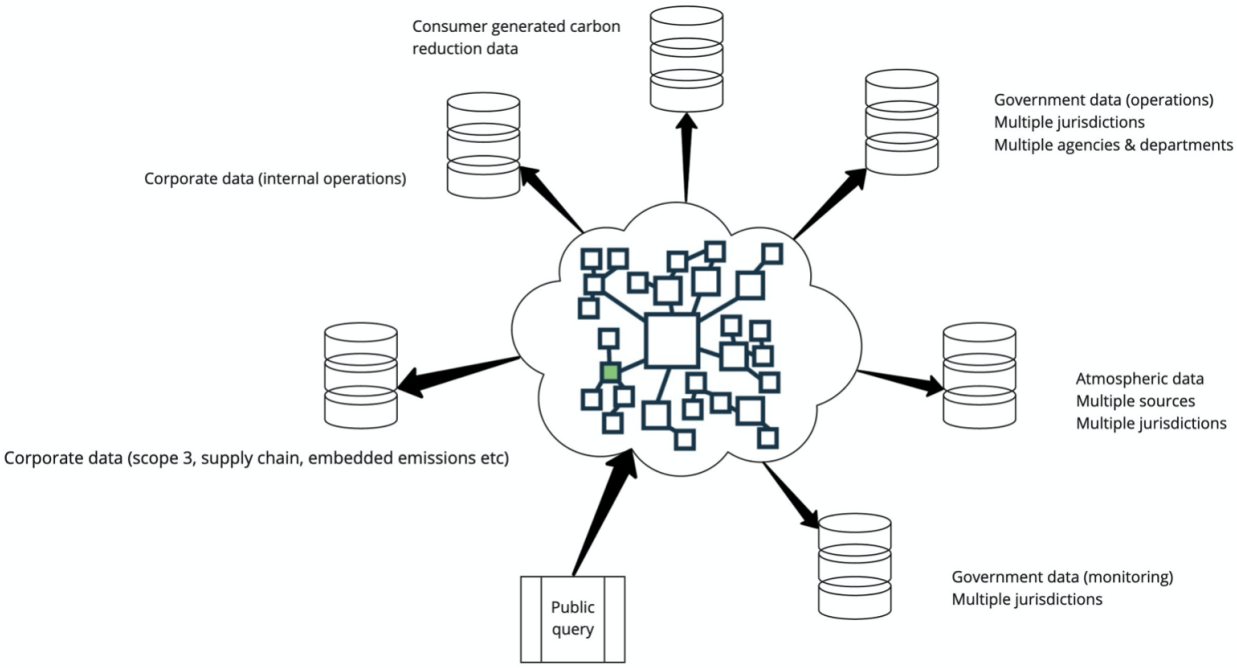


Figure 1: A blockchain base layer connected to climate databases with public query

As ideas emerge about how to appropriately leverage blockchain technology in order to support effective climate solutions, one area of study that can be further examined as a means to encapsulate both the technical and the governance aspects of the technology is computational law. In *A Perspective on Legal Algorithms*, professor Alex 'Sandy' Pentland offers a framework for building Computational Law systems, including: setting goals for the expected outcome of the system, identifying

measurement criteria used to evaluate performance, creating a series of tests to determine a system's fitness before it is deployed, conducting iterative revisions through pilots, and continuous auditing through retesting.[7] Infusing environmental policymaking with computational law tools and frameworks could simultaneously improve the current legislative and regulatory approaches, while enhancing the effectiveness and impact of climate emissions reduction initiatives. With those guideposts in place, we offer two use cases that would be substantially beneficial to the fight against climate change.

Use case: Public and private carbon data transparency

The inability to effectively measure baseline emissions and progress against carbon reduction targets means the largest carbon emitters are able to continue polluting in a relatively unabated manner and largely avoid accountability for the impact they cause to the Earth.

The current approach for monitoring climate emissions relies almost exclusively on voluntary campaigns for reporting inventories, goals, commitments, and agreements that do not require the full transparency needed to make meaningful, strategic, and rapid carbon reductions.[8] Emphasizing climate action leadership, these efforts have enjoyed significant successes in the past decades, most notably with the 2015 UN Paris Agreement.[9] By their nature, these voluntary campaigns do not record a full list of emitters, nor the full scope of carbon pollution by those reporting. Unfortunately, the result is a continuing lack of transparency from polluters that threatens to undermine the long term credibility of these important initiatives.

A new approach is needed for reporting climate data based on fully transparent, binding agreements for public and private entities. This would ensure that the world has an accurate, comprehensive climate emissions database. Such a database would enable new types of market solutions that promote evidence-based approaches to the reduction of pollution and governing the commons. As a technology that has demonstrated an ability to improve trust and coordination between a diverse network of parties where there is a low degree of trust, blockchain can be a foundational element of a global ledger of climate and pollution data.

Strengthening the current reporting regime could also offer important second order benefits. A global ledger of climate and pollution data would help facilitate the implementation of locally auditable standards, based on the needs and abilities of organizations and institutions of different sizes. In turn, this could lead to a more robust and dynamic regulation of the climate, based on the measured impact and end the practice of puffery and fraud adopted by companies who proclaim their green bona fides and environmental leadership without demonstrating meaningful proof of their true impact.[10] The sharing economy, and ride-hail companies in particular, have aggressively marketed the eco-benefits of their platforms, in spite of the fact that recent research shows they may actually be net contributors

to GHG emissions.[11] In the absence of third-party verifiable climate and emissions data, bold statements by global corporations of their intent to be net zero with emissions by 2050 also raise similar questions about the sincerity and verifiability of such claims.[12] These efforts to end greenwashing would also grow consumer confidence in environmental products and services, a key prerequisite for improving the overall marketplace dynamics for such products.

Measurement of baseline carbon pollution emissions and target setting

The first step on a path to accurately measuring the efficacy of reduction measures is to establish a complete baseline of existing GHG emissions from the entity or the jurisdiction being assessed. Unfortunately, many of the current baseline measurement regimes allow the substitution of modeled data for parts of an entity's overall carbon footprint. A requirement for complete baseline reporting with real, not modeled, data is a fundamental precondition to any rigorous empirical assessment. However, it is difficult to imagine any central entity that could serve as a single repository for this global climate data.

In order to capture a comprehensive baseline measurement at a global scale, a technology infrastructure capable of detecting, recording, and monitoring global emissions is essential. In the case of climate reporting, this is a particular challenge with Scope 3 emissions, which include upstream and downstream emissions and waste emissions.[13] A comprehensive reporting regime for Scope 3 emissions should require bottom-up data collection and third party monitoring technologies as part of the design to capture the most complete and accurate data.

Properly designed, a decentralized public blockchain ecosystem could provide an infrastructure capable of accommodating and digitally knitting together national, subnational, and corporate data networks and create a gap-free data regime, as well as provide an integrated data platform for a wide range of recording and measurement technologies.

Perhaps the most feasible implementation of this concept would involve an oracle network that provides a feed of information that is recorded on a public blockchain. For example, a hardware solution employing edge sensor technology could become sufficiently decentralized as to be made tamper-resistant. Then, combined with incentive mechanisms such as staking and slashing, additional mechanisms for ensuring safety and data integrity could further reduce vulnerability to corruption. Combining such information with raw data and information from open data platforms could be used to extend this idea even further and enable business competitors to begin holding each other accountable.

This is not to say that there are not concerns with these types of technological implementations. The opportunity for erasure and correction of data, for example, raises an interesting challenge at the individual level. On the corporate side of things, the ability to protect intellectual property could also

be weakened by more robust reporting standards. However, promising developments in the form of zero-knowledge proofs and other encryption techniques may serve as a mechanism by which to reveal insights from the data (e.g., how much pollution is taking place in a certain area?) without revealing the source or relevant parties to the data (e.g., specific levels of GHG pollutant) without revealing other unrelated information from the emitter (e.g., business practices and related intellectual property).

With a complete baseline in hand, it is then possible to set very specific reduction targets. Part of the target setting process should include details about the technologies and methodologies to be applied in the reduction efforts as part of the public recording of data. Doing so at the time targets are set and recording them in an immutable way will provide a measure of confidence of the authenticity of the technologies and methodologies used in order to enable effective third party auditing.

Measurement of progress against targets and efficacy of reduction strategies

Once targets are set, public and private entities need the tools to measure progress against set carbon reduction targets[14] and utilize the best available technologies to meet these targets. This process requires definitively knowing, rather than merely modeling, whether and how much progress is being made against stated reduction targets. A requirement to record these goals contemporaneously on a public blockchain would provide a way to monitor progress and act as a verifiable check that builds additional trust in the process.

As in the case of measuring initial GHG emissions, it will be necessary to require fully transparent reporting of emissions when measuring actual progress against stated carbon emissions reduction goals or targets.[15] In addition, to be able to capture a comprehensive measurement of the effectiveness of reduction measures on a global scale, it will be necessary to build a technology infrastructure capable of recording the full range of initiatives in an integrated, publicly accessible, and tamper-resistant manner.[16] The ability to continuously monitor these emissions could be addressed by combining the blockchain infrastructure with IoT sensor and EO satellite technologies. This approach could address the temporal gap that exists with the current regime, where complete emissions inventory reporting is done infrequently, often several years apart, during which time changed conditions are not monitored and any adjustments to climate action plans are delayed until the next inventory is complete.

Public blockchain could be used to record and make publicly available the relative efficacy of implemented technology solutions. Such reports could include comprehensive details about the technologies utilized and protocols followed in a way that would allow others to verify for themselves the efficacy of a strategy or solution and implement the same with the required fidelity to ensure similar impacts. Third party verifications or audits could be recorded on the public blockchain so

others could determine the validity of these audits, acting as a protection against incomplete, inaccurate, and even fraudulent outside verification. Since the record of the audit itself would be permanent and available for review by regulatory authorities, the incentive to cheat the audit process would be less appealing and could even result in additional penalties for the auditor. Here again, the integration of emerging global digital monitoring technologies such as satellites, ground sensors, cameras, and other non-integrated observation technologies could provide a coordinated and universally accessible data infrastructure for such third party audits.

The proper incorporation of blockchain technology into the domain of climate reporting offers the possibility of expanding the collective understanding of computational law. In addition to digitizing regulations and allowing for programmatic execution of rules, the combination of these practices with oracles and other sets of information can help build toward a full computational law stack. Legal instruments encoded as smart contracts, with triggering conditions and built-in execution could transform not only data gathering and transparency, but also improve outcomes for government subsidies of development projects, penalties, and third party contracts. The addition of more reliable data sources (affordances inherent in a well-functioning blockchain network) would likely provide additionally important use cases. Given these possibilities, it would be wise to consider the positive implications of such decentralized oracle networks.

Use case: Incentivizing consumer behavior change

Any comprehensive effort to address the climate crisis must include strategies to influence and change individual consumer behaviors. Increasingly, policymakers are turning their attention on how to use positive economic incentives to drive carbon reduction efforts. Public blockchain architecture could be a key component of a global climate reduction incentives system. In such an ecosystem, the use of a digital token connected to a public blockchain platform could be used to incentivize eco-positive actions by consumers through the creation of a smart contract that rewards holders with a digital payment when their activities are verified.

The use of incentives has applicability across a range of consumer activities where individual action will be key to the viability and sustainability of a low-carbon economy: the use and re-use of products, aligned with the drive to zero non-compostable solid waste; the efficient use and conservation of clean water; the smart, efficient use of energy, products, and resources; and a move to clean transportation alternatives. Already there are some promising early efforts to pilot such concepts.[17]

Rewarding clean trips and encouraging eco-mobility

We know that carbon emissions from the transportation sector comprise a significant percentage of a jurisdiction's total footprint. Transportation's share of California's overall carbon footprint was an astonishing 60% in 2017, with personal vehicles making up the largest part of these emissions.[18]

Imagine a blockchain-based digital currency or rewards program that is connected to a transportation system. Such an eco-mobility system would connect multiple modes of low-carbon transport options — rail, bus, bicycle, and other zero emissions vehicles — across multiple jurisdictions using a public blockchain platform. Users of the platform would record the use of connected, low-carbon options through an app, take their alternative low-carbon trip, and receive a digital token or a reward for the trip that is based on the difference between the carbon emissions of the environmentally conscious trip and a baseline fossil-fuel powered trip in a single occupancy vehicle. This approach could also be used to create more localized carbon credits for use in the various carbon markets, with the credit representing units of actual, verifiable reductions in emissions.[19]



***Figure 2**: a blockchain rewards system for eco-mobility trips*

At the macro level, this implementation could work in a manner similar to data collection oracles, with a few notable differences. The simplest implementation would be a mobile application that uses GPS technology to record a user's location, in addition to some biometric information, and then applies machine learning to self-reported data, and determines a range of options and probabilities about the user's most likely mode of transportation. Under this implementation, each mobile device on the network acts as an oracle, which has the result of offering greater visibility into the actions of participants, with a cost of slightly less reliable data for each individual. When combined with a series of smart contracts, such a network would be able to record and share data for computation and incentivize participants toward more climate-friendly actions. This level of granularity would be a breakthrough for increasing public and private carbon data transparency. Particularly notable is the value that could be created from this source of immutable, decentralized baseline data. Finally, in all iterations of such applications, the network effects of collecting and maintaining anonymized individual data from these networks can be useful to those interested in modeling trends, calculating deltas, and identifying viable future scenarios for climate-centered innovation.

Users of this blockchain ecosystem could be rewarded by public and private entities for the digital tokens earned through their clean trips, regardless of political jurisdiction, encouraging ongoing use of low-carbon options, and creating a growing pool of people who embrace eco-mobility globally. It is

likely that a range of such applications will emerge as mobile computing continues to grow in popularity and decentralized applications increase the economic viability of digital micropayments.

Under this model, low-carbon transport companies and investors would benefit from investing in the system as a highly targeted form of direct marketing and business development, while the public sector — cities, counties, states, and agencies — could verifiably track progress toward their efforts to reduce transportation emissions. This data could be used to fund programs and components of the ecosystem that work well and advance public policy objectives, while providing a politically popular new approach to fighting climate change.

Recording clean trips on a public blockchain platform would enable consumers, regulators, and other stakeholders to track the amount of carbon emissions reduced in real time and enable more targeted and timely interventions, incentivizing those modes and programs that demonstrate the greatest impact. Second layer solutions, like those using zero knowledge encryption technology, could limit the identifiable information that is shared, while still providing a rich source of meta-data for innovators to create new enterprises that grow the low carbon transportation sector.

Conclusion

Climate action efforts — including reporting, target setting, and carbon trading systems — would benefit from a serious examination of the role blockchain could play as part of a comprehensive, large scale strategy to drive down carbon pollution emissions. Properly designed, a public blockchain could help solve for some of the existing governance challenges that exist in a way that is more efficient and more trustworthy than what exists now. A fully transparent reporting framework for any and all jurisdictions, along with the security of public, and tamper-resistant verification, could address some of the challenges that have shaped the current climate reporting landscape into what it is today.

Legislative and regulatory efforts responding to climate change and other environmental phenomena are particularly well-suited for new approaches to policy making, such as the application of Pentland's framework, through an aligning program and software development, policy development, and continued development of the underlying scientific research.

Ultimately, much of the utility of blockchain solutions for climate action will depend on factors that are external to the use of blockchain as a ledger. For example, the "Oracle Problem" will need to be better addressed.[20] However, the potential options for building this infrastructure are myriad, ranging from consumer-facing liquid markets for earned tokens, to the creation of a decentralized oracle network with subsidized incentives for participating businesses.

Finally, the exploration of blockchain technology as an application to address the climate crisis should open up similar examinations of other environmental and public health challenges where risks and

consequences have been socialized without the parallel provision of resources to address such challenges. Now is the time for blockchain developers and advocates to engage with partners that have deep, sector specific knowledge of these global challenges in order to create customized solutions that meaningfully address our shared challenges.

Disclosure

The authors are co-founders of BlueVista (https://www.bluevista.co/earth-points) building the Earth Points (TM) digital carbon accounting system and clean transportation app to give companies and individuals the ability to accurately track and reduce their climate pollution emissions.

About the Authors

Michael Schmitz is an attorney and Fellow at CodeX Stanford where he is the Project Lead of the Climate Data Policy Initiative (https://law.stanford.edu/projects/cdpi/) and member of the CodeX Blockchain Group, co-managing RegTrax, the group's regulatory tracking initiative and co-founder of BlueVista.

Catherine Atkin is an attorney and social impact entrepreneur. She is Principal of Carbon Accountable, a policy and strategy engine for initiatives to create comprehensive carbon data ecosystems that drive climate engagement, action and accountability, and contributor to the Climate Data Policy Initiative (https://co2accountable.com/)and co-founder of BlueVista.

Reuben Youngblom, JD, is a Fellow at CodeX Stanford, a member of the CodeX Blockchain Group, and co-manages RegTrax, the group's regulatory tracking initiative (https://law.stanford.edu/codex-the-stanford-center-for-legal-informatics/regtrax/). He is also a contributor to the Climate Data Policy Initiative and a co-founder of BlueVista.

Footnotes

1. Christina Figueres, *The Future We Choose: Surviving the Climate Crisis*. Knopf Doubleday Publishing Group, 2020. ISBN: 0525658351. ↩
2. Paul Hawken, *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming*. Penguin Books. April 2017. ISBN: 9780143130444.

Mark Z. Jacobson, Mark A. Delucchi, Mary A. Cameron, Stephen J. Coughlin, Catherine A. Hay, Indu Priya Manogaran, Yanbo Shu, and Anna-Katharina von Krauland, "Impacts of Green New Deal Energy Plans on Grid Stability, Costs, Jobs, Health, and Climate in 143 Countries" One Earth 1, 449-463, December 20, 2019. https://doi.org/10.1016/j.oneear.2019.12.003. ↩

3. Blockchain and DLT, or decentralized ledger technology. In this article the term blockchain will be used to reflect this broader class of technologies. ↩

4. Doug J. Galen, Nikki Brand, Lyndsey Boucherle, Rose Davis, Natalie Do, Ben El-Baz, Isadora Kimura, Kate Wharton, Jay Lee. "Blockchain for Social Good: Blockchain for Social Impact" Center for Social Innovation, RippleWorks. April 11, 2018. https://www.gsb.stanford.edu/faculty-research/publications/blockchain-social-impact ↩

5. Environmental, social and governance (ESG) criteria are a set of standards for a company's operations that socially conscious investors use to screen potential investments. (https://www.investopedia.com/terms/e/environmental-social-and-governance-esg-criteria.asp) ↩

6. For an excellent and comprehensive review of these technologies as applied to climate data modeling see Next-Generation Digital Ecosystem for Climate Data Mining and Knowledge Discovery: *A Review of Digital Data Collection Technologies*. Hsu A, Khoo W, Goyal N and Wainstein M (2020). Front. Big Data 3:29. doi: 10.3389/fdata.2020.00029. ↩

7. Pentland offers design principles for developing legal algorithms rooted in the fundamentals of the scientific method and offered for application in the policymaking process. Pentland, A. "Sandy." (2019). A Perspective on Legal Algorithms. MIT Computational Law Report. Retrieved from https://law.mit.edu/pub/aperspectiveonlegalalgorithms. ↩

8. None of the current voluntary reporting campaigns require full transparency - reporting all emissions across all scopes. Leading examples of these reporting initiatives include the largely public sector initiative, the Global Covenant of Mayors for Climate & Energy, composed of local governments from across 6 continents and 132 countries (https://www.globalcovenantofmayors.org/) and CDP (formerly the Carbon Disclosure Project) that includes companies, cities, states and regions from over 90 countries (https://www.cdp.net/en/). ↩

9. The Paris Agreement was crafted as a hybrid response to the question of how to report emissions reductions progress, with voluntary diplomatic engagement amongst member states through the UN process (led by the UNFCCC) and efforts to intersect with growing social movements calling for increasing accountability. The agreement combined elements of a binding treaty governing the process for ratifying member states, with elements of a voluntary, non-prescriptive reporting framework of intended nationally determined commitments (NDC) that each party to the agreement determines outside of the purview of the agreement. https://www.un.org/sustainabledevelopment/blog/2016/09/the-paris-agreement-faqs/ ↩

10. see Berg, Florian and Kölbel, Julian and Rigobon, Roberto, Aggregate Confusion: The Divergence of ESG Ratings (May 17, 2020). Available at SSRN:

https://ssrn.com/abstract=3438533 or http://dx.doi.org/10.2139/ssrn.3438533↩

11. A report from the Union of Concerned Scientists underscored the climate impacts of ride-hailing trips, finding that "ride-hailing trips result in an estimated 69 percent more climate pollution on average than the trips they displace." Anair, Don, Jeremy Martin, Maria Cecilia Pinto de Moura, and Joshua Goldman. 2020. "Ride-Hailing's Climate Risks: Steering a Growing Industry toward a Clean Transportation Future." Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/ride-hailing-climate-risks ↩

12. Microsoft, Apple and Amazon are among the largest of global Fortune 500 companies to publicly pledge deep carbon pollution reductions recently. See David Roberts, "Microsoft's Astonishing Climate Change Goals, Explained"*Vox*, July 30, 2020, (https://www.vox.com/energy-and-environment/2020/7/30/21336777/microsoft-climate-change-goals-negative-emissions-technologies) and "Apple Commits to be 100 percent carbon neutral for its supply chain and products by 2030", Apple press release, July 21, 2020, https://nr.apple.com/dE9n5d3o7T. Amazon pledged to be net carbon zero by 2040, in a public statement June 23, 2020. (https://sustainability.aboutamazon.com/environment/sustainable-operations/carbon-footprint). Joseph Pisani, "Despite Green Pledges, Amazon's carbon footprint grew 15%" APWire, June 23, 2020, (https://apnews.com/article/95986c4ba779f1d35ac4ca2afdd745c3). ↩

13. Scopes refer to the categorization of the source of GHG emissions, as defined by the World Business Council for Sustainable Development and the World Resources Institute in "Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard - Revised Edition", and widely followed by governmental and corporate actors trying to address their carbon footprint. Scope 1 emissions are all direct emissions, from the activities under the control of a firm, which includes fuel combustion by the company. Scope 2 emissions are indirect emissions, from electricity purchased and used by a firm. Emissions are created during the production and eventual use of that energy by the firm in the course of doing business. Scope 3 emissions are all other indirect emissions, from activities of a firm, stemming from sources that the firm does not own or control, including emissions associated with business travel, employee commute, procurement, waste and water usage. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf ↩

14. The *Science Based Targets* initiative offers a model for this. The initiative defines targets setting as "science-based" if aligned with the goals of the Paris Agreement and consistent with current scientific assessment of the requirements to meet the Paris goals. *Science Based* Targets is a collaboration between CDP, the United Nations Global Compact (UNGC), World Resources Institute (WRI), and the World Wide Fund for Nature (WWF) and one of the We Mean Business Coalition commitments. https://sciencebasedtargets.org/. ↩

15. Reporting progress against the meeting of air emissions targets is currently required under the federal Clean Air Act (CAA), offering a model for an enforcement regime for carbon emissions. That act requires the creation of a State Implementation Plan (SIP) to be promulgated as part of the mandated action plan of a state, territory, or local air district to reduce air pollution in areas that do not meet National Ambient Air Quality Standards, or NAAQS. Performance against the SIP is the basis of enforcement actions to ensure the goals of the Clean Air Act are achieved. Clean Air Act of 1970 (1970 CAA). https://www.epa.gov/sips/basic-information-air-quality-sips ↩

16. To achieve this data system upgrade, regulators could add a requirement to use the Best Available Technology (BAT), an approach that has been embraced broadly in recent years for plans to achieve air pollution reduction targets. A BAT requirement for a carbon pollution reporting regime would enable regulated entities to have flexibility in selecting the technology pathway to achieving reductions, but ensure that the most effective technology is deployed given the chosen pathway. *See* OECD (2018), Best Available Techniques (BAT) for Preventing and Controlling Industrial Pollution, Activity 2: Approaches to Establishing Best Available Techniques Around the World, Environment, Health and Safety, Environment Directorate, OECD. https://www.oecd.org/chemicalsafety/risk-management/approaches-to-establishing-best-available-techniques-around-the-world.pdf. ↩

17. For example, SolarCoin (https://solarcoin.org/) rewards producers of solar energy with digital rewards, Nori (https://nori.com/) rewards farmers who store carbon in the soil, Terra0 (https://terra0.org/) rewards the maintenance of forests. ↩

18. Dan Lashof, Devashree Saha, "California Shows How the U.S. Can Reduce Transport Emissions" World Resources Institute, September 24, 2020. Available at: (https://www.wri.org/blog/2020/09/). ↩

19. While carbon markets have existed for since the mid-2000s, there have been very few examples of transportation related carbon reduction protocols being proposed as the basis of offset credits. The vast majority are based on the preservation and protection of land, usually either sustainable agricultural practices or forest preservation. ↩

20. Jimmy Song, "The Truth about Smart Contracts." Medium. June 11, 2018. Available at: https://medium.com/@jimmysong/the-truth-about-smart-contracts-ae825271811f ("In a decentralized context, smart contracts only work if there's some definitive link between the digital version and the physical version. That is, whenever the digital version of the house changes ownership the physical version has to also change ownership. There's a need for the digital world to 'know' about the physical world. This is known as the 'Oracle problem'.") ↩