International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

Role of Blockchain Technology Integration for Green Bonds Issuance with Sustainability Aspect

Neeti Misra[1,2] , Sumeet Gupta[1], Kawerinder Singh Sidhu[2], Anil Kumar[3] , Harishchander Anandaram[4*], T.Joji Rao[5] , Rajesh Singh[6], Anita Gehlot[6], Shaik Vaseem Akram[6], Kapil Joshi[6]

[1]School of Business, University of Petroleum and Energy Studies, Dehradun, India, India
neeti.cm@gmail.com (NM), sumeetgupta@ddn.upes.ac.in (SG)
[2]Uttaranchal Institute of Management, Uttaranchal University, Dehradun 248007, kssidhu0410@gmail.com
[3]Tula's Institute, Dehradun-248197, Uttarakhand, India; dahiyaanil@yahoo.com
[4]Centre for Computational Engineering and Networking, Amrita School of Artificial Intelligence, Coimbatore, Amrita Vishwa Vidyapeetham, India; harishchander.a@gmail.com
[5]O.P. Jindal Global University, Sonipat, Haryana, 131001; jojirao2003@gmail.com (T.J.R)
[6]Uttaranchal Institute of Technology, Uttaranchal University, Dehradun 248007, Uttarakhand, India; drrajeshsingh004@gmail.com (R.S) ; dranitagehlot@gmail.com (A.G); vaseemakram5491@gmail.com (S.V.A); kapilengg0509@gmail.com (K.J)

Abstract— Green bonds have gained significant attention in supporting sustainable development goals for achieving sustainability. During the issuance of green bonds, there are a few concerns such as standardization, greenwashing, and lack of benefits that can be gained with green bonds. However, blockchain technology is a promising solution for green bond issuance because it has already shown its impact on different finance activities. This study aims to address and analyze the role and significance of green bond issuance for meeting sustainability with blockchain technology and also suggested recommendations for future research. Decentralized application based on the Algorand blockchain and high-level architecture proposed for the issuance of green bonds is at the primary level. There is no discussion regarding standardizing the environmental data, and the number of benefits gained by the green bond is not addressed in the previously published literature. From the analysis, it has been identified that a similar framework of blockchain cannot be implemented as the geographical and environmental parameters are quite different for every nation. So, every nation needs to customize the framework according to the nation's requirements. This study is the first attempt to combine information from previously published research about green bond issuance and integration of blockchain for green bond issuance, enlightening the disruption caused in the issuance of green.

Keywords- Green bonds; sustainability; blockchain; sustainable development goals.

I. INTRODUCTION

The United Nations has formulated sustainable development goals to achieve sustainability by 2030 for eradicating poverty as well as other setbacks should be combined with strategies to enhance education and health, lessen inequality, and stimulate economic growth, while also tackling climate transition and attempting to safeguard our oceans and forests [1]–[3]. To achieve sustainability, many industries and organizations around the world are implementing various strategies to reduce carbon emissions and be more environmentally friendly [4] [5]. Developing countries like India are looking for scaling up their investments in sustainable infrastructure to achieve the target of the Paris agreement of low-carbon emissions [6]. Green bonds enable the funding of capital and assets for existing and new environmental projects. A green bond is an innovative income instrument that is specially assigned to raise capital for projects focused on the environment and climate oriented. According to [7], green bonds are a strong facilitator for sustainable investing for institutional investors. [8] opined that green bonds are critical for funding environmental projects using the low-carbon financing approach. These bonds are asset-linked and supported by the issuance entity.

Credentials, supply, and credibility are all important aspects in the green bond market. The price benefit of green bonds is still unclear due to a lack of knowledge about the benefits and a perception that these bonds are expensive. Compared to conventional bonds, compliance verification from many stakeholders is time-consuming and increases the issuer's costs. Another issue that may arise with green bonds is greenwashing, which refers to bond issuers providing false information about the company's environmental commitment without actually having a significant, long-term impact through the project. Green bonds have significantly increased in popularity over the past ten years and have become a popular financial instrument globally [9]. According to the UN, the world has to invest $90 trillion in climate change by 2030 to accomplish these goals [10][11]. Investors prefer to stay away from greenwashing, and issuers produce the data that helps build investor trust. This creates a special connection between the two parties. All the aspects addressed above, triggered the

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

attention towards the blockchain technology that can overcome the problems involved in green bonds [12]. Blockchain can enable the decentralization of the settlement and clearing of green bonds [13]. A trustable green bond business can be established by combining profit utilization and effect reporting, which can be automated with the help of blockchain technology [14], [15].

Authors in [16] discussed the role of environmental investments in the green bond and also concluded that these bonds would reshape the financial markets and strengthen the sustainability of the economy. Authors in [17] proposed an architecture for the enhancement of security infrastructure in green bond issuance, and it is implemented on a small scale for proof of concept. Authors in [18] carried out a qualitative study, in which it addressed the data analysis, and interviews, with market participants regarding green bond issuance. Authors in [19] implemented the blockchain based on the Algorand for issuing the Green Bonds with an architecture. A decentralized app is also developed for realizing the proof of concept of the proposed architecture. Authors in [20] implemented smart contracts with blockchain for adapting the operation of green bond issuance and also overcoming the problems of agency and risk aversion of main entities in green bonds. From all the studies it has been identified that few studies have discussed the role of green bonds for sustainability and few studies have proposed frameworks and architecture for realization of blockchain for green bond issuance.

The novelty of this study is, that it aims to analyze the different studies that have addressed the role of green bond issuance with blockchain integration for overcoming the challenges in it. The objective of the study is to analyze progress of blockchain technology integration in the green bond for different applications. This study is the first to attempt to combine information from previously published research about green bond issuance and integration of blockchain for green bond issuance, enlightening the disruption caused by the issuance of green bonds and the need for enhancement of the green bond issuance process for sustainability. Based on this motivation, this study analyzed different studies that have discussed the implementation of blockchain for green bonds. The contribution of the study is:

- The significance of green bonds with a perspective on sustainability is detailed and presented in this study.
- The need for blockchain is explained for green bonds and studied different architectures proposed by the different studies for enhancing the infrastructure of green bond issuance.
- Finally, the article provides detailed recommendations that can be implemented in future work. One of the vital recommendations is the integration of a multitude of Industry 4.0 technologies such as the Internet of Things, machine learning, big data, and natural language processing with blockchain technology empower to enhance the liquidity, transparency, and verification of green bonds.

The organization of the study*:* section 2 covers methodology of the study; section 3 presents the Overview of green bonds integration with blockchain technology; section 4 presents the Blockchain frameworks for green bonds issuance; section 5 covers the discussion.

II. METHODOLOGY OF THE STUDY

The current study is analyzing the significance and progress of implementing blockchain for the green bond, which is predominantly adapted to the environmental projects that work towards sustainability by 2030. The primary question that is framed for this study is "How the blockchain technology implementation is useful for enhancing green bond issuance?".

We searched articles in Scopus and Web of Science databases (last searched 10th October 2022) by utilizing different keywords with the help of Boolean operations. In the study, we have applied the following keywords: "Green bond", "sustainable development goals AND green bonds", "sustainability AND green bonds", "environment AND green bond", "blockchain AND green bonds", "Climate AND green bonds", "Blockchain framework AND issuance of green bond". In this study, the exclusion criteria followed for the exclusion of articles are: non-peer reviewed articles are not considered for review. The article does not provide the full abstract, these are not included in this study. Thesis of doctorate and master are also included in this study for review and research articles that applied same methodologies are not incorporated in this article.

Only articles published in English was taken into account in this inclusion criteria. Regarding the time frame, a six-year span (2014-2022) was selected for this systematic review. In addition to this, we have focused on those studies that have discussed the fundamentals of green bonds with their types, characteristics, benefits, and challenges. The study addressed the blockchain for finance and also this study considers the previous research that implemented a blockchain framework for the issuance of green bonds. The studies are organized according to research questions, such as those that explain the significance and issues of green bonds, those that discuss blockchain concepts, and those that present the role and applications of blockchain for green bonds. The study has considered high-quality articles from reputed journals including Environment and Development Economics, Security and Privacy, Expert Systems with Applications, Business Horizons, Future Internet, Journal of Risk and Financial Management, Blockchain Cybersecurity, Trust and Privacy, IEEE Access, Journal of Asset Management, Journal of Information Management, Sustainability, International Journal of Corporate Social Responsibility, IEEE Consumer Electronics Magazine,

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

Energy Economics, Future Generation Computer Systems, Journal of Purchasing and Supply Management, Harvard Business Review, International Journal of Accounting Information Systems, Journal of Securities Operations & Custody, IEEE Communications Surveys & Tutorials, Artificial Intelligence in Agriculture and ICT Express. Along with these journals, the study also considered United Nations reports and frameworks.

As the aim of the study discussed that, this study discussed role of blockchain technology for issuing green bond. In this study, the authors focused that how blockchain is implemented for green bond issuance and what are types of problems that green bond is facing during issuance. In this manner, the authors have collected data from the research articles. In the United Nations reports, the authors focused on the statistical data of green bond issuance and reasons behind choosing for the green bond issuance in current context.

After obtaining the articles, we analyzed different studies based on green bond issuance with blockchain technology. Specifically, this analysis focused on how blockchain is implemented for green bond issuance and what types of problems the green bond is facing during issuance. The outcomes are discussed in the section below by categorizing in different aspects as discussed in the text. This study first discussed the green bond and later identified the challenges from the different studies. Based on previous studies, it has identified blockchain technology. So, this study presented the progress of blockchain for the issuance of green bonds. The current study is about the studying the role of blockchain for issuance of green bond. The current study does not require any kind risk of bias justification, as the study focused on a narrative synthesis of previous literature, it does not include any participants to justify the role of blockchain for green bond issuance.

III. OVERVIEW OF GREEN BONDS INTEGRATION WITH BLOCKCHAIN TECHNOLOGY

A. Significance of green bonds and problems

Green bonds are considered climate bonds in the early stages of the twenty-first century. Essentially, green bonds are a wider concept of impact to projects with a beneficial environmental impact, while climate bonds are specifically employed to finance activities that eliminate carbon emissions. According to [21] the green bonds issuance keeps the firm's existing shareholders in an advantageous position. Green bonds outperform conventional bonds. SDGs are set to be achieved with an outcome of sustainability with a time horizon of 2030. Climate Bonds defined six of the seventeen SDGs for which accelerated green investment and expansion in green bond markets offer significant benefits, especially in developing economies (Figure 1) [22]. The majority of revenue from green bond sales to date has been used to finance climate adaptation, mitigation, and resilience, with only a small portion contributing to other green assets [23]. In addition to supporting sustainable forestry and agriculture (3%) and enhancing life on land (SDG15), green bonds also play a modest role.

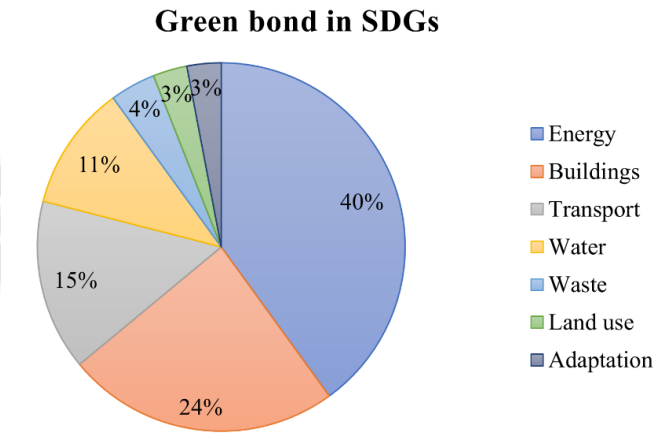

Fig. 1 Green bond wide adopted SDGs [23]

The World Bank, a major green bond issuer, released $14.4 billion in green bonds between 2008 and 2020. These subsidies have financed 111 projects all over the world, with a focus on agriculture and land use (15%), sustainable transportation (27%), and renewable energy and efficiency (33%) [16]. Green bonds may encompass tax benefits to increase their appeal to a certain investor. Green bonds are a component of a greater effect tendency in environmentally, socially, and governance (ESG) investing. The following are distinct kinds of green bonds [24] and they are: Use of Proceeds Bonds, Asset-Backed Securities (ABS), Project Bonds and Securitization Bonds and Covered Bonds. Green bonds function comparably to every other corporate or government bond. Borrowers initiate these securities to secure funding for projects that will profit the environment, such as ecological restoration or pollution reduction [25]. Investors begin to receive profits as the bond matures, and green bonds are generated by mutual funds, endowments, and hedge funds that have the ability to invest large sums in debt measurement [26].

After the bond's original statement, only authorized third-party verifications may guarantee that financing would support a particularly sustainable project [27] [28]. Compared to conventional bonds, compliance verification from many stakeholders is time-consuming and increases the issuer's costs [29]. Another problem that might occur with green bonds is greenwashing, which refers to bond issuers giving false information about the company's commitment to the environment without actually having a sizable, sustainable influence through the project. According to [29] the market for green bonds lacks precise objectives, unambiguous definitions,

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

and long-term sustainability plans from the government. In 2018, the Climate Bond Initiative reported that 72 percent of the total green bonds were oversubscribed. The market's infancy does not deliver sufficient data for individuals to make knowledgeable investment decisions. A lack of understanding about the gains of green bonds, or the perspective of an added charge related to a green bond issuance [30]. Furthermore, several green bond issuers, including the International Nordic Investment Bank, and Asian Development Bank have framed their green bond frameworks [31].

B. Role of blockchain in green bonds

Blockchain technology represents the Fourth Industrial Revolution, which is going to play a revolutionary role in the different domains from financial to non-financial sectors along with supply chains [32][33]. Blockchain has revolutionized from 1.0 to 4.0, where blockchain 1.0 (Year: 2004) emerged from the distributed ledger technology, where it is shared among the distinct participants for avoiding the double spending scenarios [34][35]. Bitcoin is the application of distributed ledger technology (DLT,) which empowered the establishment of the internet of money. Blockchain 2.0 (2014) is based on smart contracts with proof of consensus mechanisms. Ethereum is the second-generation blockchain that utilizes the smart contract for executing transactions. Proof of authority and Proof of stake is the consensus mechanism that is implemented in Blockchain 3.0 (2018) for boosting the computing power with speed for executing the smart contract with zero transaction fee. Blockchain 4.0 promises to scale up blockchain as a business-usable environment for creating and running more improved and mainstreamdApps. Prasaga blockchain is based on blockchain 4.0, where it delivers the features of mass adopt usability, user experience and speed [36].

In finance, the blockchain is implemented for multiple applications such as decentralized currency [37], decentralized payment services [38], decentralized contracting [39], and decentralized fundraising [40]. An initial coin offering (ICO) is a type of decentralized fundraising in which a project-specific token is created on a public blockchain and marketed to potential investors to raise funds [41]. In decentralized contracting, the contracts are established on the blockchain network in order to facilitate financial contracting by subsisting with smart contracts and it leads to the rise of peer-to-peer financial contracting. A decentralized contract enables one to overcome the costs of drafting, negotiating, and enforcing.

Blockchain technology for green bond applications is divided into three broad categories: issuance and distribution, ownership transfer and settlement, and quality standards and reporting [42], [43] (Figure 2). The authors in [44] contented that Blockchain technology is an easy way for bond issuance by completely digitizing the entire issuance process. The efficiency of blockchain-enabled bond issuance is ten times more efficient as compared to non-blockchain bond issuance traditional systems. The use of blockchain also offers a wide range of benefits about transparency, safety, and faster settlement.

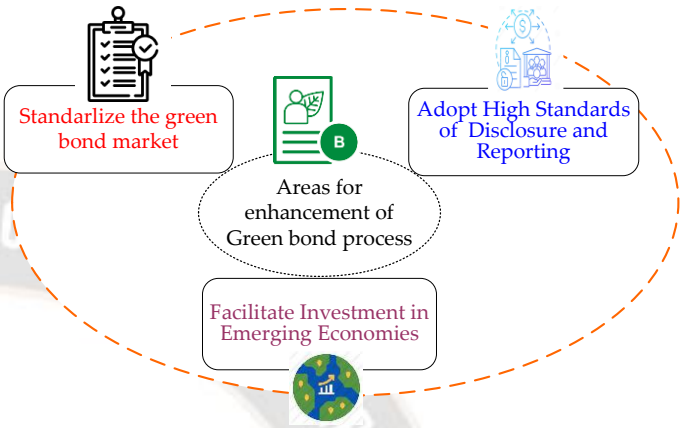

Fig. 2 Attributes of implementing blockchain for green bond

Blockchain technology offers unique security identifiers in the trade lifecycle processes with a special focus on bond issuance. [45] opined that investors are exploring the issuance of green bonds using blockchain technology. Blockchain technology still has many issues which remain unaddressed in relation to bond issuance [46]. The digital ledger additionally incorporates geographical and environmental data that stakeholders can utilize for a wide range of purposes [47]. In this technology, the actors are included performing in collaboration to create the best possible value. It also provides an array of benefits in many non-financial applications such as monitoring and tracking of the supply chain [48]. [49] outlined how a company may integrate blockchain technology into its supply chain and production processes.

IV. BLOCKCHAIN FRAMEWORKS FOR GREEN BONDS ISSUANCE

In this section, we discuss the different blockchain based frameworks for issuance of green bonds.

A. Blockchain based framework

Generally, the blockchain architecture for green bond comprises of steps such as initialization, preparatory, launching, trading, and archiving [50]. The bond issuer determines the conditions and circumstances of a bond issuance at commencement. In the preparatory stage, the impact of investment on the green economy is validated and a report is issued by the validators. Launch: Once the necessary paperwork has been submitted, regulatory approval is needed. And after that, the digital bond is open for trading. Trading: Transactions are carried out and are awaiting system settlement. Validators

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

process transactions and document the outcomes on the blockchain. Archiving: The audit traces persist on the blockchain for compliance and the entire transaction history is stored upon maturity. A decentralized approach is necessary to satisfy the standards for process transparency and bond chain of custody in green bonds. A smart contract is a transaction protocol that automatically carries out, manages, and records legally significant events and activities in accordance with a contract's conditions [51].

Figure 3 illustrates the blockchain-based architecture that is proposed for issuing a green bond in the real-estate [52]. In the architecture, issuers, validators, and investors are connected in a distributed network. The issuers initiate the creation of green bonds by employing geographic standards, and global guidelines and adding other documentation of their framework. After the creation of the bond, the validators (research institutions and construction companies) evaluate the bond and provide necessary input information including climate, land register, construction data, transport, and risk with certifications of green building. In addition to this, the data will be evaluated by other independent entities based on the location and circumstances of every project through satellite images combined with reports from local engineering organizations. After completion of this process, it enables the investors to access the data with the private electronic key, which will be received by different participants with relevant information. Any real-time updation in the information will be reflected in everyone in the blockchain network and able to access the updates.

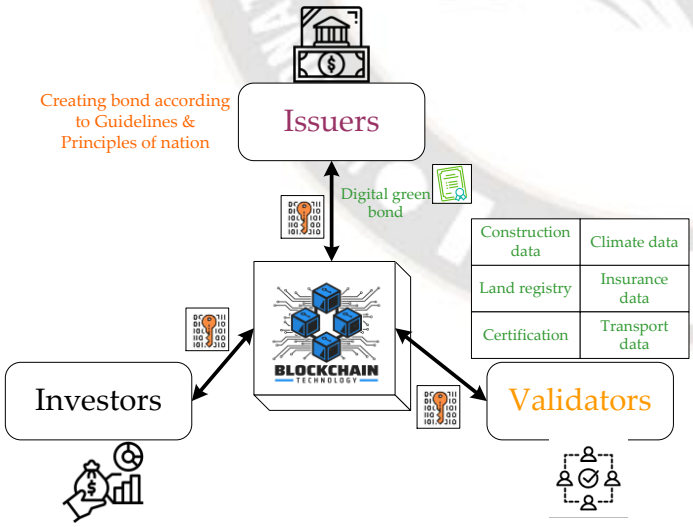

Fig. 3 Blockchain-based framework for green bond issuance

B. *High level architecture*

A high-level blockchain architecture (Figure 8) is proposed in this study [17], which also comprises five steps for the initialization of green bonds. Initialization, preparatory, launching, trading, and archiving are the five steps involved in the proposed blockchain architecture. Figure 4 illustrates the green bond smart contract, where the validators and regulator are empowered with the feature of approving the documents before the publishing of the bond and following the investor's start trading it. The post- and pre-issuance services for green bonds, such as interest payments to bondholders regularly and par value repayments whenever the bond's maturity date approaches, are handled through green bond smart contracts. We should tokenize the bonds in order to adapt bond issuance procedures to a blockchain-enabled architecture. The bond is prepared for tokenization once the legal documentation has been examined by the system's validators. Using a specified protocol, a smart contract is used to generate the digital token.

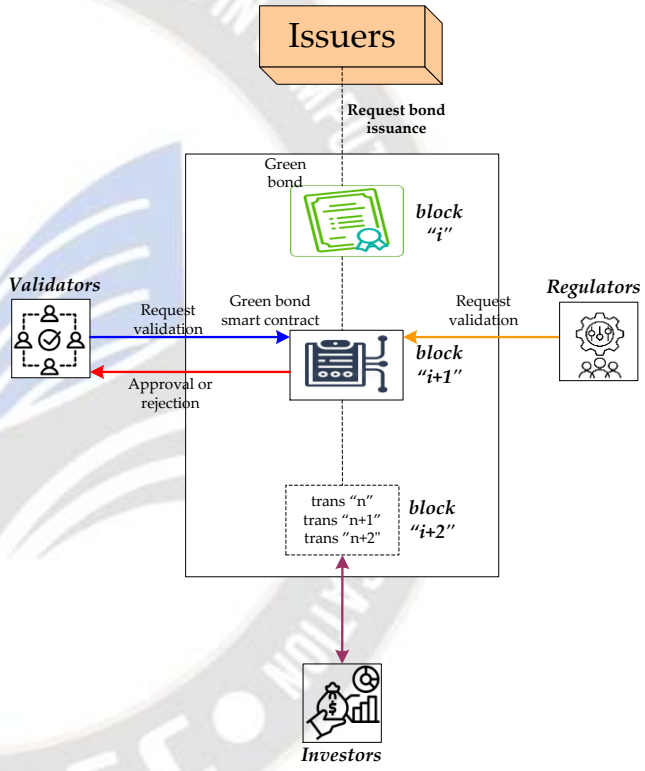

Fig. 4 High-level architecture

Blockchain can also deliver transparency in green bond issuing, which will help to promote the sustainability transformation. The suggested architecture offers major advantages in auditability in addition to transparency. The limitations addressed for high-level architecture are lack of implementing strong authorization and authentication and also the blockchain is used for the payment but partially used for tokenization. Moreover, the system can be implemented on a large scale in the future. The post- and pre-issuance services for green bonds, such as interest payments to bondholders regularly and par value repayments whenever the bond's maturity date approaches, are handled through green bond smart contracts. We should tokenize the bonds in order to adapt bond issuance

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

procedures to a blockchain-enabled architecture. The bond is prepared for tokenization once the legal documentation has been examined by the system's validators. Using a specified protocol, a smart contract is used to generate the digital token. Blockchain can also deliver transparency in green bond issuing, which will help to promote the sustainability transformation. The suggested architecture offers major advantages in auditability in addition to transparency. The limitations addressed for high-level architecture are lack of implementing strong authorization and authentication and also the blockchain is used for the payment but partially used for tokenization. Moreover, the system can be implemented on a large scale in the future.

C. Algorand framework for green bond

A framework is developed based on the Algorand blockchain for green bond issuance with cost-effectiveness from issuance to maturity [24]. A public blockchain called Algorand employs proof of stake to achieve consensus. All online users with Algos can cast more votes for and add a certain block to the blockchain. In each round, just one block is accepted and added to the chain. We can confirm transactions in less than five seconds by leveraging its finality property. When discussing blockchain, the terms layer-1 and layer-2 are frequently used. Layer-1 is the fundamental main blockchain architecture, while Layer-2 pertains to the layered network created on the pinnacle of the blockchain. Smaller investors and issuers can participate in the market encourages fractional asset ownership and low issuance fees. Stablecoin can be received by bond issuers and investors through principals and coupons. Additionally, green bonds can be bought and sold cheaply in the secondary market. The novel system enables the issuer to upload necessary reports that will be evaluated by a green validator.

The published green ratings have a significant effect on the coupon equates and issuer. The issuer struggles not only with reputation damage but also with economic fines. Finally, the financial regulator has the authority to freeze tokens to maintain market integrity. Before purchasing a green bond on the primary or secondary market, an investor must first be preapproved. Along with the framework, a decentralized ap-plication (DApp) has also been created for demonstrating user interaction in the platform [24]. With this app, the users can play a role as issuers, investors, and financial regulators. In practice, a user would have to be authorized before even being granted these special rights. A frontend user interface and a backend server are used by the DApp to interact with the Algorand blockchain. Through the front end, users can authorize transactions utilizing their keys that are kept securely. The backend interacts with the blockchain via private keys, which are used in the stablecoin dispenser and issuance. A connected database is also available for off-chain storing of information like addresses connected to user accounts. Green Sanctions including Blockchain Oracles on Primary Market Automated Transactions can be developed for future work.

V. DISCUSSION

The management of green bond issuance requires the ideal digitization process to be effective which is also the backbone of blockchain technology. The Green Bond issuance helps to mobilize funds that contribute to sustainable infrastructure investments. It is pertinent to mention here that green bonds have deviating guidelines which create confusion amongst market participants and might lead to information that is not credible leading to greenwashing. The study was related to increased awareness of green bond issuance on the environmental impact and climate change. Based upon the above limitation, this study aims to suggest recommendations that can be implemented for future work:

- There are numerous issues with the environment, social, and governance data because the three dimensions such as environment, social, and governance are simply different [53]. They are more quantitative and more standardized in the case of environmental data. Natural disasters and pandemics, on the other hand, are unpredictable. The social and governance data are unstandardized and qualitative as they emphasized more on the social sciences. The implementation of the same kind of blockchain network by every nation limits the efficiency of the blockchain-based system. It is suggested to implement other industry 4.0 technologies such as artificial intelligence to identify the ideal features and parameters that need to consider for the large-scale implementation of blockchain for the issuance of green bonds toward sustainability [54][55].
- Although blockchain technology is widely used for green bond issuance by various studies and organizations, there is still a lack of an effective real-time monitoring system with the Internet of Things integration for obtaining environmental data of the specific organization/entity that motivates towards SDGs. A BIS Innovation Hub and the Hong Kong Monetary Authority (HKMA) recently successfully established two prototype digital platforms that assist the investor to invest the amount in government bonds [56]. Along with this, the investor can track the real-time data on clean energy and the rate of CO_2 emissions. To determine whether a company is properly implementing an environmental project, the validators can utilize IoT to provide real-time data [57], [58]. In addition to this, IoT-based edge devices are encouraged to validate the environment data, as edge computing provides the facility to analyze the data at the edge network [59].
- From studies, it has been concluded that blockchain is widely implemented in issuing the green bond on a small scale, where

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

they have limited focus on authorization and authentication in employing the blockchain on the large scale. Along with this, the researcher needs to focus on carrying out the study on implementing the blockchain for tokenization on large scale with a multitude of features in it. Furthermore, real-time implementation and proof of concept-based studies also needed to be carried out in the future for identifying the limitations that are causing the companies to implement blockchain for a green bond. The integration of a multitude of Industry 4.0 technologies such as the Internet of Things, machine learning, big data, and natural language processing with blockchain technology empower to enhance the liquidity, transparency, and verification of green bonds [60]

VI. CONCLUSION

Green bond has gained significant attention and adoption by different industries for achieving the sustainability target set by United Nations. During the issuance of green bonds, they are a wide range of challenges such as lack of standard data for concluding it as a green bond, risk of greenwashing, the high transaction fee for issuing the green bond, and lack of policies about the benefits of the green bond. In this study, we have discussed the concept of the green bond and its features with the challenges involved in it. Following this, it has presented the studies that have implemented the blockchain for the issuance of green bonds. The different frameworks and architecture of previous studies are detailed and included in the article for providing an idea regarding the progress and implementation of blockchain for green bonds. From the analysis, it has been identified that a similar framework of blockchain cannot be implemented as the geographical and environmental parameters are quite different for every nation. So, every nation needs to customize the framework according to the nation's requirements. Finally, the article discussed the recommendations that can support the researchers for future work. The integration of a multitude of Industry 4.0 technologies such as the Internet of Things, machine learning, big data, and natural language processing with blockchain technology empower to enhance the liquidity, transparency, and verification of green bonds.

Conflicts of Interest

"The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper".

Funding Statement

The current study did not receive any external funding.

Acknowledgments

All authors have contributed equally to this work.

REFERENCES

[1] "SDG 7: Affordable And Clean Energy." https://in.one.un.org/page/sustainable-development-goals/sdg-7/ (accessed Jan. 19, 2022).

[2] "SDG 9: Industry, Innovation And Infrastructure." https://in.one.un.org/page/sustainable-development-goals/sdg-9/ (accessed Jun. 03, 2022).

[3] "THE 17 GOALS | Sustainable Development." https://sdgs.un.org/goals (accessed Dec. 28, 2020).

[4] E. Seyedsayamdost, "Sustainable development goals," *Essent. Concepts Glob. Environ. Gov.*, pp. 251–253, 2020, doi: 10.5005/jp/books/13071_5.

[5] S. V. Akram *et al.*, "Blockchain Enabled Automatic Reward System in Solid Waste Management," *Secur. Commun. Networks*, vol. 2021, 2021.

[6] "The Paris Agreement | UNFCCC." https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed Oct. 20, 2022).

[7] S. R. Foster and C. Iaione, "Ostrom in the city: Design principles and practices for the urban commons," in *Routledge Handbook of the Study of the Commons*, Routledge, 2019, pp. 235–255.

[8] J. C. Reboredo, "Green bond and financial markets: Co-movement, diversification and price spillover effects," *Energy Econ.*, vol. 74, pp. 38–50, 2018.

[9] P. Krueger, Z. Sautner, and L. T. Starks, "The importance of climate risks for institutional investors," *Rev. Financ. Stud.*, vol. 33, no. 3, pp. 1067–1111, 2020.

[10] A. Bhattacharya, C. Contreras, M. Jeong, A.-L. Amin, G. Watkins, and M. Silva, "Attributes and Framework for Sustainable Infrastructure," *Idb*, p. 49, 2019, [Online]. Available: https://publications.iadb.org/en/attributes-and-framework-sustainable-infrastructure

[11] T. Nitlarp and S. Kiattisin, "The Impact Factors of Industry 4.0 on ESG in the Energy Sector," *Sustain.*, vol. 14, no. 15, 2022, doi: 10.3390/su14159198.

[12] A. Poberezhna, "Addressing water sustainability with blockchain technology and green finance," in *Transforming climate finance and green investment with blockchains*, Elsevier, 2018, pp. 189–196.

[13] Y. Chen and U. Volz, "Scaling up sustainable investment through blockchain-based project bonds," *ADB-IGF Spec. Work. Pap. Ser. "Fintech to Enable Dev. Investment, Financ. Inclusion, Sustain.*, 2021.

[14] M. Janssen, V. Weerakkody, E. Ismagilova, U. Sivarajah, and Z. Irani, "A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors," *Int. J. Inf. Manage.*, vol. 50, pp. 302–309, 2020.

[15] S. V. Akram, P. K. Malik, R. Singh, G. Anita, and S. Tanwar, "Adoption of blockchain technology in various realms: Opportunities and challenges," *Secur. Priv.*, vol. 3, no. 5, pp. 1–17, 2020, doi: 10.1002/spy2.109.

[16] G. Cortellini and I. C. Panetta, "Green Bond: A Systematic Literature Review for Future Research Agendas," *J. Risk Financ. Manag.*, vol. 14, no. 12, p. 589, 2021, doi: 10.3390/jrfm14120589.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

[17] V. Malamas, T. Dasaklis, V. Arakelian, and G. Chondrokoukis, "A Block-Chain Framework for Increased Trust in Green Bonds Issuance," *SSRN Electron. J.*, 2020, doi: 10.2139/ssrn.3693638.

[18] P. Deschryver and F. de Mariz, "What Future for the Green Bond Market? How Can Policymakers, Companies, and Investors Unlock the Potential of the Green Bond Market?," *J. Risk Financ. Manag.*, vol. 13, no. 3, p. 61, 2020, doi: 10.3390/jrfm13030061.

[19] G. Katten, "Issuing Green Bonds on the Algorand Blockchain," 2021, [Online]. Available: http://arxiv.org/abs/2108.10344

[20] K. J. Lee and H. Jeong, "A Framework for Digitizing Green Bond Issuance to Reduce Information Asymmetry," in *Green Digital Finance and Sustainable Development Goals*, Springer, 2022, pp. 309–327.

[21] S. Pearson *et al.*, "Are distributed ledger technologies the panacea for food traceability?," *Glob. Food Sec.*, vol. 20, pp. 145–149, 2019.

[22] V. P. Guidelines *et al.*, "Green bonds - A bridge to the SDGs," *Clim. Bond. Initiat.*, vol. 1, no. June, p. 8, 2018, [Online]. Available: https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/%0Ahttp://pubdocs.worldbank.org/en/768111536944473808/WB-Green-Bond-Proceeds-Management-and-Reporting-Guide.pdf%0Ahttp://www.un.org/sustainabledevelopment/sustainabl

[23] M. Filkova, C. Frandon-Martinez, and A. Giorgi, "Green Bonds: The State of the Market 2018," *Clim. Bond. Initiat.*, pp. 1–28, 2018.

[24] I. Shishlov, R. Morel, and I. Cochran, "Beyond transparency: unlocking the full potential of green bonds," *Inst. Clim. Econ.*, vol. 2016, pp. 1–28, 2016.

[25] B. Hachenberg and D. Schiereck, "Are green bonds priced differently from conventional bonds?," *J. Asset Manag.*, vol. 19, no. 6, pp. 371–383, 2018.

[26] J. Kochetygova and A. Jauhari, "Climate change, green bonds and index investing: the new frontier," *Retrieved*, vol. 20, p. 2017, 2014.

[27] J. Freytag, "CHALLENGES FOR GREEN FINANCE IN INDIA An Analysis of Deficiencies in India's Green Financial Market," *UMEA Univ.*, 2020, [Online]. Available: https://www.diva-portal.org/smash/get/diva2:1532467/FULLTEXT01.pdf

[28] A. Chaudhary, V. N. Tiwari, and A. Kumar, "A new intrusion detection system based on soft computing techniques using neuro-fuzzy classifier for packet dropping attack in manets," *Int. J. Netw. Secur.*, vol. 18, no. 3, pp. 514–522, 2016.

[29] C. Anh Tu, T. Sarker, and E. Rasoulinezhad, "Factors Influencing the Green Bond Market Expansion: Evidence from a Multi-Dimensional Analysis," *J. Risk Financ. Manag.*, vol. 13, no. 6, p. 126, Jun. 2020, doi: 10.3390/JRFM13060126.

[30] M. Doran and J. Tanner, "Critical challenges facing the green bond market," *Int. Financ. Law Rev.*, pp. 22–25, 2019, [Online]. Available: https://www.bakermckenzie.com/-/media/files/insight/publications/2019/09/iflr--green-bonds-(002).pdf?la=en

[31] E. S. Sartzetakis, "Green bonds as an instrument to finance low carbon transition," *Econ. Chang. Restruct.*, vol. 54, no. 3, pp. 755–779, 2021.

[32] F. Casino, T. K. Dasaklis, and C. Patsakis, "A systematic literature review of blockchain-based applications: Current status, classification and open issues," *Telemat. informatics*, vol. 36, pp. 55–81, 2019.

[33] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An overview of blockchain technology: Architecture, consensus, and future trends," in *2017 IEEE international congress on big data (BigData congress)*, 2017, pp. 557–564.

[34] P. Mukherjee and C. Pradhan, "Blockchain 1.0 to blockchain 4.0—The evolutionary transformation of blockchain technology," in *Blockchain technology: applications and challenges*, Springer, 2021, pp. 29–49.

[35] J. Xie *et al.*, "A survey of blockchain technology applied to smart cities: Research issues and challenges," *IEEE Commun. Surv. Tutorials*, vol. 21, no. 3, pp. 2794–2830, 2019.

[36] A. Chaudhary, V. Tiwari, and A. Kumar, "A novel intrusion detection system for ad hoc flooding attack using fuzzy logic in mobile ad hoc networks," in *International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014)*, 2014, pp. 1–4.

[37] Y. Chen and C. Bellavitis, "Blockchain disruption and decentralized finance: The rise of decentralized business models," *J. Bus. Ventur. Insights*, vol. 13, p. e00151, 2020.

[38] W. Cai, Z. Wang, J. B. Ernst, Z. Hong, C. Feng, and V. C. M. Leung, "Decentralized Applications: The Blockchain-Empowered Software System," *IEEE Access*, vol. 6, pp. 53019–53033, 2018, doi: 10.1109/ACCESS.2018.2870644.

[39] A. Murray, S. Kuban, M. Josefy, and J. Anderson, "Contracting in the smart era: The implications of blockchain and decentralized autonomous organizations for contracting and corporate governance," *Acad. Manag. Perspect.*, vol. 35, no. 4, pp. 622–641, 2021.

[40] H. Baber, "Blockchain-based crowdfunding," in *Blockchain Technology for Industry 4.0*, Springer, 2020, pp. 117–130.

[41] M. Chanson, N. Martens, and F. Wortmann, "The Role of User-Generated Content in Blockchain-Based Decentralized Finance," *ECIS 2020 Proc.*, 2020.

[42] O. Sanderson, "How to trust green bonds: Blockchain, climate, and the institutional bond markets," in *Transforming climate finance and green investment with blockchains*, Elsevier, 2018, pp. 273–288.

[43] R. Shankar, "Potential of Blockchain Based Tokenized Securities for Green Real Estate Bonds," in *Infrastructure Development–Theory, Practice and Policy*, Routledge, 2022, pp. 88–99.

[44] R. On and I. Oxygen, "Gateway for sustainability".

[45] H. Workie and K. Jain, "Distributed ledger technology: Implications of blockchain for the securities industry," *J. Secur. Oper. Custody*, vol. 9, no. 4, pp. 347–355, 2017.

[46] L. J. Cohen, *Broken Bonds: Yugoslavia's disintegration and Balkan politics in Transition*. Routledge, 2018.

[47] M. Kouhizadeh and J. Sarkis, "Blockchain practices,

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6
DOI: https://doi.org/10.17762/ijritcc.v11i6.7300
***Article Received**: 22 March 2023 **Revised**: 29 April 2023 **Accepted**: 18 June 2023*

potentials, and perspectives in greening supply chains," *Sustainability*, vol. 10, no. 10, p. 3652, 2018.

[48] A. F. B, "Advances in Intelligent Networking and Collaborative Systems," vol. 23, pp. 170–182, 2019, doi: 10.1007/978-3-319-98557-2.

[49] D. Bumblauskas, A. Mann, B. Dugan, and J. Rittmer, "A blockchain use case in food distribution: Do you know where your food has been?," *Int. J. Inf. Manage.*, vol. 52, p. 102008, 2020.

[50] V. Malamas, T. Dasaklis, V. Arakelian, and G. Chondrokoukis, "A Block-Chain Framework for Increased Trust in Green Bonds Issuance," *Available SSRN 3693638*, 2020.

[51] S. Wang, L. Ouyang, Y. Yuan, X. Ni, X. Han, and F.-Y. Wang, "Blockchain-enabled smart contracts: architecture, applications, and future trends," *IEEE Trans. Syst. Man, Cybern. Syst.*, vol. 49, no. 11, pp. 2266–2277, 2019.

[52] J. Bauer and B. Bachmaier, "A framework of blockchain technology for green real estate bonds," 2020, [Online]. Available: https://www.diva-portal.org/smash/record.jsf?pid=diva2:1446215

[53] P. S. Sisodia, V. Tiwari, and A. Kumar, "A comparative analysis of remote sensing image classification techniques," in *2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, 2014, pp. 1418–1421.

[54] A. Ekramifard, H. Amintoosi, A. H. Seno, A. Dehghantanha, and R. M. Parizi, "A systematic literature review of integration of blockchain and artificial intelligence," *Blockchain cybersecurity, Trust Priv.*, pp. 147–160, 2020.

[55] Y. Zhang, F. Xiong, Y. Xie, X. Fan, and H. Gu, "The impact of artificial intelligence and blockchain on the accounting profession," *Ieee Access*, vol. 8, pp. 110461–110477, 2020.

[56] S. Gurbanov and F. Suleymanli, "Analytical Assessment of Green Digital Finance Progress in the Republic of Georgia," in *Green Digital Finance and Sustainable Development Goals*, Springer, 2022, pp. 205–222.

[57] A. Reyna, C. Martín, J. Chen, E. Soler, and M. Díaz, "On blockchain and its integration with IoT. Challenges and opportunities," *Futur. Gener. Comput. Syst.*, vol. 88, pp. 173–190, 2018.

[58] L. Hang and D.-H. Kim, "Design and implementation of an integrated iot blockchain platform for sensing data integrity," *Sensors*, vol. 19, no. 10, p. 2228, 2019.

[59] T. M. Fernández-Caramés and P. Fraga-Lamas, "A Review on the Use of Blockchain for the Internet of Things," *Ieee Access*, vol. 6, pp. 32979–33001, 2018.

[60] K. Rabah, "Convergence of AI, IoT, big data and blockchain: a review," *lake Inst. J.*, vol. 1, no. 1, pp. 1–18, 2018.