BLOCKCHAIN-BASED SUSTAINABLE ENERGY TRADING FOR ELECTRIC VEHICLES

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Use Case Report

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CERTIFICATE

This is to certify that the Use Case report entitled **"BLOCKCHAIN-BASED SUSTAINABLE ENERGY TRADING FOR ELECTRIC VEHICLES "** is being submitted by **N. Sampreeth Chowdary (22501A05D0)** as part of Assignment-1 and Assignment-2 for the **Blockchain Technology**(**20CS4601C)** course in **3-2** during the academic year **2024-25**.

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INDEX

S. No.	Chapter	Page No.
1	Introduction	1
2	Background	2
3	Blockchain Basics	3
4	Use Case Overview	5
5	Implementation	7
6	Benefits	12
7	Challenges	15
8	Conclusion	17
9	SDG’s Addressed	20
10	References	22
11	Appendix A	23

1. INTRODUCTION

Blockchain technology has emerged as a transformative force in various industries, including finance, healthcare, supply chain management, and energy distribution. At its core, blockchain is a decentralized, distributed ledger that records transactions securely and transparently without the need for intermediaries. This document explores a specific application of blockchain technology in energy trading for electric vehicle (EV) charging stations in smart cities.[1]

The growing adoption of EVs demands a more efficient, transparent, and decentralized approach to energy distribution. Traditional centralized energy grids struggle with inefficiencies such as transmission losses, fluctuating electricity prices, and reliance on fossil fuels. Blockchain introduces a peer-to-peer (P2P) energy trading model where EV owners can directly procure energy from renewable sources, ensuring fair pricing, security, and reduced dependence on large utility providers.[1]

This document presents a comprehensive use case for blockchain-based energy trading, covering the background, technological fundamentals, system architecture, implementation details, benefits, challenges, and its alignment with the United Nations Sustainable Development Goals (SDGs).[1]

2. BACKGROUND

Smart cities are rapidly evolving, integrating advanced digital technologies to improve urban living. A critical challenge in this evolution is the sustainable and efficient management of energy resources. As EV adoption accelerates, so does the demand for charging infrastructure.[1],[3]

However, centralized power grids present limitations, including:

- **Grid Overload**: Increased EV usage puts stress on existing infrastructure.
- **High Transmission Losses**: Energy losses occur due to long-distance transmission from centralized power plants.
- **Price Fluctuations**: Energy prices vary based on grid demand and supply constraints.
- **Limited Renewable Energy Utilization**: Traditional grids prioritize fossil fuels, limiting clean energy adoption.[1][3]

Blockchain technology offers a decentralized alternative, enabling P2P energy trading where renewable energy providers can directly sell excess power to EV owners. By leveraging blockchain's immutability and transparency, the system ensures trust, reduces reliance on intermediaries, and facilitates real-time transactions.[3]

3. BLOCKCHAIN BASICS

Blockchain technology operates as a secure, decentralized ledger that records transactions across multiple nodes. Figure 3.1 shows the blockchain Architecture for energy trading. The following features make it ideal for energy trading:

3.1 Key Concepts

- **Decentralization**: Transactions occur directly between participants without central authority intervention.
- **Immutability**: Once data is recorded on the blockchain, it cannot be altered, ensuring security.
- **Smart Contracts**: Self-executing contracts automate transactions when predefined conditions are met.[5],[10]

3.2 Consensus Mechanisms

Consensus mechanisms validate transactions before adding them to the blockchain. The most relevant mechanisms for energy trading are:

- **Proof of Authority (PoA)**: A faster and energy-efficient consensus mechanism where trusted nodes validate transactions.
- **Proof of Work (PoW)**: Requires solving computational puzzles but is highly energy-intensive.
- **Proof of Stake (PoS)**: Validators are chosen based on their staked tokens, making it more energy-efficient than PoW.[2]

3.3 Smart Contracts in Energy Trading

Smart contracts automatically execute agreements between energy buyers and sellers. In an EV charging scenario, smart contracts handle:

- **Auction Bidding**: EV owners request energy, and suppliers place bids.
- **Verification**: The system confirms energy availability and price validity.
- **Transaction Execution**: Once validated, energy transfers are recorded on the blockchain.[5],[10]

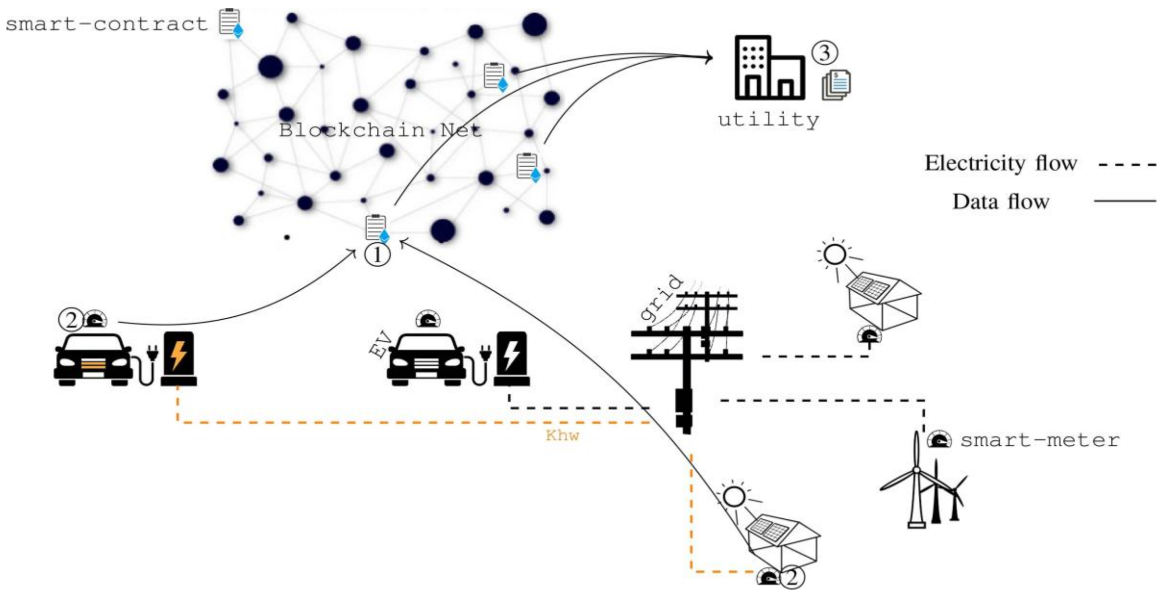

Figure 3.1: Blockchain architecture for energy trading.

4. USE CASE OVERVIEW

4.1 Overview of the System

The proposed blockchain-based energy trading system allows direct transactions between **renewable energy providers** and **EV owners** by eliminating the need for intermediaries. The system ensures **efficient, secure, and cost-effective** energy distribution by integrating blockchain with **smart contracts, IoT-enabled smart meters, and real-time data analytics**.[1],[4],[8]

4.2 Components of the System

1. **Electric Vehicles (EVs)**
    - EV owners can request energy by specifying the amount required, the maximum price they are willing to pay, and the preferred charging time.
    - Requests are processed using blockchain-based smart contracts, ensuring transparency and automated settlements.
2. **Energy Providers (EPs)**
    - Renewable energy sources such as **solar farms, wind turbines, and household solar panels** can directly supply energy to EV owners.
    - EPs place **bids** on charging requests in an auction-based system, ensuring competitive pricing.
3. **Smart Meters (SMs)**
    - Smart meters are deployed at both the energy provider and the EV charging station to **track the amount of energy supplied and consumed**.
    - They **automatically update the blockchain** with verified energy transfer data.
4. **Utility Company**
    - The utility company remains involved for **grid management and billing**, ensuring regulatory compliance while integrating decentralized transactions.
5. **Blockchain Network**
    - A **private Ethereum blockchain** is used for recording all transactions.
    - **Smart contracts automate** auctions, validate transactions, and process energy payments.[1],[2]

4.3 Workflow of Energy Trading

Step 1: EV owner initiates a charging request via the blockchain network.

Step 2: Renewable energy providers submit bids.

Step 3: The **second-price auction mechanism** selects the best bid.

Step 4: The winning provider delivers energy to the EV charging station.

Step 5: Smart meters **verify the energy transfer** and update the blockchain.

Step 6: Payment is **automatically processed** via the smart contract.[2],[4],[8]

5. IMPLEMENTATION

5.1 Smart Contract for Energy Auction(Visually presented in Figure 5.1)

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract EnergyTrading {
  address public owner;

  enum AuctionState { Created, Bidding, Ended }

  struct ChargingRequest {
    uint requestId;
    address payable evOwner;
    uint energyRequired; // in kWh
    uint maxPrice; // in Wei per kWh
    uint auctionEndTime;
    AuctionState state;
  }

  struct Bid {
    address payable provider;
    uint bidPrice; // price per kWh
  }

  uint public auctionCounter = 0;
  mapping(uint => ChargingRequest) public chargingRequests;
  mapping(uint => Bid[]) public bids;

  event ChargingRequestCreated(uint requestId, address evOwner, uint energyRequired, uint maxPrice);
  event BidPlaced(uint requestId, address provider, uint bidPrice);
  event AuctionEnded(uint requestId, address winner, uint finalPrice);

  modifier onlyOwner() {
    require(msg.sender == owner, "Only contract owner can perform this action.");
    _;
  }

  modifier auctionActive(uint requestId) {
```

```
        require(block.timestamp < chargingRequests[requestId].auctionEndTime, "Auction has ended.");
        _;
    }

    constructor() {
        owner = msg.sender;
    }

    // Function to create a new charging request
    function createChargingRequest(uint _energyRequired, uint _maxPrice, uint _auctionDuration) public {
        auctionCounter++;
        chargingRequests[auctionCounter] = ChargingRequest({
            requestId: auctionCounter,
            evOwner: payable(msg.sender),
            energyRequired: _energyRequired,
            maxPrice: _maxPrice,
            auctionEndTime: block.timestamp + _auctionDuration,
            state: AuctionState.Bidding
        });

        emit ChargingRequestCreated(auctionCounter, msg.sender, _energyRequired, _maxPrice);
    }

    // Function to place a bid
    function placeBid(uint requestId, uint _bidPrice) public payable auctionActive(requestId) {
        require(msg.sender != chargingRequests[requestId].evOwner, "EV owners cannot bid.");
        require(_bidPrice <= chargingRequests[requestId].maxPrice, "Bid exceeds max price.");

        bids[requestId].push(Bid({
            provider: payable(msg.sender),
            bidPrice: _bidPrice
        }));

        emit BidPlaced(requestId, msg.sender, _bidPrice);
    }

    // Function to finalize the auction
    function finalizeAuction(uint requestId) public {
```

```
            require(block.timestamp >= chargingRequests[requestId].auctionEndTime, "Auction still active.");
            require(chargingRequests[requestId].state == AuctionState.Bidding, "Auction already finalized.");

            Bid memory winningBid;
            uint minBid = chargingRequests[requestId].maxPrice;
            address payable winner;

            // Find the lowest bid (Second-Price Auction)
            for (uint i = 0; i < bids[requestId].length; i++) {
              if (bids[requestId][i].bidPrice < minBid) {
                minBid = bids[requestId][i].bidPrice;
                winningBid = bids[requestId][i];
              }
            }

            // If a valid bid was found
            if (winningBid.provider != address(0)) {
              winner = winningBid.provider;
              chargingRequests[requestId].evOwner.transfer(minBid * chargingRequests[requestId].energyRequired);
              chargingRequests[requestId].state = AuctionState.Ended;

              emit AuctionEnded(requestId, winner, minBid);
            }
          }
        }
```

[1],[5],[9],[10]

5.2 Code Explanation

1. **Creating Charging Requests**
   - EV owners submit charging requests with energy requirements and max acceptable price.
   - Smart contract records the request and assigns an auction duration.
   - **Event ChargingRequestCreated is emitted** to log the request.
2. **Auction Mechanism (Second-Price Auction)**
   - Renewable energy providers submit bids offering a price per kWh.
   - **Function placeBid()** ensures that bids do not exceed the maximum price set by the EV owner.
   - **Event BidPlaced is emitted** to track bid submissions.

3. **Finalizing Auction and Selecting Winner**
    - Once the auction ends, the **finalizeAuction()** function identifies the **lowest bid**.
    - The energy provider with the lowest bid wins the auction.
    - The EV owner pays the winning provider based on the agreed price.
    - **Event AuctionEnded is emitted** to record the successful transaction.

Every step of the process is shown in detail in **Figure 5.1** [1],[6],[9]

5.3 Enhancements for Practical Implementation

- **Integration with IoT Smart Meters**:
    - Smart meters can trigger transactions once energy is transferred.
    - Blockchain records verified energy usage before settling payments.
- **Dynamic Pricing Model**:
    - AI-driven predictions for demand-based pricing adjustments.
    - Adjustments can be made within smart contract parameters.
- **User-Friendly Mobile/Web Interface**:
    - Frontend applications can interact with the blockchain contract via **Web3.js**.
    - EV owners and energy providers can monitor transactions in real-time.[3],[6],[7],[10]

5.4 Example Transactions (Shown in Table 5.1)

Scenario 1: EV Owner Creating a Charging Request

Transaction Call: *createChargingRequest(50, 100, 300);*

- **EV owner requests** 50 kWh at a **max price of 100 Wei per kWh**, with an auction duration of 5 minutes.[5]

Scenario 2: Energy Provider Bidding

Transaction Call: *placeBid(1, 90);*

- Energy provider **bids 90 Wei per kWh** for request ID **1**.[5]

Scenario 3: Finalizing the Auction

Transaction Call: *finalizeAuction(1);*

- **Lowest bid wins**, and energy transfer begins.[5]

5.5 Table and Diagram

Function Name	Description
createChargingRequest()	Allows EV owners to request energy with price limits.
placeBid()	Energy providers submit their bids.
finalizeAuction()	Determines the lowest bidder and executes transactions.

Table 5.1 Smart Contract Functions and Their Purpose

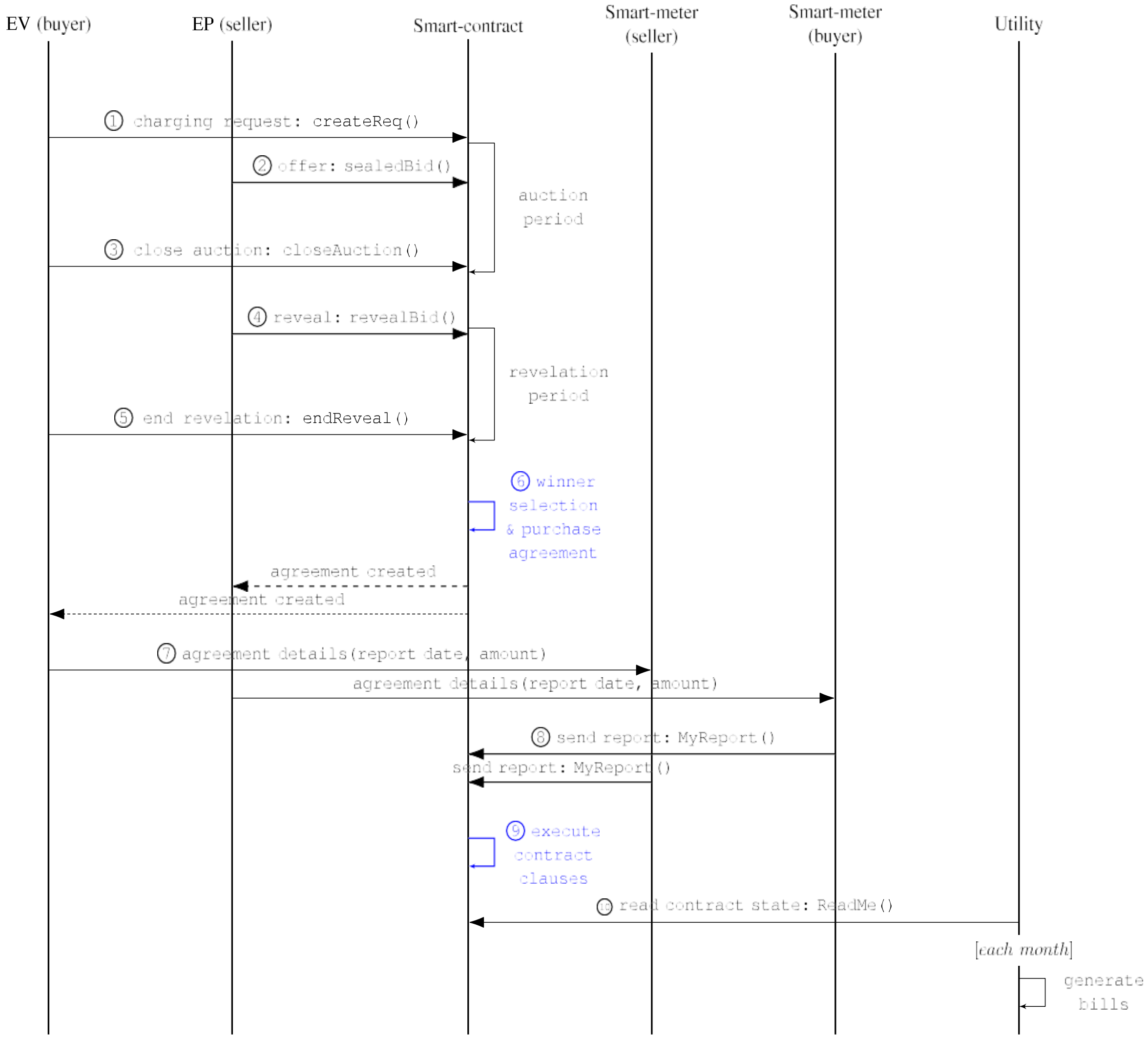

Figure 5.1 Peer-to-peer energy trading scheme for EVs charging sketch.

6. BENEFITS

6.1 Technical Benefits

- Decentralization: Eliminates reliance on central authorities.
- Security & Immutability: Blockchain ensures tamper-proof transaction records.
- Real-time Monitoring: Smart contracts and IoT-enabled meters provide real-time transaction validation.[4]

6.2 Economic Benefits

- Cost Efficiency: Eliminating intermediaries reduces transaction fees.
- Market Competition: Auction-based pricing ensures fair electricity rates.[6]

6.3 Environmental & Sustainability Benefits

- Increased Renewable Energy Usage: Encourages small-scale renewable energy trading.
- Reduced Carbon Emissions: Supports green energy adoption, reducing reliance on fossil fuels.[10]

6.4 Increased Energy Accessibility

- Localized energy trading allows EV owners to access energy from nearby renewable sources, reducing dependency on centralized grids.
- Supports rural and underserved areas by enabling microgrid energy transactions.[7]

6.5 Fraud Prevention and Transparency

- All transactions are recorded on an immutable ledger, eliminating billing fraud.
- Smart meters verify energy consumption and prevent overcharging.[4]

6.6 Demand-Supply Optimization

- The auction-based model dynamically balances supply and demand.
- Encourages optimal energy allocation by prioritizing high-demand areas.[4]

6.7 Reduced Energy Transmission Losses

- Peer-to-peer (P2P) trading reduces the distance electricity must travel, minimizing transmission losses.
- Enhances grid stability by distributing loads efficiently.[5]

6.8 Energy Resilience and Decentralization

- Decentralized energy grids prevent single points of failure and improve resilience against blackouts and cyberattacks.
- Ensures uninterrupted power availability in emergency situations.[7]

6.9 Lower Operational Costs for Energy Providers

- Automated smart contracts reduce administrative expenses.
- Small-scale renewable energy providers can directly sell energy without relying on costly intermediaries.[6]

6.10 Real-time Billing and Faster Settlements

- Instant payments via blockchain eliminate delays associated with traditional utility billing systems.
- Users can track energy usage and costs in real-time dashboards.[6],[10]

6.11 Incentivizing Green Energy Production

- Individuals with solar panels or wind turbines can monetize their surplus energy, fostering a green energy marketplace.
- Governments and organizations can introduce tokenized incentives for renewable energy contributions.[4]

6.12 Scalability for Future Expansion

- The system can expand to accommodate vehicle-to-grid (V2G) trading, where EVs supply excess energy back to the grid.
- Blockchain’s modular nature allows integration with smart city infrastructure, AI, and IoT.[6]

6.13 Compliance with Carbon Reduction Goals

- Supports governments and corporations in **achieving carbon neutrality**.
- Blockchain-based tracking can be used for **carbon credits and sustainability reporting**.

Category	Benefit
Technical	Immutable ledger prevents fraud and ensures transparency.
Economic	Auction-based bidding reduces electricity costs for consumers.
Efficiency	Automated smart contracts speed up transactions and settlements.
Grid Stability	Decentralized energy distribution minimizes power outages.
Environmental	Encourages renewable energy adoption and reduces carbon emissions.
Consumer Experience	Real-time billing and tracking improve user control over energy consumption.
Sustainability	Supports microgrid energy sharing and green energy incentives.
Scalability	Can integrate with **V2G trading** and future smart city infrastructure.
Energy Accessibility	Ensures energy availability in underserved and rural areas.
Government Compliance	Helps in tracking carbon footprints and achieving sustainability goals.

Table 6.1 Summary of Benefits

The above table i.e., table 6.1 Summarizes the benefits of blockchain for energy trading.

7. CHALLENGES

7.1 Technical Challenges

- **Network Scalability**: A high volume of transactions can slow the blockchain network.
- **Latency Issues**: Blockchain confirmations may delay energy transactions.[2],[8]

7.2 Regulatory Challenges

- **Legal Uncertainty**: Many regions lack clear regulations for decentralized energy trading.
- **Interoperability**: Integrating blockchain with traditional power grids requires careful planning.[4]

7.3 Security and Privacy Risks

- **Data Protection**: Ensuring privacy while maintaining transparency is complex.
- **Cybersecurity Threats**: Blockchain networks must be secured against attacks.[6],[7],[9]

7.4 High Initial Setup Costs

- Deploying a **private blockchain network** requires significant investment in **hardware, software, and infrastructure**.
- **Smart meters, blockchain nodes, and secure network connections** must be installed, which increases upfront costs.[2]

7.5 Energy Consumption of Blockchain Operations

- While Proof of Authority (PoA) is more efficient than Proof of Work (PoW), **validating transactions still requires computational power**.
- Running blockchain nodes continuously can **increase operational energy consumption**, affecting sustainability goals.[3],[9]

7.6 Limited Awareness and Adoption

- Many **energy providers and consumers** lack knowledge about blockchain technology.
- **User adoption is slow** due to skepticism about decentralized energy markets.[3],[6]

7.7 Smart Contract Vulnerabilities

- **Bugs in smart contract code** can lead to security risks, such as **hacks, fund losses, or manipulation of bidding mechanisms**.

- Once deployed, **smart contracts cannot be altered easily**, making **security audits crucial**.[5]

7.8 Lack of Standardization in Energy Markets

- Different countries and regions have **varying regulations for energy trading and blockchain applications**.
- **Interoperability challenges** arise when integrating blockchain-based energy systems with **existing grid networks**.[4]

7.9 Connectivity and Network Latency Issues

- Blockchain transactions **require continuous internet connectivity** for verification.
- Areas with **poor network infrastructure** may face **delayed transaction confirmations**, affecting real-time energy trading.[2],[8]

7.10 Resistance from Traditional Energy Companies

- **Large utility companies may oppose decentralized energy trading** as it threatens their **monopoly and revenue models**.
- Governments may be **pressured by big energy corporations** to impose **restrictions on peer-to-peer (P2P) energy trading**.[5]

8. CONCLUSION

8.1 Summary of Key Findings

The integration of **blockchain technology in energy trading** for **EV charging stations** presents a transformative approach to **decentralized, secure, and efficient energy distribution**. Throughout this document, we have explored how **peer-to-peer (P2P) energy trading** allows renewable energy providers to sell electricity directly to EV owners without reliance on intermediaries.

The proposed system utilizes:

- **Smart contracts** to automate transactions and enforce transparent agreements.
- **Auction-based bidding mechanisms** to optimize energy pricing dynamically.
- **IoT-enabled smart meters** to verify real-time energy consumption and prevent fraud.
- **Private Ethereum blockchain with Proof of Authority (PoA)** for high-speed, low-cost energy trading.

The benefits of this system include **cost reduction, energy efficiency, enhanced security, and environmental sustainability**. However, **challenges such as scalability, regulatory compliance, infrastructure costs, and adoption barriers** must be addressed for successful implementation.

8.2 Comparative Analysis of Blockchain-Based vs. Traditional Energy Trading

Feature	Traditional Grid-Based Trading	Blockchain-Based Trading
Transaction Speed	Slow due to centralized processing	Instant settlements via smart contracts
Transparency	Prone to billing fraud and inefficiencies	Fully auditable and tamper-proof ledger
Intermediaries	Requires energy suppliers, billing companies, and regulators	Peer-to-peer transactions remove intermediaries
Scalability	Limited by centralized infrastructure	Scales through decentralized energy markets
Energy Source	Mostly fossil fuels	Prioritizes renewable energy
Security	Susceptible to cyberattacks and manipulation	Secure through cryptographic verification

Table 8.1 Comparative Analysis

8.3 Future Enhancements & Research Directions

To further optimize blockchain-based energy trading, future work should focus on:

1. Layer-2 Scaling Solutions

- Implement **rollups and sidechains** to reduce transaction congestion and increase throughput.
- Optimize **block validation times** to enhance real-time energy trading.

2. Privacy-Preserving Technologies

- **Zero-Knowledge Proofs (ZKP)** can be integrated to allow **transaction verification without exposing private data**.
- **Confidential smart contracts** will ensure **secure energy bidding** without leaking sensitive pricing information.

3. AI-Driven Predictive Analytics

- **Artificial Intelligence (AI)** can dynamically **adjust pricing** based on real-time demand and supply trends.
- Machine learning models can **forecast energy shortages** and optimize grid balance.

4. Integration with Smart City Infrastructure

- Expand beyond **EV charging** to **smart buildings, decentralized grids, and industrial energy trading**.
- Leverage **5G networks and edge computing** for faster transaction processing.

5. Regulatory Framework Development

- Governments should **establish clear policies** to promote **blockchain-based P2P energy trading**.
- Incentives for **renewable energy adoption** via blockchain-based carbon credit tracking.

8.4 Long-Term Impact on Smart Cities & Sustainability

The implementation of blockchain-based energy trading will play a crucial role in the development of **smart cities** by:

Reducing carbon footprints by integrating renewable energy sources into EV charging networks.

- **Decentralizing energy markets**, allowing consumers to **control their energy transactions**.

- **Creating financial incentives** for small-scale renewable energy producers, boosting green energy adoption.
- **Enhancing urban resilience** by distributing energy sources across multiple microgrids, reducing dependence on **single-point failures**.

By overcoming current **technical, economic, and regulatory barriers**, blockchain can revolutionize **how we generate, distribute, and consume energy**, leading to a more **sustainable, efficient, and decentralized energy ecosystem**.

8.5 Final Thoughts

The **energy sector is at a pivotal moment**, where **technological advancements and sustainability** must work hand in hand. **Blockchain-powered energy trading is a game-changer**, offering **cost-efficient, transparent, and environmentally friendly solutions** for EV charging and beyond.

However, widespread adoption requires:

- **Robust infrastructure investment**
- **User awareness and education**
- **Government policy support**
- **Scalability improvements**

If these factors align, **blockchain technology will drive the next generation of decentralized, intelligent energy networks**, fostering a future where **clean energy is accessible, affordable, and efficiently distributed** worldwide.

9. SDGs ADDRESSED

Blockchain-based energy trading for EV charging stations aligns with multiple **United Nations Sustainable Development Goals (SDGs)** by promoting **renewable energy, urban sustainability, and climate resilience**. The system encourages **energy efficiency, decentralization, and transparency**, making cities **smarter, cleaner, and more sustainable**.

Goal 7: Affordable and Clean Energy

Ensure access to affordable, reliable, sustainable, and modern energy for all.

Justification:

The **blockchain-based energy trading platform** actively supports **renewable energy adoption** by allowing **peer-to-peer (P2P) transactions** between EV owners and energy producers. This system:

- **Increases renewable energy accessibility:** Small-scale solar and wind energy producers can directly sell surplus electricity to consumers.
- **Reduces dependency on fossil fuels:** By **prioritizing green energy sources**, the platform supports a transition to a **low-carbon economy**.
- **Ensures fair and competitive pricing:** The **auction-based model** optimizes electricity pricing, reducing costs for EV owners while ensuring fair compensation for energy providers.
- **Minimizes energy transmission losses: Local energy trading** ensures that electricity is **consumed closer to where it is produced**, reducing inefficiencies.
- **Encourages decentralized microgrids:** The system facilitates **local energy sharing networks**, empowering communities to become **self-sufficient in energy production**.

Goal 11: Sustainable Cities and Communities

Make cities and human settlements inclusive, safe, resilient, and sustainable.

Justification:

The integration of blockchain-based **EV energy trading** aligns with **smart city initiatives**, making urban energy management more **efficient, secure, and transparent**. The system supports **urban sustainability** in several ways:

- **Reduces stress on centralized power grids:** By promoting **local energy generation and consumption**, cities can better manage **energy demand peaks** and avoid grid failures.

- **Enhances energy resilience: Decentralized trading** reduces the risk of **single-point failures** in urban electricity distribution.
- **Supports EV adoption:** The system **improves the availability of affordable charging infrastructure**, encouraging more consumers to transition to **electric vehicles**.
- **Improves air quality and urban health:** Increased **EV usage and renewable energy adoption** reduce reliance on **polluting fossil fuels**, leading to **cleaner air and improved public health**.
- **Integrates with other smart city solutions:** The platform can be linked with **IoT-enabled smart grids, AI-based energy forecasting, and 5G networks** for optimal urban energy management.

Goal 13: Climate Action

Take urgent action to combat climate change and its impacts.

Justification:

The blockchain-based energy trading platform plays a key role in **mitigating climate change** by promoting **low-carbon energy solutions**. This system contributes to **Goal 13** in multiple ways:[8]

- **Reduces greenhouse gas emissions:** Encouraging **renewable energy usage** minimizes the dependence on **coal, oil, and gas-fired power plants**, directly lowering **CO_2 emissions**.[8]
- **Encourages carbon-neutral mobility: EVs powered by clean energy** reduce the carbon footprint of **transportation**, one of the largest contributors to global emissions.[7]
- **Enables transparent carbon credit tracking:** The blockchain ledger can be used to **record and verify** renewable energy consumption, helping organizations meet **sustainability targets** and comply with **carbon credit regulations**.[7]
- **Supports climate-resilient infrastructure:** By decentralizing energy distribution, cities **reduce their vulnerability** to **climate-related power disruptions** caused by storms, heatwaves, or other extreme weather events.[7]
- **Promotes responsible energy consumption: Smart contracts enforce optimal energy usage**, preventing energy waste and enhancing overall energy efficiency.[8]

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11. APPENDIX A

The following QR code redirects to a drive folder that contains the documentation, abstract and a Video presentation of this use case

Or use

(https://drive.google.com/drive/folders/1ftvyuON8c4FJutsQHgRu2gIgEHbVXNr2?usp=sharing)