A TRANSPARENT BLOCKCHAIN MODEL FOR ENERGY TRADING

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Introduction

The rise of renewable energy has turned consumers into prosumers who both produce and use electricity. Traditional centralized energy systems are inefficient, costly, and offer low returns to small producers. Blockchain enables secure, transparent peer-to-peer energy trading without intermediaries. Smart contracts automate transactions, improving fairness and efficiency. However, challenges like scalability, regulation, and data reliability remain.

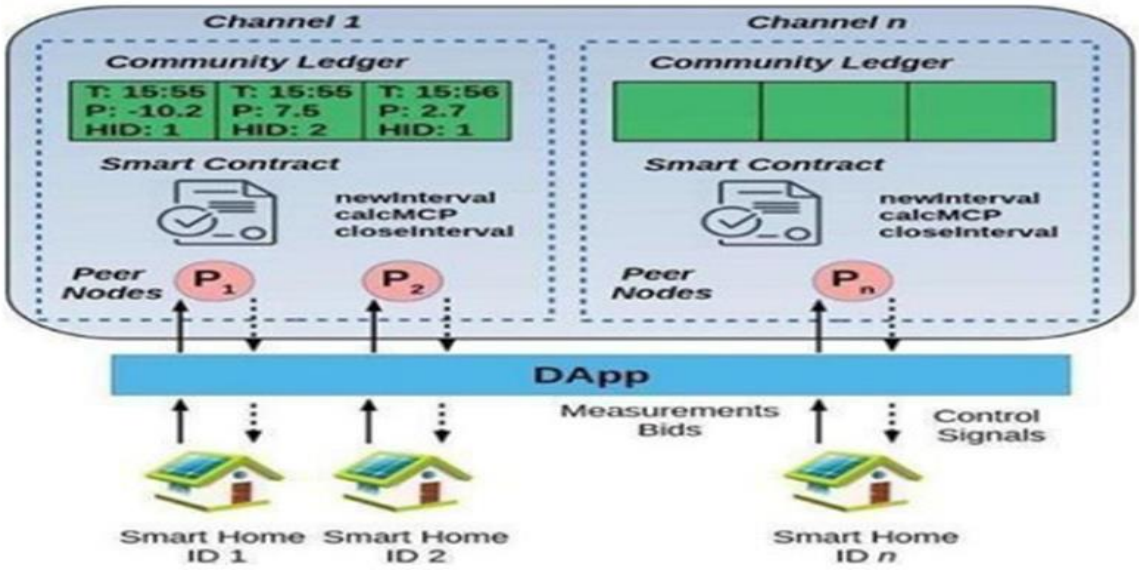
Objectives

1. Develop a decentralized blockchain-based platform enabling secure, transparent, and automated peer-to-peer (P2P) renewable energy trading between prosumers and consumers.
2. Deploy smart contracts on Ethereum to automate trade creation, validation, pricing, token issuance, and settlement without human or third-party intervention.
3. Implement an energy tokenization mechanism (ERC-20 tokens) that creates a one-to-one digital representation of physical energy units, enabling easy and auditable trading.
4. Apply a double-auction market-clearing algorithm off-chain to match buy and sell bids efficiently, then settle matched trades on-chain at a computed Market Clearing Price (MCP).
5. Ensure system security through end-to-end encryption, JWT-based authentication, role-based access control (producer/consumer/regulator), and protection against duplicate transactions and tampering.
6. Provide a React.js-based user dashboard for real-time monitoring of energy usage, token balances, bid history, and transaction records.

Methodology

1. **Data Collection and Processing:**

The system gathers real-time electric reading from smart meters, renewable sources, grid parameters, and user inputs. This information is cleaned, normalized, and synchronized to remove errors, handle missing values, and prepare consistent datasets for analysis.



2. **Blockchain Integration and Smart Contracts:**

All validated data is linked to a blockchain framework where smart contracts automate pricing, trading,and transaction settlement. Energy units are tokenized, and the consensus mechanism ensures secure,transparent, and tamper-proof energy exchanges between users.

3. **Trading Execution and User Interaction:**

The platform forecasts energy availability, updates dynamic prices, and executes trades in real time.Users interact through a dashboard displaying market trends, trading history, alerts, and insights that support informed decision-making.

Materials & Technologies

- Blockchain Platform: Ethereum (Hardhat for local development/testing)
- Smart Contract Language: Solidity — EnergyToken (ERC-20) and EnergyMarket contracts
- Backend: Node.js + Express.js with Web3/ethers.js for contract interaction
- Database: PostgreSQL (off-chain data — user profiles, bids, transaction summaries)
- Frontend: React.js with real-time charts and dashboards
- Hardware: Standard i5 processor, 8 GB RAM

Results And Conclusions

The implemented platform successfully demonstrated end-to-end P2P energy trading. Key results observed during testing and performance analysis include:

- All five formal test cases (invalid energy data, insufficient token balance, duplicate transaction, distributed ledger update, regulatory audit) passed with expected outcomes.
- A 5-minute market interval was created, bids were submitted, MCP was computed via double-auction, and tokens were transferred on-chain — the full cycle completed in under 30 seconds on a local Hardhat network.
- The dashboard showed real-time Grid vs. P2P cost comparison.
- Transaction history, bid summaries, and interval details were rendered accurately and in real time, confirming the transparency and usability of the platform.

Finally, the project validates that blockchain technology can effectively overcome the transparency, efficiency, and access barriers of conventional centralized energy markets.

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Scope For Future Work

1. AI/ML-Driven Pricing & Forecasting — Incorporate machine learning models to forecast renewable energy generation, predict demand patterns, and propose dynamic bid prices, improving market efficiency.
2. Fraud Detection & Anomaly Identification — Apply AI-based anomaly detection on smart meter data streams to flag tampered readings or unusual consumption patterns before tokenization.
3. Mobile Application — Develop a lightweight Android/iOS app with push notifications for bid outcomes, price alerts, and settlement confirmations, increasing accessibility for users in remote or rural areas.