iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.66811

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Blockchain-Based Energy Trading System

Prof.T PManasa[1], Swarnim Srijan[2], Sara Shree[3], Yashvardhan Srivastava[4], Shivam Singh Saini[5]
Dept. of CS &E Bangalore Institute of Technology Bangalore, India

Abstract: The traditional energy market suffers from inefficiencies, high transaction costs, and a lack of transparency, often limiting small-scale producers from participating effectively. Blockchain technology offers a decentralized, secure, and transparent solution for peer-to-peer (P2P) energy trading. This paper presents a blockchain-based energy trading platform utilizing smart contracts for automated transactions and ensuring real-time energy tracking. The proposed system enhances trust, eliminates intermediaries, and promotes sustainable energy practices by encouraging participation from small-scale renewable energy producers. Future advancements include AI-driven predictive analytics and integration with IoT devices for optimized energy management.
Keywords: Blockchain, Energy Trading, Smart Contracts, Decentralization, Renewable Energy.

I. INTRODUCTION

The energy sector is undergoing a significant transformation with the rise of decentralized technologies aimed at improving efficiency, transparency, and accessibility. Traditional energy trading systems rely on centralized intermediaries such as utility companies, which often result in high transaction costs, regulatory complexities, and limited participation from small-scale energy producers. These inefficiencies hinder the optimal distribution and utilization of renewable energy resources, discouraging a transition towards sustainable energy models.

Blockchain technology, with its inherent features of decentralization, immutability, and security, presents an innovative solution to these challenges. A blockchain-based energy trading system enables peer-to-peer (P2P) transactions, allowing energy producers to sell surplus electricity directly to consumers without the need for intermediaries. Through the implementation of smart contracts, transactions can be automated, reducing administrative overhead, enhancing transparency, and ensuring fair pricing mechanisms.

This paper explores the feasibility and implementation of a blockchain-based energy trading system. It outlines the design of a decentralized marketplace where energy transactions are recorded securely on a distributed ledger. By leveraging Ethereum-based smart contracts, the proposed system ensures trust, enhances security, and facilitates real-time energy trading. Additionally, the paper discusses key challenges, including scalability, regulatory considerations, and integration with existing energy grids, while proposing potential solutions for widespread adoption.

II. RELATED WORK

A. Litearture Review

Blockchain-based energy trading has gained significant attention due to its potential to enhance transparency, security, and efficiency in energy markets. Various research studies have explored different methodologies to integrate blockchain into energy trading platforms.Myles et al. (2022) proposed a blockchain-enabled P2P trading system that uses a McAfee-priced double auction mechanism to optimize energy distribution. Their findings highlight a 75% improvement in user welfare, a 25% reduction in consumer energy costs, and a 50% increase in prosumer revenues. However, the study points out challenges in computational complexity and blockchain scalability, which could impact large-scale implementation.Horvat et al. (2022) introduced a distributed ledger-based energy trading platform focusing on sustainability and reducing carbon footprints. Their system, implemented on a Beowulf cluster, demonstrated significantly lower carbon emissions (0.19 grams of CO2 per transaction) compared to Ethereum's traditional blockchain (20 grams per transaction). Despite these advancements, the reliance on high-end infrastructure limits accessibility, especially in developing regions.Danish Khan et al. (2022) developed a decentralized transaction system (DTS) for microgrid-based energy trading. Their blockchain framework incorporated smart contracts for automated transactions and dynamic pricing. While this system ensured secure and transparent transactions, scalability issues and financial burdens associated with hardware-based security mechanisms remained key concerns.Ali et al. (2023) introduced a Local Energy Market (LEM) framework leveraging blockchain to enable P2P energy trading with battery storage integration. Their study demonstrated improved energy efficiency and cost savings for participants. However, high infrastructure costs and regulatory complexities were noted as significant barriers to adoption.

B. Existing Solutions and Limitations

Blockchain-based energy trading enhances decentralization, transparency, and efficiency. Peer-to-peer (P2P) trading platforms like Power Ledger and WePower enable direct energy transactions using smart contracts, reducing intermediaries. However, regulatory and infrastructure challenges limit adoption.

Decentralized microgrids utilize blockchain to manage localized energy distribution, allowing communities to trade surplus renewable energy. While they improve sustainability, high initial investments remain a challenge.

Tokenized energy markets allow trading energy units as digital assets, increasing liquidity and accessibility. However, issues with token valuation stability and user acceptance persist.Despite its potential, blockchain-based energy trading faces challenges:

- Scalability: Proof-of-Work (PoW) networks suffer from slow transaction speeds and high energy consumption, while Proof-of-Stake (PoS) alternatives require further optimization.
- Regulatory Uncertainty: Many regions lack clear policies for decentralized energy trading, leading to legal adoption barriers.
- Infrastructure Barriers: Reliable internet, smart meters, and blockchain-compatible grids are needed, which can be costly.
- Security Risks: Smart contracts are vulnerable to cyber threats, necessitating strong security audits.
- Financial Viability: High initial investments and fluctuating transaction fees make adoption challenging for small-scale producers.

Addressing these issues through improved blockchain scalability, regulatory policies, and infrastructure enhancements will be essential for the success of decentralized energy trading.

III. SYSTEM DESIGN

A. Sequence Diagram

The sequence forUploadingandProcessingData is as follows:

1) Signing Up & Getting Started

Producers and consumers first create an account on the platform.Producers list how much energy they have available for sale, while consumers browse for options.

2) Connecting a Wallet

Users link their MetaMask wallets to the platform.

This connection allows them to trade energy securely using blockchain technology.

3) Buying & Selling Energy

A consumer picks an energy listing that suits their needs.They confirm their purchase and approve the payment through MetaMask.A smart contract verifies the details and records the transaction on the blockchain.

4) Completing the Transaction

Once confirmed, the system updates the producer’s and consumer’s energy credits.The payment is automatically transferred from the buyer to the seller.

5) Keeping Track of Everything

Users can check their transaction history anytime.Smart contracts ensure that all pricing and trading rules are followed.Since everything is stored on the blockchain, transactions are secure and tamper-proof.

B. ActivityDiagram

The activity diagram in your blockchain-based energy trading system represents how users interact with the platform, from logging in to completing energy trades. Let's walk through each step in a simple, understandable way.

1) Getting Started – Logging In & Connecting Wallet

Users (both producers and consumers) start by logging into the platform.If they haven’t already, they connect their MetaMask wallet, which acts like a digital bank for handling transactions.If the wallet is not connected, the system prompts them to do so before proceeding.

2) Selling Energy – How Producers List Their Energy for Sale

Producers (people generating surplus energy, like from solar panels) enter the details of the energy they want to sell. The system checks if their information is valid. If everything looks good, a smart contract is triggered to store the listing on the blockchain. Once confirmed, the energy is officially available for purchase, and the producer gets a notification.

3) Buying Energy – How Consumers Purchase Energy

Consumers browse through the available listings on the platform. Once they find a seller with the right offer, they place a purchase request. The system asks for transaction approval from the consumer.If the user approves, a smart contract is executed, processing the transaction on the blockchain. Both the seller and buyer receive a confirmation notification once the transaction is complete.

4) Keeping Track – Transaction History & Monitoring

Users (both buyers and sellers) can view their transaction history anytime. All past trades, including energy volumes, prices, and timestamps, are securely stored. Since the blockchain cannot be tampered with, this ensures complete transparency.

5) Automation & Security – How the System Handles Everything Smoothly

The smart contract automates price calculations, energy transfers, and payments. It also ensures that all transactions follow the platform's rules, making it secure and reliable. Since no central authority controls the transactions, users can trust the system without worrying about fraud..

C. UserInterface Diagram

1) Clean & User-Friendly Design – The platform is designed for easy navigation, making it simple for both energy buyers and sellers.
2) Wallet Integration – Users can securely connect their MetaMask wallet for seamless transactions.
3) Real-Time Listings – Buyers can browse available energy offers instantly.
4) Transaction History – Users can track their past trades with complete transparency.
5) Mobile & Desktop Friendly – Works smoothly on all devices for better accessibility

IV. IMPLEMENTATION

This section outlines the design, technologies, and architecture used to implement the blockchain-based energy trading system. The following subsections detail the system’s core technologies, modules, data structures, and implementation strategy.

A. Feature Technology

1) Ethereum Blockchain – Used to facilitate secure, transparent, and decentralized energy transactions via smart contracts.
2) Solidity – The primary language for developing smart contracts to automate and enforce trading rules.
3) MetaMask Wallet – Enables users to interact with the blockchain and execute transactions securely.
4) Truffle Suite – A development framework for deploying and testing smart contracts efficiently.
5) MongoDB – A NoSQL database for storing non-blockchain data, such as user profiles and energy history.
6) Web3.js – A JavaScript library for connecting the frontend to the Ethereum blockchain.
7) React.js – Used to build the user interface, providing a seamless trading experience.
8) Chainlink Oracles – Fetch real-time energy prices and external data for smart contract execution.

B. MajorModules

The system comprises multiple modules designed to streamline decentralized energy trading, ensuring security, efficiency, and usability.

1) User Authentication & Wallet Integration

Users register and authenticate via a secure login system. MetaMask wallet is connected to enable blockchain-based transactions. Authentication is decentralized, reducing dependency on centralized databases.

2) Energy Listing & Marketplace Module

Energy producers list available energy for sale, specifying price and quantity. Consumers browse the marketplace for available energy offers. Listings are stored on the blockchain, ensuring transparency and trust.

3) Smart Contract Execution Module

Smart contracts handle trade execution, payment transfers, and automated verification. Once a consumer initiates a purchase, a smart contract verifies funds availability and processes the transaction. Ensures tamper-proof and secure energy trading with minimal latency.

4) Real-Time Energy Trading & Pricing Module

Energy pricing is dynamically adjusted based on supply and demand using Chainlinkoracles.Ensures fair pricing for both producers and consumers. Implements automated settlement of transactions to eliminate delays.

5) Transaction History & Analytics Module

Every transaction is recorded permanently on the blockchain. Users can view past trades, energy credits, and transaction details. Smart contracts ensure immutable record-keeping for audit and security purposes.

6) Decentralized Storage & Security Module

Non-transactional data (e.g., user profiles, trading preferences) is stored in MongoDB. Blockchain-based storage ensures data security and integrity. Implements role-based access control to prevent unauthorized modifications.

7) Dashboard & UI/UX Module

A React-based frontend provides an intuitive, user-friendly interface. Users can monitor energy balances, view transaction history, and trade seamlessly. Mobile and desktop support for enhanced accessibility.

C. Data Structures

Energy Listings Collection

Stores available energy for sale, including seller details, energy amount, and pricing.

```
{
  "listingID": "string",
  "sellerID": "string",
  "energyAmount": "float",
  "pricePerUnit": "float",
  "listingStatus": "string", // "Available", "Sold", "Expired"
  "timestamp": "datetime"
}
```

Users Collection

Stores user details, including role (producer or consumer), wallet address, and energy statistics.

```
{
  "userID": "string",
  "name": "string",
  "email": "string",
  "walletAddress": "string",
  "role": "string",  // "Producer" or "Consumer"
  "energyGenerated": "float",
  "energyConsumed": "float",
  "registrationDate": "datetime"
}
```

Transactions Collection

Records successful energy trades, tracking buyer, seller, transaction amount, and status.

```
{
  "transactionID": "string",
  "buyerID": "string",
  "sellerID": "string",
  "energyAmount": "float",
  "totalPrice": "float",
  "transactionStatus": "string",  // "Completed", "Pending", "Failed"
  "timestamp": "datetime"
```

D. Algorithm Design

The algorithm for blockchain-based energy trading consists of several key steps, divided into user registration, energy listing, trading, and settlement. Each stage is governed by smart contracts that automate and enforce transaction rules.

1) User Registration & Authentication

Input: User details such as name, role (producer or consumer), and blockchain wallet address.

- The user accesses the energy trading platform and submits registration details.
- The system verifies user identity and ensures the uniqueness of credentials.
- Upon successful verification, a blockchain wallet is linked to the user's account.
- A unique user ID is generated and stored securely on the blockchain.

Output: A successfully registered user with authentication credentials.

2) Energy Listing by Producers

Input: Energy details such as the amount of energy available, price per unit, and producer's wallet address.

- Producers log into the platform and specify the energy they wish to sell.
- The system validates the energy details and ensures they meet market requirements.
- A smart contract is executed to record the listing on the blockchain.
- The listing is made publicly available on the marketplace for consumers.

Output: Verified and listed energy units ready for trading.

3) Consumer Energy Purchase

Input: Consumer selects an energy listing and initiates a purchase request.

- The consumer browses available energy listings and selects the desired option.
- The smart contract verifies the availability of energy and the consumer's wallet balance.
- The consumer confirms the purchase, triggering a transaction request.
- The required energy units are deducted from the seller and credited to the buyer.
- The smart contract locks the payment until the transaction is completed.

Output: A successful energy trade initiated and recorded on the blockchain.

4) Transaction Settlement & Ledger Update

Input: Completed energy trade details.

- The smart contract verifies that the transaction has been completed successfully.
- Funds are transferred from the consumer's wallet to the producer's wallet.
- The blockchain ledger updates energy balances and transaction history.
- Both parties receive a confirmation notification with transaction details.

Output: A completed and transparent transaction recorded on the blockchain.

5) Security & Fraud Prevention Measures

- Smart Contract Audits: Regular code reviews to detect vulnerabilities.
- Multi-Factor Authentication (MFA): Ensuring secure user access.
- Decentralized Identity Verification: Prevents fraudulent accounts.
- Anomaly Detection Algorithms: Identify unusual trading patterns.

6) Scalability Considerations

- To ensure the platform can handle increasing user activity and transactions:
- Sharding: Splitting blockchain data to improve processing speed.
- Layer-2 Scaling Solutions: Off-chain transactions for enhanced efficiency.
- Dynamic Pricing Models: AI-driven price adjustments based on supply and demand.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

V. TESTING AND EVALUATION

A. Testing Approach

Software testing involves examining the code under various conditions to ensure it performs as expected. The goal is to verify whether the software does what it's supposed to and meets the required functionality. In modern software development, testing is often done by a separate team from the developers.

Testing typically serves the following purposes:

- Improving quality
- Verifying correctness
- Estimating reliability

B. Unit Testing

Unit testing focuses on the smallest components or modules of the software. It ensures that each part works correctly in isolation before moving on to larger parts of the system.

Scope: Tests individual components, modules, or functions of the software.

Objective: Verify that the module performs as expected and handles edge cases.

Process:

- First, test the module interface to ensure data is correctly received and returned.
- Next, check the data structure to ensure data integrity is maintained throughout execution.
- Test boundary conditions to verify the system's behavior at limits.

Ensure all control paths are exercised to confirm the module implements all logic.

Finally, test error-handling paths to ensure errors are managed appropriately.

Approach: A bottom-up approach is used, starting with the smallest functions and modules. Any identified issues are corrected immediately, followed by retesting.

C. Integration Testing

Integration testing is an extension of unit testing, where already tested units are combined into larger components to verify their interaction.

- Scope: Combines multiple tested units into a single component to verify their interaction and interfaces.
- Objective: Ensure that the individual units work together as expected when combined.
- Process:

Units are tested together starting with the smallest components.

Focus is on testing the interfaces between the units, as errors are often found in these areas.

Once individual components pass the integration test, they are combined to test the entire process.

- Approach: Uses a bottom-up approach, testing components from the smallest to the largest modules to ensure all interfaces and interactions are functioning correctly.

This methodical, step-by-step approach ensures that both individual components and their interactions within the system are thoroughly tested.

VI. RESULTS

To provide results for a blockchain-based energy trading system, the outcomes would depend on several factors such as the system's design, the blockchain platform used, the participants (energy producers, consumers, and traders), and the test cases applied. However, I can summarize the potential results or findings from such a system:

1) Transparency: All energy transactions are recorded on an immutable ledger, ensuring complete visibility for all participants.
2) Decentralization: Peer-to-peer energy trading eliminates the need for intermediaries, allowing producers and consumers to transact directly.
3) Cost Efficiency: Reduced reliance on intermediaries leads to lower transaction costs and potentially more affordable energy for consumers.
4) Real-Time Settlement: Smart contracts enable instant execution and settlement of energy trades, improving speed and efficiency.

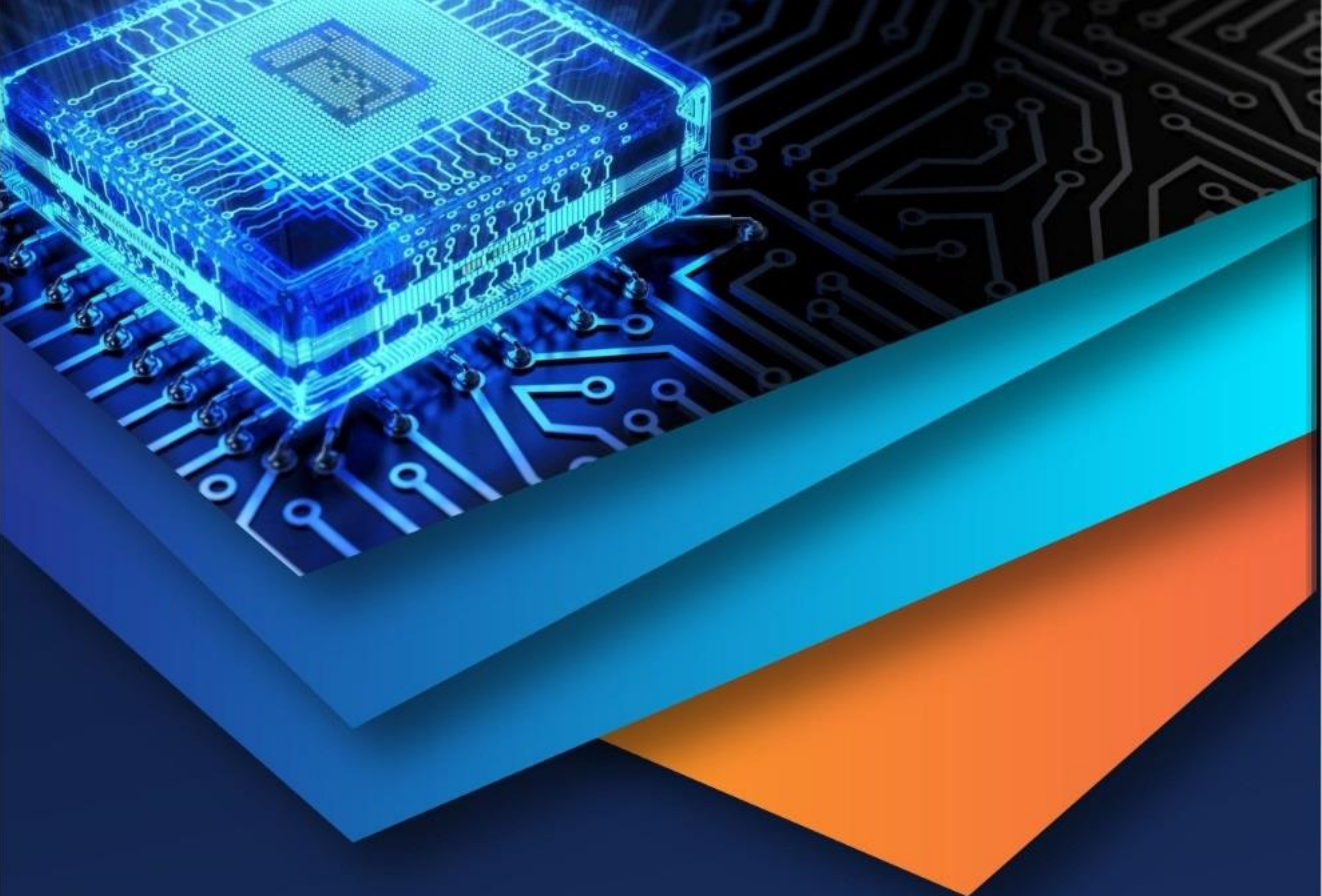
5) Security: Blockchain's cryptographic features ensure secure, tamper-proof records, minimizing fraud risks.
6) Grid Optimization: Real-time data from blockchain can enhance grid management, improving energy distribution, especially in decentralized systems like microgrids.
7) Increased Trust: With a shared, verifiable ledger, participants can trust the system without needing central authority intervention.
8) Regulatory Compliance: Blockchain enables easy tracking of energy transactions, aiding regulatory adherence.
9) Environmental Impact: Facilitates the tracking of renewable energy certificates and carbon credits, promoting sustainable energy usage.

VII. ACKNOWLEDGMENT

We would like to express our sincere gratitude to T P Manasa, Assistant Professor, Department of Computer Science and Engineering, Bangalore Institute of Technology, for their invaluableguidance,support,andmentorshipthroughoutthe course of this research. Their insights and suggestions were instrumentalinshapingthisprojectandenhancingitsoverall quality.
We would also like to thank Bangalore Institute of Technology for providing the necessary resources and infrastructure that facilitated thesuccessful completionof this research.
Finally,weextendourappreciationtofamilyandfriends for their continuous support and motivation during this research journey.

REFERENCES

[1] "Blockchain-Based Energy Trading" by Kodali and Yerroju (2018): This paper discusses the application of blockchain technology in energy trading, highlighting its potential to enhance transparency and security. semanticscholar.org
[2] "Energy Trading Systems on Blockchain Networks" by Matthew T. (2003): This article explores the integration of blockchain networks in energy trading systems, focusing on the benefits and challenges of such implementations. engineegroup.us
[3] "Application of Blockchain Technology in Energy Trading: A Review" by Zhang et al. (2021): This systematic literature review examines various studies and projects related to blockchain-based energy trading, providing insights into current developments and future directions. frontiersin.org
[4] "A Blockchain-Based Energy Trading Platform for Smart Homes in a Smart Grid Environment" by authors (2018): This research proposes a renewable energy trading platform using Ethereum's smart contracts to ensure secure and automated energy trading without third-party intermediaries. ieeexplore.ieee.org
[5] "Implementation of Blockchain-Based Energy Trading System" by authors (2018): This study investigates the application of blockchain technology to power trading, aiming to address complexities and risks associated with centralized trading systems. researchgate.net
[6] "Blockchain-Based Power Energy Trading Management" by authors (2019): This paper discusses the use of blockchain to record transactions and reach consensus in energy trading, with payment clearing executed via smart contracts. dl.acm.org
[7] "A Blockchain-Based Lightweight Peer-to-Peer Energy Trading Framework" by Khorasany et al. (2020): This work proposes a lightweight blockchain framework for location-aware peer-to-peer energy trading, addressing challenges in decentralized energy markets. arxiv.org
[8] "An Architecture for Distributed Energy Trading in Byzantine-Based Blockchain" by Guo et al. (2020): This research presents an architecture for distributed energy trading using a Byzantine-based blockchain, focusing on security and efficiency in energy transactions.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY