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Empowering Sustainable Communities Through Decentralized Energy Trading

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INTRODUCTION

The transition to renewable energy is crucial to achieving global climate targets and ensuring affordable, sustainable energy for communities [1].

Peer-to-peer (P2P) energy trading empowers individuals to produce, consume, and trade energy directly without intermediaries. It enables lower costs, encourage the use of distributed energy resources (DERs) and increases grid reliability. According to a study conducted on the first real-world P2P market, participants became more motivated to invest in distributed energy resources such as photovoltaic systems [2].

Although you might sell energy to your neighbor, the financial flow in traditional P2P energy markets is still controlled by grid operators. This work aims to address that limitation by leveraging blockchain technology to decentralize the financial flow, ensuring that transactions are trustless, transparent, and independent of centralized entities.

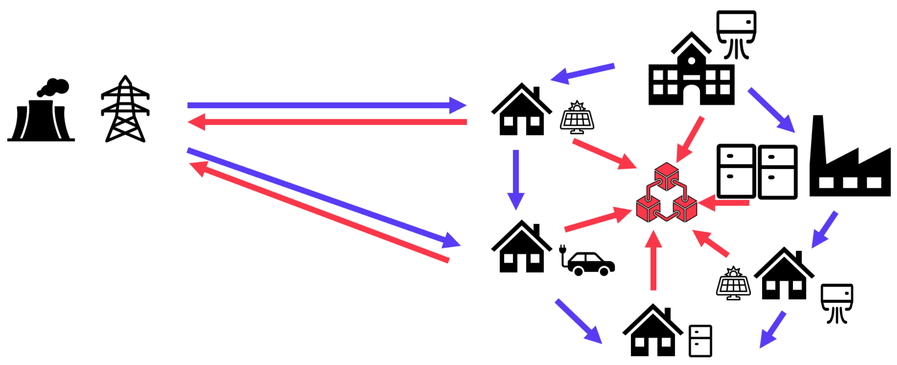

Fig. 1. Decentralized energy trading system facilitated by blockchain technology. The blue arrows indicate the flow of energy. The red arrows represent the financial transactions recorded on the blockchain

In a uniform bidding market, also referred to as a single price auction, the winning bidders pay or receive the same market-clearing price. This price is established at the point where supply and demand are equal within the marketplace, as illustrated in Fig.2. Because all participants are treated equally and no advantages may result from bidding tactics or market timing, such a market design simplifies the transaction process and fosters fairness [5].

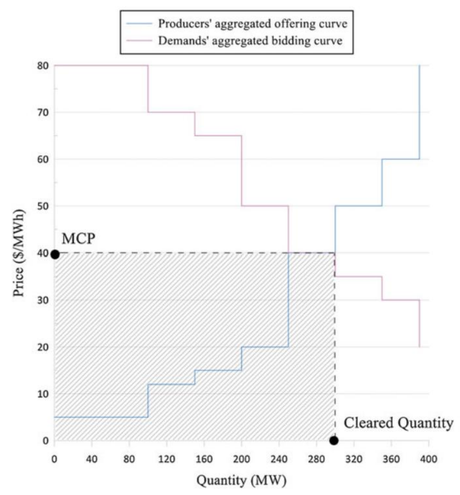

Fig. 2. The mechanism of a uniform price auction. Source: [6]

Blockchain technology offers an ideal framework for decentralized peer-to-peer energy markets by enabling trustless, transparent, and secure transactions without the need for intermediaries [3]. Its immutable ledger ensures all energy trades are recorded accurately and transparently, fostering trust among participants. By decentralizing market operations, blockchain eliminates reliance on central authorities, empowering prosumers and consumers to interact directly.

Arbitrum Orbit, an advanced Layer 3 (L3) blockchain solution, is central to this innovation. It provides scalability, low-cost transactions, and a secure decentralized ecosystem for energy trading, surpassing the limitations for cheap transactions and scalability of traditional Layer 1 and 2 architectures.

METHODS AND MATERIALS

Market Design:

- A uniform bidding market ensures fairness by setting a market-clearing price that reflects real-time supply and demand.
- Simplified participation fosters inclusivity, allowing both consumers and prosumers to engage in the energy market effectively

Technology Features:

- Blockchain-backed decentralized trading platforms eliminate the need for a central authority, empowering energy communities.
- Interoperable frameworks enable regulatory compliance and adaptability across varying jurisdictions

Arbitrum Orbit:

- Enables the creation of app-specific rollup chains tailored for energy trading, integrating seamlessly with Ethereum's ecosystem.
- Reduces transaction costs by leveraging rollups to aggregate transactions off-chain before settlement

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RESULTS & DISCUSSION

We have successfully implemented an hourly uniform bidding market in Solidity[7], making it executable on any Ethereum Virtual Machine (EVM)-compatible blockchain. The market operates as illustrated in Fig. 3, following a structured timeline for energy bid submissions, ask submissions, and market clearing. This implementation has been deployed on an Ethereum Layer 3 using Arbitrum Orbit, achieving full decentralization and seamless interoperability with the broader permissionless crypto ecosystem.

Key Benefits:

- **Transparency**: Immutable blockchain records ensure trust among participants.
- **Scalability**: Arbitrum Orbit's rollup technology addresses the high transaction volume of energy trading.
- **Decentralization**: Removes intermediaries, fostering self-sustained energy communities. Permissioneless rollup technology fosters a true decentralized blockchain network, boosting trust among users.
- **Cost Efficiency**: Reduced transaction costs promote wider adoption.

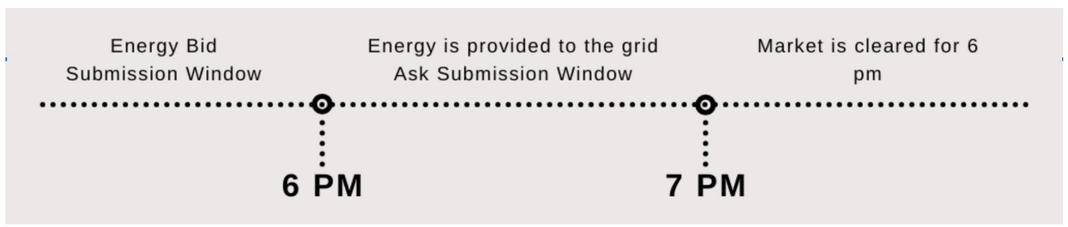

Fig. 3. Uniform bidding market submission timeline for 6 PM. The energy bid submission window remains open until 6 PM, allowing participants to submit their buy offers. Following this, the ask submission window for energy sales is open until 7 PM. At 7 PM, the market clears, and financial transactions are executed, ensuring a transparent and efficient exchange between buyers and sellers.

CONCLUSION

Our deployment of an hourly uniform bidding market, written in Solidity and operating on an Ethereum Layer 3 via Arbitrum Orbit, demonstrates the feasibility of a fully decentralized and interoperable energy trading platform. This implementation not only ensures transparency and cost efficiency but also enables scalability, a critical challenge in energy markets with high transaction volumes.

The hypothesis—that a decentralized, blockchain-based energy trading market can address traditional inefficiencies while fostering trust and inclusivity—was strongly supported. By leveraging permissionless rollup technology, we achieved a self-sustained ecosystem that empowers energy communities to operate independently and connect seamlessly with the wider crypto market.

This outcome is particularly significant because it bridges the gap between energy markets and decentralized technologies, showcasing how blockchain can address real-world challenges. It offers a practical pathway toward sustainable, fair, and accessible energy trading for communities globally, setting a precedent for future energy markets and blockchain academic research.

ACKNOWLEGEMENTS

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