

From Chain to Change: Blockchain as a Catalyst for SDG 7

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Abstract: Achieving SDG 7 (Sustainable Development Goal 7)—ensuring universal access to clean, reliable, and affordable energy—requires technological innovations that can address technical, economic, and social challenges. Blockchain technology, with its inherent transparency, decentralization, and traceability, is emerging as a potential catalyst for accelerating this transition. This paper examines the main blockchain applications in the energy sector that support SDG 7, including solutions for decentralized grid management, renewable energy tracking, peer-to-peer energy trading, and innovative financing and incentive mechanisms. This research also investigates a set of case studies from diverse geographical and regulatory contexts, aiming to assess the effectiveness, scalability, and sustainability of ongoing initiatives. The academic implications of this paper lie in advancing the theoretical debate on integrating decentralized technologies into energy systems. Managerial and policy implications relate to strategies, business models, and regulations that enable the adoption of blockchain solutions consistent with global sustainability goals.

Key words: Blockchain, Sustainable Development Goal 7, clean energy access, decentralized energy systems, peer-to-peer energy trading, energy policy.

1. Introduction

Ensuring universal access to affordable, reliable, sustainable, and clean energy is not only a pressing socio-economic challenge but also a foundational enabler for achieving SDG 7 (Sustainable Development Goal 7) [1]. While notable progress has been made in expanding electricity access globally, the most recent estimates indicate that approximately 675 million people still lack access to electricity, with the majority concentrated in Sub-Saharan Africa. Additionally, nearly 2.3 billion people remain dependent on inefficient and polluting cooking systems [2]. In addition, even in electrified regions, affordability, reliability, and the transition toward renewable sources remain uneven, hampered by infrastructural, institutional, and financial constraints.

Meeting SDG 7 requires not only scaling up renewable energy generation but also transforming

how energy is produced, distributed, and consumed. Technological innovations in the fields of digitalization, decentralization, and democratization of energy systems are increasingly recognized as pivotal to this transformation [3]. Among these, blockchain technology—a form of distributed ledger technology that enables secure, immutable, and transparent peer-to-peer (P2P) transactions without the need for centralized intermediaries—has attracted considerable scholarly and industry attention in recent years [4, 5]. Its features have been leveraged in various experimental and commercial initiatives aimed at enhancing the traceability of renewable energy, enabling P2P energy trading, automating market transactions through smart contracts, and facilitating innovative financing models for energy access projects [6-8].

Despite a growing body of literature and numerous pilot projects worldwide, the integration of blockchain into energy systems remains in an early stage of

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maturity, characterized by technological experimentation, regulatory uncertainty, and mixed evidence on scalability and long-term sustainability. Academic discussions have so far primarily focused on the technical architecture of blockchain applications and their potential for market innovation. At the same time, less attention has been devoted to synthesizing these findings in the context of SDG 7 and assessing their real-world implications from a policy, managerial, and socio-economic perspective. This gap underscores the need for comprehensive studies that bridge technological discourse with broader sustainable development objectives.

This paper aims to bridge this knowledge gap by exploring how blockchain technology can contribute to the achievement of SDG 7. Rather than treating blockchain as a monolithic innovation, the analysis unpacks the technological principles that make it particularly suited for applications in the energy sector, such as decentralization, immutability, and transparent record-keeping. Building on this foundation, the discussion delves into several key domains where blockchain is already making an impact. These thematic explorations are grounded in evidence drawn from carefully selected case studies spanning diverse geographical regions and regulatory environments. Together, these elements provide a comprehensive understanding of both the technical and socio-economic potential of blockchain to advance the global clean energy transition.

This analysis is guided by two main objectives. On one hand, it aims to contribute to the ongoing academic debate about the role of decentralized technologies in sustainable energy transitions. On the other hand, this paper aims to provide practical insights for managers, policymakers, and practitioners seeking to utilize blockchain to enhance access to clean energy. By integrating technological, managerial, and policy perspectives, this research offers a multidimensional understanding of how blockchain can be operationalized to accelerate progress toward SDG 7.

2. Theoretical Background and Research Question

2.1 Energy Transition and SDG 7

The global energy transition refers to the structural shift from fossil fuel-based systems toward renewable, low-carbon, and more efficient energy systems [9]. In the context of SDG 7, this transition is not limited to decarbonization but also encompasses universal access to energy services and improvements in affordability and reliability [1]. Achieving such a multidimensional goal demands not only large-scale deployment of renewable generation technologies but also a systemic transformation in how energy is produced, distributed, and consumed [3].

This transformation is increasingly conceptualized through the “3D” paradigm of decarbonization, decentralization, and digitalization [10]. Decentralization involves shifting from centralized utility-scale generation to distributed, often community-owned systems. Digitalization integrates advanced information technologies into energy systems to enhance efficiency, flexibility, and user participation. The intersection of these trends creates opportunities for more democratic and participatory energy markets, but also raises challenges in governance, coordination, and trust [11].

2.2 Blockchain as a Technological Enabler

As already said, blockchain technology offers a decentralized, transparent, and tamper-resistant infrastructure for recording and verifying transactions [12, 13]. In energy systems, these features enable a range of applications directly relevant to SDG 7, including:

- P2P energy trading: Facilitating direct transactions between prosumers and consumers without central intermediaries, potentially reducing transaction costs and increasing local energy resilience [6, 7].
- Renewable energy certification and traceability: Recording the provenance of energy in immutable

registries, allowing consumers and regulators to verify compliance with sustainability standards [5].

- Decentralized grid management: Coordinating DERs (distributed energy resources) such as rooftop solar, storage systems, and electric vehicles through automated smart contracts [14].

- Innovative financing models: Enabling micro-investments and tokenization schemes for renewable energy projects, particularly in underserved markets [4].

By embedding trust into the technological infrastructure, blockchain can help address some of the governance and coordination problems that arise in traditional energy systems, where actors may have conflicting incentives and limited prior relationships.

2.3 Research Gap and Relevance

Although pilot projects and academic studies have explored various blockchain applications in the energy sector, most research has focused on technical feasibility or conceptual frameworks, with less emphasis on assessments of their contribution to SDG 7 in real-world contexts [5, 15].

Addressing these gaps requires a multidisciplinary approach that integrates insights from energy systems engineering, information technology, economics, and public policy. This paper contributes to this emerging field by synthesizing the main blockchain use cases for SDG 7, analyzing evidence from international case studies, and deriving implications for academia, practitioners, and policy-makers. In doing so, this paper seeks to answer the following research question:

What lessons can be drawn from major international case studies regarding the implementation of blockchain-based solutions for sustainable energy?

3. Literature Review

3.1 P2P Energy Trading

P2P energy trading allows prosumers—entities that both produce and consume energy—to directly exchange surplus electricity with other users, bypassing

traditional intermediaries. Blockchain plays a pivotal role in these systems by providing a secure, immutable, and transparent transaction ledger, enabling automated settlement via smart contracts [6]. Early implementations, such as the Brooklyn Microgrid in New York, demonstrated the feasibility of local energy markets where participants trade solar-generated electricity using blockchain-based platforms [6, 7]. Similar initiatives have been tested in Europe, Australia, and parts of Asia, highlighting potential benefits in cost reduction, grid resilience, and consumer empowerment [16]. However, scalability remains limited by regulatory barriers, interoperability issues, and the absence of standardized market designs.

3.2 Renewable Energy Certification and Traceability

Guaranteeing the provenance of electricity is crucial for promoting renewable energy adoption and meeting sustainability targets. Blockchain-enabled EACs (energy attribute certificates) provide an immutable record of renewable generation, allowing buyers to verify the source of their electricity in near real-time [5]. Projects such as Power Ledger in Australia and Energy Web Foundation's Origin platform have demonstrated the use of blockchain for certifying renewable energy transactions across borders [17]. This application not only facilitates compliance with renewable portfolio standards but also enables voluntary green energy markets by enhancing transparency and consumer trust. Academic research has emphasized blockchain's potential to reduce fraud in certificate trading while lowering administrative costs compared to centralized registries [18].

3.3 Decentralized Grid Management

The integration of DERs—including rooftop photovoltaics, battery storage, and electric vehicles—into power grids poses challenges in coordination, balancing, and market participation. Blockchain can serve as a decentralized coordination layer, enabling DERs to participate in local flexibility markets,

ancillary services, and demand response programs [14]. Smart contracts automate the activation and remuneration of flexible services, while distributed consensus mechanisms ensure trust among participants without the need for centralized operators. Pilot projects, such as the Enerchain platform in Europe, have explored wholesale energy trading on a blockchain, while microgrid-level applications have demonstrated automated load balancing among community members [19].

3.4 Innovative Financing Models for Energy Access

In emerging economies, blockchain can facilitate innovative financing schemes to expand energy access, particularly in off-grid and mini-grid contexts. Tokenization of renewable energy projects enables micro-investors to fund infrastructure, with blockchain technology ensuring the transparent tracking of investment flows and energy production outcomes [4]. For example, the Sun Exchange platform enables individuals worldwide to purchase solar cells for deployment in African schools and businesses, with payments managed through blockchain-based systems. This reduces transaction costs for cross-border financing and increases investor confidence by providing immutable performance records [20].

3.5 Challenges and Limitations

Despite promising applications, blockchain adoption in the energy sector faces several obstacles. Technical challenges include the scalability of consensus mechanisms, high energy consumption of certain blockchain types (e.g., Proof-of-Work), and the need for interoperability with existing grid management systems [13]. Regulatory frameworks often lag behind technological developments, creating uncertainty regarding the legality of P2P trading or tokenized energy markets [16]. Additionally, the socio-economic impact of blockchain in energy access projects requires careful consideration, as benefits may not be equitably distributed without deliberate policy design [11].

4. Methodology

4.1 Research Design and Case Selection

This paper adopts a qualitative multiple-case study approach to explore the role of blockchain technology in advancing SDG 7. Case studies are particularly useful for investigating contemporary phenomena within real-world contexts, especially when the boundaries between the phenomenon and its environment are not clearly defined [21]. By examining multiple cases, this paper captures a wide range of technical, organizational, and regulatory dimensions, offering a detailed and nuanced understanding of how blockchain is applied in energy systems.

Cases were carefully chosen to reflect diversity in geographic location, scale, and application type. Key selection criteria included relevance to SDG 7, active use of blockchain technology for energy transactions or certifications, and availability of data. The selected cases—Brooklyn Microgrid in the United States, Power Ledger in Australia, Enerchain in Europe and Sun Exchange in South Africa—represent different approaches to P2P energy trading, renewable energy certification, decentralized Grid Management and tokenized solar investments. This diversity allows for a rich comparative analysis, highlighting both common patterns and context-specific challenges.

4.2 Data Collection and Data Analysis

Data were collected from multiple sources to ensure a comprehensive understanding of blockchain applications in energy systems. Academic literature, including journal articles and conference papers, provided theoretical foundations and prior findings. Grey literature, such as reports from energy agencies, NGOs, blockchain consortia, and project websites, offered practical insights into real-world implementations. Policy and regulatory documents were also reviewed to understand the legal and governance frameworks shaping blockchain adoption. Whenever possible, expert insights from project

managers, developers, and policymakers were included to enrich the analysis. By integrating these diverse sources, the study creates a triangulated dataset that captures both the technical details and the socio-economic impacts of blockchain-enabled energy solutions.

The collected data were analyzed using a thematic content analysis approach [22]. Key themes were identified iteratively, focusing on technical implementation, operational outcomes, policy and regulatory aspects, and socio-economic or managerial implications. Cross-case comparisons were then conducted to identify recurring patterns, critical success factors, and context-specific challenges. This process allowed the study to move beyond descriptive accounts and develop actionable insights for academics, managers, and policymakers.

5. Results and Discussion

The analysis of the selected cases reveals the diverse ways in which blockchain technology is being applied to advance SDG 7. While each project operates in a different context and employs distinct technological solutions, several common themes emerge, highlighting both opportunities and challenges of blockchain adoption in the energy sector.

5.1 P2P Energy Trading: Brooklyn Microgrid

The Brooklyn Microgrid is a pioneering P2P energy trading platform that enables local prosumers to buy and sell solar-generated electricity directly among themselves. Smart contracts automate transactions, ensuring that energy exchanges are secure, transparent, and recorded on the blockchain [6].

This case illustrates how blockchain can enhance local energy autonomy and promote community engagement. From a managerial perspective, it provides energy service companies with new opportunities to design flexible tariffs and create micro-market structures. Academically, it serves as an example of how decentralized energy systems can be

conceptualized and evaluated. Policy-wise, it highlights the need for regulations that facilitate P2P energy trading while safeguarding consumers and ensuring grid stability. Despite these advantages, significant challenges remain, including scalability, user adoption, and integration with existing infrastructure.

5.2 Renewable Energy Certification and Traceability: Power Ledger

Power Ledger is a blockchain-based platform that allows households and businesses to trade electricity and track renewable energy certificates efficiently [5]. By tokenizing renewable energy credits, the platform reduces administrative costs, increases transparency, and enhances trust between market participants.

The case illustrates how blockchain can bridge technical and financial aspects of renewable energy deployment. For managers, it highlights the potential to streamline sustainability reporting, facilitate carbon accounting, and develop innovative business models. Academically, Power Ledger provides empirical evidence supporting theories of blockchain-enabled transparency and decentralized governance. Policy implications are also notable. In fact, governments can leverage such systems to improve monitoring, reporting, and verification processes for renewable energy compliance and voluntary green markets.

5.3 Decentralized Grid Management: Enerchain

The Enerchain project, launched in 2017 by the Hamburg-based company Ponton in collaboration with over 40 European energy companies, represents one of the first large-scale experiments of blockchain in the wholesale electricity market.

Unlike local microgrid projects, Enerchain focuses on enabling direct P2P trading between established utilities across different countries, eliminating the need for centralized intermediaries. By recording trades immutably on a distributed ledger, the project demonstrated how blockchain can reduce transaction

costs, accelerate settlement times, and increase transparency in cross-border electricity markets.

However, the initiative also revealed significant challenges related to regulatory harmonization within the EU, the scalability of blockchain platforms, and the willingness of traditional energy players to adapt their business models. Despite these barriers, Enerchain remains a pioneering case that highlights the potential of blockchain to transform not only local energy exchanges but also the structure of regional and continental electricity markets.

5.4 Innovative Financing Models for Energy Access: Sun Exchange

Sun Exchange operates by tokenizing solar investments, enabling individuals worldwide to fund off-grid solar installations in schools, businesses, and communities across Africa [4]. Blockchain technology tracks the ownership of solar cells and the production of energy, providing transparency and accountability for both investors and beneficiaries.

This case highlights the potential of blockchain to mobilize global micro-investments for sustainable energy, particularly in regions where traditional financing is limited. From a managerial standpoint, it demonstrates how innovative financing mechanisms can be designed to expand access to renewable energy. Academically, it offers a model for examining the interplay between technology, finance, and development objectives. Policy implications highlight the need for regulatory frameworks that can accommodate tokenized assets, cross-border investments, and innovative financial instruments while safeguarding the interests of local stakeholders.

5.5 Cross-Case Analysis

The comparative examination of these case studies reveals a set of recurring patterns that cut across geographical boundaries and regulatory environments.

One of the most consistent findings is the way blockchain enhances transparency and trust. Whether it

is the P2P exchange of locally generated electricity, the issuance and trading of renewable energy certificates, or the tracking of micro-investments in solar projects, blockchain's immutable ledger offers a shared and verifiable source of truth. This feature not only reduces the potential for disputes among participants but also strengthens confidence in new, decentralized market arrangements, particularly in contexts where institutional trust may be limited.

A second recurring theme is decentralization, which fundamentally reshapes the flow of value and decision-making in energy systems. By reducing dependence on traditional central intermediaries, blockchain enables community-level energy markets, allowing prosumers to transact directly with one another. This shift does more than just alter market mechanics; it empowers individuals and communities to play an active role in energy generation, distribution, and consumption, fostering a greater sense of ownership and engagement in the energy transition.

However, the cases also highlight persistent operational and technical challenges that hinder broader adoption. Scalability remains a significant concern, as blockchain networks—especially those relying on energy-intensive consensus mechanisms—struggle to handle the volume of transactions required for large-scale deployment. Data privacy issues add another layer of complexity, as the need for transparency must be balanced against the protection of sensitive user information. Furthermore, user adoption is not guaranteed; the success of these initiatives often depends on the willingness of individuals to embrace unfamiliar technologies and adapt to new market structures.

Ultimately, the analysis highlights the crucial role of multi-stakeholder engagement. The deployment of blockchain-based energy solutions requires coordinated action from policymakers, energy companies, technology providers, investors, and local communities. Policymakers can create enabling regulatory environments, energy companies can integrate blockchain into their service

models, and communities can drive adoption through active participation. The interplay among these actors determines not only the technical success of blockchain applications but also their long-term sustainability and social legitimacy.

6. Limitations

While this methodology provides rich and detailed insights, it also has certain limitations. The case study approach limits the generalizability of the findings across all regions or energy markets. Data availability varied across cases, as some operational and financial information was proprietary, which may restrict the comprehensiveness of the analysis. Additionally, the rapid evolution of blockchain technology means that some technical solutions or business models could become outdated over time. Finally, the socio-economic and regulatory environments of each case significantly shape the feasibility of replicating similar solutions elsewhere. In particular, political contexts marked by skepticism toward international sustainability agendas may hinder adoption, whereas supportive policy frameworks can act as powerful enablers. Despite these constraints, the methodology offers a systematic and in-depth understanding of blockchain's potential for the energy sector.

7. Implications

The findings of this paper have significant implications across academic, managerial, and policy domains. Academically, the research contributes to the literature on blockchain-enabled energy systems by providing evidence of its applications in achieving SDG 7, highlighting both opportunities and adoption challenges. It also opens avenues for future research on scalability, integration with smart grids, and socio-economic impacts of decentralized energy solutions. Managerially, the study demonstrates that energy companies, startups, and community operators can leverage blockchain to enhance operational efficiency, create innovative business models, and engage local

stakeholders in energy markets. This insight supports strategic decision-making in renewable energy deployment and digital transformation. From a policy perspective, the research underscores the need for adaptive regulatory frameworks that facilitate decentralized energy trading, renewable energy certification, and blockchain-based financing, while safeguarding consumer protection and market integrity. Collectively, these implications offer a roadmap for aligning technological innovation with sustainable energy goals.

8. Conclusion

To address the research question, this paper has explored the multifaceted role of blockchain technology in advancing SDG 7, with a particular focus on renewable energy access, energy efficiency, and the development of decentralized energy markets. By examining case studies, this analysis has captured not only the technological mechanisms underpinning blockchain applications but also their operational, managerial, and policy-related dimensions.

The findings suggest that blockchain has the potential to significantly enhance transparency and trust within energy systems, providing secure, immutable records of transactions that reduce disputes and facilitate market confidence. Moreover, by enabling P2P trading, renewable energy certification, and tokenized financing models, blockchain fosters innovative business opportunities that can democratize energy production and distribution. These benefits extend beyond purely technical improvements, influencing stakeholder engagement and enabling the creation of community-driven energy ecosystems.

At the same time, this paper has identified several persistent challenges that constrain the widespread adoption of blockchain in the energy sector. Scalability issues limit the ability of current blockchain infrastructures to process the volume of transactions required for large-scale deployment, particularly in regions with growing energy demands. Regulatory

compliance remains a complex and often fragmented landscape, where differences in national and local frameworks can slow or even prevent adoption. Furthermore, data availability and interoperability continue to pose practical barriers, particularly when integrating blockchain platforms with legacy energy systems and diverse metering technologies.

Looking ahead, future research could provide deeper insights by conducting longitudinal studies that track the real-world impact of blockchain-enabled energy systems over extended periods, allowing for a better understanding of their sustainability, resilience, and adaptability. Another promising avenue lies in examining the synergistic integration of blockchain with emerging technologies such as the Internet of Things and Artificial Intelligence, which could enable advanced energy analytics, predictive maintenance, and automated demand-response mechanisms. Equally important is the need to investigate the socio-economic implications of decentralized energy markets across different cultural, economic, and regulatory environments, to ensure that innovation contributes to inclusivity and equitable energy access.

In sum, this research offers a comprehensive framework for academics, managers, and policymakers seeking to leverage blockchain as a transformative tool in the global energy transition. By understanding both the opportunities and the constraints, stakeholders can work towards implementing solutions that are not only technologically robust but also socially inclusive, economically viable, and environmentally sustainable, bringing the world closer to the realization of SDG 7.

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