Blockchain-Enabled Implementation of Supply–Demand Matching for Local Electricity Markets

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Abstract. This work introduces a permissioned blockchain architecture to support a Supply–Demand Matching strategy for local peer-to-peer (P2P) electricity markets. The strategy computes time-varying bilateral coefficients that favour trades between households whose surplus and deficit profiles are temporally aligned. Market clearing is formulated as a decentralised optimisation problem and solved using the Alternating Direction Method of Multipliers (ADMM). The proposed blockchain layer records bilateral proposals at each iteration, preserves an immutable audit trail, and enables verifiable agreement on final trades, while keeping raw generation and load data off-chain to protect household privacy. The design includes a chain-code API, a lightweight on-chain data model for trading proposals and iteration summaries, and endorsement and identity policies tailored to residential deployments. The approach is evaluated on the case-study platform, with blockchain performance assessed by chain-code execution time. Results show that a permissioned ledger can effectively coordinate the Supply–Demand Matching mechanism with acceptable latency while providing auditability, tamper resistance, and exposing only aggregated, non-sensitive information on-chain.

Keywords: Peer-to-Peer electricity markets · Permissioned Blockchain · ADMM-based Distributed Optimization

1 Introduction

The growing penetration of renewable distributed energy resources (DERs), together with the extensive deployment of smart meters, home energy management systems, and behind-the-meter storage, is reshaping the operation of low-voltage networks. In this context, local peer-to-peer (P2P) electricity markets

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have emerged as a promising mechanism for enabling prosumers and consumers to trade electricity directly within a community. Such schemes can increase self-consumption, enhance local flexibility, and keep economic value within the local area [8–10,14]. Compared with conventional centralised market structures, P2P approaches are better suited to explore spatial and temporal complementarities among households and can also support a more refined coordination between generation surpluses and consumption deficits [9,10,25]. Nevertheless, their practical deployment still faces major challenges related to transaction trust, privacy preservation, settlement integrity, and scalable coordination across multiple participants [9,25,28].

Blockchain technology has been widely investigated as a suitable infrastructure for local electricity trading because it can provide a tamper-resistant ledger, transparent transaction recording, and automated execution through smart contracts [13,15,20,27]. In particular, and according with [13,15,20], permissioned blockchain architectures are especially attractive for residential energy communities when compared with public blockchains, considering that they enable controlled participation, identity management, and lower computational overload, while preserving auditability and distributed trust. Most existing blockchain-based electricity trading approaches focus primarily on transaction logging, payment settlement, or auction execution, and often treat the blockchain layer as a stand-alone coordination mechanism rather than as an integral component of the market-clearing process [13,15,20,27]. From this view, connecting blockchain-based coordination with optimisation-driven matching mechanisms remains an open challenge. As a result, the challenge of coupling blockchain-based coordination with optimisation-based matching mechanisms remains insufficiently addressed.

From another perspective, market-clearing formulations based on distributed optimisation have shown strong potential for local electricity trading, especially when the objective is to match supply and demand while accounting for temporal complementarity. Among these methods, the Alternating Direction Method of Multipliers (ADMM) has become a widely adopted solution strategy because, as stated in [26], it decomposes the global clearing problem into local sub-problems that can be solved in parallel, enforcing consensus through iterative coordination. This makes ADMM well-suited to P2P electricity markets, where each household retains autonomy over local decisions but still participates in a globally consistent clearing process [26,28]. However, when such distributed mechanisms are implemented in practice, the coordination layer must also guarantee traceability of proposals, verifiable agreement, and protection of sensitive data [9,13,20].

The present study addresses these challenges by proposing a permissioned blockchain architecture to implement a Supply–Demand Matching strategy for local P2P electricity markets. The proposed strategy constructs time-varying bilateral coefficients that prioritise energy trades between households whose surplus and deficit profiles are temporally aligned, thereby strengthening local matching quality and improving the effectiveness of decentralised market clearing. The clearing problem is solved using ADMM, while the blockchain layer

records, in a lightweight on-chain format, per-iteration bilateral proposals, consensus-related summaries, and final trade outcomes. Raw consumption and generation data remain off-chain, limiting exposure of sensitive information and preserving household privacy. The proposed architecture further defines a chaincode interface, on-ledger data structures, and identity and endorsement policies suitable for residential deployments [13,15,26,27].

The main contributions of this work are threefold. First, it introduces a blockchain-enabled coordination architecture tailored to a decentralised Supply–Demand Matching mechanism for local energy communities [9,10,20]. Second, it demonstrates how a permissioned ledger can support iterative market clearing with immutable auditability and verifiable settlement while minimising on-chain data exposure [13,15,20,27]. Third, it evaluates the feasibility of the proposed design through a case study and blockchain execution analysis, showing that the architecture can support decentralised coordination with acceptable latency and operational transparency [13,20,27].

The remainder of this paper is organised as follows. Section 2 reviews the relevant literature on local electricity markets and peer-to-peer electricity trading. Section 3 presents the case study and describes the residential energy community under consideration. Section 4 details the proposed methodology, including the market-clearing and trading mechanisms. Section 5 introduces the blockchain implementation architecture and technological infrastructure. Section 6 presents the results and feasibility analysis. Finally, Sect. 7 concludes the paper and outlines future research directions.

2 State of the Art

The transition toward decarbonised and decentralised electricity generation systems has accelerated the deployment of distributed renewable generation, smart metering infrastructures, home energy management systems, and behind-the-meter storage. These developments are reshaping the operating model of low-voltage distribution networks, which are increasingly evolving from passive infrastructures into active environments populated by heterogeneous prosumers, flexible loads, and opportunities for local balancing. Within this setting, local peer-to-peer (P2P) electricity markets have gained attention as a promising way to enable direct electricity exchanges among community members, so that local surplus generation can be matched with nearby demand. Such arrangements can enhance self-consumption, lessen dependence on the upstream grid, improve the use of local flexibility, and keep economic benefits within the community [3,16,18,19].

The literature on local electricity markets also reveals a gradual shift from conceptual market formulations towards frameworks that are much more focused on real-world implementation. Earlier studies, such as [3,16–18], were mainly concerned with theoretical market structures, prosumer participation incentives, and bilateral trading mechanisms. However, recent works have examined practical solutions for settlement, transaction verification, and market coordination.

A consistent finding is that local electricity markets are most effective when they explicitly exploit both spatial and temporal complementarities among participants. In practice, trading is not only about balancing total energy volumes, but also about aligning generation and consumption patterns over time. This is especially relevant in residential contexts, where the temporal mismatch between photovoltaic surplus and household demand strongly influences the local exchange.

A second and growingly important line of research relates to the use of blockchain as a trust and coordination layer for these markets. Blockchain has been widely proposed because it provides a tamper-resistant ledger, distributed transaction recording, and programmable execution through smart contracts. In local electricity trading, these characteristics are attractive because they preserve the traceability of offers, bids, and settled trades while reducing reliance on a central, trusted intermediary. Permissioned blockchain architectures are particularly well-suited to residential energy communities, as they support controlled membership, identity management, and lower computational overhead than public blockchain systems, while still ensuring auditability and resistance to unauthorised data manipulation [3,12,19,21].

Despite this promise, most blockchain-based local electricity market solutions still focus on transaction logging, settlement automation, or auction execution, rather than on a close integration with the market-clearing logic itself. In many proposals, blockchain functions primarily as a record-keeping layer, while the actual matching of supply and demand is performed by an external optimisation engine. Although this separation is understandable from a computational perspective, it also highlights an important gap in the literature: the coordination mechanism and the market-clearing algorithm are often developed independently, even though they are functionally interdependent in real deployments. Consequently, there remains limited work on architectures that combine blockchain-based verifiability with optimisation-based clearing within a unified design [5,19,21].

In parallel with blockchain research, distributed optimisation has become a central tool for solving local market-clearing problems in decentralised energy systems. Among the available methods, the Alternating Direction Method of Multipliers (ADMM) has received significant attention due to its ability to decompose a global optimisation problem into smaller local sub-problems that can be solved in parallel, while enforcing consensus through iterative coordination. This makes ADMM particularly attractive for P2P electricity markets, where each household or agent can solve its own local problem using private information, and only aggregated or consensus-related variables need to be exchanged across iterations. The method therefore aligns well with the privacy and autonomy requirements of decentralised energy communities [1,11,29].

In the context of electricity trading, ADMM-based formulations have been used to coordinate dispatch decisions, match supply and demand, and enforce network or market constraints in a distributed way. However, while these approaches are algorithmically elegant, they do not by themselves solve the

issues of trust, traceability, and settlement integrity. In practice, an ADMM-driven market-clearing process still requires a reliable coordination layer capable of storing iteration-level proposals, identifying the evolution of consensus, and producing an auditable record of the final trade outcome. This is precisely where blockchain can complement distributed optimisation: ADMM can handle the numerical market clearing, while blockchain can provide the immutable coordination and verification infrastructure needed for deployment in real communities [11,23,29].

Another important aspect addressed in the literature is privacy. Local electricity markets require the exchange of information that may reveal sensitive behavioural patterns, such as occupancy, appliance use, or regularity in lifestyle. Since raw generation and consumption profiles are highly sensitive, many implementations avoid placing them directly on-chain and instead rely on aggregated, hashed, or off-chain representations. This design choice is especially relevant in residential environments, where confidence in the platform depends not only on economic efficiency but also on data minimisation and alignment with privacy expectations. Accordingly, recent blockchain-based market designs increasingly adopt lightweight on-chain structures, off-chain data storage, and selective disclosure mechanisms to limit exposure of household-level information [7,12,19,22].

Another major constraint relates to scalability. Local electricity markets may require repeated bargaining or iterative clearing among participants, which can create significant communication and computational overload. In blockchain-based systems, this challenge is intensified by ledger update latency, endorsement procedures, and consensus costs. For this reason, recent studies are proposing permissioned architectures, hybrid off-chain/on-chain workflows, and compact transaction payloads to preserve operational feasibility [7,19]. On the whole, the literature suggests that blockchain is most effective when used as a lightweight coordination and verification layer, rather than as the component that performs all optimisation directly on-chain [6,18].

From the above, and synthesising, blockchain-enabled local electricity markets are progressing towards more practical and deployable architectures, although several open issues remain, as follows: the integration of market clearing with blockchain-based coordination, the design of efficient permissioned infrastructures, privacy preservation without loss of auditability, and scalable algorithms that can operate under residential communication and computational constraints. Distributed optimisation methods such as ADMM provide a strong mathematical basis for decentralised matching, while blockchain contributes trust, immutability, and verifiable settlement [6,16]. The combination of these two paradigms appears particularly promising for local P2P electricity markets, especially when the trading mechanism is designed to exploit temporal complementarity between local surplus and deficit profiles.

3 Case Study

This chapter introduces the case study adopted in this work, providing a platform to evaluate the performance of the previously introduced decentralised P2P

trading strategy. The case study consists of a synthetic residential community of ten households, including consumers and prosumers, but without storage systems. The deliberate exclusion of energy storage reflects current market realities, where installed residential battery systems remain comparatively costly and their adoption is limited, so modelling without storage better represents the present-day majority of households while remaining readily extensible for future studies. The analysis focuses on quantifying P2P trade volumes, grid import/export, self-consumption, and procurement cost. This scenario enables assessment of both economic efficiency and operational impacts on the local distribution network, which will be presented in the following chapters.

3.1 Synthetic Dataset Description

The case study is based on a real dataset from a single residential household, spanning nearly five years (2014–2020) [24]. The full dataset contains 201,604 observations recorded at 15-minute intervals. For this study, synthetic profiles for ten households are generated by scaling the original household data using predefined factors. This approach introduces diversity across households while preserving the temporal structure, statistical variability, and seasonal characteristics of the source data, thereby providing realistic representations of both consumption and generation profiles and supporting community-level analysis. A representative day, 19 August 2020, was selected to maintain computational tractability while preserving realistic intra-day dynamics. With its 15-minute temporal resolution, this dataset offers detailed information on electricity consumption and distributed renewable generation, forming a solid basis for modelling dynamic household energy behaviour, with particular emphasis on three main variables: electricity consumption, residential wind generation, and residential solar photovoltaic (PV) generation.

3.2 Grid Topology

The community is composed of ten households, connected to the low-voltage grid in a radial configuration via a point of common coupling (PCC) on the low-voltage side of a distribution transformer in the utility grid. Among the ten households, five are modelled as prosumers, equipped with solar photovoltaic panels and small wind turbines, while the remaining five operate solely as consumers. Figure 1 depicts the prosumers with solar panels, representing households with photovoltaic generation, while the wind turbine icon denotes households with wind energy conversion systems. The blue lines indicate the traditional grid connections linking all participants to the transformer and subsequently to the utility electricity grid.

3.3 Preprocessing and Operational Assumptions

All time series were analysed at their native 15-min resolution in order to capture short-term fluctuations in both demand and generation. The evaluation considers

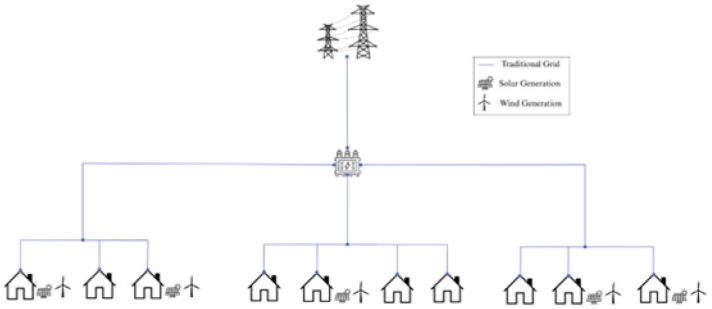

Fig. 1. Topology and distribution of households.

a single daily horizon. Prior to the analysis, the dataset was inspected for missing or corrupted entries; missing values were handled so as to preserve data integrity, and all series were retained at the original 15-min granularity to ensure temporal alignment between load and generation profiles. These preprocessing steps ensure that subsequent comparisons across households and scenarios are conducted on a consistent and reliable basis.

For simplicity, the case study uses fixed grid purchasing and selling prices rather than dynamic tariffs. The grid purchasing price was set at €0.18/kWh, while the grid selling price was defined as 20% of the purchasing price, corresponding to €0.036/kWh. This simplification serves two purposes. First, it removes the confounding effects of hourly or seasonal price variability, allowing the analysis to isolate the impact of P2P trading strategies on grid interaction and household costs. Second, the selected values are representative of realistic retail and feed-in tariff magnitudes, while the asymmetric relationship between purchasing and selling prices reflects common market conditions in which exported energy is remunerated at a substantially lower rate than imported energy. Consequently, the use of fixed prices facilitates a transparent evaluation of the mechanisms under study and highlights the distributional effects of P2P energy exchanges without adding the complexity of tariff design.

4 Methodology

This chapter describes, in a reproducible manner, the methodology adopted in this study. It integrates the mathematical modelling of the peer-to-peer (P2P) electricity trading problem, the bilateral matching strategies under analysis, the decentralised formulation solved via an optimisation algorithm, the Alternating Direction Method of Multipliers (ADMM), implementation details, and evaluation metrics.

4.1 Mathematical Model of the P2P Problem

This study considers a residential energy community composed of a set of nodes N, indexed by $i = 0, 1, ..., N$. Although a node can represent a household or a

building within the distribution network, this study focuses solely on households. All households are connected to the main grid and can inject/withdraw power through that connection. Their electricity demand is characterised by a load profile. The baseload demand of household i at timestep t is denoted as $P^l_{i,t}$, and is assumed to be deterministic. The power withdrawn from and injected into the grid is denoted as $p^g_{i,t}$ and is associated with corresponding tariffs for energy purchased from and sold back to the grid. These tariffs are fixed on timestep t for all households in the community. In P2P trading, each household can exchange a net amount of power with other households in the network. The net power exchange is denoted by $p_{i,t}$. A positive value indicates surplus power, i.e., power available for export, while a negative value represents residual demand, i.e., power that must be imported.

4.2 Mathematical Formulation of ADMM for Bilateral Trading

In this study, a P2P market model is employed as a particular instance of the unified formulation presented in [4]. This model assigns a unique bilateral trading coefficient to each trade, ensuring that every transaction is weighted by its specific characteristics. It is assumed that all households on the network act as rational, non-strategic market participants. The primary objective is to minimise the overall costs for all households (denoted by N) over a given time horizon T. These costs encompass both the expenses (or revenues) associated with withdrawing power from or injecting power into the grid, as well as those arising from bilateral electricity trading among households.

Each household independently optimises its own sub-problem, and the individual solutions are then reconciled to satisfy the global coupling constraints. After solving its local sub-problem, each household produces its own optimal local trading quantity schedule. Consensus between households is achieved when both parties propose equal values for their bilateral trades, a condition ensured by the ADMM algorithm at convergence, which is guaranteed under convexity assumptions of the optimisation problem [4]. Importantly, the decentralised setup preserves agent privacy; locally measured series (generation, demand) remain private and are not shared across the network.

4.3 Bilateral Trading Strategy

To aggregate all bilateral trading coefficient values between any household and its peers in the network, a matrix of bilateral trading coefficients, Γ, should be defined. This matrix is used to indicate preferred trading partners and enable product differentiation. According to the formulation, lower values of $y_{ij,t}$, indicate a higher preference for trading between households i and j. In this approach, a Supply-Demand Matching strategy for defining the matrix Γ is proposed, being inspired by the work presented in [2]. In this study, the strategy is implemented as a time-varying matrix Γ to capture temporal and economic complementarity between households. A time-varying approach produces dynamic matching

patterns and requires recomputation and coordination at each scheduling interval, potentially affecting traded volumes, sensitivity to forecast errors, and the computational/communication burden of ADMM coordination.

In this strategy, the bilateral trading coefficients, $y_{ij,t}$, are determined by matching households' power demand and surplus power generation [2]. It privileges temporal and economic complementarity between households. Households are preferentially paired when one's surplus production temporally matches another's demand. The principal objective is to maximise local utilisation of renewable generation and minimise aggregate imports from the main grid by promoting trades that increase system-level self-consumption. Analysis under this strategy, therefore, focuses on traded volumes aligned with generation profiles, reductions in grid dependence, sensitivity to forecasting errors, and distributional outcomes that arise from temporal complementarity. To implement these assumptions in the bilateral trading coefficients, several steps are followed:

1. The expected net budget matrix P^{net} is determined, containing the net power of all households across all time steps.
2. From this matrix, two additional matrices, P^{buy} and P^{sell}, are defined, representing the amount of net power each household intends to buy or sell at each time step.
3. Each row of P^{buy} and P^{sell} is normalised with respect to the maximum deficit and surplus values in that row.
   Normalisation ensures that preference values are comparable across households with different scales, bounds the bilateral coefficients within a predefined range (i.e., $[0, \chi]$), and preserves the temporal patterns of surplus and deficit while converting absolute energy quantities into relative trading preferences.
4. Subsequently, the matrices $\Gamma^{(b,\text{rel})}$ and $\Gamma^{(s,\text{rel})}$ are constructed.

The matrices $\Gamma^{(b,\text{rel})}$ and $\Gamma^{(s,\text{rel})}$ represent the relative willingness of households to buy or sell energy, expressed through trading coefficients. The maximum baseline value for the bilateral trading coefficients is defined by the parameter χ. Using $\Gamma^{(b,\text{rel})}$ and $\Gamma^{(s,\text{rel})}$, the final three-dimensional matrix of bilateral trading coefficients, Γ, is constructed.

Functionally, χ, acts as an upper bound that prevents bilateral coefficients from attaining excessively large magnitudes, which could otherwise lead to unrealistic P2P prices or destabilise exchange allocations. The value of χ is determined through an empirical calibration procedure to tune the strategy for the case study under analysis. This process seeks a practical trade-off between matching efficiency and economic stability.

When $y_{i,j,t} = 0$, households i and j are considered highly unlikely to engage in trading at time step t.

5 Blockchain Implementation Architecture and Technological Infrastructure

To validate the proposed strategy, a highly decoupled, multi-tier blockchain architecture was implemented. The environment was constructed using Hyperledger Fabric v2.5 and its permissioned network capabilities, ensuring privacy, immutability, and deterministic consensus.

5.1 Blockchain Network Topology

The core blockchain consortium, defined as the "SmartLEM Channel", consists of three distinct organisations representing the key stakeholders in a localised energy grid to meet the infrastructure requirements needed for setting the blockchain nodes:

- **Organisation 1 (Aggregator):** responsible for orchestrating the market, aggregating prosumers data, and initiating the settlement of energy transactions.
- **Organisation 2 (Auditor):** acts as an impartial regulatory observer, ensuring that community market guidelines are followed.
- **Organisation 3 (DSO – Distribution System Operator):** monitors the ledger to assess grid impact and physical power flows.

To ensure fault tolerance and high availability, each organisation operates two peer nodes (e.g., peer0 as the anchor peer and peer1 for redundancy), resulting in a 6-peer network. The ordering service utilises a Raft consensus mechanism (etcdraft) to provide crash fault tolerance and deterministic block creation. Figure 2 includes an overview illustration of the blockchain architecture, as well as the operations sequence for each payload requested by the experiment application.

The smart contract (chain-code), implemented in Node.js, acts as the gatekeeper to the ledger's LevelDB state database. It exposes critical market functions, primarily RegisterDeal, which standardises the asset data structure (Deal ID, Buyer, Seller, Amount, and Price). The channel enforces a majority endorsement policy, cryptographically mandating that at least two of the three organisations execute and agree on the transaction outcome before it can be committed to the ledger.

5.2 Experimental Setup and Methodology

To facilitate this experiment, the architecture was divided into two primary interacting components: a market experiment application and a blockchain integration gateway. The experiment application acts as the Aggregator's market-clearing algorithm. Once local energy supply and demand are matched, this engine packages the resulting trades and securely transmits them to the integration gateway. The gateway serves as middleware that abstracts the complexities of the underlying blockchain network. It automatically routes the proposed

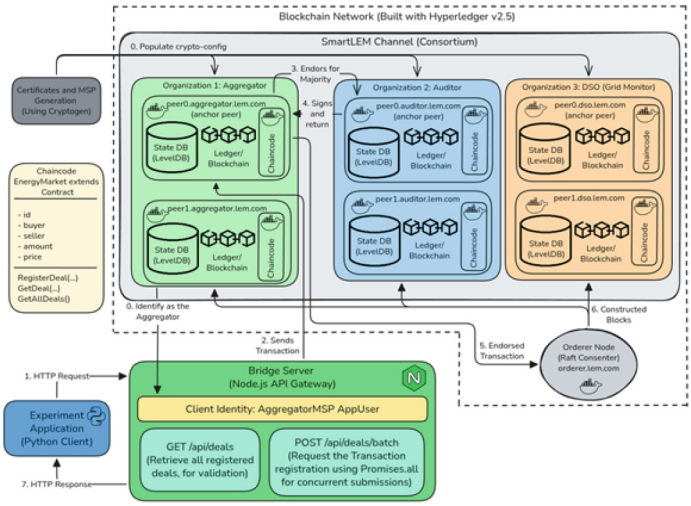

Fig. 2. Blockchain Architecture within the Experiment application and Bridge Interfaces.

energy transactions to the necessary stakeholder nodes, managing the communication required to achieve the majority consensus. This ensures that trades are only permanently registered on the distributed ledger once the required regulatory and operational agreements are met.

A core requirement of real-world local electricity markets is the ability to settle secure trades within rigorous time windows; for this experiment, a standard 15-minute market interval was utilised. The primary objective was to evaluate the blockchain system's throughput (processing capacity) and latency (processing delay) to confirm its operational feasibility for these temporal constraints. To simulate a realistic market-clearing event, the experiment aggregator application was configured to generate batches of electricity transactions. To efficiently manage this influx, the integration gateway was optimised for concurrent processing. The system enables the distributed network to validate, order, and commit the entire batch of transactions in parallel, rather than evaluating trades sequentially. This concurrent architecture maximises the network's operational speed while ensuring it can handle the dense transaction spikes typical of localised electricity market settlements.

This aggregated data was stored and is illustrated in Fig. 3. The primary metrics recorded during the experiment were:

1. Total Round-Trip Processing Time: The elapsed time (in seconds) from the moment the Python client dispatches the batch until the blockchain network fully commits the blocks and returns a success response.
2. Transactions Per Second (TPS): The network's throughput efficiency during the batch processing window.

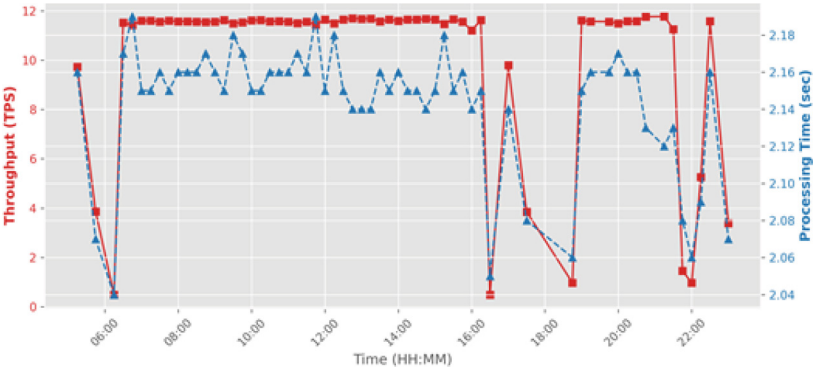

Fig. 3. Transactions per second and processing time benchmarks.

6 Results and Feasibility Analysis

The experimental simulation spanned a full 24-hour cycle, in order to capture the natural fluctuations of solar-based electricity generation. As shown in Table 1, the total amount of energy imported from the main grid, injected into it, and traded peer-to-peer (P2P) on the selected day reveals the balance between centralized supply, local surplus, and internal exchanges. Here, 'Grid import' sums all positive net withdrawals, 'Grid export' all net injections, and 'Total P2P traded energy' aggregates bilateral transfers within the community.

Table 1. Energy exchange metrics for different scenarios

Scenario	Grid Import (kWh)	Grid Export (kWh)	P2P Volume (kWh)
Baseline	56.85	27.32	–
Supply Demand Matching	47.50	17.95	9.37

As evidenced by Table 2, community self-consumption of locally generated renewables increases once P2P is used, i.e., the portion retained for local use ('Self-Consumed') grows substantially, underlining the efficiency of internal trading.

As shown in Table 3, the total procurement cost decreases from 9.25 euros in the baseline case to 7.91 euros in the supply-demand matching. This reduction is mainly explained by the traded energy volume in Supply–Demand Matching, which shifts demand from grid purchases to peer-to-peer exchanges at lower effective prices. Therefore, Supply–Demand Matching provides the best performance in terms of reduced grid-imports, enhanced self-consumption, and total cost savings, demonstrating the economic viability of the proposed decentralized market.

Table 2. Self-consumption metrics across scenarios

Scenario	Total Generation (kWh)	Self-Consumed (kWh)	Self-Consumption Rate (%)
Baseline	70.29	42.97	61.14
Supply Demand Matching	70.29	52.34	74.46

Table 3. Total cost comparison across scenarios

House	Supply–Demand Matching (euro)	Baseline (euro)
1	−0.05	0.11
2	−0.05	0.08
3	1.67	1.82
4	1.59	1.73
5	1.74	1.91
6	0.06	0.17
7	1.44	1.55
8	0.07	0.19
9	1.49	1.60
10	−0.05	0.09
Total	7.91	9.25

As shown in Fig. 4, the volume of traded electricity and total trade value (in euros) rose significantly during daylight hours (from 08:00 to 14:00), correlating with maximum photovoltaic generation. The average price remained highly stable at approximately 0.12 euros/kWh during this operational window.

The blockchain infrastructure had a robust performance when subjected to the batch transaction loads. During the peak trading periods, the network maintained a consistent throughput of nearly 12 TPS. The total processing time for these concurrent batches remained highly stable, ranging from 2.14 to 2.18 s. While throughput naturally dropped during off-peak night hours due to smaller batch sizes, the processing latency remained strictly bounded, never exceeding 2.2 s.

These results strongly validate the feasibility of the proposed architecture. In a real-world scenario, the market-clearing mechanism requires all local trades to be settled and registered within a 15-min (900-s) window. While this simulation was conducted in a localised Docker environment, meaning network propagation latency between geographically distributed nodes was minimised, the baseline processing time of $\sim$ 2.18 s leaves an exceptional operational margin. Even if physical deployment across distributed municipal and DSO servers introduces significant network latency, scaling the processing time by a factor of 10 or even 50 would still result in block commitments well under a single minute. Therefore,

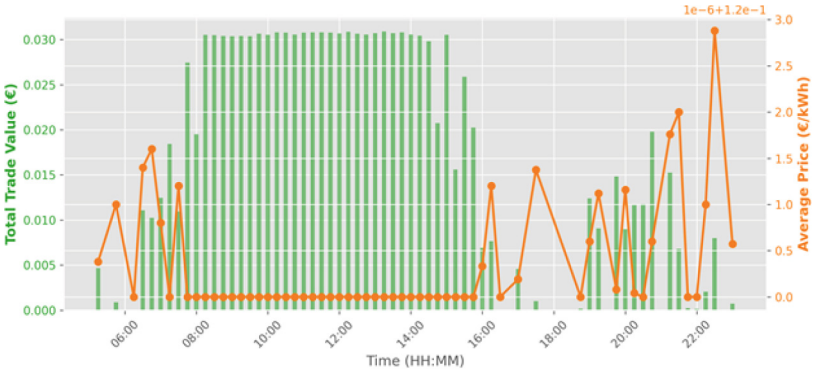

Fig. 4. Total Traded Value and Average Price during the day.

the Hyperledger Fabric infrastructure easily scales to meet the rigid temporal demands of a 15-min localised electricity market.

7 Conclusion and Future Work

This work presents a permissioned blockchain architecture for implementing a decentralized Supply-Demand Matching strategy in local peer-to-peer (P2P) electricity markets. The proposed framework combines a distributed market-clearing mechanism with a Hyperledger Fabric-based infrastructure designed to ensure privacy, immutability, and deterministic consensus. By separating the application, middleware, and ledger layers, the proposed architecture enables secure trade registration while preserving a clear boundary between sensitive household information and on-chain market records.

The results obtained for a single day indicate that the matching strategy is effective in aligning local surplus with local demand, thereby increasing the use of photovoltaic generation within the community, reducing reliance on the upstream grid, and improving self-consumption. The observed daytime trading patterns show that exchanges are concentrated during periods of high renewable production, which enhances both technical and economic performance. Moreover, the blockchain infrastructure proved capable of handling the transaction workload generated by the market-clearing process, maintaining stable processing times and operational feasibility within the timing requirements of local electricity markets.

Overall, the findings demonstrate that blockchain and distributed optimisation can be combined effectively to support local energy communities through secure, transparent, and operationally viable P2P trading. The proposed architecture therefore represents a practical step toward deployable decentralised electricity market platforms.

Future work should focus on extending the framework in both in terms of methodology and real-world deployment. On the market side, further work

will explore alternative matching strategies and adaptive pricing mechanisms to improve how trades are allocated under different demand and generation profiles. It is also important to test the approach over longer horizons and in more diverse operating scenarios, such as seasonal ups and downs and also larger communities.

From the blockchain perspective, scalability experiments involving more participants and heavier transaction loads are needed to define the limits of the proposed architecture under more demanding conditions. In addition, privacy-enhancing techniques such as selective disclosure, off-chain storage, and cryptographic access control should be explored to reduce exposure of sensitive data while preserving auditability.

Finally, it's worth examining how this architecture might work alongside distribution system operators and external market platforms. That kind of interoperability would help the system evolve from a local proof of concept into a broader, real-world solution for community electricity trading.

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