OPTIMIZATION OF RENEWABLE ENERGY PENETRATION IN SMART GRIDS USING BLOCKCHAIN TECHNOLOGY

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Abstract

India is considered as world's third largest energy consumer and 14th largest energy producer. India being the developing country requires incessant supply of energy for future progress. International Energy agency (IEA) has envisaged 70% increase of world's energy demand by 2040. Gratifying such a huge increase in demand can only be attainable by integration of all the available energy sources viz., conventional, sustainable and renewable in an 'Energy Efficient Supply System'. There is an urgent requirement of implementing a smart energy management system to monitor, assess, and control energy flow in an efficient and cost effective manner. The continuous degradation of the environment and the United Nations Paris Agreement, 2016 (to which India is a party) mandates the use of sustainable and renewable energy sources to reduce carbon footprints and curb global warming. Smart grids integrate distributed energy resources and manages its storage, transmission and distribution in bidirectional way. Blockchain technology being decentralised, distributed, immutable, secure and transparent in nature, is aptly suitable for combining energies from distributed sources into the smart energy management system. The peer to peer data structure and ability to perform smart contract can be utilised for transparent and cost effective energy trading. In this paper, the analysis for technical and framework requirements for Blockchain based smart energy management system alongwith the challenges present in its governance and regulation are critically examined.

KEY WORDS: Renewable Energy, Blockchain, Smart Grid, Distributed Energy Management System, Blockchain legal framework, Renewable energy laws

I. INTRODUCTION

THE ENERGY consumption has a direct impact on the growth and is considered vital for economic and human development. Kyoto Protocol[1], 1997 and Paris Convention,[2] 2016 made it obligatory for all countries to adopt measures and implement policies, which continuously monitor, review and comply to not only achieve the goal of reduction in carbon footprints but also trim down Green House Gas (GHG) Emissions to set target. International Renewable Energy Agency (IRENA) expected the share of renewable energy to be 57% of the total energy generation by 2030. India, being a developing country is in an imperative want of energy to sustain its socio-economic development. Government of India[3] informed that India is the third world's largest consumer of energy. The ratio between GDP and energy requirement is high for India. This excessive demand of energy cannot be satisfied by dependence on fossil fuel or traditional energy sources. The transition from traditional energy sources to sustainable energy sources has become inevitable. Government of India has also adopted various means and measures to reduce the emissions and have energy security. To meet Paris Agreement's targets, it has become quite essential for India to rely on renewable resources which include solar power, tidal power, geothermal energy, wind power and hydroelectric power *etc.*

"India's RE-Roadmap-2030" of Niti Ayog[4] has identified profuse and un-trapped Renewable Energy sources in India due to its geological position. As per the report, the India has potential of more than 10,000 GW solar potential and more than 2,000 GW wind potential. But for inclusive exploitation of these resources, the government should introduce and adopt new initiatives, policies and programs to encourage all stakeholders to engage participate and adopt the changes. This report suggests:[5]

We should not get into the mindset that RE is the intruder and conventional energy is the main player. Why not consider RE to be main occupants of the 'house' and then work out the rest of the system around RE, essentially, because RE is the future?

India's initiatives like smart cities and smart grid systems are few steps taken towards a clean and green environment by promoting generation and use of green energy. Smart Grid,[6] integrates traditional and sustainable energy sources to the power distribution network, monitors demand response and manage outage. The smart grid allows interoperability of

[1] *Available at*: https://unfccc.int/process/the-kyoto-protocol/mechanisms/emissions-trading (last visited on May 15, 2022).

[2] *Available at:* https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (last visited on May 15, 2022).

[3] Minister for Petroleum and Natural Gas, Shri Rameswar Teli in Lok Sabha, *available at*: https://www.psuconnect.in/news/India-ranked-3rd-largest-primary-energy-consumer-in-the-world/31843/#:~:text=New%20Delhi%3A%20As%20per%20India,Teli%20in%20Lok%20Sabha%20today(last visited on May 20, 2022).

[4] Indias-RE-Roadmap-2030.pdf (niti.gov.in), *available at:* https://www.niti.gov.in/writereaddata/files/Indias-RE-Roadmap-2030.pdf, last visited on May 15, 2022).

[5] (Former Member (Energy), erstwhile Planning Commission of India)

[6] Smart Grid Processes, People and Policies, International Smart Grid Action Network discussion paper Annex 4, Subtask 3.1, 2013, *available at*: /https://www.nsgm.gov.in/sites/default/files/ISGAN-Smart-Grid-Processes-People-Policies-Discussion-Paper-April-2013.pdf (last visited on May15, 2022).

energy utility service providers, consumers, producers in the ecosystem. Smart Grid reduces the load on the conventional power distribution system. It provides equal opportunity to all *i.e.,* producers, consumers and prosumers to involve and partake equally in the energy ecosystem irrespective of their energy share. The fundamental requirement of smart grid is a secure, dependable, immutable energy management system which caters to its dispersed energy ecosystem. Blockchain[7] is the most up-to-date technology, having decentralised[8] database structure, immutability, transparency and security, that accomplishes all the demands for a secure and energy efficient green energy management system.

II. Constitutional or statutory provisions and government initiatives

It is "fundamental in the governance of the country"[9] and also duty of Government of India and every citizen to promote the use of sustainable energy sources.[10] The Indian government is taking all steps to make the available resources be used in efficient manner and for the common good. Article 39B, [11] and 38th entry[12] to concurrent list allows the state as well as Government of India to legislate for electricity. Entry 33 of list III[13] and entry 97[14] list I read with article 248[15] guides the Indian government to legislate for energy trade and state government[16] to monitor and tax the energy trading. It is also imperative for Government of India to proceed towards and formulate legislations[17] for promotion of use of renewable or sustainable energy and reduce carbon foot printing due to international treaty compulsions.
The Energy Conservation Act, 2001[18] which stresses on efficient use and conservation of energy, introduces certified energy Auditors,[19] Energy Management Centres,[20] Energy

[7] M. Crosby, Nachiappan, P. Pattanayak, S. Verma, and V. Kalyanaraman, "Blockchain Technology - BEYOND BITCOIN," *Berkley Eng.*, 2016

[8] Powergrid Corporation of India Limited, "Renewable Energy Integration- Transmission an Enabler - A Report.," 88 (2016). *Available at:* http://www.powergridindia.com/_layouts/PowerGrid/User/ContentPage.aspx?PId=154&LangID=English.

[9] Constitution of India, 1950, Art. 48A Protection and improvement of environment and safeguarding of forests and wild life: The state shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country

[10] *Id.,* art. 51A (g) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;

[11] *Id.,* art. 39 B (b) that the ownership and control of the material resources of the community are so distributed as best to subserve the common good.

[12] Concurrent List (List III)-38- Electricity.

[13] *Id.,* entry 33 reads –" Trade and commerce in, and the production, supply and distribution of,— (a) the products of any industry where the control of such industry by the Union is declared by Parliament by law to be expedient in the public interest, and imported goods of the same kind as such products;"

[14] *Id.,* entry 97 reads: Any other matter not enumerated in List II or List III including any tax not mentioned in either of those Lists.

[15] *Id.,* Residual power of legislation (a) Parliament has exclusive power to make any law with respect to any matter not enumerated in the concurrent list or state list. (b) Such power shall include the power of making any law imposing a tax not mentioned in either of those Lists

[16] LIST II State List entry 52 Taxes on the entry of goods into a local area for consumption, use or sale therein, Entry 53 is Taxes on the consumption and sale of electricity

[17] Union List entry 13: Participation in international conferences, associations and other bodies and implementing of decisions made thereat.

See also, entry 14: Entering into treaties and agreements with foreign countries and implementing of treaties, agreements and conventions with foreign countries.

[18] The Energy Conservation Act, 2001 ACT NO. 52 OF 2001 [Sep. 29, 2001.];.

Managers[21] , Energy Saving Certificates[22] and accreditations for Energy efficiency by Bureau of Energy Efficiency.[23] All stakeholders *viz.*, industry, nation and global are benefitted by observing energy efficiency measures by improving quality and productivity, reducing Green House Gas (GHG) Emission and improving energy security. Energy security means the continuous energy flow at competitive prices which may be categorised as long term (self reliance of a nation on energy demand for sustainable development) or as short term (monitoring and managing supply which is based on demand response at a given time) energy security.

The Electricity Act, 2003[24] mandated the right to electricity at reasonable price along with encouragement of well-organized energy management systems and environmentally benevolent policies.

On the directions of Prime Minister of India, an expert committee[25] was constituted in 2006 by Planning Commission to review energy situation in India and suggest reforms to maximize efficiency at all levels *viz.* energy generation, transmission, distribution, tariff aspects, energy security, and environment friendliness. It suggested integrating renewable sources to the conventional grid system and incentivising the use of green energy.

'National Solar Mission (NSM), 2010 was launched[26] to encourage sustainable growth and upholding energy security. The foremost target was to create an environment for solar technology incursion in the nation at centralized or decentralized level.[27]

To combat climate change, degradation in environment, reduce green house gas emission and acquiring energy security, Government of India planned to introduce e-vehicles or hybrid vehicles through following three programmes:

1. In the year 2013- National Electric Mobility Mission Plan (NEMPP) 2020 – to adopt use of e-vehicle and developing infrastructure support for the purpose.
2. In the year 2015, Faster Adoption and Manufacturing of E-vehicle (FAME II), was announced to support and develop e-vehicle/hybrid vehicle manufacturing, marketing and support ecosystem.
3. In the year 2017, Government of India[28] announced the transition of adoption of e-cars

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[19] id s. 2 (a)
[20] id, s. 2 (l)
[21] id.,s. 2 (m)
[22]id, s. 2 [(ma)
[23]id, s. 3.
[24] The Electricity Act, 2003.
[25] The Integrated Energy Policy 2006.
[26] GERMI's Final Report MNRE CST Scheme Evaluation_R03.pdf, at https://mnre.gov.in/img/documents/uploads/file_f-1607698654092.pdf (last visited on May15, 2022).

[27]The Constitution of India 1950, art. 39(b).
(b) that the ownership and control of the material resources of the community are so distributed as best to subserve the common good

to 100% by 2030. This target was reduced to 30% after receiving concerns from the automobile industry.

4. In the year 2021, at COP26, Global Climate Conference, Glasgow, India pledged to meet 50% of its energy demand by renewable energy, reduction of green house gas emission by 1 ton by 2030 and to net zero by 2070.
5. Finance Act 2022, imposed 30% taxation on the income generated out of transfer of virtual assets or the crypto currency along with 1% TDS (Tax deducted at source) for any annual transactions in excess to Rs. 50,000/- indicating introduction of digital currency by the Indian government.

Recently, Government of Delhi has deployed 300 e-buses[29] to curb pollution and reduce carbon emission. The Government of Delhi also planned to procure a total of 3000 e-buses in next two year in phased manner.

Government of Delhi also planned to increase solar electricity[30] produce from current capacity of 230 MW to 500 MW by 2023 end. The target was initially set for 2700 MW Solar Power Generation under National Solar Power Mission in June 2015. It has been decided to install solar power panels on roof tops of all government buildings. The electrical energy generated in such a way will be utilised for the energy requirements of the area and the extra energy may be traded with the utilities or neighbouring areas.

Ever since the India has adopted various policies to promote the E-vehicle use, sale of e-vehicles is approaching northward. The charging of these vehicles also need a stable and secure charging system which can satisfy their demand for electricity at affordable prices. The tracing of the e-vehicles and type of energy used for charging is also of utmost challenge. NITI Aayog's initiative – "The India Energy Security Scenarios 2047 (IESS 2047)" framed out cost and benefit analysis of implementing Renewable Energy objectives to meet up India's emergent energy demand. In November 2013, Government of India has escalated the power generation from 20 GW to 100 GW by Solar Power and reducing the target year from 2022 to 2019. Additional Wind Power generation was also enhanced from 15 GW to 40 GW by 2019.

Electricity (Amendment Act), 2014 has defined the "Decentralised distributed generation" along with other sustainable energy friendly provisions like exemption from getting licence for renewable energy generation and supply, ten percent renewable energy capacity in all power stations based on non renewable energy sources. Penalty for non compliance of provisions was also implemented. The exemption from open access charge and cross subsidy was also provided for sale of sustainable energy.

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[28] Nitin Gadkari, Minister of Transport, Government of India

[29] Sidhartha Roy, "Green Ride over 100 E-Buses Likely to Hit Delhi Roads Next Week" *Times of India*, May 14, 2022.

[30] Atul Mathur, "Govt. May Set Up Solar Panels on Roof-Tops of All its Buildings", *Times of India*, May 13, 2022.

India envisaged the increased adoption of green energy by enacting "The National Renewable Energy Law Draft Bill, 2015". This act gave the moral fibre framework and policies to plan and implement complete energy management system integrating electricity, transport and heat to the same energy ecosystem. It constitutes the institutions for policy formation, develops supportive ecosystem for development, utilization and investment in the energy system, It also explained the renewable energy applications namely distributed renewable energy access applications and grid connected renewable electricity.

Kyoto protocol (article 21) and Paris Agreement has given birth to a new commodity called "Carbon Credit. SEBI has notified carbon credits and energy as commodity.[31] The carbon credits are the permit for GHG emission of certain limit by the stakeholders. Higher the emission more will be the carbon credit used. The embracing of green energy is advantageous as the reduced emission resulted in use of lesser carbon credit and residual carbon credits can be traded further.

Ministry of New and Renewable Energy, Government of India has approved the green energy corridor project for integration of large scale renewable generation to mainstream power distribution network and make available uninterrupted renewable energy supply across the country at affordable prices. "Access to Electricity for All". Renewable energy has a share of 26.53% in the total installed renewable energy capacity.

NITI Aayog identified Blockchain as potentially transformative technology for government and private sector. Main characteristics of the Distributed Ledger Technology[32] (DLT) or Block chain are digitised, decentralised and entity-less trust systems

III. Blockchain Technology

Initially, time stamping of documents was done using Blockchain Technology to impede any fraud caused by backdating documents. In 2008 Satoshi Nakamoto[33] has demonstrated the potential of Blockchain by using this technology in cryptocurrency BITCOIN. He presented Bitcoin as a secure and encrypted electronic money transaction platform which needed no involvement of any intermediary like banks *etc.* The financial transactions using BITCOIN are completely secure, transparent and immutable. Blockchain technology ensures decentralization, security, transparency, and immutability. Initially used for timestamping documents, it gained prominence with Bitcoin, introduced by Satoshi Nakamoto in 2008. Blockchain's key components include data structure, validation algorithms, and cryptographic systems. Each transaction is stored as a block and validated through consensus mechanisms such as Proof of Work (PoW), Proof of Stake (PoS), or Practical Byzantine Fault

[31] Notification dated Sep 28, 2016, *available at:* https://www.sebi.gov.in/legal/circulars/sep-2016/list-of-commodities-notified-under-scra_33359.html. (last visited on May 10, 2022).
[32] *Available at*: https://www.niti.gov.in/sites/default/files/2020-01/Blockchain_The_India_Strategy_Part_I.pdf
[33] S. Nakamoto, "Bitcoin : A Peer-to-Peer Electronic Cash System," *Whitepaper*, 2008, [Online]. *Available at*: https://bitcoin.org/bitcoin.pdf.(last visited on May 12, 2022).

Tolerance (PBFT). Blockchain easily trounce the security threat through identification, authorization and authentication[34]

3.1 Blockchain architecture

Blockchain shared the encrypted data with each node and hence have the distributed architecture with no central validating authority. Every node is connected to the previous block with the hash of that block. Hence it forms a chain of blocks. Every transaction or information in the Blockchain is added to the existing chain in the form of a new block. The new block is added only after getting validation by each block present in the block chain. This validation process[35] is called "Consensus". There is no central validating authority in the Blockchain

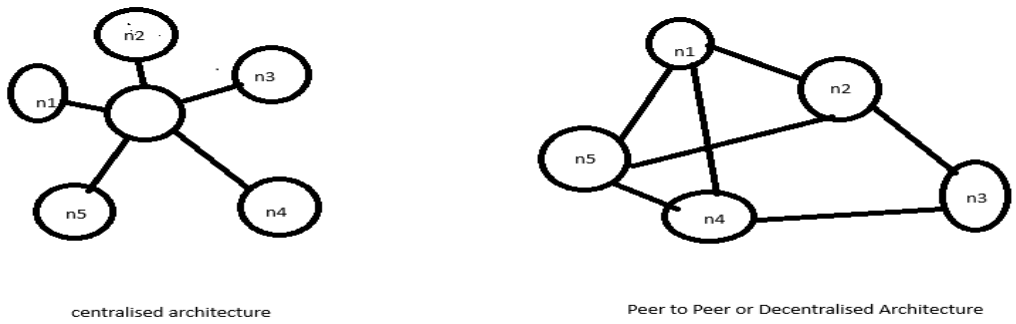

Figure 1: Centralised and peer to peer architecture

3.2 Blockchain data structure: In each block of the Blockchain, three things *i.e.*, data, hash function of the prior block and the identification number or hash function of the same block are present. Hash function is created by encrypting the data present in the block with encryption algorithm (SHA 256 or SHA 512). Hash value of the node is unique identifier value and known as fingerprint of the block. All blocks are connected in chain like structure through the HASH function of the previous block. By adding nonce value, which is a 32 bit arbitrary string, to the data present in the block *i.e.*, (Nonce + block data), unique hash[36] value for a block can be calculated. If at any stage, the data of any block changes or corrupts, its hash value changes due to which the connection between the blocks cannot be maintained or the continuity of Blockchain ceases.

[34]A. Lewis, "Blockchain Technology Explained," *Blockchain Technologies*, 2015
[35]Shijie Zhang, Jong-Hyouk Lee, "Analysis of the main consensus protocols of Blockchain", ICT Express, Volume 6, Issue 2, 2020,p93-97
[36] *Supra* note 34

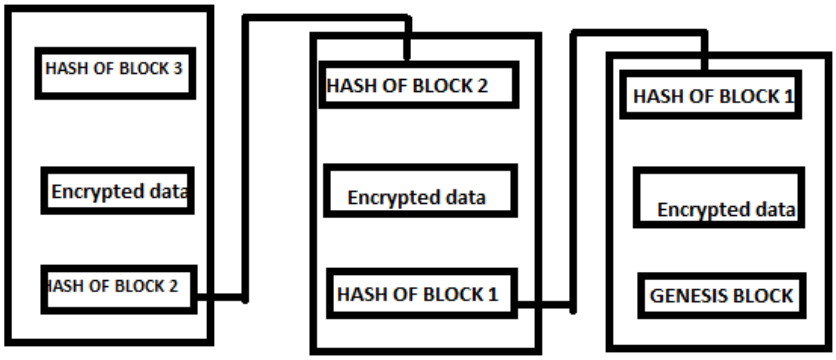

Figure 2: Data structure of the block chain

3.2 Block validation or mining

It is the procedure to find the Hash of the new block. When a new transaction of change of data is required to be updated, new block is added to the Blockchain. The Miner blocks or all present blocks start solving the puzzle and computing the Hash of the function using algorithm like SHA 256 or SHA 512. The block which discover the Hash first, broadcast the Hash Value along with the nonce to all. Data validation of the newly added block is accomplished by a procedure called consensus. The nodes which validate the data are called data validator nodes and they receive some incentive for the work of validation. Different incentive is provided in different Blockchain *e.g.,* in BITCOIN, reward is Crypto currency called BTC or Bitcoin. Various mechanisms to find out the block validators are Proof of Work (PoW) as in BITCOIN, Proof of Stake (PoS) as in Ethereum, Proof of Activity (PoA) as in Decred (DCR) cryptocurrency to avoid 51% spend attack. In permissioned Blockchain to establish mining rights Proof of Elapsed time (PoET) is used. To reduced power consumption, Proof of Burn (PoB) is used. If the faulty nodes are present in the Blockchain, PBFT(Practical Byzantine Fault Tolerance) is used to get the consensus. In E governance Blockchains,[37] Proof of concept and proof of existence[38] consensus algorithms are used by NIC[39].

3.3 Types of Block Chain[40]

There are three types of Blockchains:

[37] O. Pal and S. Singh, "Blockchain Technology and It's Applications in E-Governance Services," 8(4) *Int. J. Recent Technol. Eng.*5795–5802 (2019), doi: 10.35940/ijrte.d8599.118419

[38] "Government of India Ministry of Electronics and Information Technology (MeitY) Jan. 1, 2021 Table of Contents," no. Jan, 2021.

[39] S. Prof. Shivendu, "National Strategy for Blockchain India," *Natl. Inst. Smart Gov.*, 1–41 (2019), [Online]. *Available at:* https://4c44db83-35be-491f-a87f-fc7c6a312fd0.filesusr.com/ugd/cc85ab_6dd677ce70124618b88c70be071f3eac.pdf.(last visited on May, 20, 2022).

[40] M. Xu, X. Chen, and G. Kou, "A systematic review of Blockchain," *Financial Innovation* (2019)doi: 10.1186/s40854-019-0147-z.

3.4.1 Open or Public Blockchain: As name suggests, this kind of Blockchain is permission less and non-restrictive. Anyone can join these kind of Blockchain. Equal rights are available to all nodes. Examples are BITCOIN, Litcoin and Ethereum *etc*.

3.4.2 Private or Permissioned Blockchain: This kind of Blockchain is closed networked and restrictive in nature. Before joining this type of Blockchain, permission is required. Only specific members or organizations can join these Blockchain. This is more centralized than public Blockchain. Examples are Hyperledger Fabric, Corda and Hyperledger Sawtooth *etc*.

3.4.3 Consortium or federated Blockchain: This is the hybrid combination of public and private type of Blockchains. Here, there are two or more central authorities which provide access to preselected blocks or node for specific purposes. Examples are Energy Web Foundation and IBM Food Trust etc.

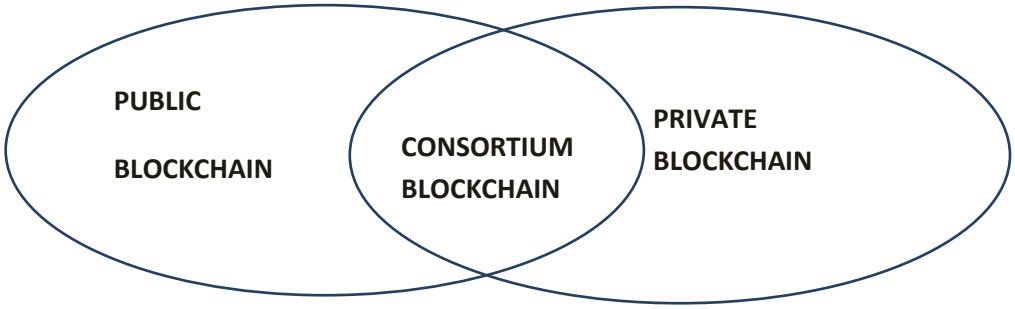

Figure 3: Types of Blockchain

3.4.4 Smart contract: Introduced by Nick Szabo in 1994, these are self-executing digital contracts triggered by predefined conditions. Smart contracts ensure transparency and efficiency in transactions without intermediaries or or centralised intervention[41]

3.4.5 Generations of the Blockchain

Various generations of Blockchains[42] are as follows:

Blockchain1.0, used mainly for virtual or cryptocurrency e.g. BITCOIN in early years *i.e.*, in 2008 onwards. Consensus algorithm followed by this generation was PoW which was excessive power consuming. The main application was in exchange of Crypto currency in decentralized manner where no central validating authority is required.

Blockchain 2.0, used by Ethereum, hyper ledgeror BITCOIN 2.0 in year 2013 onwards. It utilizes smart contracts, Decentralised Apps (DApps), Decentralized Autonomous Organizatios (DAO) and Decentralized Auto corporations (DACs) etc. It extended the application of Blockchain in areas like finance, securities, insurance and trading *etc*. Proof of stake (PoS) and Proof of Burn (PoB) consensus algorithm was mainly used.

[41] S. K. Kim and J. H. Huh, "A study on the improvement of smart grid security performance and Blockchain smart grid perspective," 11(8) *Energies* (2018) doi: 10.3390/en11081973.
[42] M. Xu, X. Chen, and G. Kou, "A systematic review of Blockchain," *Financial Innovation* (2019) doi: 10.1186/s40854-019-0147-z

Block chain 3.0, created opportunity in other fields like E-Government, health sector, supply chain management etc. It utilizes advanced smart contract format providing more security and autonomy. In Blockchain 3.0 smart contracts are combined with Tokens which are issued at the time of execution of smart contract as a proof of right. This is extremely exploitable feature for the industry and governance. Ethereum 2.0 uses this to provide ERC(20) token representing some value or right. Proof of concept and proof of identity was used to get the consensus validation.

Blockchain 4.0 combines various other technologies like AI, Machine Learning, sharding, data compression etc to overcome the shortcomings of preceding generations. This was used by Cos Idaho, US in JD Coin in April,2018 and still work is going on to improve the scalability and interoperability of the Blockchain. Multi layered Proof of Stake (mPoS), Proof of Reputation (PoR) and Proof of History (PoH) consensus algorithms are used to increase scalability, speed, interoperability *etc*.

IV. Smart Grid

Renewable Power plants can be used only for limited period of time due to its dependency on the availability of the renewable energy resource. Therefore the conventional fossil fuel operated power plants cannot be completely ignored. In 2014, Government of India initiated pilot project of Smart Grid in India[43] with aim to "Transform the Indian power sector in to a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders."

Smart Grids are self curative, digitised, cost effective, energy efficient power distribution network which allows not only bidirectional (i.e. from grid to consumer and from consumer to grid) flow of electricity and data transmission but also provides equal participation by all stakeholders. Difference between Conventional Grid and Smart Grids are as given in table 1

Sl. No.	**Traditional Power Grid**	**Smart Grid**
	The flow of electricity is unidirectional	The Flow of Electricity is bidirectional
	Energy Inefficient transmission and distribution system	Energy Efficient transmission and distribution system
3	Based on principle of supply follows demand	Based on the principle of demand follows supply
4	No data availability is there	Communication technology is integrated to update the stakeholders about latest data
5	Major reliance on conventional power energy sources	Integration of Renewable and Non Renewable Energy Resources
6	Non healing grid structure	Self healing grids

[43] *Available at:* https://www.nsgm.gov.in/en/smart-grid (last visited on May 15, 2022).

7	No monitoring and control	Real time monitoring and control
8	Expensive and not completely reliable	Cost effective and reliable
9	Having adverse affects on environment due to use of convention a fossil fuels as main component of electricity generation	Beneficial for environment due to maximum utilization of available renewable resources and reducing carbon emission

V. Efficient Green Energy Management System

Major challenge for implementing the renewable energy provisions is its integration with the present grid system in such a way that there should be minimum transmission and distribution losses. The stakeholders of the grid system like utility companies, consumers, regulatory body etc must have real time reliable data for demand response and outage management. Blockchain technology can be adopted for efficient, secure, transparent and immutable Energy management. In Block chain source of data can be traced back to its origin because it is time stamped and immutable. It is almost impossible to change or manipulate the data in a Blockchain due to availability of mirrored database at all nodes. The Green Energy management system can be developed either on public Blockchain like Etherium[44] or Permissioned Blockchain like Hyperledger fabric. Use of Hyperledger fabric Blockchain based Green Energy Management System can be considered favourable. It is because of its ability of providing rights to institutional or regulatory authorities to certify and categorise diverse stakeholders or energies. Distributed energy transactions are supported by Blockchain based peer to peer green energy management system. The source of energy can be categorised based on their origin and amount of carbon emission during generation process. The regulatory authorities are the validators here to validate all the transactions and energy trading. The prosumers (who can consume and produce energy), consumers, utilities and other stakeholders can join the Blockchain and get the corresponding certification. The energy source which has more carbon footprints in the process of energy generations are provided with non green certification automatically by executing smart contracts on Blockchain. Use of more green energy will be incentivising by providing more green tokens which can be traded with carbon credits. All the information related to type of energy, producer, prosumers. And consumers will available to all the nodes in the Blockchain. Prosumers can supply or consume the energy based on the requirement. Whenever anybody wants to sell the energy, the message will be broadcasted to the entire participating node about the price, type, category and seller of energy. The validator node will validate the energy information. The energy trading can be performed directly between energy supplier and consumer without the involvements of Discoms or any other third party. The energy trading will be done by executing smart contracts. The contract for energy trade is executed automatically when the terms are met and validation process is completed. After validation, this transaction is added to the Blockchain as a new block and price of the energy as per the

[44] J. Dargan, N. Gupta and L. Singh, "Blockchain Based Energy Management System: A Proposed Model," *2021 International Conference on Technological Advancements and Innovations (ICTAI)* 510-514 (2021)., doi: 10.1109/ICTAI53825.2021.9673233.

transaction details deducted from the consumer's e-wallet and credited to energy supplier's e-wallet. Based on the energy consumption carbon credits are issued

VI. Legal framework of Blockchain in India

There is no policy or regulation to standardize or provide legal framework for Blockchain. In 2018, the advisory issued by the Reserve Bank of India banning crypto-currencies in India has created a general impression that use of Blockchain is banned. But this was the ban on use and trade of crypto-currency and not on the technology. Hon'ble Supreme Court of India in Internet and Mobile Association of India v. reserve Bank of India decision[45] overturned the ban of RBI citing lack of RBI's regulatory power for crypto-currency. The efficacy, potential and rapid technological development of the emergent Blockchain technology was acknowledged by the Government of India. NITI Aayog[46] in its discussion paper "Blockchain: The India Strategy", 2020 and Meity in "National Strategy on Blockchain",[47] 2021 proposed Blockchain use cases and present strategy for adoption and implementation of national level Blockchain framework . To encourage the embracing of Blockchain technology, Meity started Blockchain as a service platform named Vishvasya and NBF Lite to help in deployment of Blockchain based e-governance applications and to cater the research challenges in Se[temebr 2024. The major challenge in implementing the Blockchain technology is that there is no single regulatory authority for its regulation as Reserve Bank of India (RBI) should do the regulation of crypto-currency; Trading of crypto-currency and crypto-token should be regulated by Security Exchange Board of India (SEBI) and application specific regulatory bodies e.g. IRDAI for insurance related applications, must provide the essential guidelines. Smart Contracts deployed on Blockchain must have all the essential components of the valid and enforceable contracts as per Indian Contract Act, 1872, sec.10. Although, sec.10 of The Information Technology Act, 2000 (IT Act) recognizes Smart Contract but still clarity in regulations needs to be done. One more required change is in Intellectual Property Rights (IPR) Laws. There is no available law which provides protection of Blockchain under any IPR Law viz a viz. Patent Act, 1970 (may be used for Dapps) or Copyright Act, 1957. Sec. 13 A of the Copyright Act,1957 may be considered for claiming IPR in Blockchain for written codes or programmes.

VII. Conclusion

Increase in Energy consumption is unavoidable for developing countries like India. Large consumption of energy elevates carbon emissions and resulted into global warming. It is paramount to accept and extend sustainable energy integration into present power grid system. Many rural areas in India do not have grid connectivity. Green energy based smart microgrids have significant task of continuous supply of affordable and sustainable energy

[45]Internet and Mobile Association of India v Reserve Bank of India,2020, SCC online SC275

[46] NITI Aayog, Government of India, " Blockchain: The India Strategy",2020 , *Available at*: https://static.psa.gov.in/psa-prod/psa_custom_files/Blockchain_The_India_Strategy_Part_I.pdf

[47] Ministry of Electronics and Information Technology , Government of India," National Strategy on Blockchain", 2021 *Available at :* h https://negd.gov.in/sites/default/files/NationalStrategyBCT_%20Jan2021_final_0.pdf

for such places. Block chain due to its distinctiveness of decentralization, security, transparency, confidentiality, traceability and immutability, is appropriate for the energy efficient management system. Use of Proof of Stake consensus mechanism solves the problem of excessive power consumptions. A comprehensive legislative or policy framework must be prepared which in comprehensive and transparent way promotes the use of renewable energy and endorses green energy as "resource of national importance". Although the Indian government has identified the use of Blockchain technology[48] in various use cases but there is no regulatory framework has been developed. There is an urgent need to develop the national infrastructure framework for promoting and implementing Blockchain based applications which are security resilient, transparent, inherent public trust and with privacy based data sharing capability. This system may be used to alleviate and avert the ecological damage caused due to make use of conventional energy, but we still have a long way to go. Many countries like China, Sweden, Canada, Estonia etc has already adopted[49] Blockchain. However, achieving this vision necessitates a comprehensive legal and policy framework. Leveraging Blockchain's potential can transform energy management and drive India toward a sustainable future. Open discussions on challenges and solutions are imperative to accelerate adoption and implementation.

[48] *Available at:* https://blockchain.meity.gov.in/ (last visited on October 2024).

[49] *Available at: https://legalbots.in/legal-blog/blockchain-technology-and-its-impact-on-the-legal-system-part-i and https://legalbots.in/legal-blog/blockchain-technology-and-its-impact-on-the-legal-system-part-ii (last visited on May 15,2023) Abstract*