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Digitizing water management: Toward the innovative use of blockchain technologies to address sustainability

Edy Sriyono[1*]

Abstract: Water has always been considered as a physically scarce resource, particularly in North Africa, Central Asia, West Asia, among others. On the other hand, the current water management system is facing substantial difficulties due to the depletion of resources, the complexity of regulation, as well as the increasing demand of water in society. This article attempts to show the possibility of using blockchain technologies in managing scarce resources, such as water, to address environmental sustainability. Those applications could consolidate the seamless integration of the existing water management system through keen agreements which dwell on the blockchain and take into account automated work processes. It is expected that the implementation of blockchain technology will ensure trust, transparency, and accountability among individuals and other economic actors.

Keywords: smart water management; environmental sustainability; distributed ledger; review
Subjects: Civil Engineering; Water Resources Management; Environmental Sustainability

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Additional information is available at the end of the article

1. Introduction

Ever since 1987, when the World Commission on Environment and Development published the report "Our Common Future," the grand idea of sustainability has become an essential part of the public debate (WCED, 1987). Environmental sustainability is not merely reducing waste, recycling used products, or developing green products. Nowadays, tending to environmental change is just one of the numerous aspects of what is known as an inclusive green way of thinking, which adds to the ecological and biological system changes (Iman, 2019).

Although the notion of environmental sustainability has been embraced for more than 30 years, its meaning is contested. Furthermore, its operationalization is hindered, and its complexity is

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PUBLIC INTEREST STATEMENT

Managing scarcity is and has never been easy. In the case of water, we are currently facing difficulties not only in contributing to the aquifer, in extracting the groundwater, or in using the water, but more importantly, in distributing the water. New emerging technologies such as blockchain or distributed ledger can be used to manage water distribution and water management more effectively and cheaply. This implementation of blockchain could not only lead to the eventual creation of more effective use of water resources but also increase the transparency and accountability in society.

escalated. For example, Dryzek (1997) posits that companies translate "development" as "growth," developing countries suffer from global inequality, and environmentalists attempt to establish in intrinsic values of the ecology. Imaginative organizations have the force to produce benefit, yet to take care of fundamental ecological issues, tending to more great difficulties and adding to networks. Consequently, policymakers should know some biology, and a decent scientist should know some finance and policy strategies.

With regards to water management, the third World Water Forum (2003) states that fresh and clean water is "a precious and finite resource central to sustainable development, economic growth, social stability, and poverty alleviation." Global water security becomes a problem faced by every country globally. For quite a while, managing water has depended on old technologies and complicated procedures that might be irrelevant today. Yet, there is a need to address such a problem using non-conventional approaches, such as using decentralized blockchain technology (Lin et al., 2018). Blockchain is the architecture that consists of an internet-based application layer being processed on the current stack of protocols, establishing a new level of structure to enable transparent and democratic economic transactions (Swan, 2015).

The purpose of this article is to explore the possibility of exploiting the use of blockchain technologies to help us in managing water resources effectively and efficiently. In this case, the use of blockchain could support the congruity of value and amount, wherein the core of the procedures are key creative arrangements that would encourage development and interface forms into a closed-end cycle. In this era where everything emerges with the state-of-the-art technology, it is expected that this article could shed some light on both academics and practitioners to embrace the benefit and potential of blockchain, particularly in helping us address the environmental sustainability issue together.

To perform the review and analysis, we compile top-tier interdisciplinary journals in relation to water resource management and blockchain technology. Such journals were manually searched within Google Scholar in the last couple of years for papers that contained such keywords anywhere in the text. From there, we reviewed, examined, and coded those articles to be interpreted further. This became the foundation for our conceptualization and analysis toward the use of blockchain technology for water management in addressing sustainability.

In so doing, the structure of this essay is as follows. The next section elaborates on the digitalization process in the current world economy and describes the emergence of blockchain technology. The two sections that follow will focus on the application and implementation of blockchain technology in the water industry and the significance of digitizing water management. Lastly, the final section presents several conclusions, implications, and suggestions for future research avenues.

2. Digitalization and blockchain technology

Computerized change has become a vital piece of the frameworks and procedures enhancement (Yoo et al., 2010). New rising advances, including blockchain, big data, artificial intelligence (AI), internet of things (IoT), and machine learning (ML), are quickly supplanting inheritance frameworks and quickening progress in the society. More specifically, a blockchain or a distributed ledger, initially block chain, is a continuously evolving structure of digital records that are interrelated using agreeable standard protocols. Each block has an embedded cryptographic hash of the previous transaction, a time record, and information exchange (Swan, 2015). According to its structure, a distributed ledger is impervious to modify the information. This is why blockchain can be applied to many different industries and sectors (see Table 1).

The critical test for blockchain is to be considered as an inventive integrative arrangement that can give an offer over various business forms, as opposed to a virtually troublesome innovation (see Table 2). The upside of distributed ledger technology is its improvement to make new

Table 1. Blockchain applications

Class	Examples
Currency	Bitcoin, Ethereum, Litecoin, Monero, Dash, ICON, XRP, Hypercash
General	Escrow transactions, bonded contracts, third-party arbitration, multiparty signature transactions
Financial transactions	Stock, private equity, crowdfunding, bonds, mutual funds, derivatives, annuities, pensions
Public records	Land and property titles, vehicle registrations, business licenses, marriage certificates, death certificates
Identification	Driver's licenses, identity cards, passports, voter registrations
Private records	IOUs, loans, contracts, bets, signatures, wills, trusts, escrows
Attestation	Proof of insurance, proof of ownership, notarized documents
Physical asset keys	Home, hotel rooms, rental cars, automobile access
Intangible assets	Patents, trademarks, copyrights, reservations, domain names

Source: Adapted from Swan (2015, p. 10)

Table 2. Documents registered digest from proof of existence

Sample Document Digest	Timestamp
320c891df43f3505acdfa3bd4db02fbce691fdda6 8e10bfa65c42902cbfc7cc1	2020–02-11 09:09:54
45ff928c5364b1556bf2480bc64cf74bc88e6ec140 fe5648d368fdeae3091f8b	2020–01-29 01:05:00
071f1ef9de294ebab5858b06f4ee1b54fd8ec748653 962cce289298518d6c517	2019–11-30 03:55:30
c8ef33b52bd36c975ec91a7e29307e46b4 cdf22777d80e3ca2240d5386d4b58a	2019–09-03 14:22:35

Source: calculated using SHA-256 Hash

structured plans of action for multiple kinds of associations and to digitize resources (Swan, 2015). Blockchain or distributed ledger is a central innovation that sits as a structure hinders beneath different organizational forms, empowering enterprises, and organizations to structure their associations and processes in a general sense of new ways. Inside the water utility part of agriculture (Lin et al., 2017), blockchain arrangements can computerize back-end, regulatory and legitimate procedures, regardless of whether it is charging and customer management or water resources digitization and exchange.

Blockchain innovation can likewise assist with building a confided in an environment with one rendition of reality. Rather than requiring separate frameworks for every organization that necessities to run procedures and save information, blockchains give a solitary distributed sensible structure inside that organizations can work as a team with their partners (Swan, 2015). This makes a confided in condition between members where, generally, numerous manual procedures and compromise procedures will often be necessary. From the money related perspective, it is about incomes and expenses. A new test would be to make a roundabout economy activity with sophisticated income models, which then would eventually be monetarily and biologically flexible.

A current case of a distributed ledger application is discount vitality, which operates on different ledgers to give required levels security, unchanging nature, and adaptability (Poberezhna, 2018). This implementation diminishes the expense of working discount vitality exchanging back workplaces. Likewise, in the water exchanging form, blockchain will give not only standards, endorsements, and designation. By putting away these on a mutual record, counterparty information the board—a procedure which regularly costs millions over an industry division—can turn into an inconsequential issue (Lin et al., 2017).

3. Blockchain applications for the water industry

The calls to utilize blockchain technology to solve the distribution problems, mitigate the risk involved, and monitor the water management system proactively is relatively new in the literature (see Dogo et al., 2019). For a reason for recordkeeping, blockchain can help water area organizations to oversee adjusting and settlement all the more effectively, in contrast with the currently applied techniques (Poberezhna, 2018). All data, including utilization and value-based records, can be naturally put away on a permanent record. Blockchain and shrewd agreements can conceivably help water part organizations and government bodies to get to ongoing information in regards to pieces of the overall industry, utilization designs, the executives of service bills of buyers, and different prospects. Overseeing records on a blockchain stage can fundamentally decrease the expense of record keeping.

Besides, blockchain can be utilized for information compromise. By making a circulated information archive using a system of PCs, each of which would hold a duplicate of the record, as opposed to centralized power, could empower controllers to screen and manage the status of allocated distributions, water licenses, and the condition of exchanges, approving accessibility of assets progressively, as opposed to following the customary administrative revealing procedure. Secure decentralized ledger for the private biological system, yet guarantee security and information consistency streams to all economic actors involved in the water resources management.

Departing from that argument, the distributed ledger innovation can assist with forestalling theory in water exchanging, which is critical in such a delicate segment. This is accomplished by making more noteworthy straightforwardness to reviewers and controllers through account exchanges and activities on the chain. One of the necessities to empower water exchanging is to make another computerized character for associations (that is, ranchers) and digitize the water resources (for example, privileges,

Thirdly, blockchain could be utilized for reporting, compliance, and audit review. Distributed ledgers in the water industry could be utilized to monitor the means asked by guidelines from the government and regulator. Recording activities, as well as their yields changelessly in a blockchain, would make a review trail for controllers and streamline consistency. Such a change would lessen the required time and exertion drastically (and in this manner cost) that monetary establishments spend on administrative detailing, just as increase the quality, precision, and trust all the while.

Water management blockchain gives unchanging nature, quickness, and straightforwardness of data, where partners can be a piece of the continuous procedure as opposed to being beneficiaries of posterior analysis and examinations. The novel plan of some distributed ledger stages can give amazing, yet lightweight frameworks with the center qualities, for example, easy versatility over various systems, reliable isolation of information for industry-grade security, and adaptable repetition across allowed hubs (Lin et al., 2017).

Finally, bond issuance could be utilized on the water management blockchain. Innovation in distributed ledger focusing on water industry could disentangle the issuance of the green bond, by giving a shared-space to the different offices associated with the confirmation of prerequisites, the process of such bond issuance, the compliance and protections toward government regulations

and customer rights, as well as the possible exchanging of the green bonds. In particular, water resources management can utilize blockchain in gathering finances and managing investment in water-related sectors.

We posit that such practices can be considered as a smart water management system. Smart water management or intelligent water management is an optimization of the use of information and communication technology, which provides automatic real-time data on water resources and environmental conditions as well as forecasts of weather and climate conditions (see Dogo et al., 2019). The smart water management system has also been implemented by national authorities in many different countries to support the flood early warning system and drought early warning system.

The potential for applying smart water management or intelligent water management in the management of water resources is indeed very broad (Dogo et al., 2019). This includes managing the quantity, quality, efficiency of irrigation water use, monitoring the security of natural resource infrastructure, handling risks related to natural disasters related to water, as well as drought. These data can later be used in resolving challenges related to water resource management that has been carried out based on integrated natural resources management. Another application is to real-time monitor water source infrastructure through the dam operational and improvement safety project program as well as various uses and strategies to optimize the use of water resources.

4. Digitizing water management

The interest for new water is relied upon to outperform reserve by no less than 40% inside the following twenty years. In numerous ongoing publications, including World Bank's "High and Dry: Climate Change, Water and the Economy," it features that the cost of shortage in clean and fresh water, worsened by environmental dynamics, would impact a few locales a massive sum of their country's Gross Domestic Product (GDP), spike relocation, and duplicate the danger of contention. The two researchers and financial specialists concur that under the same old thing situation, high water worry in the next 30 years puts in danger almost half of worldwide GDP, basically influencing rare water territories, for example, the Middle East, Central Africa, as well as East Asia (UN Water, 2012).

Water as an asset is urgent in the vitality of water network and nourishment, and vitality squander nexus, that agrarian use represents about 70% of worldwide withdrawal of water, 20% of industrial use, and 10% for civil utilization. Vitality creation represents 15% of worldwide withdrawal of water, and could conceivably increment by 20% in less than 15 years (UNESCO, 2014). Thus, in order to drive economic improvement and establishment, it is urgent to examine parts of the security and availability of water that are profoundly related with water nourishment and vitality of such resources. Similarly, water money needs interests in the framework, data innovation, foundations, and networks. Those complex activities can be managed using technologies such as blockchain, AI, or big data (see Table 3).

Across local indicators, there are numerous issues in the part of water management. Such issues include flooding, dry spells, shortage, matured foundation, water quality, wasteful water the executives, and ineffectively controlled utilization. Be that as it may, the most testing task is to set up the correct measurements and motivating forces for evaluating water, which will support progressively productive water the executives, improve better water quality and abatement contamination, and invigorate greater interest in water foundation. In contrast with other reasonable improvement objectives (SDGs), the water part needs speculation, advancement, and coordinated effort (Iman, 2019).

Despite the way that water is the primary worldwide vital asset, speculation into the part is substantially less in correlation with other comparable critical assets. Low overall revenues and rewards, contextualism of issues, the nonattendance of framework or aging, semi proprietorship,

Table 3. Criteria for sustainability in water management

Criteria	Indicators	Technology
Ecological sustainability	• Annual recharge rate • Pollution rate	AI, big data
Social sustainability	• Water-related disease • Access to water	AI, big data
Economic sustainability	• Cost price of water • Efficient use of water • Highest economic return	Blockchain, IoT
Technical sustainability	• Durability of water system • Promoting efficient use of water system	Blockchain, IoT, AI
Political sustainability	• Integrating water policies • Institutional capacity • Open and democratic planning	Blockchain

Source: Adopted from Donkers (2000) and Klostermann and Cramer (2007).

complicated, multilayered guideline, closely related business and political interests, enormous passage boundaries—every one of these variables frequently brings about a diminishing amount of utility tasks in water and postponed progression of the company, when all is said in done. As indicated by the World Bank's (2016) analysis, interest in this particular segment in developing countries was 1 USD.9 billion in 2016, or about half compared with the five-year normal of about 4 billion USD. This report also indicates that the utilization of water tasks pulled in just 669 USD million of private interest, a substantial decrease from the past five-year normal of 88%.

Taking into account that nourishment assurance is exceptionally subject to water assets and the reality that agricultural creation would increase twofold within twenty years because of the expanding populace, financing scarce resources such as water is critical for such ventures, particularly for water or nourishment subordinate, areas of counties worldwide. Departing from the OECD (2016) report, the several agendas of activity joined that can incentivize interest in the security of water, and maintainable development are (1) Maximizing an incentive from current water speculations in security and availability, (2) Choosing venture roadmap that diminishes water hazards in any event cost after some time, (3) Ensuring collaborations and complementarities with interests in different areas, and (4) Upscaling financing through appealing danger bring distribution back. Thus, our overall proposed framework can be seen in Figure 1.

The essential financial and ecological issue is of duplicating request, against diminishing, rare assets. This foundational issue requires an all-encompassing and inventive methodology that ought to be implemented not only in open segments but also in private sectors and furthermore rehashed on over outskirt section. Given the unpredictability of the problems and unpredicted difficulties in water management, an all-encompassing, inventive arrangement is required, which thus would incorporate green money, creative technology, and parts of water stewardship. Uniting various open and private associations will be a significant methodology to accomplish a few SDGs concerning industry, advancement and framework, maintainable urban areas and networks, capacity utilization and creation, atmosphere activity, and organizations, for the objectives (SDGs 6, 9, 11, 12, 13, and 17).

A private distributed ledger is relied upon to be utilized to upgrade current and anticipated recordkeeping in the future, strengthen the audit process but also make it easier, and consistency revealing, whenever necessary, with an emphasis on divulgence of natural effects (supportability

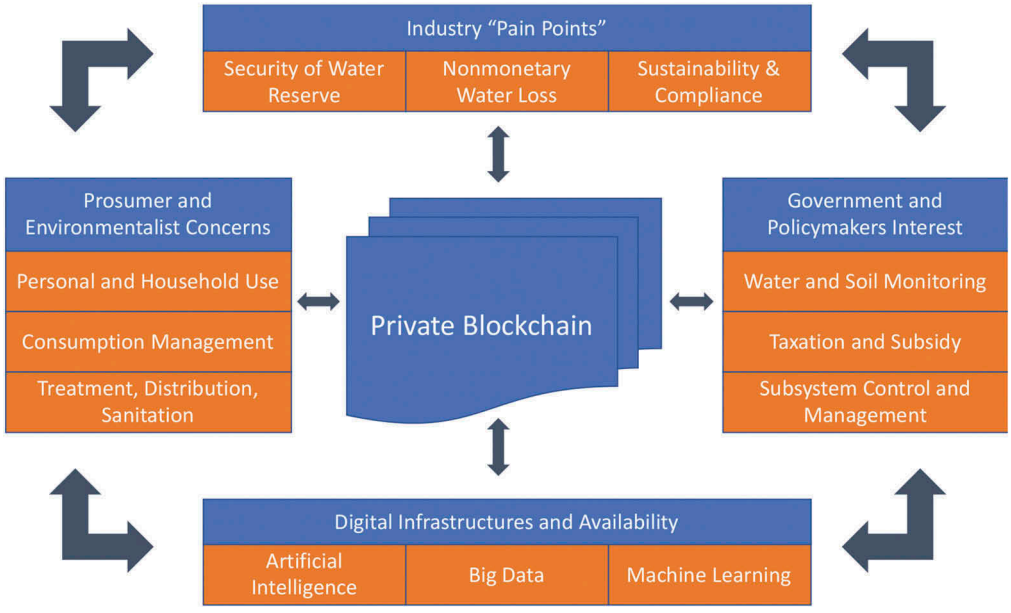

Figure 1. Proposed framework for water management blockchain.

Source: Author

lists, CSR, ESG, and comprehensive evaluations menus, not to mention Thompson Reuters, MSCI, Trucost, or S&P Dow Jones), furnishing different leaders with the brought together the information they have to change conduct.

Utilizing the innovation such as distributed ledger as an autonomous examiner and a believed wellspring of distributed data would assist with giving fundamental straightforwardness and confirmed responsibility to the market. A capacity to win, collect, trade and exchange transactions would be executed, verified, and saved on the mutual record. Water management blockchain would likewise be a piece of the guarding instrument against deluding correspondence or theory. The capacity to exchange water has been fundamental in keeping up water system segment earnings during severe drought and also required to be much progressively significant within environmental change situations. In spite of the fact that water asset the executives is confused, it should not be mind-boggling.

Australia is broadly recognized as a worldwide pioneer in water assets the board (Power Ledger, 2017), and all the more explicitly in the utilization of markets for water and exchanging as a critical device to distribute such scarce resources among contending utilizes including city usage, factory, the earth, and horticulture (see Figure 2). As regulators, all-inclusive, keep on transforming their water assets, the executives notwithstanding environmental change and more noteworthy culmination between clients, a lot of them are beginning to move to the exchange market of water. China, for instance, is merely starting to grasp water exchanging. The EU recently has made conventions, and Spain needs a water exchanging stage. In the US, opportunities for a necessary exchanging stage apparent in California, Nevada, as well as Texas (Poberezhna, 2018). To give a more comprehensive illustration of the case, please see the Box 1—case of Puerto Rico.

Distributed ledger on water management was relied upon to give significant incentives to cash for governments, add to expanded income for irrigators, and continue cultivating networks stable and giving extra water to the environment. To accomplish most extreme outcomes in the briefest conceivable time, coordinated effort and use of integrative arrangements are essential, both in general society and private divisions. The idea of blockchain reconciliation could be an ideal case of

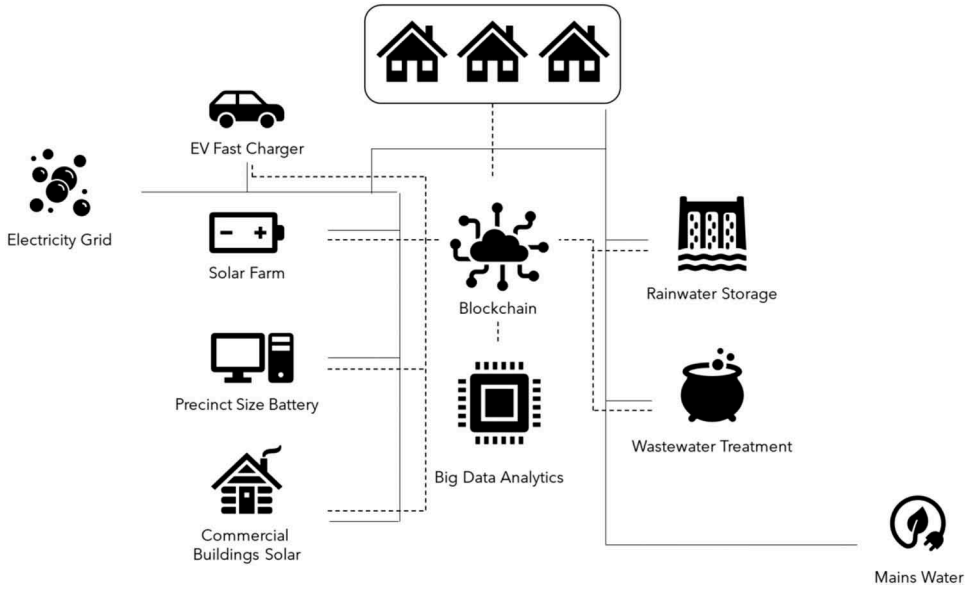

Figure 2. The proposed infrastructure of blockchain in water management.

Source: Author

creative reasoning and opportunities for collaboration, that is planned to examine the foundational issue of shortage.

As explained above, we can confidently conclude that distributed ledger can be used not only for water use management but also for water reuse as well. For instance, we can develop peer-to-peer water trading platforms to facilitate wastewater exchange and rainwater harvesting that could lay a foundation for a further prosumer market. Prosumers can obtain wastewater for further treatment, reuse, and recycling, as well as disposal over its water production life cycle. Thus, blockchain can fundamentally transform the way we manage water resources, from carefully exploiting clean and fresh water, into settlement and payment processing in water consumption, into water usage and periodic reporting (Lin et al., 2018).

5. Conclusion

This article exhibits that several ventures and initiatives are already exploiting blockchain innovation, focusing on setting up a demonstrated and confided in condition to construct a straightforward, as well as increase economic water creation and dissemination, coordinating critical partners into the store network.

There are important lessons that can be drawn from this overview. Blockchain or distributed ledger is a promising new technology that encourages more straightforward use to store and manage a network of scarcity resources. However, numerous risks might challenge the implementation of the system despite everything exist. It could obstruct its more exponential notoriety among farmers, ranchers, and water supply networks. On the other hand, the not so distant future will appear if and how these difficulties could be tended to by legislative and private endeavors, to set up distributed ledger innovation as a protected, robust, and straightforward approach to guarantee sanitation and respectability. To conclude, it is very enthusiastic about imagining how blockchain could be combined along with other emerging advancements, such as AI, ML, RFID, IoT, NFC, and so forth, towards more intensive robotization of the water supply networks, improved with full accountability and transparency.

From an approach point of view, different moves can be made, for example, by empowering the development of blockchain-disapproved of biological systems in environmentally sustainable ways of life, supporting the innovation as a component of the general objectives of advancing the

intensity and guaranteeing the supportability of the water network, just as planning a reasonable administrative structure for blockchain usage. The financial manageability of the current activities, as they have been introduced right now, should be surveyed, and the results of these monetary investigations are required to impact the ubiquity of the blockchain innovation sooner rather than later, applied in the agriculture and water network area.

Despite such benefits, obviously, there are also significant problems and issues that shall be comprehended, beyond those at a functional level. For instance, in order to lessen the boundaries of such implementation and exploitation, governments and policymakers should encourage how water management blockchain is performed and promote the establishment toward a more transparent and accountable organization. At the regional level, in particular, cross-departmental collaboration is needed to coordinate such efforts in promoting the use of blockchain technology altogether. Indeed, such an initiative is also perfectly aligned with the smart city. Smart water, for example, has become one of the foundations that constitute a smart city. We believe that such a bottom-up approach to be more efficient and effective in addressing sustainability.

More importantly, governments and policymakers likewise shall devote more resources in research and development (R&D) activities, such as in preparing and testing the system, installing the system, promoting the use of such water management blockchain, and prove that the concept has the significant benefits of this water management distributed ledger. Gupta (2017) examines the conceivable change of governments towards the utilization of the blockchain, taking note of the way that administrations and their appropriate offices ought to watch and comprehend the specific "pain points," tending to them as needs be. By doing so, we could maximize the use of our water resources, and at the same time, address the sustainability challenges in a smarter and more effective way.

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