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A DECENTRALIZED ENERGY TRADING PLATFORM FOR DISTRIBUTION SYSTEM OPERATORS

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A B S T R A C T

The transitioning electricity market is characterized by increased use of renewable energy sources in the power system. There is a growing need to accommodate decentralised energy transactions through distributed energy resources (DERs). This paper presents solutions to identified issues in the current energy market and offers a detailed description of the methodologies, technologies, and functioning of the decentralised energy trading platform. We demonstrate a distribution system operator (DSO)-to-consumer flexibility market platform deploying blockchain-based smart contracts for local grid congestion and voltage management. The paper additionally evaluates the DeEnTP platform against the Strategic Alignment Model (SAM) criteria and employs a Non-Functional Requirements (NFR) decomposition tree to assess goal satisfaction across strategic, tactical, and operational decision levels. The use case illustrates a disruptive approach to energy trading that takes advantage of blockchain's inherent strengths in decentralisation, transparency, and security.

1. INTRODUCTION

Blockchain technology has emerged as a promising solution to evolving energy landscapes, and distribution system operators (DSOs) are facing increasingly challenging challenges from integrating and widely electrifying renewable energy sources (RES). The technology's inherent characteristics (decentralized trust architecture, distributed validation mechanisms, and the invariability of transaction records) offer critical advantages for managing flexible resources in distribution networks without centralized intermediaries (Musleh et al., 2019). These characteristics align with the path toward decentralization of the energy sector and address key concerns relating to data security, transaction transparency, and operational resistance to potential system failures and cyber threats (Djokic & Zahar Djordjevic, 2026). In flexibility markets, blockchain provides a robust framework for secure, transparent, and efficient coordination between DSOs, flexibility service providers (FSPs), and prosumers (Gazioğlu et al., 2023). The technology's ability to preserve transaction privacy while maintaining validation capability creates new opportunities for market participation and value exchange in distributed energy systems (Kirli et al., 2022). Furthermore, blockchain's immutable ledger ensures regulatory compliance and auditability, critical factors for establishing trust among participants with potentially competing interests in emerging flexibility markets (Andoni et al., 2019; Brilliantova & Thurner, 2019).

The decentralized energy trading platform for Distribution System Operators (DSOs) that is presented in this paper allows prosumers and DSOs to exchange flexibility services. The goal is to find strategies to

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support DSOs in managing energy flows on the network with greater flexibility and direct involvement. On the same platform, it simplifies the requirements of DSOs and prosumers. Blockchain-based distributed ledger technology (DLT) (Adhami et al, 2018; Ali et al., 2022; Bambara et al., 2018; Berntzen et al., 2021; Vemuri, 2018) will be used to create efficient signaling systems and proper coordination. We want to increase efficiency in several areas of the trading process, such as asset registration, metering data validation, and settling related financial procedures that might be handled with DLT and smart contracts.

The paper uses a strategic modeling framework (Yu, 1997, 2011) to model the trading platform. To do this, we suggest an organization setting for creating a blockchain-based energy trading platform. In this approach, the organizational setting and management structures are represented using strategic modeling tools. This approach is implemented inside certain stages to align the processes in the blockchain-based energy trading platform development. Additionally, this paper evaluates the platform against the Strategic Alignment Model (Henderson & Venkatraman, 1999) and a Non-Functional Requirements decomposition tree (Chung et al., 2000). This dual evaluation bridges organisational intent with technically tractable quality goals across three decision levels.

The structure of this paper is as follows. Section 2 introduces the research approach and methodology. Section 3 illustrates the development model for the blockchain-based energy trading systems named DeEnTP. A use case is shown in Section 4, while Section 5 evaluates the platform against the SAM and NFR frameworks. Section 6 discusses the platform's implications, and Section 7 concludes.

2. RESEARCH APPROACH AND METHODOLOGY

2.1 Research Question

This section provides sufficient detail about the study question to maintain focus on our investigation. After the preliminary investigation, we will conduct the following research inquiry based on the research context and purpose: ***How can organisational modelling for a blockchain-based energy trading platform be represented, and how does the resulting system satisfy non-functional requirements across strategic, tactical, and operational levels?***

By offering organizational modelling, project managers can guide development processes that meet stakeholder requirements and expectations for IT/Business alignment. The second dimension, goal satisfaction across levels, is to accommodate the SAM and NFR frameworks introduced in this paper. The next section illustrates the steps involved in conducting research.

2.2 Research Approach and Method

This section describes the research approach and builds up and validates the entire systems development process in terms of blockchain technology and software engineering disciplines. By offering a management layer for the blockchain-based energy trading system that is integrated with the current software engineering layers, the proposed model essentially expands the agile paradigm. Following the generic agile development process (Dingsøyr et al., 2012) and the generic DevOps (Ebert et al., 2016; Senapathi et al., 2018), practitioners in this management layer are guided by the organizational setting and management structures, which are expressed through strategic modelling methodologies.

2.3 Design Science

Based on the Design Science Research (DSR) methodology for information systems (Hevner et al., 2004; Peffers et al., 2007), the research process outlined in this paper begins with an explanation of the solution's goals: a suitable method for creating a decentralized energy trading platform for DSOs that are in line with stakeholders' long-term strategy. Table 1 displayed the steps of the acquisition architecture that we applied in our study.

Table 1. DSR Methodology for Information Systems: Acquisition Architecture's Steps.

Steps	Description
1. Problem identification and motivation	The core problem is enabling DSOs to manage energy flows on the network with greater flexibility and direct involvement, pursuing trading contracts that address concerns of control, trust, and cost (Section 1).
2. Definition of the objectives for a solution	The objectives are to explore how a blockchain-based energy trading system fits with an organisation's long-term plan and to provide the organisational setting for its development.
3. Design and development	Primarily focused on the organisational context of blockchain-based energy trading systems, characterising the system as an organisation composed of multiple dependent stakeholders using i* diagrams (Dalpiaz et al., 2016) at various stages (Section 2).
4. Demonstration	Illustrates how effectively operational energy trading processes may be aided by the blockchain-based system. A thorough use case is provided in Section 4.
5. Evaluation	The organisational structure for the blockchain-based energy trading system is evaluated in light of the long-term organisational strategy, the SAM criteria, and the NFR decomposition tree (Section 5).
6. Communication	Fulfilled through the present paper.

3. MODEL

The generic model called DeEnTP for describing the blockchain-based energy trading platform is illustrated in this section. We depict the organizational setting for the creation of the systems within the framework of agile modelling methodologies in this model. Additionally, it provides an overview of the platform from both an organizational modelling and a systems architecture perspective.

The DeEnTP integrated paradigm for the development of blockchain-based energy trading platforms with Agile principles is explained in this section. This paradigm extends the Agile model. This extension aims to make it feasible to design an agile blockchain-based energy trading system that can satisfy stakeholders' demands and expectations. Figure 1 displays the DeEnTP development model. The model has three organizational decision levels (the strategic level, the tactical level, and the operational level). DeEnTP is mostly structured in the same way as a generic Agile approach, with a vertically presented discipline for developing a blockchain-based energy trading platform and a horizontally depicted phase sequence.

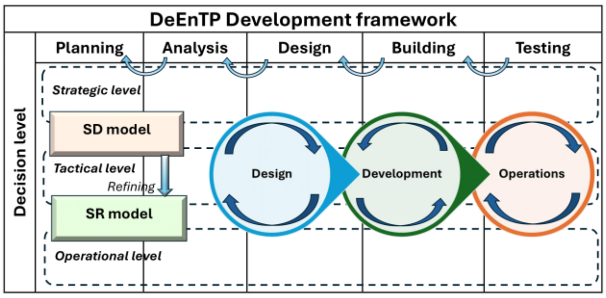

Figure 1. The DeEnTP model.

Figure 2 illustrates the main i* elements and their graphical representation used in the diagrams of the paper.

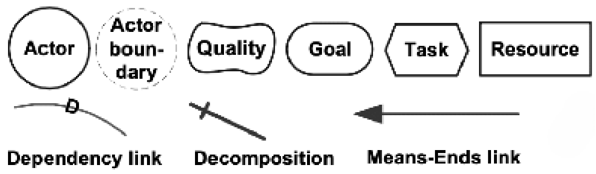

Figure 2. i* Elements and their Graphical Representation.

The long-term development strategy is acknowledged as the DeEnTP's strategic-level goal at the strategic decision level. This level is beneficial to top managers. It examines the environment for managing blockchain-based agile development processes. It enables the parties concerned to reach an agreement on a comprehensive understanding of the dependencies that development methods should support before, during, and after development. The Strategic Dependency (SD) model of the i* modelling framework (Yu et al., 2011; Dalpiaz et al., 2016) for acceptable representations of the tactical-level functional demands of systems development is made up of actors and connections that connect them. Middle managers who monitor attaining the strategic level's goals can benefit from using sophisticated organizational concepts such as tasks, goals, qualities, resources, and the actors who rely on them.

The SD diagram has six main actors (*Buyer*, *Seller*, *Matching Engine*, *Smart Contract*, *Network Exchange*, and *Network Ledger*), resources (*Requests*, *Offers*, *Tokens*, *Transaction*, and *Regulations*), quality (*Ensure continuous transactions)*, and task (*Perform contracts*). This also illustrates the dependencies between actors.

In the SD diagram, the *Matching Engine* depends on the *Buyer* and the *Seller* to ensure the offers data and the requests data are secured. The *Smart Contract* depends on the *Matching Engine* to ensure the regulations are secured and continuous transaction quality is achieved based on performing contracts. The *Smart Contract* depends on the *Network Exchange* to ensure the tokens are validated. The *Smart Contract* depends on the *Network Ledger* to ensure the transaction data is recorded. Figure 3 depicts an SD diagram applied at the strategic level as well as at the tactical level of the DeEnTP.

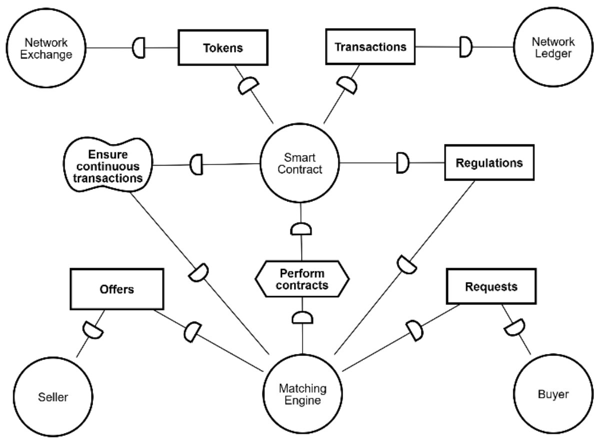

Figure 3. DeEnTP as a strategic dependency diagram.

Figure 4 presents the SR diagram applied at the operational level of the DeEnTP. It is refined from the SD model. Each component required for the operational fulfillment of the systems is carried out by atomic tasks that supervise the completion of the strategically selected sub-processes. This level can benefit front-line managers and operators. The tactical-level models are then converted into several design models, which are then displayed at this level from different perspectives. For sufficient descriptions of the functional and non-functional requirements of the systems, we propose using the i* modelling framework's Strategic Rationale (SR) model (Yu et al., 2011; Dalpiaz et al., 2016).

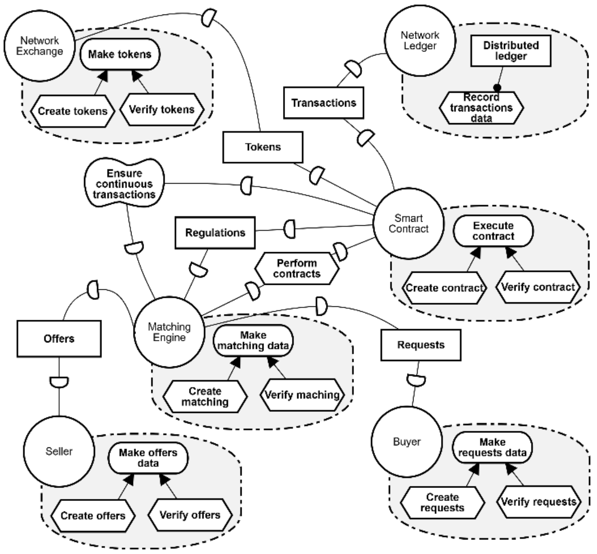

Figure 4. DeEnTP as a strategic rationale diagram.

In the SR diagram, the *Buyer* performs two specific tasks (*Create requests*, and *Verify requests*) to make request data. The Seller performs two specific tasks (*Create offers*, and *Verify offer*) to make offer data. The *Matching Engine* performs two specific tasks *(Create matching*, and *Verify matching*) to make matching data. The *Network Exchange* performs two specific tasks (*Create tokens*, and *Verify tokens*) to make tokens. The *Smart Contract* performs two specific tasks (*Define contract*, and *Verify contract*) to execute contracts. The *Network Ledger* performs one task (*Record transaction data*) on the distributed ledger.

4. USE CASE

In this section, we illustrate the DeEnTP flexibility services for long-term congestion management, which allows more renewable connections without unreasonable DSO network investments. Flexibility services for operational congestion management reduce the impact of outage events or forecast deviations. Flexibility can be used to balance the energy of a balanced group. Energy suppliers generate forecasts each day for the next day (day-ahead forecast). In intraday, a prediction is computed again each hour for the following hours. Flexibility can be used to equilibrate the difference between forecasted and consumed energy and thus to reduce the penalties paid by the energy suppliers. DeEnTP transactions involve two key parties: buyers (DSOs) and sellers (FSPs and/or prosumers). The transaction begins with the purchase of the token, and the participant enters the platform by purchasing a specific trading token. These tokens serve as the main mechanism of energy exchange and create standardized value units for different regions and service providers. Once a token is acquired, the participant can submit purchase requests and offers through the matching engine of the platform using advanced algorithms to optimize energy trading based on supply, demand, and regional characteristics.

Figure 5 illustrates the DeEnTP in use.

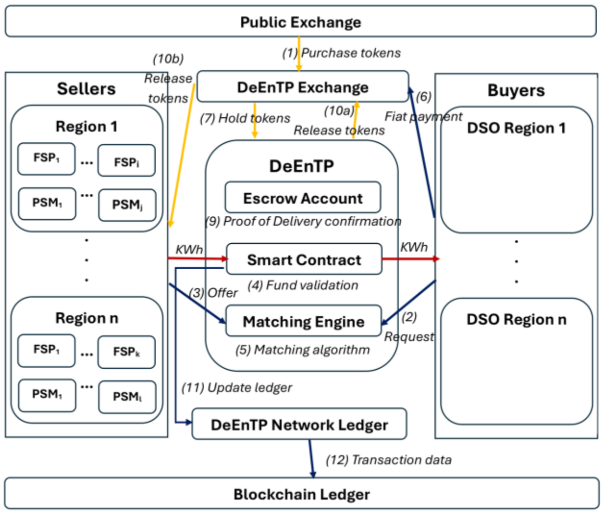

Figure 5. The DeEnTP in use.

The main components of the system are its robust verification and validation mechanisms. When the transaction is initiated, the platform conducts comprehensive fund validation to ensure the financial integrity of the exchange. The matching algorithm then accurately coordinates between sellers (represented by flexible service providers (FSPs), prosumers (PSMs), and buyers (such as distribution system operators (DSOs)) in different regions. This process allows granular energy trade that can consider local energy production, consumption patterns, and regional changes.

The platform includes escrow accounts and smart contract infrastructures that provide additional security and trust. The technology components ensure that tokens are securely held during the transaction process and released only after successful delivery verification. The delivery confirmation proof mechanism adds another important checkpoint, ensuring that the energy is actually transferred as agreed before the transaction is completed. The entire system is based on blockchain technology, with two interconnected ledgers, the DeEnTP network ledger and the blockchain ledger, which maintain transparent and invariable records of all transactions. Every transaction is precisely documented, from the initial token purchase to the final energy supply, establishing a verification trace that enhances accountability and trust. By allowing many players to participate in a secure, decentralized market, this public exchange mechanism significantly opened up the energy trading process.

The platform's design is particularly scalable and flexible, accommodating several regions with different energy production and consumption characteristics. Each region has multiple FSPs and PSMs, allowing a complex and dynamic energy trading environment. The system supports fiat payments in addition to token exchanges and combines traditional financial systems with innovative blockchain technologies.

The use of the platform for flexibility services in congestion management proves its practical utility in allowing additional renewable connections while avoiding excessive DSO network investments. The token-based transaction system, along with rigorous verification and validation processes, enables a dependable marketplace for energy flexibility that is consistent with the sector's evolving philosophy of decentralization and democratization. DeEnTP promotes more efficient energy distribution and the transition to sustainable energy ecosystems by optimizing the matching of energy supply and demand across diverse locations.

5. STRATEGIC ALIGNMENT AND NFR EVALUATION

The foregoing sections have described DeEnTP in terms of its architecture and organisational modelling. This section shifts to an evaluative register, using two established frameworks, the Strategic Alignment Model (Henderson & Venkatraman, 1999) and the Non-Functional Requirements (NFR) decomposition tree (Chung et al., 2000), to assess the extent to which the platform achieves its goals across three levels of organisational decision-making.

5.1 The Strategic Alignment Model (SAM)

Henderson and Venkatraman’s (1999) Strategic Alignment Model identifies two primary domains: Business and IT. Each domain contains an external perspective (competitive positioning) and an internal perspective (organisational capabilities). Four alignment perspectives emerge from the cross-domain relationships: (1) Strategy Execution, where business strategy drives IT infrastructure; (2) Technology Transformation, where IT strategy shapes both business strategy and IS infrastructure; (3) Competitive Potential, where emerging IT capabilities inform business strategy; and (4) Service Level, where IS infrastructure is aligned with internal organisational requirements.

The original SAM was articulated in the context of large enterprise IT alignment, where business strategy and IT strategy were often developed in parallel without explicit integration mechanisms (Luftman et al., 1993). Its subsequent applications in e-commerce, supply chain management, and public-sector IT have consistently shown that alignment, or its absence, is a strong predictor of system adoption and value realisation (Avison et al., 2004; Chan & Reich, 2007). The energy sector presents a particularly acute alignment challenge because the business strategies of DSOs are tightly regulated, while the IT domain is transforming rapidly through distributed ledger, smart metering, and IoT technologies.

5.2 Applying the SAM to DeEnTP

Table 2 maps the four SAM perspectives against the DeEnTP platform, identifying the relevant business strategies, IT strategies, IS infrastructure components, and alignment mechanisms in each case.

Table 2. SAM Analysis of the DeEnTP Platform.

SAM Perspective	Business Strategy (External)	IT Strategy (External)	IS Infrastructure (Internal)	Alignment Mechanism in DeEnTP
Strategy Execution	DSO decarbonisation mandate; integration of renewable DER without grid overinvestment	Permissioned DLT; smart contract automation; token-based settlement	SD model; i* actor dependencies; Network Ledger	Business strategy drives IS infrastructure through i* strategic rationale at operational level.
Technology Transformation	Peer-to-peer energy market democratisation; FSP/prosumer participation at grid edge	Blockchain decentralisation reshapes market structure; eliminates bilateral clearing houses.	Matching Engine; Escrow accounts; Delivery confirmation proofs	Blockchain’s disruptive potential reconfigures how the DSO interacts with the market externally.
Competitive Potential	Positioning DSOs as enablers of local energy markets; reducing reliance on centralised TSO balancing	Token economy for multi-region energy trading; interoperable DLT infrastructure	Agile/DevOps development cycles; iStar 2.0 modelling	Emerging IT capabilities (blockchain scalability) inform new DSO market positions.
Service Level	Regulatory compliance; grid reliability commitments; auditability requirements	Smart contract logic enforces regulatory constraints; the ledger ensures auditability.	Network Ledger immutability; verification tasks in the SR model	IS infrastructure calibrated to satisfy internal DSO service-level obligations

5.3 SAM Perspective Analysis

5.3.1 Strategy Execution

Under the Strategy Execution perspective, a dominant coalition, here the DSO or a group of energy regulators, defines the business strategy and subsequently designs an IS infrastructure to execute that strategy (Henderson & Venkatraman, 1999). In the DeEnTP context, the business strategy is the decarbonisation mandate and the need to integrate DERs at the grid edge without triggering expensive capital investments in network capacity. The IT strategy operationalises this mandate through DLT-based settlement and smart contract automation. The i* SD diagram at the strategic level captures exactly this dependency structure: the Matching Engine, acting on behalf of the organisation's strategic goals, coordinates Buyer and Seller dependencies to manage congestion without requiring DSO capital expenditure on new infrastructure. Henderson and Venkatraman (1999, p. 475) note that strategy execution "assumes the classical hierarchy," meaning that senior management articulates strategic goals and IT management translates these into operational capabilities. In DeEnTP, this hierarchy maps cleanly onto the three-level decision structure: strategic (SD model), tactical (SR model actors and their goals), and operational (atomic tasks such as *Create matching* and *Verify contract*).

One tension within this perspective is that the classical hierarchy assumes a stable regulatory environment, whereas the energy market is subject to rapid regulatory evolution. The EU's Clean Energy for All Europeans package (European Commission, 2019), for example, introduced new roles for aggregators and flexibility providers that were not anticipated in most existing DSO IT systems. DeEnTP's use of smart contracts to enforce contractual obligations provides a degree of adaptability: new regulatory constraints can be encoded into contract logic without redesigning the underlying platform architecture. This is consistent with Avison et al.'s (2004) finding that alignment is not a static property but must be actively maintained through iterative governance mechanisms.

5.3.2 Technology Transformation

The Technology Transformation perspective inverts the classical hierarchy: IT strategy becomes the catalyst that both informs business strategy and determines IS infrastructure design (Henderson & Venkatraman, 1999). This perspective is arguably the most relevant to DeEnTP. Blockchain technology is genuinely disruptive, its properties of decentralisation, transparency, and immutability do not merely automate existing energy market processes but fundamentally restructure who can participate and how value is exchanged. Prosumers, who in the traditional market model were passive consumers, become active sellers of flexibility services. FSPs, previously operating through bilateral agreements with DSOs, can now participate in a competitive matching market. This restructuring was not derived from existing DSO business strategy; rather, blockchain's properties enabled a new market configuration that business strategy subsequently adapted to.

Chan and Reich (2007) argue that the Technology Transformation perspective is underutilised in alignment research because most organisations are reluctant to allow IT decisions to drive fundamental changes in market positioning. The energy sector's regulated character makes this reluctance especially pronounced. DeEnTP's design challenge, therefore, is not merely technical but institutional: the platform must convince regulators, DSOs, and prosumers that blockchain-driven market reconfiguration is compatible with their existing obligations. The integration of iStar 2.0 organisational modelling serves this purpose by providing a formal representation of stakeholder intentions and dependencies that can be reviewed by non-technical governance actors.

5.3.3 Competitive Potential

The Competitive Potential perspective holds that emerging IT capabilities create new competitive opportunities that reshape business strategy (Henderson & Venkatraman, 1999). For DSOs, the relevant competitive dynamic is not traditional market competition, DSOs are natural monopolies, but rather regulatory positioning and operational efficiency benchmarking. A DSO that can demonstrate that its congestion management costs are lower because it has successfully deployed a flexibility market platform is better positioned in regulatory price reviews and investment approval processes.

DeEnTP's token economy and multi-region interoperability are particularly relevant here. As Andoni et al. (2019) document in their systematic review, most blockchain energy projects have been limited to local pilots with a single market operator. DeEnTP's design explicitly accommodates multiple FSPs and prosumers across different regions with different energy production and consumption characteristics. This scalability is an emerging IT capability that could redefine the DSO's market position as an enabler of cross-regional flexibility aggregation.

5.3.4 Service Level

The Service Level perspective focuses on the internal alignment between IS infrastructure and the organisation's operational service commitments (Henderson & Venkatraman, 1999). For DSOs, service-level obligations are codified in grid codes, network connection agreements, and regulatory performance targets. The DeEnTP's Network Ledger provides immutable transaction records that satisfy auditability requirements, while the Smart Contract's Verify contract task enforces regulatory constraints at the point of transaction rather than through post-hoc compliance checking. Brilliantova and Thurner (2019) note that blockchain's compliance-by-design property, where regulatory logic is encoded directly into the transaction mechanism, represents a qualitative shift from ex-post auditing to ex-ante enforcement, with significant implications for both cost and reliability.

5.4 NFR Decomposition Tree

Chung et al. (2000) developed the NFR framework as a systematic approach to eliciting, modelling, and operationalising non-functional requirements (NFRs), also referred to as quality goals or softgoals. The core mechanism is a decomposition tree in which a high-level softgoal is decomposed into sub-goals, and the eventual satisficing of the leaf-level sub-goals contributes, through propagation, to the satisficing of the root goal. The NFR framework acknowledges that softgoals, unlike functional goals, cannot be fully satisfied but can be "satisficed" to a sufficient degree (Simon, 1996, as cited in Chung et al., 2000).

In the DeEnTP context, three root-level NFR softgoals are identified, each decomposed through the three organisational levels of the DeEnTP model (strategic, tactical, operational):

- Security: ensuring that all transactions, participant identities, and energy data are protected against unauthorised access and tampering.
- Transparency: ensuring that all market participants have verifiable access to transaction records and market outcomes.
- Scalability: ensuring that the platform maintains performance and reliability as the number of participants, transactions, and geographic regions increases.

5.4.1 NFR Decomposition: Security

At the strategic level, the Security softgoal is decomposed into two sub-goals: (a) Maintain data integrity of transaction records, and (b) Ensure participant authentication. These sub-goals correspond directly to the SD model's resource dependencies: the Smart Contract's dependence on the Network Ledger to record transactions immutably satisfies the data integrity sub-goal, while the Buyer's and Seller's task of Verify requests/offers satisfies the authentication sub-goal at the tactical level.

At the operational level, the SR model's atomic tasks, Verify requests, Verify offer, Verify matching, Verify contract, Verify tokens, constitute the leaf-level satisficing conditions for Security. The blockchain's cryptographic hashing of each transaction block provides a technical basis for data integrity that propagates upward through the decomposition tree. As Musleh et al. (2019) observe, the immutability of DLT records makes retroactive data manipulation detectable, which is a necessary (though not sufficient) condition for satisfying the Security softgoal in a grid environment where false demand signals could trigger physical infrastructure decisions.

5.4.2 NFR Decomposition: Transparency

The Transparency softgoal decomposes into (a) Auditability of transaction history and (b) Market price discovery visibility. At the strategic level, auditability is addressed by the Network Ledger actor's role in maintaining a permanent, distributed record of all transactions. At the tactical level, the SR model's explicit recording task, Record transaction data, operationalises the auditability sub-goal. Price discovery visibility is partially satisfied by the Matching Engine's Create matching task, which applies deterministic matching algorithms whose outputs are recorded on the ledger.
A limitation in satisficing the Transparency softgoal, however, is that while the ledger records what was traded and at what price, the matching algorithm's internal logic may not be fully transparent to all participants. This is particularly relevant for FSPs and prosumers who may not have the technical capacity to audit smart contract code. Kirli et al. (2022) identify this as a recurring challenge in blockchain energy systems: the shift from trust in institutions to trust in code does not automatically produce transparency for non-technical market participants. The DeEnTP model does not currently address this sub-goal at the operational level, representing a gap in NFR satisficing that future iterations should resolve through mechanism design (e.g., human-readable contract summaries or third-party code auditing requirements).

5.4.3 NFR Decomposition: Scalability

The Scalability softgoal decomposes into (a) Transaction throughput under peak load and (b) Geographic extensibility to multiple market regions. At the strategic level, the SD model's quality goal Ensure continuous transactions directly addresses throughput. At the tactical level, the Network Exchange's token management and the Matching Engine's algorithmic coordination are the primary scalability mechanisms. At the operational level, the atomic verification tasks must be designed to execute within latency bounds that do not impede real-time grid operations.

Blockchain scalability is a well-documented technical constraint. Public blockchains such as Ethereum process on average 15 to 30 transactions per second, several orders of magnitude below the throughput of centralised settlement systems (Andoni et al., 2019). DeEnTP's use of a permissioned ledger architecture (rather than a public chain) partially addresses this constraint by reducing the consensus overhead. However, as the platform's discussion section notes, handling thousands of concurrent transactions from grid users at scale requires further technical specification of the consensus protocol, sharding strategy, or layer-two solutions. This leaves the Scalability softgoal only partially satisficed in the current design. Table 3 summarises the NFR decomposition and satisficing status across levels.

Table 3. NFR Decomposition Tree: Goal Satisficing Status Across Levels.

Root NFR	Strategic Level Sub-goal	Tactical Level Sub-goal	Operational Tasks (SR Model)	Satisficing Status
Security	Maintain data integrity; Ensure participant authentication (SD: Smart Contract → Network Ledger)	Verify matching; Verify contract; Token validation (Network Exchange)	Verify requests; Verify offer; Verify tokens; Record transaction data	Satisficed (cryptographic immutability + verification chain)
Transparency	Auditability of transaction history; Market price discovery visibility (SD: Network Ledger permanence)	Create matching (deterministic algorithm); Token audit trail (Network Exchange)	Record transaction data; Define contract (Smart Contract); Delivery confirmation proof	Partially satisficed (ledger transparency; contract logic readability gap for non-technical users)
Scalability	Transaction throughput under peak load; Geographic extensibility (SD: Ensure continuous transactions)	Matching Engine algorithm optimisation; Network Exchange token throughput; Multi-region FSP/PSM support	Create tokens; Create matching (latency-bound); concurrent verification tasks.	Partially satisfied (design supports multi-region; consensus throughput under peak load requires further specification)

5.5 Cross-Level Goal Satisficing

The NFR decomposition tree and SAM analysis together reveal a consistent pattern: DeEnTP’s design satisfies its NFRs most completely at the strategic level (where the SD model captures the essential dependency structure) and least completely at the operational level (where atomic task latency bounds, protocol specifications, and user interface considerations remain underspecified). This is characteristic of early-phase requirements engineering (Yu, 1997), where goal models establish the desired direction of satisficing without prescribing implementation details. The i* framework’s capacity to represent degrees of satisficing, through contribution annotations (⊕, ⊕⊕, ⊖, ⊖⊖) on the goal tree, would allow future versions of the DeEnTP model to make these partial satisficings explicit and traceable.

From an alignment perspective, the SAM analysis reveals that DeEnTP’s strongest alignment is in the Technology Transformation and Strategy Execution quadrants. The Competitive Potential quadrant is partially addressed through the multi-region design, and the Service Level quadrant is addressed through smart contract compliance enforcement but remains dependent on regulatory interpretation of blockchain-based auditability as a substitute for traditional documentation-based compliance. Chan and Reich (2007) note that alignment quality is not uniform across all four SAM perspectives and that organisations typically optimise for two perspectives while under-investing in the remaining two. The identification of partial satisficing in Transparency (technical readability) and Scalability (throughput specification) indicates where the DeEnTP’s next design iteration should focus its effort.

6. DISCUSSION

The decentralized energy trading platform (DeEnTP) presented in this paper offers a transformative approach to managing energy distribution and trading within distribution system operators (DSOs). By leveraging blockchain technology, the platform addresses several critical challenges in the current energy market, including the integration of renewable energy sources, congestion management, and transaction transparency.

One of the key advantages of the DeEnTP platform is its ability to facilitate secure and transparent transactions without the need for centralized intermediaries. This is achieved through the use of blockchain's decentralized trust architecture and distributed validation mechanisms, which ensure that all transactions are immutable and verifiable (Musleh et al., 2019). This characteristic is particularly important in the energy sector, where trust and transparency are paramount for effective market participation and regulatory compliance (Andoni et al., 2019).

The platform's strategic modelling framework, which integrates agile and DevOps methodologies, provides a robust foundation for the development and deployment of the DeEnTP system. By aligning the organizational setting and management structures with the strategic, tactical, and operational decision levels, the platform ensures that all stakeholders' requirements and expectations are met (Yu et al., 2011; Dalpiaz et al., 2016). This approach not only enhances the efficiency of the development process but also ensures that the platform can adapt to the evolving needs of the energy market.

The use case presented in the paper demonstrates the practical utility of the DeEnTP platform in managing long-term congestion and balancing energy supply and demand. By using tokens for transactions and incorporating rigorous verification and validation mechanisms, the platform provides a dependable marketplace for energy flexibility. This is particularly beneficial for DSOs, as it allows them to manage energy flows on the network with greater flexibility and direct involvement, thereby reducing the need for costly network investments (Gazioğlu et al., 2023). The implementation of smart contracts within the platform not only enhances the efficiency of energy trading processes but also ensures that all transactions are compliant with regulatory requirements and auditability standards (Brilliantova & Thurner, 2019).

The SAM and NFR evaluation conducted in this paper identifies two residual gaps. First, the Transparency softgoal is only partially satisficed because smart contract code, while publicly visible on the ledger, is not readily interpretable by prosumers or small FSPs without technical expertise. This represents a governance design challenge rather than a purely technical one. Second, the Scalability softgoal requires further specification of the consensus mechanism's throughput characteristics, particularly in scenarios where intraday flexibility is required at sub-hourly intervals across multiple simultaneous grid events. Addressing these gaps through future design iterations would move DeEnTP from a promising prototype to a deployable market platform.

Flexibility marketplaces like the DeEnTP platform can make the procurement process to make it easier for aggregators and flexibility providers to view the local opportunities and to participate in the procurement process. P2P (peer-to-peer) trading is expected to give multiple benefits to the grid in minimizing the peak load demand and energy consumption costs and eliminating network losses. However, installing P2P energy trading on a broader level in electrical-based networks presents a number of modelling problems in physical and virtual network layers. On a larger scale, when there are more users and thousands of transactions happen, the platform should be capable of handling a significant amount of grid users with sufficient efficiency and security levels. For a P2P platform to be successful, it is crucial that people be educated and given awareness about new technologies and provided incentives to accommodate devices such as smart meters.

7. CONCLUSION

The DeEnTP is an innovative blockchain-based platform designed to facilitate complex energy trading across multiple regions. The platform creates a decentralised ecosystem and provides seamless interaction between energy suppliers and buyers through a layered technology framework. By using blockchain technology, the system ensures transparency, security, and efficiency in energy transactions and moves beyond traditional centralised energy trading models.

Evaluated against the Strategic Alignment Model (Henderson & Venkatraman, 1999), the DeEnTP demonstrates strong alignment along the Strategy Execution and Technology Transformation perspectives. The Technology Transformation perspective is especially notable: blockchain's disruptive properties reconfigure not just the IS infrastructure but the market structure itself, enabling prosumers and FSPs to participate in flexibility markets that were previously inaccessible to them. The NFR decomposition tree (Chung et al., 2000) reveals that the Security softgoal is well satisficed through the verification chain in the SR model and the cryptographic immutability of the ledger; the Transparency softgoal is partially satisficed, with a gap in smart contract readability for non-technical participants; and the Scalability softgoal, while architecturally supported, requires further protocol specification.

DeEnTP ultimately represents a compelling approach to energy trading, leveraging the inherent strengths of blockchain decentralisation, transparency, and security. The system can optimise energy distribution, reduce inefficiency, and support the transition to a more flexible and sustainable energy ecosystem. Future work should address the identified NFR gaps, particularly through the development of user-facing transparency tools for non-technical market participants and the specification of consensus throughput requirements for high-frequency intraday trading scenarios.

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