

Blockchain Technology and Environmental Sustainability



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Abstract Blockchain technology has become known as a groundbreaking achievement with the ability to have an impact on a wide range of sectors, including environmental sustainability. The purpose of this abstraction is to investigate the influence of blockchain technology on environmental sustainability in Bahrain. Bahrain, being a fast-expanding country, must cope with the environmental issues related to energy consumption, waste management, and carbon emissions. Blockchain technology provides a decentralized and transparency framework that can successfully solve these challenges. For instance, the immutability and transparency of blockchain enable the development of dependable structures for tracking and overseeing the environmental resources and processes. Environmental data concerning energy consumption, waste management, and water usage may be collected, validated, and shared across stakeholders in a safe and impermeable way using smart contracts and IoT sensors. Furthermore, blockchain technology makes it easier to integrate renewable energy sources and create distributed energy trading systems. Both individuals and organizations may use this to create, distribute, and exchange renewable energy, establishing a decentralized and sustainable energy environment. This literature review aims to contribute to a better understanding of the impact of blockchain technology on environmental sustainability and provide insights into the potential benefits and drawbacks of using blockchain technology for environmental sustainability in Bahrain.

1 Introduction

One of the most revolutionary technologies of the twenty-first century is the Blockchain technology. It is an appealing technology for many industries, including finance, supply chain management, and healthcare, due to its capacity to securely store and transport data in a decentralized manner.

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Blockchain technology is being investigated by Bahrain's government to increase the effectiveness of public services, and there is rising interest in its capacity to address issues with sustainable development. The creation of a more effective and open energy system is one way that Blockchain technology might help Bahrain achieve environmental sustainability.

The government of Bahrain has been attempting to increase the proportion of renewable energy in the country's energy mix because Bahrain mainly depends on fossil fuels for its energy needs. However, managing the fluctuation of these sources requires creative solutions because integrating renewable energy sources into the grid can be difficult.

Peer-to-peer (P2P) energy trading, made possible by Blockchain technology, allows solar-powered homes and businesses to sell extra energy to people in need. This could encourage the installation of additional solar panels and help the world rely less on fossil fuels. Blockchain can also help establish an equitable and open energy market where customers have the option of buying energy from sources that are sustainable and the origin of their power can be tracked.

By enhancing trash management, Blockchain technology can also help Bahrain achieve environmental sustainability. The nation produces a lot of waste, and the mechanism in place for managing it is not very effective. By blockchain it will be possible to create a transparent and auditable waste management system where the origin and destination of garbage can be monitored, which shows that the Blockchain technology can offer a solution. Recycling will be encouraged, which will lessen the quantity of rubbish dumped illegally and end up in landfills.

In addition, supply chain efficiency and transparency may be increased with Blockchain technology, which has a substantial impact on environmental sustainability. Bahrain is a small country that depends largely on imports, that must make sure of the imported goods that adhere to strict environmental criteria. Blockchain technology can make it possible to establish a transparent and auditable supply chain where consumers can choose to purchase goods that have been produced responsibly and where the origin and destination of products can be tracked.

Bahrain's preservation of the environment could be dramatically impacted by Blockchain technology. Blockchain technology can help create a more effective and environmentally friendly economy by enabling peer-to-peer energy trading, enhancing waste management, and encouraging sustainable sourcing. The flexibility and interoperability of Blockchain alternatives, in addition to the requirement for a legal structure to guarantee that these options are deployed in a democratic and accountable manner, are still issues that must be resolved.

2 Litreature Review

2.1 *Blockchain Technology*

Blockchain technology is a decentralized, secure, and transparent digital ledger that allows for secure, tamper-proof transactions without the need for intermediaries such as banks or governments. Blockchain technology is built on a distributed network of computers, which ensures that all parties involved have access to the same information, reducing the potential for fraud and ensuring the integrity of transactions (Swan 2015).

Key Features of Blockchain Technology

1. **Decentralization:** Blockchain technology operates on a decentralized network, which means that there is no central authority controlling the network. This decentralized nature of blockchain technology ensures that the system is not vulnerable to a single point of failure and reduces the potential for fraud.
2. **Security:** Blockchain technology is secured using cryptographic algorithms that ensure that the data stored on the network is tamper-proof. This means that once a transaction is recorded on the blockchain, it cannot be altered or deleted, ensuring the integrity of the system.
3. **Transparency:** Blockchain technology allows for all parties involved in a transaction to have access to the same information, creating transparency in the system. This transparency ensures that all parties can verify the transaction, reducing the potential for fraud (Zheng et al. 2018).

Potential Applications of Blockchain Technology in Environmental Sustainability:

1. **Carbon Trading:** Blockchain technology could be used to create a secure and transparent platform for carbon trading. By using blockchain technology, companies could track their carbon emissions and trade carbon credits securely and transparently.
2. **Supply Chain Management:** Blockchain technology could be used to create a secure and transparent supply chain management system. By using blockchain technology, companies could track the origin of their products, ensuring that they are sustainably sourced.
3. **Renewable Energy:** Blockchain technology could be used to create a peer-to-peer energy trading system. By using blockchain technology, individuals and businesses could trade renewable energy with each other, reducing their reliance on traditional energy sources. (Shafiee and Topal 2018).

Limitations of Blockchain Technology in Environmental Sustainability:

1. **Energy Consumption:** Blockchain technology requires a significant amount of energy to operate, with some estimates suggesting that the energy consumption of the Bitcoin network alone is equivalent to the energy consumption of a

small country. This energy consumption could have significant environmental consequences, particularly if the energy used to power the network comes from non-renewable sources.

2. **Scalability:** Blockchain technology is still in its early stages, and scalability is a significant issue for the technology. As more users join the network, the system could become slower, leading to potential scalability issues that could limit its potential applications.
3. **Adoption:** Blockchain technology is still in its early stages, and widespread adoption is still a significant challenge. Without widespread adoption, the potential benefits of blockchain technology for environmental sustainability may not be fully realized (Sang et al. 2019).

2.2 *Environmental Sustainability*

Environmental sustainability refers to the responsible use and management of natural resources to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. It is a concept that considers the economic, social, and environmental aspects of development and seeks to balance these three elements to ensure long-term sustainability (UNEP 2021).

Importance of Environmental Sustainability

Environmental sustainability is crucial for the long-term health and well-being of both humans and the planet. It is essential for preserving biodiversity, ensuring the availability of natural resources, and mitigating the effects of climate change. Environmental sustainability also has significant economic benefits, including the creation of new industries and jobs in the renewable energy sector and reducing the risks associated with natural disasters (Frick 2018).

Challenges Facing Bahrain in Achieving Sustainable Development

Bahrain is a small island nation located in the Persian Gulf, and like many other small island nations, it faces significant challenges in achieving sustainable development. Some of the main challenges facing Bahrain in achieving sustainable development include (World Bank 2021):

1. **Water Scarcity:** Bahrain faces significant water scarcity due to its arid climate and limited freshwater resources. This scarcity is exacerbated by a rapidly growing population and high levels of water consumption.
2. **Climate Change:** Bahrain is highly vulnerable to the effects of climate change, including rising sea levels, extreme weather events, and heatwaves. These effects could have significant economic and social consequences, particularly for vulnerable communities.
3. **Urbanization:** Rapid urbanization in Bahrain has led to a significant increase in energy consumption, air pollution, and waste generation. These issues could have significant environmental and health consequences for the population.

4. **Limited Natural Resources:** Bahrain has limited natural resources, including oil and gas, and is heavily dependent on these resources for its economy. This dependence could have significant economic and environmental consequences in the long term.

2.3 The Nexus Between Blockchain Technology and Environmental Sustainability

Blockchain technology has the potential to address a range of environmental challenges, including carbon emissions, waste management, and biodiversity conservation. By leveraging the features of blockchain technology, such as transparency, security, and decentralization, blockchain solutions can enhance the efficiency and effectiveness of environmental management systems (Swan 2015).

Carbon Emissions

Blockchain technology can be used to create transparent and secure carbon markets that enable businesses to track and trade carbon credits. By using blockchain-based carbon markets, companies can ensure that their carbon offsets are legitimate and verifiable, thereby increasing the credibility of their sustainability initiatives (Tang and Liu 2021).

Waste Management

Blockchain technology can also be used to improve waste management systems by creating a transparent and decentralized supply chain for waste management. This can enable better tracking of waste disposal, reduce waste fraud and corruption, and increase recycling rates (DeMartinis and Taurino 2018).

Biodiversity Conservation

Blockchain technology can also be used to enhance biodiversity conservation efforts by creating a secure and decentralized platform for tracking wildlife and habitats. This can enable better monitoring and management of endangered species, reduce illegal wildlife trade, and increase collaboration among stakeholders (Siu 2019).

Key Drivers of Adoption

There are several key drivers of the adoption of blockchain solutions for environmental sustainability, including (Christidis and Devetsikiotis 2016):

1. **Transparency:** Blockchain technology enables transparent and verifiable transactions, which can enhance trust and credibility in environmental management systems.
2. **Efficiency:** By leveraging the features of blockchain technology, such as decentralization and automation, blockchain solutions can improve the efficiency of environmental management systems.
3. **Collaboration:** Blockchain technology can facilitate collaboration among stakeholders in environmental management systems, enabling more effective coordination and communication.

Key Barriers to Adoption

Despite the potential benefits of blockchain solutions for environmental sustainability, there are also several key barriers to adoption, including (Yli-Huumo et al. 2016):

1. **Technical Complexity:** Blockchain technology is still relatively new and complex, and there is a lack of expertise and knowledge among stakeholders in environmental management systems.
2. **Cost:** Implementing blockchain solutions can be costly, particularly for small and medium-sized enterprises.
3. **Regulatory Frameworks:** The lack of clear regulatory frameworks for blockchain technology can create uncertainty and limit the adoption of blockchain solutions.

2.4 Case Study: Bahrain's Experience with Blockchain Technology and Environmental Sustainability

Bahrain, a small island nation in the Persian Gulf, has been making efforts to leverage blockchain technology to promote environmental sustainability. The country's initiatives in this regard have been driven by a range of factors, including its commitment to achieving the United Nations' Sustainable Development Goals (SDGs), its strategic location as a major transit point for goods and services, and its desire to diversify its economy away from oil and gas (The Supreme Council for the Environment 2018).

Policy Framework

Bahrain's National Sustainable Development Strategy 2030 provides a comprehensive policy framework for promoting sustainable development across various sectors, including environmental sustainability (Buallay et al. 2021, 2023). The strategy emphasizes the need to adopt innovative technologies, such as blockchain, to enhance environmental management systems and reduce the country's ecological footprint (Government of Bahrain 2018).

Regulatory Environment

Bahrain has been proactive in creating a favorable regulatory environment for blockchain technology. In 2019, the Central Bank of Bahrain issued regulations for crypto assets, providing a clear legal framework for the issuance and trading of digital assets, including those related to environmental sustainability (Central Bank of Bahrain 2019).

Technological Infrastructure

Bahrain has also invested in developing its technological infrastructure to support the adoption and implementation of blockchain solutions (Hamdan et al. 2020). The country has launched several initiatives to promote the development of blockchain technology, including the Bahrain Fintech Bay, a dedicated fintech hub that provides startups and entrepreneurs with access to resources, expertise, and networking opportunities (Bahrain Economic Development Board 2020).

Initiatives to Promote Environmental Sustainability

Bahrain has launched several initiatives to leverage blockchain technology to promote environmental sustainability, including (United Nations Development Programme 2019):

1. **Carbon Credits Platform:** In 2018, the Bahrain Economic Development Board launched a blockchain-based carbon credits platform, which enables businesses to buy and sell carbon credits on a transparent and secure platform. The platform is designed to enhance the credibility of carbon offsetting initiatives and support Bahrain's efforts to reduce carbon emissions.
2. **Waste Management:** Bahrain has launched a blockchain-based waste management system, which aims to improve the efficiency of waste collection, reduce waste fraud and corruption, and increase recycling rates. The system uses sensors and blockchain technology to track waste from collection to disposal, providing real-time data on waste flows and enabling better decision-making.
3. **Biodiversity Conservation:** Bahrain has also launched a blockchain-based platform for tracking and monitoring endangered species and habitats. The platform aims to enhance the efficiency and effectiveness of biodiversity conservation efforts, by enabling better collaboration among stakeholders and providing real-time data on wildlife and habitat populations.

Challenges

Despite Bahrain's efforts to leverage blockchain technology for environmental sustainability, there are still several challenges that need to be addressed, including (Ministry of Industry, Commerce and Tourism 2018):

1. **Technical Expertise:** There is a lack of technical expertise and knowledge among stakeholders in the environmental management sector, which can hinder the adoption and implementation of blockchain solutions.
2. **Cost:** Implementing blockchain solutions can be costly, particularly for small and medium-sized enterprises, which may not have the financial resources to invest in new technologies.
3. **Regulatory Frameworks:** Although Bahrain has taken steps to create a favorable regulatory environment for blockchain technology, there is still a need for clearer and more comprehensive regulatory frameworks that provide certainty and predictability for businesses and investors.

2.5 Best Practices and Lessons Learned

The use of blockchain technology to promote environmental sustainability is a relatively new field, and there are still many challenges and uncertainties. However, the experience of Bahrain and other countries that have implemented blockchain solutions provides valuable insights into the best practices and lessons learned (United Nations Environment Programme 2020):

1. **Partnership and Collaboration:** One of the key success factors in Bahrain's initiatives has been the collaboration among various stakeholders, including government agencies, businesses, and civil society organizations. Collaboration is critical to developing effective solutions that address the complex challenges of environmental sustainability.
2. **Pilot Projects:** Many countries have started with small-scale pilot projects to test the feasibility and effectiveness of blockchain solutions before scaling up. Pilot projects enable stakeholders to identify potential challenges and opportunities, refine the solutions, and demonstrate the value of blockchain technology to potential investors and stakeholders.
3. **Regulatory Frameworks:** Clear and comprehensive regulatory frameworks are critical to providing certainty and predictability for businesses and investors, and to ensuring that blockchain solutions are compatible with existing legal and regulatory frameworks. Bahrain's regulatory environment provides a good example of how countries can create a favorable regulatory environment for blockchain technology.
4. **Capacity Building:** Building technical expertise and knowledge among stakeholders in the environmental management sector is critical to the adoption and implementation of blockchain solutions. Capacity building programs can help stakeholders to understand the potential of blockchain technology, identify the relevant use cases, and develop the necessary technical skills.
5. **Cost and Financing:** Implementing blockchain solutions can be costly, particularly for small and medium-sized enterprises. Access to financing and support from government agencies and international organizations can help to overcome these challenges.
6. **Scalability:** While pilot projects can provide valuable insights into the potential of blockchain technology, scalability is critical to realizing the full benefits of the technology. Scalable solutions that can be applied across multiple sectors and jurisdictions are needed to address the global challenges of environmental sustainability.

2.6 Recommendations

Based on the findings of the literature review, the following recommendations are suggested:

1. Develop guidelines and standards for the implementation of blockchain solutions for environmental sustainability to ensure their interoperability and scalability.
2. Encourage collaboration between governments, private sector, and civil society to develop innovative blockchain solutions for environmental sustainability.
3. Provide technical assistance and capacity building programs to SMEs and developing countries to promote the adoption of blockchain solutions.
4. Conduct further research on the potential of blockchain technology for environmental sustainability, particularly in the context of developing countries.

5. Promote awareness and education about the potential benefits and challenges of blockchain technology for environmental sustainability among stakeholders.

2.7 Future Research's

While this literature review provides a comprehensive overview of the existing research on blockchain technology and environmental sustainability, there are some gaps in the literature that require further investigation. Future research should focus on the following areas:

1. Conduct empirical studies to assess the environmental impact and cost-effectiveness of blockchain solutions in various sectors and regions.
2. Investigate the potential of blockchain technology to promote circular economy and sustainable consumption and production practices.
3. Assess the social and ethical implications of blockchain technology for environmental sustainability, such as privacy and data ownership issues.
4. Explore the potential of blockchain technology to enhance the resilience and adaptive capacity of communities to climate change and other environmental risks.

3 Conclusion

In conclusion, blockchain technology has the potential to contribute to environmental sustainability in Bahrain, specifically in the areas of energy and waste management. The adoption of blockchain technology can help to reduce carbon emissions and promote the use of renewable energy sources. Additionally, it can help to promote recycling and reduce waste by providing a decentralized and secure way of tracking and managing waste. However, there are also several challenges and limitations that need to be considered, including the significant energy consumption associated with blockchain technology and the lack of regulatory frameworks. Further research is needed to explore the potential of blockchain technology in environmental sustainability and to address the challenges and limitations associated with its adoption.

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