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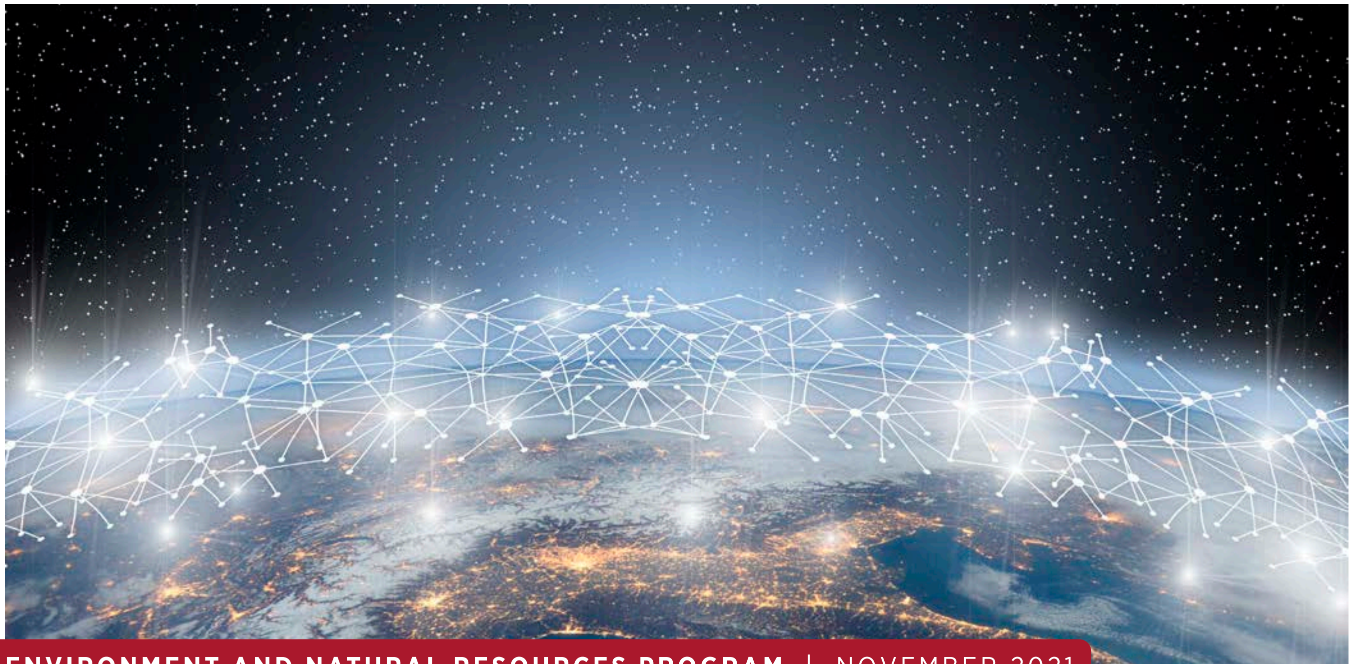

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The Role of Blockchain in Renewable Hydrogen Value Chains

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A rainbow of colors currently dominates almost every conversation on the transition to a low-carbon economy: green, grey, blue, turquoise, pink, yellow[1]—an ever-increasing palette to describe the same colorless, odorless, and highly combustible molecule, hydrogen. The only difference is the chemical process used to produce it.

The colors of hydrogen are crucial for the energy transition because each production pathway generates different amounts of greenhouse gas emissions. For example, while grey hydrogen, produced from fossil fuels, yields up to 20 tons of carbon dioxide per ton of hydrogen, green hydrogen,

1 The colors of hydrogen correspond to different production pathways. Green hydrogen is produced from renewable energy by water electrolysis, grey from fossil fuels, blue from natural gas with carbon capture and sequestration (CCS), turquoise from natural gas pyrolysis, pink from nuclear, and yellow from solar.

produced from renewable energy sources like solar and wind, yields no emissions. Furthermore, although these colors all refer to the same molecule, production costs differ: green hydrogen remains substantially more costly today.

With aggressive development and deployment of electrolyzers and other hydrogen technologies at scale, green hydrogen could become cost-competitive with blue hydrogen, produced from natural gas with carbon capture, by 2030 in many countries.[2] Overall, the rate at which green hydrogen costs decrease will also depend on government policies and incentives, such as carbon pricing and tax credits.

Therein lies a critical challenge for the successful transition to a low-carbon economy. As energy systems increasingly evolve from centralized to decentralized, from "grey" to "green," stakeholders will need to efficiently account for and track emissions and green molecules in a transparent, secure, and standardized way, and must be able to do so along value chains from production to consumption.

Tracking Emissions and Green Molecules along Value Chains

Stakeholders must be appropriately credited for investing in the current premium required to produce carbon-free hydrogen. Therefore, the ability to verify a hydrogen molecule's origin from clean energy sources amidst a dynamic energy landscape presents both a sizable challenge and a tremendous opportunity. Addressing this dilemma will require managing large volumes of multi-party transactions, which need to be settled quickly, securely, and inexpensively.

Today, the origin of a commodity is certified through certificates of origin. However, the certification process can be complex, requiring many intermediaries that add time, labor, and cost burdens. Furthermore, concerns over whether commodities are accurately counted and traded pose challenges to scalability. Innovative technologies like blockchain could significantly simplify carbon accounting and green certification processes.

2 IRENA (2020), "Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal" International Renewable Energy Agency, Abu Dhabi.

A blockchain is a shared, decentralized, and immutable digital ledger that securely stores transactions and enables the automated execution of "smart contracts"[3] among parties without a central authority or intermediaries.[4] At its core, the technology consists of a distributed network of independent computers, or nodes, that manages the blockchain; the nodes receive new transactions, review their legitimacy based on consensus protocols, and integrate them into a chain.

Blockchain technology is already demonstrating its innovation potential in the financial sector, thanks to its unique structural advantages of trust, efficiency, control, and security. These properties make blockchain well-suited to optimize processes, enable novel business solutions, and promote greater access to services for a broader range of users by significantly reducing costs. However, significant challenges need to be addressed to foster adoption, such as interoperability between blockchain networks, trust among users, and energy consumption.

Many trends driving profound changes in the energy sector can also benefit from and further unlock blockchain's full potential. Pilot applications are emerging in many developed and developing countries. For example, US-based Brooklyn Microgrid runs a community energy market within a microgrid[5] where members can buy and sell energy from each other using smart contracts on a blockchain.[6]

Overall, the increased adoption of distributed generation, energy storage, and smart devices, together with the need to track emissions and green molecules along value chains, creates new complexities and challenges for energy markets designed for centralized control. Indeed, blockchain technology can help policymakers and regulators address concerns over measurement, certification, and tracking.

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3 Smart contracts are programs stored on a blockchain that run when predetermined conditions are met. They are typically used to automate the execution of an agreement so that all participants can be immediately certain of the outcome, without any intermediary's involvement or time loss. They can also automate a workflow, triggering the next action when specific conditions are met.

4 Swan, M. (2015), "Blockchain: Blueprint for a new economy" O'Reilly Media Inc.

5 A small network of electricity users with local sources of supply that is usually attached to a centralized national grid but is also able to function independently.

6 Brooklyn Microgrid, https://www.brooklyn.energy/, accessed October 2021.

Conclusions and Policy Recommendations

As technology and policy pathways to decarbonization will need to rely on processes that accurately measure and record emissions and green molecules across global markets characterized by limited transparency, uneven standards, different regulatory regimes, and trust issues, blockchain can greatly accelerate the transition to a low-carbon economy. But significant barriers to adoption remain, including policy, regulatory, and technological hurdles.

Due to the substantial public and national security interests ingrained in the energy sector, policymakers and regulators will need to fully assess all opportunities and challenges, including the integrity of information on a blockchain, rules of access, transparency issues, and privacy requirements. Furthermore, blockchain's full potential will not be realized until a critical mass of users embraces the technology.

Going forward, adoption at scale will require a concerted approach to:

- Convene stakeholders across the value chain and foster collaboration in addressing first-mover risks, strategic barriers, and opportunities.
- Educate stakeholders about blockchain technology and its value proposition, as many still have limited understanding or misconceptions about its true potential (for example, conflating the concepts of blockchain and cryptocurrency). Address stakeholder concerns associated with transparency of transactions and cybersecurity risks.
- Develop a stable regulatory framework for users and adopters and structured markets and incentives to support key players, particularly utilities, in adopting blockchain and investing in digital infrastructure.
- Identify design principles, best practices, and standards for robust blockchain platforms that achieve shared agreement among key stakeholders (including mandating reasonable energy consumption levels associated with blockchain adoption).
- Support research and development efforts and pursue pilot and demonstration projects.

As governments and corporations increasingly prioritize green hydrogen in the energy transition, and as new policy, business, and regulatory models for a rapidly changing energy sector are developed, blockchain is poised to play a prominent role in supporting these strategies. If blockchain succeeds in disrupting the energy industry, stakeholders throughout the energy value chain will reap substantial benefits for years to come.

This policy brief is the fifth in the Mission Hydrogen series, a collaboration between the Harvard Kennedy School's Belfer Center and the Italian Institute for International Political Studies (ISPI) on the future of hydrogen for the G20.

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