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Adopting blockchain technology by Finnish energy companies for managing suppliers’ relationships

Drivers, barriers, and potential performance outcomes

School of Management
Master’s thesis in
International Business

Vaasa 2026

UNIVERSITY OF VAASA
School of International business
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Title of the Thesis: Adopting blockchain technology by Finnish energy companies for managing suppliers' relationships: Drivers, barriers, and potential performance outcomes
Degree: Master of Science in International Business
Programme: International Business
Supervisor: Tahir Ali
Year: 2026 **Pages:** 134

ABSTRACT:
The global energy sector is undergoing a structural transformation characterized by decentralization, digitalization, and the expansion of renewable energy systems. This transformation has increased the complexity of upstream supplier-buyer relationships, creating a need for governance mechanisms that can ensure transparency, traceability, and trust across multi-tier supply networks. Blockchain technology has been identified as a potential solution to these governance challenges, yet scholarly understanding of its adoption within the energy sector remains fragmented. Existing studies have examined drivers, barriers, or performance outcomes in isolation, whereas no integrated study has examined all three dimensions in the context of energy companies managing their supplier relationships. This thesis addresses that gap by investigating the drivers, barriers, and performance outcomes of Finnish energy companies' adoption of blockchain technology to manage supplier relationships. A conceptual model comprising 24 propositions was developed from the literature, drawing on transaction cost economics, social exchange theory, resource dependence theory, and the technology-organization-environment framework, and empirically examined through a qualitative multiple-case study of four Finnish energy-sector organizations using semi-structured interviews analyzed with thematic analysis guided by abductive reasoning. The findings confirm that supply chain traceability and sustainability compliance are the most compelling value propositions of blockchain for energy-sector supplier management, while the absence of internal blockchain expertise and the difficulty of demonstrating return on investment emerged as the most significant barriers. Scalability limitations and regulatory concerns received less support than the literature anticipates. On performance outcomes, sustainability compliance capacity was the dominant anticipated benefit for firms facing direct reporting obligations, cost-reduction potential was acknowledged but tempered by uncertainty about net returns, and relationship improvement was endorsed most strongly for complex multi-tier partnerships. Learning, decision-making, and communication outcomes were supported but conditional on the firm's level of digital maturity. Four emergent factors were identified beyond the original framework: the crowding-out effect of AI on blockchain's innovation agenda, the necessity of industry consortium coordination, the moderating role of firm size and digital maturity, and the need for a prior relational mindset shift among supply chain partners. For practitioners, the study recommends anchoring blockchain initiatives around sustainability traceability use cases, building internal competence before committing to platforms, and pursuing collaborative industry approaches rather than individual company efforts.

KEYWORDS: supplier-buyer relationship, blockchain technology, adoption, drivers, barriers, performance outcomes

VAASAN YLIOPISTO
Johtamisen akateeminen yksikkö

Tekijä:	Eetu Toivomäki
Tutkielman nimi:	Adopting blockchain technology by Finnish energy companies for managing suppliers' relationships: Drivers, barriers, and potential performance outcomes
Tutkinto:	Kauppatieteiden Maisteri
Oppiaine:	International Business
Työn ohjaaja:	Tahir Ali
Vuosi:	2026 **Sivumäärä:** 134

TIIVISTELMÄ:

Globaali energia-ala on käymässä läpi rakenteellista muutosta, jolle ovat ominaisia hajauttaminen, digitalisaatio ja uusiutuvien energialähteiden laajentuminen. Tämä muutos on lisännyt toimittajien ja ostajien välisten suhteiden monimutkaisuutta, mikä on luonut tarpeen hallintomekanismeille, joilla voidaan varmistaa läpinäkyvyys, jäljitettävyys ja luottamus monitasoisissa toimitusketjuissa. Lohkoketjuteknologia on tunnistettu potentiaaliseksi ratkaisuksi näihin hallintahaasteisiin, mutta sen käyttöönotosta energia-alalla on edelleen hajanaista tieteellistä tietoa. Olemassa olevat tutkimukset ovat tarkastelleet ajureita, esteitä tai suorituskykyvaikutuksia erillään toisistaan, eikä yksikään integroitu tutkimus ole tarkastellut kaikkia kolmea ulottuvuutta energiayhtiöiden toimittajasuhteiden hallinnan kontekstissa. Tämä opinnäytetyö täyttää tämän aukon tutkimalla suomalaisyritysten lohkoketjuteknologian käyttöönoton ajureita, esteitä ja suorituskykyä toimittajasuhteiden hallinnassa. Kirjallisuuden pohjalta kehitettiin 24 väitettä kattava käsitteellinen malli, joka perustuu transaktiokustannustalouteen, sosiaalisen vaihdon teoriaan, resurssiriippuvuusteoriaan sekä teknologia-organisaatio-ympäristö-viitekehykseen. Väitteitä tutkittiin empiirisesti neljän suomalaisen energia-alan organisaation kvalitatiivisessa monitapaustutkimuksessa puolistrukturoitujen haastattelujen avulla ja aineisto analysoitiin abduktiiviseen päättelyyn perustuvalla temaattisella analyysillä. Tutkimustulokset osoittavat, että toimitusketjun jäljitettävyys ja vastuullisuusraportoinnin tukeminen ovat lohkoketjuteknologian vahvimmat käyttötapaukset energia-alan toimittajasuhteiden hallinnassa, kun taas sisäisen lohkoketjuosaamisen puute ja investoinnin kannattavuuden osoittamisen vaikeus nousivat merkittävimmiksi esteiksi. Skaalautuvuusrajoitteet ja sääntelyyn liittyvät huolet saivat kirjallisuudessa vähemmän tukea. Suorituskykyvaikutuksista vastuullisuusraportoinnin tukeminen nousi hallitsevaksi odotetuksi hyödyksi erityisesti yrityksille, joille suorat raportointivelvoitteet ovat voimassa. Kustannussäästöpotentiaali tunnistettiin, mutta sitä varjosti epävarmuus nettohyötyjen toteutumisesta, ja toimittajasuhteiden parantumista kannatettiin vahvimmin monitasoisissa ja monimutkaisissa kumppanuuksissa. Oppimiseen, päätöksentekoon ja viestintään liittyvät vaikutukset saivat tukea, mutta ne olivat ehdollisia yrityksen digitaalisen kypsyyden tasolle. Alkuperäisen viitekehyksen ulkopuolelta tunnistettiin neljä uutta tekijää: tekoälyn syrjäyttävä vaikutus lohkoketjun asemaan innovaatioagendalla, toimialakonsortion välttämättömyys käyttöönoton onnistumiselle, yrityksen koon ja digitaalisen kypsyyden moderoiva rooli sekä tarve toimitusketjukumppaneiden väliseen asennemuutokseen kohti yhteistyöhakuisempaa suhdetta. Käytännön suosituksina tutkielma ehdottaa lohkoketjuhankkeiden ankkuroimista vastuullisuuden jäljitettävyyteen liittyviin käyttötapauksiin, sisäisen osaamisen rakentamista ennen alustavalintoja sekä yhteistyöhön perustuvien toimialamallien suosimista yksittäisten yritysten erillishankkeiden sijaan.

AVAINSANAT: toimittaja-ostaja-suhde, lohkoketjuteknologia, implementointi, edistävät tekijät, esteet, tulokset

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1 Introduction

The global energy sector is undergoing a profound structural transformation driven by decentralization, digitalization, and the accelerating transition toward renewable energy systems. For much of the twentieth century, energy production and distribution were organized through centralized models in which a small number of established utilities controlled generation, transmission, and market access. Over the past two decades, the rapid growth of distributed energy resources, the rise of prosumer participation, and the evolution of smart grid infrastructure have shifted the sector toward increasingly decentralized modes of operation (Andoni et al., 2019; Wang & Su, 2020).

This shift brings with it new governance challenges. In decentralized energy systems, multiple independent actors must exchange data, coordinate transactions, and maintain accountability across interconnected networks, all without the oversight structures that centralized models provided (Andoni et al., 2019). Achieving data reliability, ensuring the integrity of commercial transactions, and establishing mutual trust among parties with no prior relationship are recurring challenges in this environment. As a result, digital infrastructures capable of enabling secure, transparent, and tamper-resistant transactions have become strategically important for energy companies seeking to operate effectively in a decentralized landscape.

Blockchain technology has emerged as a form of infrastructure. At its core, blockchain is a distributed digital ledger that records transactions across a decentralized network, secured by cryptographic techniques that make the recorded data resistant to unauthorized alteration (Swan, 2015; Andoni et al., 2019). The technology also supports the automated execution of smart contracts, which can enforce predefined terms of an agreement without manual intervention. These properties position blockchain as a candidate technology for addressing coordination and trust challenges in multi-party supply chain environments.

While much of the existing discussion on blockchain in the energy sector centers on peer-to-peer trading platforms and grid management, the technology also holds promise for managing upstream supply chain relationships. Energy companies coordinate with extensive networks of equipment manufacturers, infrastructure providers, and service contractors, and these relationships demand reliable mechanisms for information exchange, contract enforcement, and performance monitoring (Saberi et al., 2019). Blockchain's capacity to create transparent, immutable, and shared records of interorganizational transactions may reduce information asymmetry and strengthen trust between buyers and suppliers (Schmidt & Wagner, 2019). Yet despite this potential, the application of blockchain to supplier-buyer relationship governance in the energy sector remains largely unexplored. This thesis addresses that gap by investigating the drivers, barriers, and performance outcomes of blockchain adoption for managing supplier relationships in Finnish energy companies.

1.1 Background of the study

The transformation of the energy sector has significantly increased the complexity of coordination within supply chains. Energy companies operate within extensive upstream networks that include equipment manufacturers, infrastructure providers, technology suppliers, service contractors, and regulatory stakeholders (Gariya et al., 2025). As renewable energy integration and digital technologies expand, the volume and complexity of contractual relationships within the upstream value chain continue to increase (Andoni et al., 2019).

Managing supplier-buyer relationships under such conditions requires effective mechanisms for information sharing, contract enforcement, performance monitoring, and traceability (Nyaga et al., 2010). Failures in coordination may result in operational inefficiencies, increased transaction costs, regulatory non-compliance, and reputational risks (Dyer & Chu, 2003). The growing interdependence between energy firms and their suppliers, therefore, necessitates governance structures that enhance transparency and reduce uncertainty.

Blockchain technology presents characteristics that are promising for such governance needs. The distributed validation of transactions reduces reliance on centralized intermediaries, while immutability ensures that records cannot be altered retroactively (Swan, 2015). Smart contracts enable automated enforcement of predefined agreements, potentially lowering administrative costs and reducing opportunistic behavior. From an organizational perspective, these mechanisms may strengthen trust among supply chain partners and improve coordination efficiency.

Despite growing scholarly attention to blockchain in supply chain management, the existing literature remains fragmented in its treatment of the energy sector context. Studies examining drivers of blockchain adoption have predominantly focused on general supply chain settings rather than on energy-specific supplier relationships (Gokalp et al., 2020; Agi & Jha, 2022). Research on adoption barriers in the energy sector has been limited to a small number of studies that do not simultaneously examine drivers or performance outcomes (Andreoulaki et al., 2024). Conversely, the few studies that have assessed blockchain's performance implications for supply chains have done so across multiple industries without isolating the conditions specific to the energy sector (Mishra et al., 2023; Wamba et al., 2020). To date, no single study has investigated the drivers, barriers, and performance outcomes of blockchain adoption within an integrated framework focused specifically on how energy companies manage their upstream supplier relationships. This thesis addresses that gap by examining all three dimensions within a unified study, situated in the empirical context of Finnish energy companies.

1.2 Research question and objectives of the study

The preceding discussion highlights the growing complexity of supplier-buyer coordination in the energy sector, the potential of blockchain technology to address governance challenges in upstream supply chains, and the absence of an integrated study that examines the drivers, barriers, and performance outcomes of blockchain adoption for managing supplier relationships in this context. These observations steer the course of the present thesis. The main objective of this thesis is to investigate the drivers, barriers, and performance outcomes of energy companies adopting blockchain technology for managing suppliers' relationships.

Accordingly, the main research question of this thesis is: *What are the drivers, barriers, and performance outcomes of adopting blockchain technology by energy companies to manage suppliers' relationships?*

To better understand the main research question, the following sub-objectives are developed:

1. To examine the conceptualization and significance of managing supplier-buyer (i.e., upstream value chain) relationships by energy companies.

2. To enhance understanding of the conceptualization, types, implementation process, and importance of adopting blockchain technology by energy companies for managing supplier-buyer relationships.

3. To explore the drivers, barriers, and performance outcomes of energy companies adopting blockchain technology for managing suppliers' relationships.

4. To empirically investigate the drivers, barriers, and performance outcomes of blockchain adoption by Finnish energy companies for managing suppliers' relationships.

Together, these objectives enable a thorough examination of blockchain adoption from both a theoretical and empirical perspective. By integrating perspectives on supply chain management, digital transformation, and organizational adoption, this study aims to provide context-specific insights into how blockchain technology may reshape supplier-buyer relationships within the Finnish energy sector.

1.3 Delimitations of the study

Although blockchain has been widely studied in fields such as finance, logistics, and healthcare, sectoral characteristics significantly influence adoption dynamics and implementation outcomes (Saberi et al., 2019). The energy industry is currently characterized by decentralization, renewable integration, and increasing digital interconnectivity, which generate unique coordination challenges (Andoni et al., 2019; Wang & Su, 2020). For this reason, the analysis is confined to this specific industrial context. The findings are therefore not intended to be directly generalized to other sectors.

The investigation is further limited to the upstream value chain, concentrating on supplier-buyer relationships rather than downstream trading platforms or consumer-oriented applications. Much of the existing research on blockchain in energy systems has emphasized decentralized trading mechanisms and smart grid solutions (Andoni et al., 2019). In contrast, comparatively little attention has been given to blockchain's potential role in managing interorganizational coordination between energy companies and their suppliers. Supplier-buyer relationships involve long-term contractual arrangements, regulatory compliance requirements, and capital-intensive collaboration. Restricting the focus to this dimension allows for a more detailed examination of governance and coordination mechanisms within supplier networks.

This research adopts an organizational and managerial perspective rather than a technical one. A detailed analysis of blockchain architecture, consensus mechanisms, and cryptographic foundations is therefore beyond its scope. Instead, the focus is on the key drivers of adoption, the barriers to implementation, and the performance-related implications of blockchain use. This orientation aligns with the technology-organization-environment framework, which emphasizes that the adoption of new technologies is influenced not only by their technical features but also by organizational capabilities and external environmental conditions (Tornatzky & Fleischer, 1990). As a result, greater attention is given to strategic and organizational aspects than to engineering details.

The empirical investigation is limited to a single national context. Institutional theory suggests that factors such as regulatory frameworks, sustainability agendas, and the level of digital infrastructure development shape organizational behavior and patterns of innovation adoption (DiMaggio & Powell, 1983). Finland provides a relevant setting in this regard, given its advanced digital infrastructure and strong climate policy ambitions within a tightly regulated energy sector. While this context enhances the depth and relevance of the analysis, it also limits how broadly the findings can be generalized to other countries operating under different institutional conditions.

From a methodological standpoint, the study applies a qualitative multiple-case study design. This approach enables a detailed examination of complex phenomena within their real-world settings, particularly when the distinction between the phenomenon and its context is not clearly defined (Yin, 2018). However, the objective is not statistical generalization. Rather, the aim is to achieve analytical generalization by linking empirical observations to established theoretical frameworks.

The performance implications examined in this study are based primarily on managerial assessments and observed organizational changes rather than longitudinal quantitative performance data. Blockchain implementation in the energy sector remains at a relatively early stage of diffusion, and standardized performance metrics have not yet been fully established. Prior research similarly notes that empirical measurement of long-term operational and financial impacts of blockchain adoption remains limited (Saberi et al., 2019). Consequently, the analysis focuses on perceived and reported outcomes within case organizations.

1.4 Definitions of key terms

The main concepts in this study have been defined based on their significance to understanding the research phenomenon under investigation. These terms include blockchain technology, supplier-buyer relationship, smart contract, energy supply chain, distributed ledger technology, consensus mechanism, drivers of technology adoption, barriers to technology adoption, performance outcomes, and traceability. The definitions of the main terms used in this thesis are summarized and presented in Table 1 along with the relevant references.

Table 1. Definitions of the main concepts of the study

Key terms	Definitions	References
Blockchain technology	A shared and distributed digital ledger system in which transactions are recorded, validated, and stored across a decentralized network of participants rather than through a single centralized authority. The ledger is cryptographically secured and resistant to unauthorized modification.	Adapted from Swan (2015); Andoni et al. (2019)
Supplier-buyer relationship (SBR)	A sustained interorganizational exchange between a supplying firm and a buying firm, governed by a combination of contractual and relational mechanisms, and characterized by varying degrees of mutual dependence, trust, and information sharing.	Adapted from Nyaga et al. (2010); Lumineau & Oliveira (2020)
Smart contract	A self-executing digital agreement encoded on a blockchain, in which predefined contractual terms are automatically enforced when specified conditions are met, without requiring manual intervention or third-party verification.	Adapted from Swan (2015); Chang et al. (2019)
Energy supply chain	The integrated network of organizations and processes involved in the production, transmission, distribution, and consumption of energy resources, including all upstream procurement relationships with equipment manufacturers, technology vendors, and service providers.	Adapted from Gariya et al. (2025)
Distributed ledger technology (DLT)	A broader category of technologies in which a digital ledger of transactions is shared, replicated, and synchronized across multiple network participants, of which blockchain is the most widely known implementation.	Adapted from Andoni et al. (2019)
Consensus mechanism	An algorithmic process through which participants in a distributed network agree on the valid state of the shared ledger, ensuring that all copies of the ledger reflect the same transaction history. Common	Adapted from Andoni et al. (2019)

	mechanisms include proof of work, proof of stake, and practical Byzantine fault tolerance.	
Drivers of technology adoption	The technological, organizational, and environmental factors that motivate or enable an organization to pursue the adoption of a new technology.	Adapted from Tornatzky & Fleischer (1990); Gokalp et al. (2020)
Barriers to technology adoption	The technological, organizational, and environmental factors that constrain, impede, or discourage an organization from adopting a new technology, even when motivating conditions may be present.	Adapted from Saberi et al. (2019); Kouhizadeh et al. (2021)
Performance outcomes	The measurable effects that technology adoption produces within the adopting organization and its supply chain relationships, encompassing dimensions such as cost, innovation, relationship quality, learning, decision-making, communication, and transaction security.	Adapted from Mishra et al. (2023)
Traceability	The ability to track and verify the origin, handling history, and movement of goods, components, or transactions across the supply chain, from raw material sourcing to final delivery.	Adapted from Pournader et al. (2019); Cole et al. (2019)

1.5 Previous studies

The summary of prior studies on the subject matter of this thesis is presented in Table 2 below. The table provides an overview of five studies that have examined different aspects of the research phenomenon, including blockchain technology in the energy sector, blockchain's relationship to sustainable supply chain management, adoption factors investigated through the TOE framework, barriers specific to blockchain adoption in energy applications, and the intersection of blockchain technology with buyer-supplier relationship governance.

Table 2. Previous studies

Author(s) / year	Focus of the study	Methodology	Findings of the study
Andoni et al. (2019)	Systematic review of blockchain technology applications, challenges, and	Systematic literature review of 140 blockchain research	Decentralized energy trading accounted for one-third of all initiatives. The majority

	opportunities in the energy sector.	projects and startups in the energy industry.	of projects were built on the Ethereum platform. Blockchain holds potential for transparency, P2P trading, and IoT applications, but faces scalability, regulatory, and cost barriers. A shift toward permissioned, enterprise-oriented architectures was identified.
Saberi et al. (2019)	Blockchain technology and its relationships to sustainable supply chain management, with emphasis on adoption barriers.	Conceptual framework development combining institutional theory, transaction cost economics, and resource-based view.	Identified four categories of blockchain adoption barriers: inter-organisational, intra-organisational, technical, and external. Argued that the challenge of blockchain implementation is not purely technical but also organizational and institutional. Established a foundational barrier classification widely adopted in subsequent research.
Chittipaka et al. (2022)	Empirical examination of blockchain adoption in supply chains.	Quantitative survey of 525 supply chain management professionals in India, analysed with structural equation modelling.	All eleven TOE constructs, including relative advantage, trust, compatibility, security, IT resources, higher authority support, firm size, monetary resources, rivalry pressure, business partner pressure, and regulatory pressure, had a significant influence on the blockchain adoption

			decision. Blockchain adoption was found to significantly improve firm performance through improved transparency, trust, and security.
Andreoulaki et al. (2024)	Evaluation of barriers to blockchain adoption specifically in the energy sector.	PESTLE and SWOT analyses combined with AHP for group decision-making, validated by energy and IT experts.	Legal barriers, particularly the complexity and deficiency of existing regulations, were identified as the most significant impediment. Technological barriers related to security were also important. Sociopolitical barriers related to lack of trust and economic concerns such as high upfront costs were less influential but still noteworthy.
Schmidt & Wagner (2019)	Blockchain's implications for supply chain buyer-supplier relations.	Conceptual analysis applying transaction cost theory to blockchain-enabled supply chain governance mechanisms.	Blockchain reduces transaction costs by lowering information asymmetries and the need for intermediary verification between buyers and suppliers. Smart contracts enable automated enforcement of contractual terms, reducing monitoring and enforcement costs. The technology reshapes the governance choice between market and hierarchy by introducing a new hybrid form of coordination.

The table presented above illustrates that prior research has examined blockchain technology in the energy sector (Andoni et al., 2019), identified general barrier categories for blockchain in supply chains (Saberi et al., 2019), empirically tested adoption determinants through the TOE framework (Chittipaka et al., 2022), evaluated energy-specific barriers through expert consultation (Andreoulaki et al., 2024), and analyzed how blockchain reshapes buyer-supplier governance through a transaction cost lens (Schmidt & Wagner, 2019). By incorporating multiple perspectives, these studies collectively inform the theoretical framework of the present thesis. Nonetheless, none of them has investigated the drivers, barriers, and performance outcomes of blockchain adoption within a single integrated study focused on the upstream supplier relationships of energy companies, and none has done so within the Finnish empirical context. This thesis, therefore, addresses a gap at the intersection of these research streams.

1.6 Structure of the thesis

The study is structured into five chapters. **Chapter 1** provides the introduction to the thesis. It presents the background of the study, outlines the research question and objectives, and establishes the delimitations that define the scope of the investigation. The chapter also defines the key terms used throughout the thesis, summarizes relevant previous studies, and describes the overall structure of the work. An AI disclosure statement is included at the end of the chapter.

Chapter 2 constitutes the literature review, which forms the theoretical foundation of the thesis. The chapter is organized into six sections. The first section examines the conceptualization and importance of managing supplier-buyer relationships, drawing on transaction cost economics, social exchange theory, and resource dependence theory. The second section addresses blockchain technology in the context of supplier relationship management, covering its conceptualization, types, implementation process, and importance. The third, fourth, and fifth sections examine the drivers of adoption, barriers to adoption, and performance outcomes of blockchain adoption by energy companies for managing supplier relationships, respectively. Each section concludes with research propositions derived from the literature. The sixth section presents the study’s conceptual model, integrating the 24 propositions across the three analytical dimensions into a unified framework.

Chapter 3 describes the research methodology. The chapter discusses the research approach, including the interpretivist philosophical orientation and abductive reasoning logic adopted in the study. It justifies the use of qualitative research and outlines the multiple-case study design, including the rationale for selecting the Finnish energy sector as the empirical context. The chapter further details the data collection procedures, sampling technique, and thematic analysis method employed, and concludes with a discussion of the measures taken to ensure validity and reliability.

Chapter 4 presents the empirical findings. The chapter begins with an overview of the interviewees' backgrounds and the characteristics of the case companies. It then provides within-case analyses for each case, structured around the three pillars of the conceptual model: drivers, barriers, and performance outcomes. The chapter concludes with a cross-case analysis that identifies patterns of convergence and divergence across the cases and presents a revised empirical model reflecting both theoretically anticipated and empirically emergent factors.

Chapter 5 concludes the thesis. The chapter provides a summary and discussion of the key empirical findings in relation to the research question and propositions. It discusses the study’s theoretical contributions to the blockchain adoption and supplier relationship management literatures and outlines the managerial implications for practitioners in the energy sector. The chapter closes with directions for future research and an acknowledgment of the study's limitations.

1.7 AI Disclosure

In accordance with academic transparency requirements, this section discloses the artificial intelligence tools that were used to assist in the preparation of this thesis. All tools were employed in a supportive capacity, and no substantial arguments, theoretical claims, or empirical interpretations were generated by AI. The content of this thesis has been reviewed and edited by a human at every stage of the writing process.

Claude Opus 4.6 (Anthropic) was used for brainstorming and structuring purposes during the early phases of the thesis. This included assistance with outlining chapter structures, organizing thematic content, and refining the logical flow between sections. Grammarly Premium was used for language editing and polishing, including grammar correction, sentence clarity improvements, and stylistic consistency checks across the thesis. Consensus, an AI-powered academic search engine, was used to identify peer-reviewed research articles relevant to the thesis topic. All sources identified through Consensus were independently verified for relevance, accuracy, and quality before being incorporated into the literature review. And finally, Microsoft Copilot was used to automate the transcription of interview recordings during the empirical data collection phase, converting audio files into written text for subsequent analysis. The AI-assisted edits and outputs were reviewed for accuracy, completeness, and academic integrity throughout the process. The author bears full responsibility for the intellectual content, analytical arguments, theoretical interpretations, and empirical conclusions presented in this thesis.

2 Literature Review

This chapter reviews the existing scholarly literature relevant to the research question. The chapter begins by examining the conceptualization and importance of supplier-buyer relationships in supply chain management (Section 2.1). It then discusses blockchain technology and its application to the governance of supplier relationships (Section 2.2). The subsequent sections identify the drivers (Section 2.3), barriers (Section 2.4), and performance outcomes (Section 2.5) of blockchain adoption by energy companies for managing their upstream supplier relationships, drawing on empirical and conceptual studies from both the blockchain and supply chain management literatures. The chapter concludes with the study's conceptual model, which integrates the 24 propositions developed in the preceding sections into a unified analytical framework (Section 2.6).

2.1 Managing supplier-buyer relationships (SBRs)

The management of supplier-buyer relationships constitutes one of the most extensively studied topics in the supply chain management literature. Over the past decades, scholars from operations management, industrial marketing, and strategic management have examined how firms structure, govern, and sustain their exchange relationships with upstream partners (Harland, 1996; Nyaga et al., 2010). This section provides a conceptual foundation for the thesis by first defining the supplier-buyer relationship construct and outlining the principal theoretical perspectives through which it has been analyzed (Section 2.1.1) and then discussing why the effective management of these relationships matters for organizational performance, competitive positioning, and the particular challenges facing energy companies (Section 2.1.2).

2.1.1 Conceptualization of supplier-buyer relationships

The study of supplier-buyer relationships has occupied a central position in the supply chain management literature for well over three decades. Harland (1996) was among the first to systematically distinguish between multiple levels of supply chain analysis, identifying the bilateral buyer-supplier exchange as the foundational building block upon which broader supply chain networks are constructed. At its most elementary level, a supplier-buyer relationship (SBR) refers to the ongoing exchange between two organizations in which one party (the supplier) provides goods, services, or resources to another party (the buyer) under terms that are governed by some combination of formal contracts, informal norms, and mutual expectations. What distinguishes an SBR from a one-off market transaction is the presence of continuity, interdependence, and the expectation of future exchange, all of which create incentives for both parties to invest in maintaining and developing the relationship (Nyaga et al., 2010).

Scholarly efforts to conceptualize SBRs have drawn on several complementary theoretical perspectives. Transaction cost economics (TCE), originating from the work of Williamson (1985), provides one of the most influential approaches. TCE posits that firms choose governance structures, ranging from markets to hierarchies, primarily to minimize the costs associated with transacting under conditions of bounded rationality and potential opportunism. In the context of SBRs, transaction-specific investments, contractual safeguards, and monitoring mechanisms serve as the principal instruments through which buyers and suppliers protect themselves against value appropriation by the other party (Rindfleisch & Heide, 1997). A recent review by Lumineau and Oliveira (2020) confirmed that TCE remains the dominant theoretical foundation in studies of interfirm contracting and governance, though they cautioned that its explanatory power is enhanced when it is combined with relational and institutional perspectives.

Alongside TCE, social exchange theory (SET) has offered a fundamentally different, though not incompatible, perspective on SBRs. Where TCE emphasizes the calculative logic of cost minimization, SET centers on the relational bonds that develop between exchange partners over time. According to this view, repeated interactions generate trust, norms of reciprocity, and relational commitment, which in turn reduce the need for formal contractual safeguards and facilitate cooperative behavior (Nyaga et al., 2010;

Lumineau & Oliveira, 2020). In their landmark bilateral study of collaborative supply chain relationships, Nyaga et al. (2010) found that collaborative activities such as joint effort, dedicated investments, and information sharing led to the development of trust and commitment, which subsequently improved both satisfaction and performance for buyers and suppliers alike. Importantly, their study also revealed that the two sides of the bilateral relationship differ in what they value most: buyers tend to focus on relationship outcomes, while suppliers place a higher premium on safeguarding their transaction-specific investments through ongoing information sharing.

A third perspective that has gained significant traction in the SBR literature is resource dependence theory (RDT). RDT directs attention to the distribution of power within exchange relationships, which is determined by the relative dependence of each party on the other's controlled resources (Gulati & Sytch, 2007). When dependence is asymmetric, the less dependent actor may exploit its power advantage through compulsive pricing practices, unfavorable contractual terms, or unilateral decision-making (Pulles et al., 2014). Caniels and Gelderman (2007) argued that power asymmetry shapes the strategic posture of both buyers and suppliers, influencing not only the choice of governance mechanisms but also the weaker party's willingness to invest in joint innovation and process improvement. More recently, Villena et al. (2011) provided empirical evidence from the automotive and electronics sectors showing that an optimal level of relational closeness enhances performance, but excessive closeness can, in fact, erode the buying firm's objectivity and increase the supplier's propensity for opportunistic behavior. This finding, sometimes described as the “dark side” of SBRs, underlines the importance of balancing relational depth with appropriate safeguards.

The conceptualization of SBRs is therefore not captured by any single theory, but rather by the interplay of economic and sociological mechanisms. In a comprehensive integrative review, Arranz et al. (2023) identified relationship quality as the central organizing category of SBRs, with trust, commitment, communication, and mutual adaptation constituting its core dimensions. Their synthesis of 187 articles showed that trust is the most widely cited antecedent of relationship quality, followed by information sharing and joint problem-solving. At the same time, the authors recognized that these positive relational attributes do not develop in isolation from economic considerations; rather, contractual governance and relational governance operate together, sometimes as complements and sometimes as substitutes, depending on the maturity and context of the exchange (Liu et al., 2009).

This dual governance logic was empirically investigated by Kohtamaki et al. (2017) in a study of 170 buyer-supplier relationships among Finnish small and medium-sized enterprises. Their findings demonstrated that sociological mechanisms, specifically trust and communication, were more effective at enhancing relationship commitment, whereas economic mechanisms, namely contract completeness and symmetric dependence, were more effective at reducing post-transaction costs. Critically, the two forms of governance interacted: relational mechanisms functioned as substitutes for contractual governance in terms of transaction costs, but operated as complements to symmetric dependence in building commitment. These findings highlight that effective SBR management is not simply a matter of choosing between formal and informal governance, but of configuring both in response to the specific characteristics of the exchange.

Against this backdrop, the conceptualization of SBRs adopted in this thesis integrates insights from TCE, SET, and RDT. A supplier-buyer relationship is understood here as a sustained interorganizational exchange governed by a combination of contractual and relational mechanisms, embedded within a broader institutional and competitive context, and characterized by varying degrees of mutual dependence, trust, and information sharing. This definition is consistent with the multidimensional view advocated by recent integrative reviews (Arranz et al., 2023; Brito et al., 2017) and positions the SBR concept at the intersection of economic governance and social exchange, a necessary foundation for examining how emerging digital technologies such as blockchain may reshape the way energy companies manage their supplier relationships.

2.1.2 Importance of managing supplier-buyer relationships

The academic research consistently shows that companies prioritizing the quality of their supplier relationships generally perform better than those viewing procurement as merely a transactional task. The most direct link between SBR management and firm performance runs through operational efficiency. Cao and Zhang (2011), in a large-scale survey of U.S. manufacturing firms across multiple industries, found that supply chain collaboration, defined as a partnership-based process of working together toward common objectives, improved firm performance by creating what the authors termed “collaborative advantage”. This advantage manifested in reduced costs, shorter lead times, improved product quality, and greater responsiveness to market changes. The study further demonstrated that collaborative advantage served as an intermediate variable, meaning that the benefits of collaboration were not automatic but depended on the degree to which partners succeeded in creating synergies through their joint activities. For small firms in particular, collaborative advantage fully reconciled the relationship between supply chain collaboration and performance, suggesting that these firms are especially dependent on the relational resources embedded in their supplier networks.

Beyond operational metrics, SBR quality affects innovation outcomes. Krause et al. (2007) showed that buying firms' commitment and social capital accumulation with key suppliers predicted improvements not only in cost and delivery performance but also in the supplier's capacity for product and process innovation. Their analysis of the U.S. automotive and electronics industries revealed that structural capital (information sharing, supplier evaluation, and supplier development activities) and relational capital (relationship longevity and mutual dependence) each contributed to performance, though the relative importance of these dimensions varied depending on whether cost or innovation was the outcome of interest. More recently, Hasan et al. (2024) discovered that commitment in buyer-supplier relationships directly affects both operational and innovation performance within manufacturing dyads, with supply chain integration acting as a partial mediator. This indicates that firms cannot simply enhance supplier-driven innovation by issuing specifications and monitoring compliance; instead, they must develop the relational infrastructure that facilitates knowledge sharing and collaborative problem-solving.

The financial consequences of poor SBR management can be considerable. Dyer and Chu (2003), in a cross-national study spanning the United States, Japan, and Korea, demonstrated that trustworthiness in the buyer-supplier relationship substantially reduced procurement-related transaction costs. Specifically, the least-trusted automaker in their sample incurred face-to-face contracting and negotiation costs that were approximately five times higher than those of the most-trusted automaker. The authors argued that trust is unique among governance mechanisms in that it not only minimizes transaction costs but also has a mutually reinforcing relationship with information sharing, thereby creating value beyond mere cost reduction. This result has significant practical implications: while contracts and financial hostages are necessary costs incurred to prevent opportunism, trust actively generates value by enabling richer and more frequent information exchange between partners.

The stability and continuity of SBRs also matter. Li et al. (2022), using empirical data from over 2,900 listed firms in China, found that maintaining greater stability with major suppliers and customers enhanced a firm's financial performance, whereas a higher concentration of major partners (excessive reliance on a small number of counterparts) had a negative effect. The positive impact of relationship stability outweighed the negative effect of concentration, leading the authors to recommend that firms build open, long-term relationships that are stable but not exclusive. This balance between commitment and diversification resonates with the earlier observation by Villena et al. (2011) that relational closeness has diminishing and eventually negative returns if taken to an extreme.

In the context of the energy sector, these considerations take on particular weight. Energy companies maintain extensive upstream procurement networks encompassing equipment manufacturers, technology vendors, infrastructure contractors, and raw material suppliers. These relationships are frequently capital-intensive, governed by long-term contractual frameworks, and subject to strict regulatory requirements. The transition to renewable energy and the integration of digital technologies into energy systems have further increased the number and variety of suppliers that energy firms must coordinate with (Andoni et al., 2019). The procurement of specialized components, such as turbine parts, battery storage systems, or smart metering infrastructure, demands not only competitive pricing but also reliable delivery performance, quality assurance, and the capacity for technological co-development. Under such conditions, the management of SBRs becomes a matter of strategic rather than merely operational significance, requiring governance structures that can accommodate both the transactional demands of cost efficiency and the relational demands of innovation and trust.

The energy sector's regulatory environment adds a further dimension to the importance of SBR management. Energy companies face growing accountability not only for their own operational performance but also for the environmental and social conduct of their suppliers. Managing these expectations requires governance mechanisms that promote transparency, traceability, and mutual accountability across organizational boundaries, characteristics that, as the following sections will explore, align closely with the functional properties of blockchain technology.

2.2 Blockchain technology for managing suppliers’ relationships

Having established the conceptual and strategic significance of supplier-buyer relationships in the following section, this chapter turns to how blockchain technology may contribute to the governance and management of such relationships. The section begins by defining blockchain technology and its core properties (Section 2.2.1), proceeds to outline the principal types of blockchain architectures and their relevance to supply chain applications (Section 2.2.2), discusses the process by which blockchain may be implemented within supplier-buyer relationship management (Section 2.2.3), and concludes by examining why the adoption of blockchain holds particular importance for energy companies seeking to improve their upstream coordination (Section 2.2.4).

2.2.1 Conceptualization of blockchain technology

Blockchain technology, at its foundation, functions as a shared ledger system that records and validates transactions across a network of participants rather than through a centralized authority (Swan, 2015; Saberi et al., 2019). Each transaction is grouped into a block, which is cryptographically linked to the preceding block, thereby creating a sequential and tamper-resistant chain of records. This architecture means that altering any single entry would require simultaneously modifying all subsequent blocks across most of the network, a task that is computationally prohibitive under normal operating conditions. The result is a system that offers a high degree of data integrity and resistance to unauthorized manipulation.

Several properties distinguish blockchain from conventional database systems and make it relevant to supply chain contexts. The first is decentralization; rather than relying on a single entity to maintain and validate records, blockchain distributes ledger copies among all participating nodes, eliminating the need for a trusted intermediary (Cole et al., 2019). Transparency constitutes another core property: all authorized participants can access the same transaction history, narrowing the gap in information access between exchange partners (Wang et al., 2019). The third is immutability; once a transaction has been validated and recorded, it becomes an unalterable part of the ledger, providing a permanent audit trail (Pournader et al., 2019). The fourth is consensus; transactions are validated through predefined algorithmic mechanisms, such as proof of work, proof of stake, or practical Byzantine fault tolerance, which ensure that all network members agree on the ledger's valid state before any modification is accepted (Andoni et al., 2019).

Beyond functioning as a static record-keeping system, blockchain enables the deployment of smart contracts, which are automated agreements written into the ledger's code that execute predefined actions when specified conditions are met. When predefined conditions are met, smart contracts automatically trigger the corresponding actions, such as releasing a payment upon confirmed delivery, without requiring manual intervention or third-party verification (Chang et al., 2019). In the context of supply chain management, smart contracts can automate procurement workflows, enforce compliance with contractual terms, and reduce the administrative overhead associated with dispute resolution and reconciliation (Agrawal et al., 2022).

The concept of blockchain was first introduced through Nakamoto's (2008) proposal for Bitcoin, a peer-to-peer electronic payment system. While Bitcoin demonstrated that decentralized consensus could sustain reliable financial transactions, the technology's applicability has since expanded well beyond cryptocurrencies. The development of Ethereum, with its support for programmable smart contracts, enabled the construction of decentralized applications across diverse sectors (Swan, 2015). In supply chain management, scholarly interest grew substantially from 2017 onward, as researchers recognized that blockchain's capacity for transparent and verifiable record-keeping could address longstanding problems of trust, traceability, and coordination in multi-party networks (Moosavi et al., 2021; Lohmer et al., 2022).

Saberi et al. (2019) were among the first to systematically examine the relationship between blockchain and sustainable supply chain management. Their work identified four categories of adoption barriers: inter-organizational, intra-organizational, technical, and external. This categorization proved influential, highlighting that the challenge of blockchain implementation is not purely technical but also organizational and institutional. Similarly, Wang et al. (2019) conducted a systematic review that identified trust as the predominant factor driving blockchain adoption in supply chains, with the technology's value concentrated in four domains: extended visibility and traceability, supply chain digitalization and disintermediation, improved data security, and smart contract automation.

Within the energy sector specifically, Andoni et al. (2019) provided one of the earliest and most comprehensive academic reviews, examining 140 blockchain research projects and startups. Their classification revealed that decentralized energy trading accounted for approximately one-third of all initiatives, followed by cryptocurrency-based investment models, IoT applications, and metering and billing solutions. The study also noted that the majority of energy-sector blockchain projects were built on the Ethereum platform and that a discernible shift toward permissioned, enterprise-oriented architectures was underway. These findings situate blockchain not merely as a theoretical concept but as a technology already being actively experimented with in the energy industry.

2.2.2 Types of blockchain technology

Blockchain architectures are not monolithic; they vary considerably in their access rules, governance structures, and consensus mechanisms. Understanding these variations is essential for evaluating which blockchain type is most suitable for supplier-buyer relationship management, as the choice of architecture determines who can participate, who can validate transactions, and the degree of transparency maintained.

The broadest classification distinguishes between public, private, and consortium (or hybrid) blockchains (Andoni et al., 2019; Gonczol et al., 2020). Public blockchains, such as Bitcoin and Ethereum in their original form, are fully open networks in which any participant can join, submit transactions, and participate in the consensus process. The transparency and censorship resistance of public blockchains make them well-suited for applications where universal verifiability is paramount, but they also entail significant drawbacks in transaction speed, energy consumption, and scalability (Kumar & Liu, 2019). These limitations make public blockchains generally impractical for high-frequency supply chain operations that require rapid transaction finality.

Private blockchains, by contrast, restrict network access to authorized participants. A single organization or consortium controls who can join the network, view transaction data, and participate in validation. This architecture offers considerably higher transaction throughput, lower latency, and greater control over data privacy (Santhi & Muthuswamy, 2022). Hyperledger Fabric, developed under the Linux Foundation, is one of the most widely adopted private blockchain frameworks in supply chain settings, offering modular consensus mechanisms and fine-grained access control that can be tailored to the specific requirements of an interorganizational relationship (Kumar & Liu, 2019).

Consortium blockchains occupy a middle position, distributing validation authority among a pre-selected group of organizations rather than concentrating it in a single entity or opening it to all comers. In a consortium model, multiple supply chain partners jointly govern the blockchain, each operating a validating node while agreeing on shared rules for data access and transaction approval. Kramer et al. (2021) investigated the effects of different blockchain platform types on coordination mechanisms in agri-food supply chains and found that consortium architectures were most commonly associated with successful implementations, particularly in tracking and tracing applications where a focal firm coordinates vertically integrated supply networks. Their analysis concluded that the choice of blockchain platform type is a key determinant of both the economic success of the use case and the efficiency of supply chain network management.

For supplier-buyer relationships in the energy sector, the literature points toward private or consortium architectures as the most appropriate choice. Energy supply chains involve a bounded set of known counterparties, such as component manufacturers, engineering firms, and service contractors, operating under regulatory frameworks that demand accountability and data protection. A fully public blockchain would expose commercially sensitive procurement data to all participants, which is neither practical nor desirable (Andoni et al., 2019). A consortium model, by contrast, allows energy companies and their key suppliers to share a common ledger for transaction verification while retaining control over access permissions and data visibility, thus balancing the benefits of transparency with the necessities of commercial confidentiality.

2.2.3 Implementation process of blockchain technology for managing SBRs

The implementation of blockchain technology within supplier-buyer relationships is not a straightforward technical deployment but a multistage organizational process that requires strategic planning, stakeholder alignment, and iterative development. Several scholars have proposed frameworks for understanding the stages through which blockchain adoption unfolds in supply chain settings.

Manzoor et al. (2022) proposed a four-stage model consisting of pre-adoption, adoption, implementation, and application phases. During the pre-adoption stage, organizations assess the strategic fit of blockchain by evaluating their existing supply chain challenges, the readiness of their technological infrastructure, and the willingness of supply chain partners to participate. The adoption stage involves formal decision-making, in which leadership commits to blockchain integration and selects the appropriate platform type and governance model. The implementation stage encompasses the technical development, piloting, and testing of the blockchain solution, including smart contract design, integration with existing enterprise systems, and the onboarding of supply chain partners. Finally, the application stage involves the full-scale deployment and ongoing optimization of the blockchain-enabled system in day-to-day supply chain operations.

Agi and Jha (2022) developed a complementary framework grounded in Diffusion of Innovation (DOI) theory and empirically validated through expert consultation with 37 French supply chain professionals. Their analysis identified 20 enablers of blockchain adoption organized across technological, organizational, supply chain, and external environment dimensions. The findings highlighted that the relative advantage of the technology and external pressure from customers and regulatory bodies were the most prominent enablers. In particular, the potential of blockchain to reduce transaction costs and the growing consumer interest in supply chain traceability data emerged as critical motivating factors.

Hastig and Sodhi (2020), drawing on evidence from the cobalt mining and pharmaceutical industries, identified five key business requirements that blockchain-based traceability systems must satisfy: curbing illegal practices, improving sustainability performance, increasing operational efficiency, enhancing supply chain coordination, and sensing market trends. They further specified six critical success factors for implementation: companies' capabilities, inter-firm collaboration, technology maturity, supply chain practices, leadership commitment, and the governance of traceability efforts. Their framework underscores that successful blockchain implementation depends as much on organizational and relational conditions as on the technology itself.

Within the energy sector, the implementation process carries additional complexities. Juszczyk et al. (2022) surveyed upper management professionals in the renewable energy industry using a Blockchain Maturity Questionnaire and found that while awareness of blockchain was relatively high, actual deployment remained in early stages. The authors proposed a “Roadmap for Blockchain Adoption” consisting of sequential steps: knowledge-building and awareness-raising, identification of suitable use cases, pilot project development, stakeholder engagement and ecosystem building, and finally scaling toward full operational integration. Their findings suggest that the renewable energy sector, despite its technological sophistication, faces barriers to adoption related to regulatory uncertainty, limited standardization, and the difficulty of convincing diverse supply chain partners to invest in a shared digital infrastructure.

Kouhizadeh et al. (2021) applied the technology-organization-environment (TOE) framework alongside force field theory to investigate blockchain adoption barriers specifically for sustainable supply chains. Using the DEMATEL methodology with input from both academics and industry experts, they found that supply chain barriers, such as the lack of collaboration among supply chain partners, and technological barriers, such as scalability limitations, were the most critical impediments. Their study also revealed notable differences between academic and practitioner perspectives on barrier severity, with practitioners placing greater emphasis on organizational inertia and the high initial implementation costs.

Taken together, these frameworks suggest that implementing blockchain for SBR management is best approached as an incremental, multi-stakeholder process. Rather than attempting a wholesale replacement of existing procurement and contract management systems, organizations are advised to begin with narrowly defined pilot projects, such as automating a specific contractual workflow between a buyer and a key supplier and gradually expanding the scope as trust in the technology grows and technical capabilities mature.

2.2.4 Importance of adopting blockchain technology for managing SBRs

The most frequently cited benefit of blockchain in the SBR context is its capacity to enhance trust between exchange partners. As discussed in Section 2.1, trust is a cornerstone of relationship quality, yet it is difficult to establish and maintain in complex, multi-party supply chains where information asymmetries persist. Blockchain's transparent and immutable ledger creates what Dubey et al. (2020) termed “swift trust”, a form of interorganizational confidence that arises not from personal familiarity or long relational history, but from the verifiable integrity of shared data. In their empirical study of 256 humanitarian organizations, Dubey et al. found that blockchain-enabled operational transparency significantly enhanced swift trust among supply chain actors, which in turn improved collaboration and supply chain resilience. While their study focused on humanitarian logistics, the underlying mechanism is directly transferable to industrial SBRs: when both buyer and supplier can independently verify the accuracy and completeness of shared transaction records, the need for costly monitoring and enforcement mechanisms diminishes.

Closely related to trust is the benefit of traceability and provenance verification. In energy supply chains, where components may be sourced from multiple international suppliers and must meet stringent quality and regulatory standards, the ability to trace the origin and handling history of every item is of considerable value. Pournader et al. (2019) identified traceability and transparency as one of four central clusters in their co-citation analysis of the blockchain-supply chain literature. Cole et al. (2019) similarly argued that blockchain enhances product safety and security by enabling end-to-end visibility across the supply chain, from raw material extraction to final delivery. For energy companies procuring critical infrastructure components, such as turbine blades, transformer units, or battery modules, blockchain-based traceability can provide verifiable assurance that components meet specifications and have not been tampered with during transit.

Beyond traceability, blockchain can enhance operational efficiency in SBR management by automating procurement processes through smart contracts. Chang et al. (2019) demonstrated through a comparative analysis that blockchain-based process re-engineering, incorporating smart contracts for order confirmation, shipment tracking, and payment settlement, could substantially reduce the number of intermediary steps and the associated reconciliation costs in supply chain transactions. Ezzati et al. (2024) further developed this concept by proposing an Ethereum-based online purchasing platform that uses smart contracts to automate supplier performance evaluation, enabling buyers to assess supplier reliability with real-time transaction data rather than relying solely on periodic manual reviews. These applications are particularly relevant for energy companies managing large supplier portfolios, where the administrative burden of contract management and performance monitoring across dozens or hundreds of suppliers can be substantial.

Blockchain adoption may also yield benefits in terms of regulatory compliance and sustainability reporting. The energy sector operates under extensive regulatory oversight, and companies are increasingly required to document the environmental and social performance of their supply chains. Park and Li (2021) examined blockchain's potential to support sustainability performance indicators across environmental, social, and governance dimensions, concluding that the technology's transparent record-keeping capabilities can streamline compliance processes and reduce the risk of misreporting. For energy firms subject to emissions-tracking obligations or renewable-energy certification requirements, a shared blockchain ledger that links procurement records to environmental performance data could simplify audit procedures and strengthen stakeholder confidence in reported outcomes.

The capacity to reduce imbalances in the availability of information represents a further dimension of blockchain's relevance. As established in Section 2.1, uneven access to verified data is a fundamental source of inefficiency and conflict in SBRs. Wan et al. (2020) conducted a systematic review of blockchain-enabled information sharing within supply chains and concluded that the technology's most significant contribution is its ability to ensure that all members of the chain can obtain verified information, thereby enhancing collaborative partnerships. In the specific context of SBRs, this means that disputes arising from conflicting records, such as disagreements over delivery quantities, quality measurements, or contract terms, can be largely pre-empted when both parties draw on the same immutable data source.

Taken together, the evidence reviewed in this section indicates that blockchain adoption is strategically relevant to SBR management by addressing core relational and transactional challenges that conventional governance mechanisms handle imperfectly. For energy companies, where upstream relationships are technically complex and heavily regulated, these benefits carry particular weight. The following sections examine what factors drive energy companies to adopt blockchain for these purposes (Section 2.3), what barriers constrain them from doing so (Section 2.4), and what specific performance outcomes adoption may yield (Section 2.5).

2.3 Drivers of adopting blockchain technology by energy companies for managing SBRs

The preceding sections have established what blockchain technology is, how it may be implemented within supplier-buyer relationships, and why its adoption holds strategic relevance for energy companies. This section shifts the focus from the general significance of the technology to the specific factors motivating energy companies to pursue blockchain adoption in managing their supplier relationships. Drawing on the technology-organization-environment (TOE) framework, which has become the dominant analytical lens for studying blockchain adoption at the organizational level (Gokalp et al., 2020; Malik et al., 2021; Chittipaka et al., 2022), this section identifies and discusses the key technological, organizational, and external drivers that shape the adoption decision. The section also addresses drivers that arise from the distinctive structural characteristics of the energy sector itself.

Technological drivers

The decision to adopt blockchain for SBR management is shaped by the technology's attributes and its fit with the adopting firm's existing digital infrastructure. Research grounded in the diffusion of innovation (DOI) framework consistently identifies relative advantage, that is, the extent to which blockchain is perceived as superior to the systems it would replace, as one of the strongest predictors of adoption intention (Agi & Jha, 2022; Bhardwaj et al., 2021). In the context of supplier relationship governance, relative advantage manifests in several forms: eliminating redundant reconciliation processes between trading partners, reducing paperwork and intermediary costs in procurement transactions, and enabling real-time verification of supplier compliance with contractual terms.

A second important technological driver is compatibility with existing systems. Blockchain adoption does not occur in a vacuum, it must integrate with established enterprise resource planning (ERP) systems, procurement platforms, and data management architectures. Malik et al. (2021) found that perceived compatibility was a significant determinant of organizational blockchain adoption in their sample and observed that firms with higher levels of digital maturity perceived fewer integration challenges. In the energy sector, where smart meters, IoT-enabled grid infrastructure, and digital monitoring systems are increasingly prevalent (Andoni et al., 2019), this existing digital foundation can serve as an enabling condition for blockchain deployment. In particular, the interoperability between IoT data streams and blockchain ledgers has been identified as a critical interface that enables real-time supply chain data to be captured and validated on chain (Gariya et al., 2025). Energy companies that have already invested in digital supply chain monitoring are therefore likely to perceive lower barriers and a stronger fit when evaluating blockchain solutions for SBR management.

A third technological factor concerns the maturity and perceived reliability of the technology itself. Fernando et al. (2021), in their study of manufacturing firms in Malaysia, found that a lack of technical competence within the adopting organization was one of the principal barriers to blockchain implementation. Dehghani et al. (2022) complemented the evidence by demonstrating that perceived technological volatility, the sense that blockchain standards and platforms are still evolving rapidly and unpredictably, negatively affected adoption intention among North American organizations. For energy companies considering blockchain to manage long-term supplier relationships, the question of whether the technology is sufficiently mature and stable to justify multi-year contractual commitments is a nontrivial consideration. Based on the above discussion regarding the technological attributes that shape the adoption decision, the following propositions are developed:

Proposition 1: *The perceived relative advantage of blockchain over existing procurement and supplier management systems increases the likelihood of blockchain adoption by energy companies for managing SBRs.*

Proposition 2: *Greater compatibility between blockchain technology and the energy company's existing digital infrastructure increases the likelihood of blockchain adoption to manage SBRs.*

Organizational drivers

At the organizational level, the role of top management support has emerged as one of the most consistently significant drivers of blockchain adoption across empirical studies. Chittipaka et al. (2022), in their survey of 525 supply chain professionals in India, confirmed that higher authority support had a significant positive influence on the adoption decision. The rationale is straightforward: implementing blockchain for SBR management requires cross-functional coordination, capital investment, and a willingness to restructure established procurement workflows, none of which is feasible without executive-level sponsorship. In a related study, Badi et al. (2020) investigated smart contract adoption in the UK construction sector and found that top management support was one of only four factors with a statistically significant effect on adoption intention, alongside supply chain pressure, competitive pressure, and observability of the technology's benefits.

Organizational innovativeness and learning capability represent a second cluster of organizational drivers. Malik et al. (2021) introduced organizational innovativeness, defined as a firm's openness to experimenting with new technologies and processes, as a predictor of blockchain adoption that had been overlooked in prior research. Their findings confirmed its significant positive effect. Polas et al. (2025), drawing on the resource-based view, further demonstrated that innovation capability, information-sharing capability, and technological capability all facilitated blockchain adoption among electronics firms in Bangladesh, with downstream effects on firm performance. These results suggest that blockchain adoption is not merely a matter of technological procurement, but of organizational readiness firms must possess both the internal competences and the cultural orientation to absorb and exploit new technology within their supplier management practices.

Firm size and the availability of financial resources also condition the adoption decision. Larger firms, with their greater resource base and more diversified supplier portfolios, tend to be better positioned to absorb the upfront costs of blockchain development, piloting, and organizational change management (Fernando et al., 2022). Conversely, Boakye et al. (2023) found that among Ghanaian SMEs, cost was a significant inhibitor of blockchain adoption for supply chain finance, reflecting the disproportionate burden that development costs place on smaller organizations. In the energy sector, where major procurement contracts can involve millions of euros and span multiple years, the financial threshold for blockchain experimentation may be comparatively manageable for large energy companies but prohibitive for smaller actors in the supply chain. Drawing on the organizational factors discussed above, the following propositions are developed:

Proposition 3: *Strong top management support for digital innovation increases the likelihood of blockchain adoption among energy companies to manage SBRs.*

Proposition 4: *Higher levels of organizational innovativeness and digital capability increase the likelihood of blockchain adoption for managing SBRs.*

External and environmental drivers

The TOE framework directs attention not only to characteristics of the technology and the organization but also to the external environment in which the adoption decision is embedded. Regulatory pressure has been identified as a particularly potent environmental driver in the blockchain adoption literature. Gokalp et al. (2020), applying the TOE framework with an AHP-based ranking methodology, concluded that environmental determinants were more critical than technological or organizational factors in explaining blockchain adoption in supply chain management. Among these, regulatory requirements and compliance obligations stood out. In the energy sector, where companies face an expanding set of sustainability disclosure requirements, emissions tracking mandates, and renewable energy certification obligations, the regulatory landscape creates a structural demand for the kind of transparent, auditable, and tamper-resistant record-keeping that blockchain can provide (Gariya et al., 2025; Barcelo et al., 2023).

Competitive pressure represents a second external driver. Badi et al. (2020) found that competitive pressure significantly influenced firms' intention to adopt smart contracts in supply chains, as firms perceived early adoption as a means of securing first-mover advantages in procurement efficiency and supplier coordination. Chittipaka et al. (2022) similarly reported that rivalry pressure among supply chain actors had a significant positive effect on blockchain adoption intention. For energy companies operating in liberalized, increasingly competitive markets, the adoption of blockchain by a major competitor or an industry consortium can create a signaling effect, prompting other firms to explore similar initiatives to avoid falling behind in operational capabilities and stakeholder expectations.

Trading partner readiness constitutes a third environmental driver that is particularly relevant for SBR management. Blockchain is, by nature, a multi-party technology; its value depends on the willingness and capacity of supply chain partners to participate in the shared ledger. Malik et al. (2021) found that trading partner readiness significantly predicted organizational blockchain adoption, and Chittipaka et al. (2022) confirmed the significant influence of business partner pressure on adoption decisions in the Indian supply chain context. In the energy sector, the readiness of key suppliers, whether large equipment manufacturers or specialized technology vendors, to engage with blockchain-based procurement systems is a prerequisite for meaningful adoption. A buyer that implements a blockchain ledger without supplier participation gains little more than a conventional internal database. Based on the external and environmental factors discussed above, the following propositions are developed:

Proposition 5: *Stronger regulatory pressure for supply chain transparency and sustainability reporting increases the likelihood of blockchain adoption by energy companies for managing SBRs.*

Proposition 6: *Greater competitive intensity in the energy market increases the likelihood of blockchain adoption for managing SBRs.*

Proposition 7: *Higher readiness and willingness of key suppliers to participate in shared blockchain platforms increases the likelihood of blockchain adoption by energy companies for managing SBRs.*

Energy-sector-specific drivers

Beyond the general TOE categories, several drivers are specific to the structural context of the energy sector. The ongoing transition from centralized fossil-fuel systems to distributed renewable-energy architectures has fundamentally reshaped procurement requirements. Energy companies must now source an increasingly diverse range of components, from solar panels and wind turbine parts to battery storage systems and smart grid equipment, from a broader and more geographically dispersed supplier base (Andoni et al., 2019). This procreation of suppliers and component categories intensifies the coordination challenge and raises the stakes of effective SBR governance. Blockchain's capacity to provide a single, shared source of transactional truth across a fragmented supplier network directly addresses this structural need.

The cross-border nature of energy procurement further reinforces the case for blockchain adoption. Energy infrastructure projects routinely involve suppliers from multiple jurisdictions, each operating under different regulatory regimes, quality standards, and contractual norms. Ullah et al. (2024), in their study of blockchain adoption for smart grid applications, found that relative advantage was the strongest predictor of adoption intention among energy sector experts, reflecting the technology's perceived superiority in managing complex, multi-jurisdictional transaction environments. The ability of blockchain to create a jurisdiction-neutral, cryptographically verified record of procurement transactions is especially valuable in contexts where traditional contract enforcement mechanisms are weak or slow.

Finally, the energy sector's heightened exposure to sustainability accountability creates a sector-specific pull toward blockchain adoption. Energy companies are among the most visible targets of sustainability scrutiny, and their procurement practices are increasingly evaluated by investors, regulators, and civil society organizations. The need to verify the environmental credentials of sourced materials, to trace the origin of critical minerals used in battery production, and to document compliance with ethical sourcing standards throughout the supply chain creates a demand for precisely the kind of end-to-end traceability that blockchain can deliver (Rejeb et al., 2024; Gariya et al., 2025). Based on the energy-sector-specific considerations discussed above, the following propositions are developed:

Proposition 8: *Greater complexity and geographic dispersion of the energy company's supplier network increases the likelihood of blockchain adoption for managing SBRs.*

Proposition 9: *Stronger sustainability-accountability pressures in the energy sector increase the likelihood of blockchain adoption for managing SBRs.*

2.4 Barriers to adopting blockchain technology by energy companies for managing SBRs

While the preceding section identified the factors that motivate energy companies to adopt blockchain for supplier relationship management, the decision to adopt is simultaneously constrained by a range of bottlenecks. Prior literature has established that blockchain adoption barriers can be broadly categorized into technological, organizational, and environmental dimensions (Saberi et al., 2019; Kouhizadeh et al., 2021), a classification that this section retains for consistency. However, rather than restating these general categories, the present discussion examines the specific barrier mechanisms most consequential in the energy sector's upstream supply chain, drawing on recent empirical and analytical studies that extend the earlier foundational work.

Technological barriers

Scalability remains the most widely cited technological impediment to blockchain deployment in supply chain settings. The throughput limitations of mainstream blockchain platforms, particularly those relying on proof-of-work consensus, restrict the number of transactions that can be processed per unit of time (Andoni et al., 2019). In the context of energy sector SBRs, where a single procurement cycle can involve hundreds of transactional events, from purchase orders and quality certifications to delivery confirmations and payment releases, insufficient throughput can introduce latency that negates the efficiency gains blockchain is intended to deliver. Moraes et al. (2024), in their DOI-informed framework based on a systematic review of 155 publications, identified scalability as a barrier that must be addressed at the very earliest stage of adoption, before the organization commits to a particular platform or architecture. While newer consensus mechanisms such as proof of stake and proof of authority have considerably improved transaction speeds (Gariya et al., 2025), the trade-offs among scalability, decentralization, and security, often referred to as the "blockchain trilemma", remain a fundamental design constraint.

Interoperability with existing enterprise systems constitutes a second technological barrier of particular relevance to SBR management. Energy companies typically operate complex IT landscapes comprising enterprise resource planning (ERP) platforms, procurement management software, supplier databases, and IoT-enabled monitoring systems. Integrating a blockchain layer with these heterogeneous systems requires substantial technical effort, including developing application programming interfaces (APIs), standardizing data formats, and implementing middleware solutions (Mohammed et al., 2023; Sharabati et al., 2024). Jabbar et al. (2020), in one of the first broad-ranging surveys of blockchain-enabled supply chains, highlighted that the diversity of protocol regulations across multiple distribution channels and stakeholder systems represents a persistent source of data fragmentation that blockchain alone does not resolve. For energy companies managing supplier relationships across multiple jurisdictions, the absence of common data standards between blockchain platforms and legacy procurement systems constitutes a practical obstacle that extends well beyond the initial implementation phase.

The energy consumption of blockchain networks themselves presents a third technological concern, one that carries particular irony for an industry under pressure to demonstrate environmental responsibility. While early proof-of-work systems such as Bitcoin consumed electricity at levels comparable to small nations, more recent permissioned and proof-of-stake architectures have reduced energy requirements by orders of magnitude (Gariya et al., 2025). Nonetheless, the perception of blockchain as an energy-intensive technology persists, and it can create reputational hesitancy among energy firms whose sustainability credentials are closely scrutinized by investors and regulators. Etemadi et al. (2021), in their interpretive structural modeling of blockchain adoption barriers for supply chain cybersecurity, positioned technology immaturity and scalability concerns at the base of their hierarchical model, indicating that these foundational challenges exert cascading influence on all higher-level barriers. Based on the technological impediments discussed above, the following propositions are developed:

Proposition 10: *Greater perceived scalability limitations of blockchain technology reduce the likelihood of blockchain adoption by energy companies for managing SBRs.*

Proposition 11: *Greater difficulty in integrating blockchain with existing enterprise procurement systems decreases the likelihood of blockchain adoption for managing SBRs.*

Organizational barriers

At the organizational level, the lack of blockchain-specific knowledge and expertise represents a frequently identified bottleneck. Mathivathanan et al. (2021), using Total Interpretive Structural Modeling (TISM) and MICMAC analysis, concluded that the lack of business awareness and familiarity with what blockchain can deliver is the single most influential barrier, as it impedes the organization's capacity to evaluate potential use cases, select appropriate platforms, and design governance structures for shared ledger participation. This finding resonates with the energy sector context, while energy companies may possess strong engineering and operational competencies, distributed ledger technologies require a distinct set of skills spanning cryptography, smart contract programming, and decentralized systems architecture that may not be readily available within existing technical teams. Fernando et al. (2021) similarly found that unfavorable support from top management and a lack of technical competence were the primary barriers for early blockchain adopters in Malaysian manufacturing, suggesting that knowledge deficits operate at both the strategic and operational levels of the organization.

The high upfront cost of blockchain implementation presents a related organizational barrier. Blockchain deployment for SBR management requires investment in platform development or licensing, smart contract design and auditing, integration with existing procurement systems, and the training of both internal staff and external supply chain partners. Andreoulaki et al. (2024), in their multicriteria evaluation of blockchain adoption barriers in the energy sector, using PESTLE and SWOT analyses combined with AHP-based group decision-making, found that economic concerns, including high upfront costs and uncertain return on investment, were significant but not dominant barriers. Singh et al. (2023), examining the construction supply chain, similarly identified high costs for maintaining sustainability as one of the most influential barriers. For energy companies, where procurement budgets are already subject to intense scrutiny and where investment decisions require long planning horizons, the difficulty of demonstrating a clear business case for blockchain within a reasonable payback period can stall adoption initiatives before they reach the pilot stage.

Organizational resistance to change constitutes a third barrier that operates at a more behavioral level. Choi et al. (2020) empirically demonstrated that organizational passivity, encompassing established routines, legacy system dependencies, and cultural reluctance to abandon familiar processes, significantly impeded blockchain adoption in supply networks. In the energy sector, where procurement practices are often deeply embedded in regulatory compliance frameworks and have been refined over decades, the prospect of transitioning to a fundamentally different transactional infrastructure can encounter resistance from procurement professionals, legal departments, and supply chain managers who perceive the risks of disruption as outweighing the potential benefits. Drawing on the organizational obstacles discussed above, the following propositions are developed:

Proposition 12: *Lower levels of blockchain-specific knowledge and expertise within the energy company decrease the likelihood of blockchain adoption for managing SBRs.*

Proposition 13: *Higher perceived implementation costs and uncertain return on investment decrease the likelihood of blockchain adoption by energy companies for managing SBRs.*

External and environmental barriers

Regulatory uncertainty has consistently emerged as the most critical external barrier to blockchain adoption, both in supply chain management broadly and in the energy sector specifically. Andreoulaki et al. (2024) found that legal barriers, particularly the complexity and deficiency of existing regulations governing blockchain-based transactions, ranked as the most significant impediment in their expert-validated assessment of the energy sector. Sahebi et al. (2020), using a fuzzy Delphi and best-worst method approach, similarly identified regulatory uncertainty as the single most important barrier to blockchain adoption in humanitarian supply chains. The regulatory challenge is multifaceted: blockchain-based procurement records may not yet have legal standing equivalent to that of traditional documentation in all jurisdictions, smart contracts may not satisfy existing contract law requirements, and the cross-border nature of energy procurement can subject a single supplier relationship to multiple, potentially conflicting regulatory regimes.

The tension between blockchain's transparency and data protection regulations, particularly the European Union's General Data Protection Regulation (GDPR), constitutes a well-documented regulatory barrier. GDPR cherishes the right to data erasure, which stands in fundamental tension with blockchain's immutability principle (Chiarini et al., 2022). While technical solutions such as off-chain data storage, zero-knowledge proofs, and pseudonymization have been proposed, they add complexity and may partially undermine the transparency benefits that motivated blockchain adoption in the first place. For Finnish energy companies, which operate under EU data protection law and manage supplier relationships involving sensitive commercial and personal data, this tension is not merely theoretical but carries tangible compliance risk.

The absence of industry-wide standards for blockchain interoperability represents a further external barrier. Karumba et al. (2023) conducted a systematic review of barriers to blockchain-based decentralized energy trading and found that while progress had been made on technical challenges, administrative and standardization barriers remained grossly underexplored in the literature. Without agreed-upon protocols for data formatting, transaction validation, and cross-platform communication, each energy company risks implementing a proprietary solution that cannot interoperate with its suppliers' systems, thereby limiting network effects and reducing the collective value of adoption. Based on the external and regulatory constraints discussed above, the following propositions are developed:

Proposition 14: *Greater regulatory uncertainty regarding the legal status of blockchain-based procurement records decreases the likelihood of blockchain adoption by energy companies for managing SBRs.*

Proposition 15: *Stronger tensions between blockchain immutability and data protection regulations (e.g., GDPR) decrease the likelihood of blockchain adoption for managing SBRs.*

Energy-sector-specific barriers

Several barriers arise from the distinctive structural characteristics of the energy industry. Energy supply chains are anchored in physical infrastructure, including power grids, pipeline networks, and generation facilities, whose operational requirements impose constraints that digital technologies alone cannot resolve. Andoni et al. (2019) noted that the physical exchange of electricity has historically inhibited blockchain adoption in the energy sector more than in purely financial applications, because energy transactions must ultimately be reconciled with real-time grid conditions, load balancing requirements, and system stability constraints. For upstream SBR management, an analogous challenge exists: the procurement of heavy equipment, specialized components, and infrastructure services involves physical logistics, quality inspections, and site-specific installation processes that blockchain can record and verify but cannot substitute.

The energy sector's incumbent market structure, characterized by regulated monopolies, long-established contractual frameworks, and vertically integrated supply chains, creates additional path dependencies that resist technological disruption. Vionis et al. (2023) observed that the industry's regulatory and market architecture was designed around centralized models of coordination, and that integrating decentralized blockchain-based governance requires not merely technological adaptation but institutional reform. For energy companies contemplating blockchain-based SBR management, this means that even a technically sound and organizationally supported initiative may founder on the incompatibility between blockchain's decentralized logic and the industry's centralized regulatory and contractual conventions.

Compounding these structural barriers, the multi-jurisdictional nature of energy procurement amplifies the regulatory challenges discussed above. Energy companies routinely source components from suppliers in different countries, each governed by distinct contract law, data protection, and trade compliance regimes. Bai et al. (2022), in their case study of a Chinese state-owned enterprise, identified cross-chain interoperability and data governance as major barriers to blockchain adoption in supply chain finance, noting that the new business processes required by blockchain fundamentally transform established procurement workflows. For Finnish energy companies engaged in cross-border procurement with European, Asian, and North American suppliers, the challenge of designing a blockchain governance framework that satisfies multiple regulatory regimes simultaneously is considerable. Based on the structural characteristics of the energy sector discussed above, the following propositions are developed:

Proposition 16: *Greater physical infrastructure complexity in the energy supply chain decreases the likelihood of blockchain adoption for managing SBRs.*

Proposition 17: *Stronger path dependencies in the energy sector's incumbent market and regulatory structures decrease the likelihood of blockchain adoption for managing SBRs.*

2.5 Performance outcomes of adopting blockchain by energy companies for managing SBRs

Sections 2.3 and 2.4 examined the drivers and constraints of blockchain adoption by energy companies for supplier relationship management. This section turns to the outcomes that adoption may produce once the technology is in place. While Section 2.2.4 discussed the general strategic importance of blockchain for SBRs, the present discussion focuses on specific performance dimensions that can be empirically assessed. Drawing on the emerging literature on blockchain-enabled supply chain performance, seven outcome dimensions are identified and discussed below: product innovation, cost performance, relationship improvement, organizational learning, decision-making quality, quality of communication, and transaction security. Each dimension is grounded in prior empirical or conceptual findings and formulated as a research proposition that links blockchain adoption to a discrete performance outcome in the energy sector SBR context.

Impact on product innovation

Supply chain innovation is increasingly understood as a collaborative endeavor that depends on the quality of information exchange and joint problem-solving capacity between buyers and their suppliers. The literature reviewed in Section 2.1 established that SBR quality is a significant predictor of supplier-driven innovation (Krause et al., 2007). Blockchain technology may enhance this innovative capacity through several channels. First, the transparent sharing of technical specifications, testing data, and quality records on a common ledger can reduce the information barriers that typically constrain joint product development between energy companies and their equipment or technology suppliers. Jum'a (2023), in a survey of 284 Jordanian manufacturing firms, found that blockchain adoption positively influenced supply chain innovation capabilities, which in turn contributed to improved supply chain performance. Their findings indicated that the integration of blockchain with supply chain processes supported innovative activities by enabling more reliable data flows and reducing the transactional friction that typically slows collaborative development work.

Tokkozhina et al. (2022) conceptualized innovation and data access as one of three core dimensions of blockchain's impact on supply chain management, alongside operations and supply chain relationships. Their analysis suggested that blockchain facilitates innovation by opening new channels of data access that were previously unavailable or unreliable, thereby enabling supply chain partners to identify opportunities for process and product improvements that would have remained invisible under conventional information-sharing arrangements. In the energy sector, where product innovation increasingly involves co-development between energy companies and specialized technology suppliers (for instance, in battery storage, smart grid components, or hydrogen infrastructure), blockchain's role in creating a trusted data environment for collaborative innovation may prove particularly consequential. Based on the discussion of blockchain's role in facilitating collaborative development and data exchange between supply chain partners, the following proposition is developed:

Proposition 18: *Blockchain adoption for managing SBRs positively influences product innovation outcomes for energy companies.*

Impact on cost

Cost reduction represents one of the most tangible and frequently investigated performance outcomes of blockchain adoption in supply chain contexts. Mishra et al. (2023), in their meta-analysis synthesizing findings from 37 empirical studies, concluded that blockchain adoption had the strongest impact on operational performance, with cost reduction constituting a central component. The cost-saving mechanisms operate at several levels. At the transactional level, smart contracts automate order processing, invoice reconciliation, and payment settlement, thereby reducing the administrative labor costs associated with manual procurement management. At the intermediary level, blockchain's capacity for direct buyer-supplier verification reduces the need for third-party auditors, certification bodies, and reconciliation agents, each of which adds fees to the procurement process.

Wamba et al. (2020), drawing on survey data from supply chain practitioners in India and the United States, demonstrated that blockchain-enabled supply chain transparency significantly improved overall supply chain performance, with cost efficiency as a key measured dimension. Vu et al. (2024), using system dynamics modeling in the food supply chain, provided more qualified evidence: blockchain positively affected inventory levels and lead times in the short term and costs in the long term, though they cautioned that reducing inventory buffers without careful calibration could compromise service levels. For energy companies, where procurement contracts frequently involve large capital commitments and extended payment cycles, the automation of contract enforcement and settlement through smart contracts may deliver substantial savings in both direct transaction costs and the indirect costs of dispute resolution and contractual renegotiation. Drawing on the evidence regarding transactional cost savings, process automation, and disintermediation discussed above, the following proposition is developed:

Proposition 19: *Blockchain adoption for managing SBRs reduces procurement and transaction costs for energy companies.*

Relationship improvement

The capacity of blockchain to improve the quality of supplier-buyer relationships is grounded in the same trust and transparency mechanisms discussed earlier in this thesis, but viewed here as a measurable performance outcome rather than a general property of the technology. Kamble et al. (2021), in their empirical study of the automotive industry, found that blockchain technology positively influenced supply chain integration, which fully mediated the relationship between blockchain adoption and sustainable supply chain performance. Their use of dynamic capability theory to frame blockchain as an IT resource for reconfiguring upstream and downstream ties offers a particularly relevant lens for the energy sector, where the capacity to integrate diverse supplier inputs is a competitive necessity.

Stranieri et al. (2021), in an exploratory case study of three European food supply chains where a large retailer promoted blockchain adoption, found that the technology contributed to improved management of behavioral uncertainty among supply chain agents. In practical terms, this meant that supply chain partners exhibited lower levels of opportunistic behavior and greater willingness to share sensitive commercial information when they knew that all transactions were permanently recorded and mutually visible. This finding directly echoes the transaction cost economics logic outlined in Section 2.1: when the costs of monitoring and enforcement decline, partners can redirect resources toward value-creating relational activities. For energy companies, whose supplier relationships often span decades and involve substantial co-specialized investments, the relationship-stabilizing properties of blockchain may contribute to measurable improvements in supplier retention, satisfaction, and joint performance. Based on the discussion of how blockchain-enabled transparency and verified data sharing influence interorganizational trust and collaborative behavior, the following proposition is developed:

Proposition 20: *Blockchain adoption for managing SBRs improves the quality and stability of supplier-buyer relationships for energy companies.*

Learning

Organizational learning within the supply chain context refers to the process by which firms acquire, assimilate, and apply new knowledge derived from interactions with their exchange partners. Stranieri et al. (2021) found that blockchain adoption increased firms' knowledge and supply chain management competencies among participating organizations. The mechanism they identified was straightforward, by making the full transaction history of the supply chain accessible and verifiable, blockchain created a searchable repository of operational data that firms could analyze to identify patterns, inefficiencies, and opportunities for improvement. Nandi et al. (2020), in their content analysis of 126 blockchain-enabled supply chain cases, similarly observed that the technology's information-sharing capabilities supported the development of both operational-level and strategic-level supply chain competencies.

Kramer et al. (2021), in their analysis of blockchain platform types in agri-food networks, identified collective learning as one of the key coordination mechanisms influenced by blockchain. They argued that consortium blockchains, in particular, facilitate shared learning by providing all network participants with access to the same data environment, enabling joint analysis of supply chain performance and collaborative identification of opportunities for improvement. For energy companies, where the complexity of procurement processes and the technical specificity of supplied components generate large volumes of data, blockchain-enabled learning could translate into improved supplier evaluation methodologies, better demand forecasting, and more informed procurement strategy formulation. Drawing on the evidence that blockchain creates accessible repositories of verified transaction data that support pattern recognition and competency development, the following proposition is developed:

Proposition 21: *Blockchain adoption for managing SBRs enhances organizational learning outcomes for energy companies.*

Decision making

Effective procurement decision-making depends on the availability of accurate, timely, and complete information about supplier performance, market conditions, and contractual compliance. Blockchain's contribution to decision-making quality stems from its ability to provide supply chain managers with a single, verified source of transactional truth, eliminating the discrepancies and delays that characterize conventional information systems in which each party maintains separate, potentially inconsistent records. Aslam et al. (2021), studying supply chain practices in Pakistan's oil industry, found that blockchain features, including real-time information sharing, traceability, and visibility, significantly enhanced operational performance, with information quality serving as a critical enabler of managerial decision-making.

Surucu-Balci et al. (2024), in their systematic review of digital information sharing in maritime supply chains, identified data-driven decision-making as one of five performance outcomes improved by blockchain and cloud-based platforms. Their analysis revealed that integrating blockchain with IoT data sources created decision-support capabilities not achievable with either technology alone. Blockchain ensured data integrity, while IoT provided real-time granularity. In the energy sector, where procurement decisions must account for fluctuating commodity prices, variable delivery lead times, and evolving regulatory requirements, the combination of verified historical data and real-time operational inputs on a shared blockchain ledger could meaningfully improve the speed and accuracy of procurement decision-making. Based on the discussion of how a single verified source of procurement data improves the accuracy and timeliness of managerial assessments, the following proposition is developed:

Proposition 22: *Blockchain adoption for managing SBRs improves procurement decision-making quality for energy companies.*

Quality of communication

Communication quality between buyers and suppliers encompasses not only the frequency and speed of information exchange but also its accuracy, completeness, and accessibility to all relevant parties. Traditional supply chain communication suffers from fragmentation: different parties use different systems, data formats, and communication protocols, resulting in information silos that impede coordination (Wan et al., 2020). Blockchain addresses this fragmentation by providing a unified platform on which all transaction-related data is recorded in a standardized, time-stamped, and mutually accessible format.

Hader et al. (2022), in a study of the textile supply chain, proposed a blockchain-based framework to improve traceability and information sharing and found that the technology enabled real-time access to verified production and logistics data across all supply chain tiers. Their analysis demonstrated that when all parties draw from the same data source, the volume of clarification requests, data reconciliation efforts, and dispute-related communications decreases, while the substantive quality of information exchanged increases. Alkhudary et al. (2022) complemented this evidence by showing that blockchain's unified communication platform mitigates supply chain disruptions stemming from behavioral uncertainty, weak information security, and data loss. For energy companies managing complex supplier networks with multiple tiers of sub-suppliers, blockchain-enabled communication may reduce procurement cycle times and strengthen the coordination required for large-scale energy infrastructure projects. Drawing on the evidence that a unified blockchain platform reduces data fragmentation and reconciliation efforts across supply chain partners, the following proposition is developed:

Proposition 23: *Blockchain adoption for managing SBRs improves the quality of communication between energy companies and their suppliers.*

Security of transactions

Transaction security encompasses the integrity, confidentiality, and authenticity of procurement data exchanged between buyers and suppliers. In conventional procurement systems, centralized databases are single points of failure vulnerable to both external cyberattacks and internal data manipulation. Blockchain's distributed architecture eliminates this vulnerability by replicating the ledger across multiple nodes, ensuring that no single actor can unilaterally alter the transaction record (Wang et al., 2019; Andoni et al., 2019).

Cole et al. (2019) identified enhanced product safety and security as a primary implication of blockchain in supply chain management, noting that the cryptographic validation of each transaction creates an audit trail resistant to tampering, forgery, and unauthorized modification. Aslam et al. (2021) found that cybersecurity was one of the blockchain features most valued by supply chain practitioners in the oil industry, as it addressed longstanding vulnerabilities in procurement data management. For energy companies, where procurement transactions may involve sensitive technical specifications, proprietary design data, and commercially confidential pricing arrangements, the security guarantees provided by blockchain are directly relevant to operations. Moreover, in an industry where infrastructure components must meet stringent safety standards, the ability to cryptographically verify that documentation has not been altered during the procurement process provides an additional layer of assurance that conventional systems cannot match. Based on the discussion of blockchain's distributed architecture and cryptographic validation as safeguards against data manipulation and unauthorized access, the following proposition is developed:

Proposition 24: *Blockchain adoption for managing SBRs enhances the security of procurement transactions for energy companies.*

2.6 Model of the study

The literature review conducted in the preceding sections has identified a set of factors that collectively shape the adoption and impact of blockchain technology for managing supplier-buyer relationships in the energy sector. These factors have been organized into three analytically distinct categories: drivers of adoption (Section 2.3), barriers to adoption (Section 2.4), and performance outcomes resulting from adoption (Section 2.5). Within each category, specific propositions have been derived from the synthesis of prior empirical and conceptual research. The conceptual model of the study integrates these propositions into a unified framework that serves as the analytical lens for the empirical investigation.

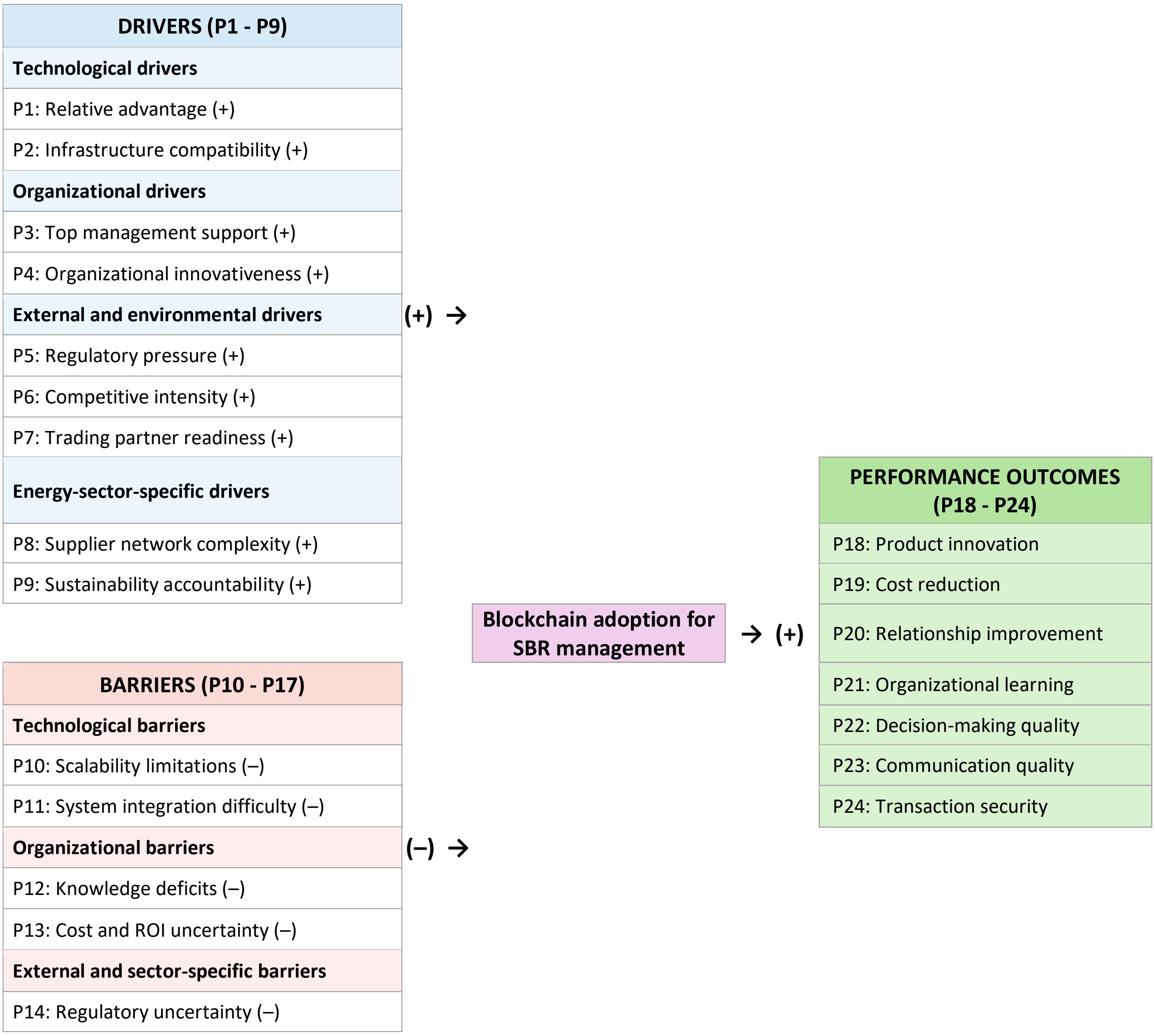
The first component of the model concerns the drivers that motivate energy companies to adopt blockchain for SBR management. Drawing on the technology-organization-environment (TOE) framework (Tornatzky & Fleischer, 1990), nine propositions (P1 through P9) capture the influence of technological factors (relative advantage and infrastructure compatibility), organizational factors (top management support and organizational innovativeness), external environmental factors (regulatory pressure, competitive intensity, and trading partner readiness), and energy-sector-specific factors (supplier network complexity and sustainability accountability pressures). These drivers collectively represent the conditions under which energy companies are more likely to pursue blockchain adoption for their upstream supplier relationships.

Barriers to adoption form the model's next component constrain or impede the adoption decision. Eight propositions (P10 through P17) identify the technological impediments (scalability limitations and enterprise system integration challenges), organizational obstacles (knowledge deficits and cost/ROI uncertainty), external constraints (regulatory uncertainty and data protection tensions), and sector-specific structural rigidities (physical infrastructure complexity and incumbent path dependencies) that may deter energy companies from adopting blockchain, even when the motivating conditions are present. These barriers do not operate in isolation from the drivers; rather, the adoption decision is shaped by the balance between the two.

The third component concerns the performance outcomes that blockchain adoption may generate within the SBR context once implemented. Seven propositions (P18 through P24) address the effects on product innovation, cost performance, relationship quality, organizational learning, decision-making quality, communication quality, and transaction security. These outcomes represent the anticipated benefits that justify the investment and organizational effort required to adopt the technology.

The relationships among these three components are depicted in Figure 1. The model posits that drivers and barriers jointly influence the likelihood of blockchain adoption by energy companies to manage SBRs, and that successful adoption, in turn, generates measurable performance outcomes across the seven identified dimensions. The arrows in the model indicate directional influence: drivers exert a positive influence on the adoption decision, barriers exert a negative influence, and adoption positively influences performance outcomes. The model does not claim strict causality, as the study's qualitative methodology does not support causal inference. Rather, it provides a theoretically grounded framework of expected relationships that will be examined through the empirical analysis.

Figure 1. Conceptual model of the study.



P15: GDPR tensions (–)
P16: Physical infrastructure complexity (–)
P17: Path dependencies (–)

Note: (+) = positive influence on adoption/outcomes; (-) = negative influence on adoption likelihood

The purpose of the empirical investigation is to compare the propositions derived from the literature with the experiences and perceptions of industry and AI specialists operating within the Finnish energy sector. By conducting semi-structured interviews with five experts, the study examines the extent to which the theoretical expectations embedded in the 24 propositions align with, diverge from, or are enriched by the practical realities of blockchain adoption in energy sector supplier management.

3 Research Methodology

This chapter presents and justifies the methodological choices made to empirically investigate the research question. The chapter begins by discussing the research approach, including the philosophical orientation and reasoning logic adopted (Section 3.1), followed by the rationale for selecting a qualitative research method (Section 3.2). It then describes the multiple case study design strategy and the Finnish energy sector as the empirical context (Section 3.3), outlines the data collection procedures and analytical techniques employed (Section 3.4), and concludes with a discussion of the measures taken to ensure validity and reliability (Section 3.5).

3.1 Research approach

Research in the social sciences and in business studies is conducted within paradigmatic frameworks that reflect different assumptions about the nature of reality and the means through which knowledge of that reality can be obtained. Positivist paradigms, which predominate in quantitative research, assume that an objective reality exists independently of the observer and that knowledge is best obtained through measurement, testing, and statistical generalization (Saunders et al., 2019). Interpretivist paradigms, by contrast, hold that social phenomena are constructed through the meanings, interpretations, and experiences of the actors involved, and that the researcher's task is to understand these subjective constructions rather than to measure objective regularities (Denzin & Lincoln, 2018).

This study is positioned within an interpretivist philosophical framework. The rationale for this positioning is twofold. On one hand, the research question asks what drives, constrains, and results from blockchain adoption for supplier relationship management in the energy sector. Answering this question requires access to the interpretive assessments, strategic reasoning, and contextual judgments of organizational decision-makers, none of which can be adequately captured through standardized measurement instruments or survey scales (Welch et al., 2011). On the other hand, blockchain adoption in supply chain management remains in the early stages of diffusion, particularly in the energy sector, where large-scale empirical datasets are not yet available. Under such conditions, qualitative inquiry grounded in interpretivist assumptions is better positioned than positivist designs to capture emergent patterns and generate context-sensitive insights (Birkinshaw et al., 2011).

The interpretivist orientation also aligns with the nature of the phenomena under investigation. Supplier-buyer relationships, as established in Section 2.1, are governed not only by formal contractual mechanisms but also by relational norms, trust, and mutual expectations that develop through repeated interaction. Understanding how blockchain technology intersects with these relational dynamics requires an approach that privileges depth and context over breadth and statistical representativeness. As Welch et al. (2022) argued in their retrospective on case study research in international business, the field benefits from approaches that reconcile theory and context rather than seeking context-free generalizations. The present study follows this guidance by situating its theoretical propositions within the specific institutional, competitive, and organizational context of the Finnish energy sector.

Alongside the philosophical positioning, the reasoning logic that connects theory and empirical data requires explicit justification. Three principal forms of reasoning are recognized in the methodology literature: deductive, inductive, and abductive (Saunders et al., 2019). Deductive reasoning proceeds from theory to data, testing predefined hypotheses against empirical observations. Inductive reasoning moves in the opposite direction, deriving theory from patterns observed in the data. Abductive reasoning occupies a middle ground, iterating between pre-existing theoretical frameworks and empirical findings in a process of continuous refinement (Dubois & Gadde, 2002).

This study adopts an abductive reasoning logic. The choice is grounded in the structure of the research design itself. On the one hand, the literature review has produced 24 theoretically derived propositions that provide a structured analytical framework for the empirical investigation. This deductive element means that the study does not enter the field with a blank slate, rather, it approaches the data with specific theoretical expectations about what drivers, barriers, and performance outcomes are likely to be relevant. On the other hand, the study's qualitative and exploratory character means that the empirical findings are not confined to confirming or rejecting these propositions. The semi-structured interview format deliberately allows for the emergence of themes, relationships, and nuances that the literature did not anticipate. The analysis, therefore, moves iteratively between the theoretical framework and the empirical data, refining, extending, or qualifying the original propositions in light of what the case evidence reveals.

Dubois and Gadde (2002) termed this iterative process “systematic combining” and argued that it is particularly well suited to case study research in business and management, where the objective is not statistical generalization, but the development of refined theoretical understanding grounded in empirical context. The abductive approach enables the researcher to leverage the explanatory power of established theories, in this case transaction cost economics, social exchange theory, and the TOE framework, while remaining open to empirically emergent insights that these theories may not fully capture. Welch et al. (2011), in their influential typology of theorizing from case studies, positioned this form of reasoning as “contextualized explanation”, a mode that seeks causal understanding without sacrificing attention to context. In other words, the 24 propositions developed in the literature review provide a starting point for the empirical investigation, but the final findings are not limited to these propositions. The analysis is expected to capture both what the theory predicts and what practitioners in the Finnish energy sector actually experience when adopting blockchain for supplier relationship management.

3.2 Research method

This study employs a qualitative research method. The choice follows directly from the research question, the nature of the phenomenon investigated, and the current state of empirical knowledge on the topic. Qualitative methods are particularly appropriate when the research objective is to understand complex organizational phenomena in depth rather than to measure the frequency or magnitude of predefined variables across a large population (Eriksson & Kovalainen, 2016). The research question guiding this thesis, what are the drivers, barriers, and performance outcomes of adopting blockchain technology by energy companies to manage supplier relationships, is exploratory in character. It does not seek to test causal relationships between measurable variables but rather to examine how and why certain factors shape organizational decision-making within a specific industry context. This type of inquiry aligns with the strengths of qualitative methods, which allow the researcher to probe beneath surface-level responses, pursue unexpected lines of reasoning, and capture the contextual nuances that standardized instruments tend to miss (Yin, 2018).

A quantitative approach was considered but ultimately deemed unsuitable for two reasons. The population of energy-sector firms with direct blockchain implementation experience remains too limited to support statistically meaningful survey-based analysis, and established measurement constructs for this specific application context have not yet been developed. As Edmondson and McManus (2007) noted, promising research topics that lack validated measurement scales are better served by qualitative designs that can generate foundational insights for subsequent quantitative investigation. Moreover, the study's interest in managerial perceptions, strategic reasoning, and relational dynamics requires a level of conversational depth that closed-ended survey questions cannot deliver. Practitioners' assessments of regulatory uncertainty, supplier readiness, or the quality of interorganizational communication are shaped by firm-specific circumstances that vary considerably across organizations and cannot be meaningfully reduced to Likert-scale responses at this stage of knowledge development.

A mixed-methods design was also considered, but while combining qualitative and quantitative elements could, in principle, offer both depth and breadth, the practical constraints of the study, including the limited number of accessible case organizations and the scope of the master's thesis, made a standalone qualitative design the more realistic and methodologically coherent option. Creswell and Creswell (2018) observed that mixed-methods research requires substantial resources for both data collection phases and carries the risk of producing two insufficiently developed analyses rather than one rigorous one.

The qualitative method is operationalized through semi-structured interviews with industry and AI specialists from the Finnish energy sector. Semi-structured interviews were selected over unstructured or fully structured alternatives because they strike a balance between theoretical guidance and empirical openness, aligning with the abductive reasoning logic described in Section 3.1 (Saunders et al., 2019). The interview guide, developed based on the 24 propositions from the literature review, provides a consistent thematic structure across all interviews while leaving room for interviewees to introduce perspectives and experiences not anticipated by the theoretical framework. This combination of structure and flexibility is well-suited to generating data that can be systematically compared across cases while preserving the richness and specificity of individual accounts (Eriksson & Kovalainen, 2016).

3.3 Research design strategy

The research design strategy specifies how the qualitative method outlined in Section 3.2 is structured to address the research question. This section discusses the choice of a multiple case study strategy (Section 3.3.1) and describes the Finnish energy sector as the empirical context in which the cases are situated (Section 3.3.2).

3.3.1 Multiple case study strategy

A case study is an empirical inquiry that investigates a contemporary phenomenon in depth within its real-world context, particularly when the boundaries between the phenomenon and its context are not clearly separable (Yin, 2018). Case studies are well-suited to research situations in which the investigator seeks to understand how and why certain processes unfold within organizations, rather than to measure how frequently they occur across a population. The decision to adopt blockchain for supplier relationship management is precisely this type of phenomenon: it is embedded in organizational routines, shaped by industry-specific regulatory conditions, and influenced by the relational dynamics between specific buyers and suppliers. Extracting it from this context for survey-based analysis would risk losing the very richness that makes the phenomenon worth studying.

Within the broader case study tradition, this thesis adopts a multiple-case study design involving four case organizations. Yin (2018) distinguished between single- and multiple-case study designs and argued that multiple cases strengthen the robustness of findings through replication logic. Each case is treated as an independent analytical unit, and the patterns observed in one case are compared with those in others. Where similar results emerge across cases operating under comparable conditions, the findings gain credibility through what Yin termed literal replication. Where cases operating under different conditions produce contrasting results, the findings contribute to theoretical replication, helping identify boundary conditions and contingencies that shape the phenomenon in different ways. Four cases were selected for this study, a number that balances analytical depth with sufficient cross-case variation to identify recurring patterns and meaningful divergences (Eisenhardt, 1989).

Eisenhardt (1989) recommended between four and ten cases for theory-building research, noting that fewer than four cases make it difficult to generate sufficient complexity, while more than ten risk overwhelming the researcher with data that cannot be managed within a reasonable scope. The four cases selected for this study fall comfortably within this range and are consistent with the scope of a master's thesis. Each case represents a Finnish energy company whose representatives were interviewed about their experiences with and perceptions of blockchain adoption in managing upstream supplier relationships. The unit of analysis is therefore the energy company's approach to blockchain adoption in its supplier relationship management, examined through the perspectives of knowledgeable informants within each organization.

The analytical procedure follows a two-stage logic. In the initial stage, a within-case analysis is conducted for each case organization, mapping the informant's responses to the 24 propositions of the conceptual model. This stage produces a detailed account of each company's specific situation regarding drivers, barriers, and anticipated or experienced performance outcomes. The subsequent stage compares the findings across all cases through a cross-case analysis, identifying patterns of convergence and divergence. This two-stage structure, consistent with the recommendations of both Yin (2018) and Eisenhardt (1989), enables the study to preserve the contextual richness of individual cases while also generating insights that extend beyond any single organization.

3.3.2 Case study context

The empirical context of this study is the Finnish energy sector. Finland was selected as the research context for several reasons that enhance both the relevance and the analytical value of the investigation. The country's energy sector is undergoing a significant structural transition, with Finland having committed to achieving carbon neutrality by 2035, one of the most ambitious targets among developed nations, driving substantial investment in renewable energy infrastructure and grid modernization (Ministry of Economic Affairs and Employment of Finland, 2023). This transition has expanded the range and geographic spread of suppliers with which Finnish energy companies must coordinate, creating procurement challenges that align directly with the research question.

Finland also occupies a distinctive position in terms of digital infrastructure and technology adoption, consistently ranking among the top performers in European digitalization indices (European Commission, 2023). This existing digital foundation, including smart metering infrastructure, IoT connectivity, and enterprise digitalization, creates enabling conditions for blockchain deployment, making the Finnish context suitable for studying adoption dynamics rather than mere awareness.

The regulatory environment provides a further justification. Finnish energy companies operate under the European Union's regulatory framework, including the GDPR, the EU Green Deal, and forthcoming sustainability reporting requirements under the Corporate Sustainability Reporting Directive (CSRD). These regulations create both incentives and constraints for blockchain adoption, as discussed in Sections 2.3 and 2.4, and studying the phenomenon within this regulatory context allows the empirical findings to speak to conditions broadly shared across EU member states.

Finally, the Finnish energy sector is sufficiently concentrated to be accessible for qualitative research while remaining diverse enough to support meaningful cross-case comparison, including large vertically integrated utilities, regional energy producers, and specialized renewable energy firms

Taken together, these characteristics position Finland as a theoretically and practically relevant context for investigating blockchain adoption in energy sector supplier relationship management. The findings, while anchored in the Finnish context, carry potential transferability to other Nordic and EU energy markets operating under comparable institutional and technological conditions.

3.4 Data collection, analysis techniques, and procedures

This section describes how the empirical data were collected (Sections 3.4.1 and 3.4.2) and how they were analyzed. The procedures are documented in sufficient detail to allow the reader to assess the transparency and replicability of the research process.

3.4.1 Sampling technique and sample size

The study employs purposive sampling, a non-probability sampling technique in which participants are selected based on predefined criteria relevant to the research question rather than through random selection (Saunders et al., 2019). Purposive sampling is the standard approach in qualitative case study research because the objective is not statistical representativeness but rather the selection of information-rich cases that can illuminate the phenomenon under investigation (Patton, 2015; Yin, 2018).

The identification of interviewees was guided by three selection criteria that collectively ensured the sample would capture informed perspectives on blockchain adoption for supplier relationship management from different professional vantage points within the Finnish energy sector. Participants were required to hold professional positions within the sector or be closely connected to it, so that their assessments would reflect genuine sector-specific experience rather than abstract views on blockchain technology. Participants also needed to occupy roles with direct or indirect involvement in supplier relationship governance, procurement processes, or technology adoption decisions, whether from a technical, financial, or operational standpoint, as the research question sits at the intersection of technology and supply chain governance rather than within a single professional domain. The sample was further composed to include deliberate variation in blockchain familiarity rather than a uniform level of prior knowledge. While some interviewees bring direct experience with distributed ledger technologies or adjacent digital technologies such as artificial intelligence, others approach the topic from a financial or supply chain operations perspective, with limited prior exposure to blockchain. This variation enables the analysis to examine whether perceptions of blockchain's drivers, barriers, and performance outcomes differ across levels of technical familiarity

The sample consists of four interviewees, each representing a distinct organization within the Finnish energy sector, a number that falls within the range recommended by Eisenhardt (1989) for theory-building case research and is consistent with the multiple case study design described in Section 3.3.1. A larger sample would have broadened the empirical coverage, but four cases provide sufficient variation to surface recurring patterns and meaningful divergences within the scope of a master's thesis, while ensuring that the cross-case analysis draws on perspectives from genuinely different organizational contexts rather than multiple voices from within a single firm.

3.4.2 Data Collection

The primary data were collected through semi-structured interviews. This format was chosen because it combines the thematic consistency needed for systematic cross-case comparison with the conversational flexibility required by the study’s abductive reasoning logic (Eriksson & Kovalainen, 2016). Each interview followed an interview guide organized into six thematic blocks corresponding to the structure of the conceptual model: background and context, current supplier relationship management practices, drivers of blockchain adoption, barriers to adoption, performance outcomes, and reflective, forward-looking questions. The guide contained open-ended questions, each mapped to one or more of the 24 propositions from the literature review. This mapping ensured that the empirical data could be systematically compared with the theoretical framework during analysis, while still allowing interviewees to introduce topics not anticipated in the literature.

Interviews were conducted in 2026 and lasted approximately 45-60 minutes each. Interviews were conducted remotely via video conferencing software, which facilitated scheduling across different geographic locations globally. All interviews were conducted in Finnish or English, depending on the interviewee's preference. With each participant's consent, interviews were audio-recorded and subsequently transcribed verbatim. Verbatim transcription preserves the original phrasing and emphasis of the interviewee's responses, which is important for a qualitative analysis that attends to nuance and context rather than merely extracting factual content (Saunders et al., 2019).

Prior to each interview, participants were provided with a brief description of the study's purpose and the main thematic areas to be discussed. This advance briefing served two functions: it enabled interviewees to reflect on their experiences before the conversation, thereby improving the substantive quality of their responses, and it fulfilled the ethical obligation to ensure informed consent. Participants were assured that their responses would be treated confidentially and that neither they nor their organizations would be identifiable in the thesis.

The interview transcripts were analyzed using thematic analysis, a method for identifying, organizing, and interpreting patterns of meaning across qualitative data (Braun & Clarke, 2006). Thematic analysis was chosen over alternative approaches such as grounded theory coding or narrative analysis because it is sufficiently flexible to accommodate the abductive logic of this study. It allows the researcher to work with both predefined themes derived from theory and emergent themes arising from the data (Braun & Clarke, 2006).

The analytical process followed a structured sequence. In the first stage, each transcript was read in its entirety to develop familiarity with the content and to note initial observations. In the second stage, the data were coded using the 24 propositions from the conceptual model as an initial coding framework. Each passage in which an interviewee discussed a driver, barrier, or performance outcome was assigned to the corresponding proposition. In the third stage, the coded data were reviewed to identify themes that cut across multiple propositions or that did not correspond to any proposition in the original framework. These emergent themes were assigned new codes and integrated into the analysis. In the fourth stage, the coded data were organized into within-case summaries for each of the four case organizations, mapping each company's position on the identified drivers, barriers, and performance outcomes. In the fifth and final stage, a cross-case analysis compared the within-case findings to identify patterns of convergence and divergence, producing the general model presented in Section 4.4. This combination of theory-driven and data-driven coding is consistent with the abductive approach described in Section 3.1 and follows the template analysis procedure recommended by King (2012), in which a predefined coding template is applied to the data but remains open to modification as the analysis progresses.

3.5 Validity and Reliability

The assessment of quality in qualitative research differs fundamentally from the statistical tests of validity and reliability applied in quantitative studies. Lincoln and Guba (1985) proposed four criteria for evaluating the trustworthiness of qualitative inquiry: credibility, transferability, dependability, and confirmability. Yin (2018) offered a complementary set of tests specifically for case study research: construct validity, internal validity, external validity, and reliability.

Credibility concerns whether the findings accurately reflect the phenomenon as experienced by the participants (Lincoln & Guba, 1985). Several measures were taken to strengthen credibility in this study. The interview guide was developed directly from the 24 propositions in the conceptual model, ensuring that the questions asked were grounded in established theory rather than in ad hoc assumptions. All interviews were audio-recorded and transcribed verbatim, which reduces the risk of selective or inaccurate recall during analysis. The use of a multiple-case study design with independent case organizations also provides a form of data triangulation, in which similar findings emerge across different informants operating in different organizational contexts, thereby increasing confidence in the credibility of those findings (Yin, 2018). Construct validity, in Yin's terminology, was addressed by using multiple sources of evidence (interview data cross-referenced with publicly available company information) and by establishing a clear chain of evidence linking interview excerpts to coded themes and propositions.

Transferability refers to the extent to which the findings can be applied to other contexts beyond the specific cases studied (Lincoln & Guba, 1985). Qualitative case study research does not aim for statistical generalization to a population, rather, it seeks analytical generalization, in which empirical findings are linked to broader theoretical propositions (Yin, 2018). The present study enhances transferability by providing detailed descriptions of the case study context (Section 3.3.2), the participant selection criteria (Section 3.4.1), and the characteristics of the case organizations (Section 4.2). These descriptions enable readers to assess the extent to which the findings may apply to energy companies operating under comparable institutional, regulatory, and technological conditions, particularly within other Nordic and EU markets. The study does not claim that its findings are universally generalizable, but the theoretical grounding and contextual detail provided support their potential relevance beyond the Finnish setting.

Dependability addresses whether the research process is consistent, well-documented, and traceable (Lincoln & Guba, 1985). This criterion parallels the concept of reliability in quantitative research. Dependability was pursued through several procedural measures. A standardized interview guide was used across all four interviews, ensuring that each participant was asked the same core questions and that the data collected were comparable across cases. The coding process followed a structured six-stage thematic analysis procedure described in Section 3.4.2, which provides a transparent and replicable analytical pathway. The mapping of interview questions to specific propositions (presented in the interview guide) creates an audit trail that connects raw data to analytical categories and final conclusions. Together, these measures ensure that the analytical process could, in principle, be followed and assessed by an independent researcher.

Confirmability concerns the degree to which the findings are shaped by the data rather than by the researcher's preconceptions or biases (Lincoln & Guba, 1985). Complete objectivity is neither achievable nor claimed in interpretivist research, but confirmability can be strengthened by making the researcher's analytical decisions visible and traceable. In this study, the use of a theory-driven initial coding framework (the 24 propositions) provides a transparent starting point for the analysis, while the inclusion of emergent codes ensures that the data are not forced into predetermined categories.

The presentation of within-case analyses with direct references to interviewee statements allows the reader to evaluate whether the interpretations are supported by the evidence. Additionally, the abductive reasoning logic adopted in this study explicitly requires the researcher to remain open to findings that contradict or qualify theoretical expectations, serving as a built-in safeguard against confirmation bias.

4 Empirical Findings

This chapter presents the empirical findings derived from semi-structured interviews conducted with four industry and AI specialists operating within the Finnish energy sector. The chapter is organized according to the analytical procedure outlined in Section 3.4. Section 4.1 provides an overview of the interviewees' professional backgrounds and their familiarity with blockchain technology. Section 4.2 describes the key characteristics of the case companies, including their industry position, size, supplier network structure, and procurement context. Sections 4.3.1 through 4.3.5 present the within-case analyses, in which each case organization is examined individually against the three pillars of the conceptual model: drivers of blockchain adoption for managing supplier-buyer relationships, barriers to adoption, and anticipated or experienced performance outcomes. Within each case, the interviewee's responses are mapped to the 24 propositions from the literature review, with attention to emergent themes that extend beyond the theoretical framework. Section 4.4 concludes the chapter with a cross-case analysis that compares findings across all four cases, identifies patterns of convergence and divergence, and presents a revised empirical model that reflects both theoretically anticipated and empirically emergent factors.

To preserve confidentiality, the case companies are referred to as Company A through Company D, and individual interviewees are identified by corresponding codes Interviewee A through Interviewee D. Direct quotations from the interviews are used where they illustrate a finding with particular clarity, but care has been taken to ensure that no commercially sensitive or personally identifiable information is disclosed. All quotations have been translated into English where the original interview was conducted in Finnish, with attention to preserving the intended meaning of the interviewee's statements.

4.1 Interviewee's background

Four semi-structured interviews were conducted with professionals working in or closely connected to the Finnish energy sector. The interviewees were selected through purposive sampling based on the criteria outlined in Section 3.4.1, ensuring variation in organizational level, functional orientation, company size, and degree of blockchain familiarity.

Table 3. Summary of interviewee backgrounds

Interviewee	Position	Energy sector experience	Functional orientation	Blockchain familiarity
Interviewee A	IT AI Center of Excellence Lead	Approx. 1 year (current role); 6 years blockchain experience from prior role	AI governance, digital innovation, blockchain development (prior)	High (6 years hands-on DLT development)
Interviewee B	AI Team Lead	Approx. 7 years	AI/ML development, predictive analytics, supply chain digitalization	Moderate (technical study, no hands-on development)
Interviewee C	Chief Financial Officer	Approx. 16 years	Financial management, commercial contract terms, administrative oversight	Limited (general conceptual understanding)
Interviewee D	Supply Chain Specialist	Approx. 4 years	Procurement coordination, supplier evaluation, logistics management	Limited (general awareness from industry sources)

As the table illustrates, the interviewees span a range of seniority levels, from operational specialists to executives, and their functional backgrounds include AI and digital innovation, financial management, and supply chain operations. Blockchain familiarity varies from extensive hands-on development experience (Interviewee A) to general awareness without technical depth (Interviewees C and D). This variation was pursued deliberately, as it enables the cross-case analysis to examine whether perceptions of blockchain's drivers, barriers, and performance outcomes differ systematically across professional roles, organizational contexts, and levels of prior exposure to the technology.

4.2 Characteristics of case companies

The four case companies represent different segments of the Finnish energy sector and vary considerably in size, organizational structure, supplier network composition, and level of digital procurement maturity. These differences were deliberately pursued as part of the case selection strategy outlined in Section 3.3.1, as they enable the cross-case analysis to examine whether the drivers, barriers, and performance outcomes of blockchain adoption differ across organizational contexts. Table 4 summarizes the key characteristics of each case company. Figures are presented as approximate ranges to preserve confidentiality.

Table 4. Characteristics of case companies

Characteristic	Company A	Company B	Company C	Company D
Industry segment	Power grid infrastructure and energy technology	Wind energy technology and turbine manufacturing	Transformer trading, supply, and consulting	Electrification and industrial automation
Company type	Subsidiary of a multinational corporation	Subsidiary of a multinational corporation	Independent SME	Subsidiary of a multinational corporation
Employees (approx.)	> 40,000 (global)	> 25,000 (global)	< 10	> 100,000 (global)
Annual revenue (approx.)	> EUR 10 billion (global)	> EUR 15 billion (global)	Approx. EUR 20 million	> EUR 30 billion (global)
Primary supplier types	Component manufacturers, rare earth material suppliers,	Blade, tower, and gearbox manufacturers, electronics suppliers, logistics providers	International transformer factories, electrical component producers	Component manufacturers, raw material suppliers, subcontractors, technology vendors

	infrastructure contractors			
Geographic scope of procurement	Global	Global	International (primarily Europe and Asia)	Global
Number of active suppliers (approx.)	Thousands	Thousands	Approx. 100 partner factories	Thousands
Primary procurement systems	ERP-based platform with digital vendor management	Integrated ERP and enterprise business network	Standard accounting/ERP software, email, spreadsheets	ERP-based systems with digital procurement tools
Digital procurement maturity	High (advanced ERP, AI initiatives, IoT integration)	High (Digital procurement, AI/ML, advanced analytics)	Low (conventional tools, no dedicated IT function)	High (advanced ERP, digital energy management, AI investments)
Blockchain adoption status	No current implementation; prior internal exploration discontinued	No current implementation; technology scouting discussions only	No current implementation; not previously considered	No current implementation; not previously considered

As the table illustrates, three of the four case companies (A, B, and D) are subsidiaries of large multinational corporations with global procurement operations, advanced digital infrastructure, and thousands of active suppliers. Company C, by contrast, is a small Finnish trading firm with fewer than 10 employees, a network of approximately 100 international factory partners, and limited digital tools. This size disparity is analytically valuable because it enables the study to examine whether the propositions developed in the literature review hold consistently across organizational scales or whether firm size and resource availability introduce meaningful boundary conditions. All four companies share one notable characteristic: none has implemented blockchain for supplier relationship management, and none is currently pursuing active implementation, though two (Companies A and B) have engaged in preliminary exploration at the discussion or technology scouting level. The case companies, therefore, represent organizations at the pre-adoption stage, making their perspectives on drivers, barriers, and anticipated performance outcomes particularly relevant to understanding the conditions under which blockchain adoption in energy-sector supplier management may or may not advance.

4.3 Within case analysis

This section presents the findings from each case organization individually. For each company, the interviewee's responses are organized around the three pillars of the conceptual model developed in Chapter 2: drivers of blockchain adoption for managing supplier-buyer relationships, barriers to adoption, and anticipated performance outcomes. Where the interviewee raised themes that extended beyond the scope of the interview guide, these are reported separately as emergent findings at the end of each case.

4.3.1 Case 1

Drivers of adopting blockchain technology

Interviewee A identified supply chain traceability and provenance as the most compelling application of blockchain for Company A's supplier management, including end-to-end visibility into the inputs used by the company's own vendors. The second area of potential was timely information sharing, which the interviewee linked to cryptographic tools such as zero-knowledge proofs that could enable real-time access to material availability and pricing without full data disclosure. A third, less immediately relevant area was blockchain as payment infrastructure for faster supplier transactions with lower fees.

On infrastructure compatibility, Interviewee A assessed Company A's internal systems as broadly ready for blockchain integration but stressed that the real challenge lies across the supply chain: “For this to work, you need every piece in the supply chain, for everybody to have sufficient level of digitalization”. A single partner lacking digital maturity would be “sufficient to break or significantly weaken the provenance chain”.

Company A's leadership shows a strong interest in digitalization generally, with an AI Nexus program and digitization among annual goals. At the same time, Interviewee A noted that no executive had ever mentioned blockchain as a significant technology, and a prior internal exploration several years ago was discontinued for lack of a convincing business case. The organizational culture was described as “dialectic”, combining a genuine pioneering spirit with pronounced risk aversion rooted in the company's critical infrastructure responsibilities.

Sustainability compliance obligations were confirmed as a genuine external pressure. However, Interviewee A reported no awareness of competitors pursuing blockchain in the power grid segment and observed that AI has displaced blockchain in both corporate attention and public interest. Supplier readiness was assessed as low, attributed not to technological limitations but to what the interviewee called “a bit of a PR problem of blockchain technology”, where the dominance of financial applications has narrowed perceptions of what blockchain can do.

The renewable energy transition has substantially increased procurement complexity at Company A. Growing demand for HVDC systems requires more suppliers, more input materials, including geopolitically sensitive rare earth elements, and longer transmission lines demanding higher-quality components. The interviewee noted that Company A currently manages this complexity primarily by hiring more supply chain staff rather than through technological innovation, characterizing this as “extensive growth rather than intensive growth” by increasing operating efficiency.

Barriers to adopting blockchain technology

A consistent theme throughout the interview was that barriers are organizational and reputational rather than technological. On scalability, Interviewee A stated that modern platforms such as Solana have resolved throughput limitations and that data privacy and transaction speed challenges are “fully solvable” with current technology. System integration was acknowledged as a real but resolvable obstacle, with specific challenges including the absence of in-house blockchain expertise, the need to build governed data pipelines with a unified data model, and the lack of experience hosting blockchain nodes. The absence of blockchain-specific knowledge was identified as the single most critical internal gap. Company A has strong competencies in innovation, data management, and supply chain operations, but no blockchain expertise whatsoever, at either the technical or strategic level.

Financial viability emerged as a prominent concern. A blockchain initiative would require “at least a multi-million investment”, and the difficulty of quantifying specific savings while costs are concrete makes building a business case challenging. Interviewee A personally believed the investment would be justified, particularly if pursued collaboratively across the industry through co-funded platforms.

Regulatory barriers were assessed as minimal. Current regulations apply to the use of financial tokens rather than to data-sharing applications, and most supply chain data would not constitute personally sensitive information. The interviewee expected standard data privacy obligations to apply but saw no blockchain-specific regulatory obstacles.

The primary sector-specific barrier was the energy industry's conservative culture. Long product lifecycles, critical infrastructure responsibilities, and a perception that blockchain sacrifices security for speed create cultural reluctance. However, Interviewee A noted that no specific regulation or practice would strictly prevent the use of blockchain technology.

Performance outcomes of adopting blockchain technology

When asked to identify the most significant performance improvements unprompted, Interviewee A prioritized two areas: compliance with sustainability and provenance requirements, and improved supplier data availability, enabling faster and more accurate customer offers with a direct positive impact on revenue.

On innovation, the interviewee saw potential for joint client offers rather than joint products, with real-time supplier data exchange enabling more collaborative and competitive proposals. Zero-knowledge data usage could also support research collaboration without compromising privacy, though this was acknowledged as more speculative.

Cost reduction was expected through three channels: automating information gathering that currently requires manual ad hoc requests to suppliers, reducing errors in customer quotations caused by incorrect supplier data, and improving overall productivity by shifting from human-mediated to automated data exchange.

Relationship improvement received a strong endorsement. Interviewee A identified three reinforcing dynamics: the joint effort of building shared infrastructure deepens the relationship itself, onboarded suppliers receive preferential treatment, creating a commitment mechanism, and fewer data-related disputes remove day-to-day friction. Learning outcomes, on the other hand, were assessed contingent on negotiated data access permissions, since blockchain's zero-knowledge philosophy limits how freely data can be repurposed for analytics.

On decision-making, Interviewee A distinguished between crisis situations, where real-time supply chain visibility could accelerate executive responses, and normal operations, where the benefit is “less about speed and more about quality”, enabling better modeling of supply chain risk for informed pricing and supplier management policies.

Communication quality was expected to improve “paradoxically by actually reducing the amount of human communication”, with automated data sharing eliminating errors from manual exchange and freeing procurement staff to focus on strategic relationship matters rather than routine information requests. Lastly, transaction security was framed as a governance design challenge rather than an automatic blockchain feature, requiring a formal data-sharing policy, with cybersecurity as a key stakeholder in system design.

Emergent themes

Two themes emerged that extended beyond the interview guide. First, Interviewee A repeatedly emphasized that AI has crowded out blockchain from the innovation agenda. In the interviewee's words, “people have limited bandwidth for which innovation to focus on, and AI has consumed all of the attention and funding”. This operates both internally and externally across the industry.

Second, the interviewee argued that the most important prerequisite for blockchain in energy supplier management is not technological but relational: “You don't just adopt the technology, you change the way you relate to your suppliers. And this is what changes first of all”. The interviewee envisioned a shift toward viewing the energy market as an interdependent ecosystem where collaborative data sharing benefits all participants, rather than treating each supplier interaction as adversarial.

4.3.2 Case 2

Drivers of adopting blockchain technology

Interviewee B identified material provenance and traceability as the area of greatest blockchain potential for Company B's supplier management, with particular emphasis on sustainability-sensitive materials such as low-emission steel and rare earth elements. The company's existing ERP-based procurement systems effectively handle transactional data with direct suppliers, but they do not provide an immutable record of what occurred further upstream in the supply chain. A shared ledger capable of tracking materials from mine or mill through to final assembly, with each handoff cryptographically verified, would address what the interviewee described as a genuine and growing gap. Closely related was the verification of sustainability credentials: when a supplier claims their steel is low-emission or their sourcing is conflict-free, Company B currently relies on certificates and periodic third-party audits, and a blockchain-based system could make those claims continuously verifiable rather than subject to periodic assessment.

On infrastructure compatibility, Interviewee B described a double-edged situation. Company B operates a highly digitized procurement environment, with an enterprise business network that already connects thousands of suppliers through standardized data formats. The platform itself has been exploring blockchain capabilities, suggesting a natural path for integration. On the other hand, the depth of the existing investment creates a form of lock-in, as any blockchain solution would need to integrate seamlessly with multiple platforms and the ERP backbone. Beyond internal readiness, the interviewee stressed the supplier-side dimension: “The blockchain is only as strong as its weakest participant”. Larger strategic suppliers are well-digitalized, but smaller component suppliers, especially in emerging markets, may still operate with basic systems.

Company B's leadership demonstrated a genuine commitment to digital transformation. The creation of a unified technology, manufacturing, and supply chain organization under a single executive in 2024 signaled that digital capability is viewed as a strategic priority rather than a support function. Yet, leadership attention is directed squarely toward AI, data analytics, and ERP platform expansion, with no mention of blockchain in any recent senior-level communication. The organizational culture was characterized as both innovative and conservative by design. Company B manufactures critical energy infrastructure with a 25-to-30-year operational life, which demands caution around technologies that have not yet proven themselves at an industrial scale. Within that framework, genuine pockets of innovation exist, including advanced weather modeling capabilities and early moves in digital procurement. The interviewee summarized the culture as “innovation-oriented within well-defined guardrails”.

Regulatory pressure on Company B has grown substantially in recent years, as multiple EU directives and national transparency laws now require increasingly detailed documentation of value chain impacts. In response, the company launched a human rights risk heatmap initiative in 2024, partnering with a third-party risk intelligence provider to map potential risks across its supplier base. Customer demands for sustainability documentation have added further urgency. Despite this, no awareness of direct competitors using blockchain specifically for supply chain management in the company's industry segment was reported, though the sector's collaborative nature through joint industry initiatives would likely have surfaced any significant activity.

Supplier readiness across Company B's network varies considerably, as strategic suppliers already engaged in digital collaboration through the company's enterprise platform have the technical capability to participate in an additional layer, while readiness itself extends beyond infrastructure to willingness. Some suppliers may resist the prospect of their production data, delivery timelines, or quality records being immutably recorded on a shared ledger, and smaller and mid-tier suppliers, particularly those in Asia and emerging markets, would face blockchain adoption as a significant organizational leap.

The transition toward larger and more powerful energy infrastructure, including offshore applications, has considerably expanded the range of required components and supplier relationships. Entirely new supply chain segments have emerged, including specialized logistics, subsea components, and installation service providers. Increasing competition for geopolitically sensitive materials and the expansion of manufacturing across multiple continents have further compounded coordination complexity. The interviewee described sustainability accountability as arguably the strongest pull factor toward blockchain. Company B's target to reduce supply chain emissions by 45 percent by 2030 requires granular data extending beyond direct suppliers, and the broader ambition for zero-waste products by 2040 demands cradle-to-grave material traceability. If blockchain can deliver this traceability more reliably and less labor-intensively than current methods, “the sustainability case alone could justify the investment”.

Barriers to adopting blockchain technology

Interviewee B directed attention to a technical concern distinct from scalability: data quality at the point of entry. Blockchain guarantees the immutability of recorded data, but cannot guarantee its accuracy when first submitted. The interviewee framed this as the “garbage in, garbage out” problem, observing that if a supplier records incorrect emissions data or quality measurements, the blockchain merely makes that error permanent. Strong validation mechanisms before the blockchain layer would therefore be essential, adding a layer of complexity that is often overlooked in discussions of the technology's benefits.

Integrating blockchain with Company B's existing systems would require considerable effort, though the interviewee did not consider it insurmountable. The depth of the company's ERP investment means that any blockchain solution must work cleanly alongside multiple platforms, and building those integration layers demands a combination of enterprise systems expertise and blockchain expertise that is rarely found within a single team. What concerned the interviewee most in this regard was the risk of creating a parallel data architecture that would fragment supply chain information rather than consolidate it.

Although Company B has strong capabilities in data engineering, AI, machine learning, enterprise systems development, and cloud infrastructure, the organization lacks internal blockchain expertise, as distributed ledger technology requires a fundamentally different skill set. The interviewee favored a consortium approach over internal development, reasoning that shared technical effort across industry partners would be more practical and more likely to achieve the network participation that blockchain requires.

Financial viability posed a significant challenge. Company B has invested substantially in its ERP ecosystem over nearly two decades, and the incremental value that blockchain would add is not immediately obvious in terms that would satisfy a finance function. Blockchain's benefits, better traceability and sustainability verification among them, are real but diffuse and do not appear directly on a quarterly income statement, while the costs of development, integration, and supplier onboarding are concrete and substantial.

Interviewee B viewed the regulatory environment as more enabling than constraining, arguing that current and forthcoming regulations are creating precisely the traceability demands that blockchain is designed to meet and that compliance pressure could ultimately serve as justification for investment rather than as a deterrent. Potential friction around data sovereignty and cross-border data sharing was acknowledged but characterized as manageable complexity rather than a fundamental obstacle. GDPR concerns were considered limited, since most supply chain data is commercial and technical rather than personal, and established technical solutions such as off-chain storage of personal identifiers were regarded as adequate.

On sector-specific barriers, Interviewee B emphasized that the underlying supply chain is fundamentally physical and logistical. Blockchain can improve how documentation around physical processes is tracked and verified, but it cannot make components arrive faster or vessels available sooner. There is a risk, the interviewee cautioned, of overestimating what the technology can achieve if the physical dimension of supply chain management is forgotten. Established industry quality frameworks and decades-old procurement contract templates create additional resistance, not because they are irrational but because they have proven effective, and stakeholders are understandably reluctant to overlay untested approaches onto working systems.

Performance outcomes of adopting blockchain technology

When asked to identify the most significant improvements without prompting, Interviewee B focused on two areas. A reliable and immutable record of the carbon intensity, sourcing origin, and chain of custody for every critical component would transform the company's ability to meet regulatory reporting requirements. The second priority was dispute resolution, where a single source of truth accessible to both parties would reduce the time and cost associated with disagreements over orders, deliveries, and contractual terms.

Interviewee B saw blockchain's contribution to innovation as indirect, noting that the main obstacle to collaborative development with suppliers is not a lack of data infrastructure but rather intellectual property sensitivities and competitive caution. The more concrete opportunity lies in collaborative sustainability efforts, where shared emissions data across the value chain could help both parties identify carbon-reduction opportunities that neither would easily detect from their own data alone.

Cost reduction was expected primarily in audit and compliance activities, where significant resources are currently devoted to third-party audits, document collection, and manual verification of supplier claims. Savings from faster dispute resolution and the potential automation of milestone-based payments through smart contracts were also identified, though the interviewee expressed uncertainty about whether these gains would exceed implementation costs in the short or medium term.

Relationship improvement received a nuanced assessment. The transition period might initially strain certain partnerships, as placing data on a permanent shared record requires a level of transparency that not all suppliers would be comfortable with.

Partners confident in their own data quality would welcome the arrangement, while those less certain might resist or reconsider the relationship. Over time the interviewee expected the net effect to be positive, with a shared record creating the kind of mutual accountability that strengthens strategic long-term partnerships.

Interviewee B, speaking from a data and AI perspective, regarded learning as one of the more promising outcome dimensions, reasoning that a blockchain aggregating verified transaction data from across the supply chain would produce a rich, trustworthy analytical dataset that is difficult to assemble through conventional means. As the interviewee put it, “a clean and trusted dataset is the most valuable thing you can have”, and the guarantee of data integrity that blockchain provides would strengthen confidence in the outputs of demand forecasting models and supply chain risk assessments.

Decision-making would benefit from removing the reconciliation step that currently requires resolving conflicting versions of the truth across different systems before a decision can be made. For strategic choices such as supplier selection or contract renegotiation, access to verified historical performance data across the entire supply chain would move the organization from decisions based on incomplete information to decisions based on verifiable evidence.

Communication quality would improve through the formalization and automation of routine information exchange. Emails, phone calls, and manual follow-ups to confirm details that should be automatically available would give way to real-time, verified data access, allowing human communication to focus on strategic discussions, joint problem-solving, and relationship-building rather than chasing information.

Transaction security was regarded as critically important, and the interviewee referenced a past cyberattack on the company as a wake-up call for the entire industry. Blockchain's distributed architecture could add resilience against certain types of attacks, but the interviewee cautioned against treating it as a comprehensive cybersecurity solution, noting that endpoints, smart contracts, and integration APIs are potential attack surfaces that require the same rigor the company applies to its operational technology security.

Emergent themes

The interview brought to the surface two themes that went beyond the structured questions. The first was a practical concern about the labor market. Even if Company B were to commit to a blockchain initiative, the pool of professionals who combine distributed ledger expertise with working knowledge of energy sector supply chains remains extremely small, as the vast majority of blockchain talent is oriented toward financial applications and Web3 development rather than toward the kind of industrial supply chain work that Company B's operations would require.

The second theme revolved around timing. Interviewee B was of the view that blockchain for supply chain management in the energy sector may not yet have reached its moment, but that the moment is approaching. Regulatory demands for traceability will continue to grow, sustainability expectations will only become more exacting, and at some point, the cost of operating without an immutable shared supply chain record will surpass the cost of establishing one. As the interviewee put it, “when that inflection point arrives, the companies that have done their preparatory thinking will move faster than those starting from zero”. Rather than pursuing blockchain as an individual company effort, Interviewee B's strongest recommendation was for coordinated industry action that builds on existing pre-competitive collaboration models and extends them to encompass shared digital infrastructure for supply chain governance.

4.3.3 Case 3

Drivers of adopting blockchain technology

Interviewee C approached the blockchain-related questions from a predominantly financial and operational perspective rather than a technical one and identified two areas where the technology could address challenges the company currently faces. The company has encountered situations where damage or delays during transport have led to disagreements over responsibility among itself, the manufacturing partner, and the logistics provider, and a shared, tamper-proof record accessible to all parties could help resolve such disputes more efficiently. A related area is concerned with quality documentation for large projects. Test protocols, material certificates, and inspection reports are currently exchanged as email attachments and stored in conventional file systems, and centralizing these in a permanent shared record would reduce the administrative effort involved and lower the risk of documents being lost or contested.

When asked about infrastructure compatibility, Interviewee C acknowledged that Company C's current digital setup, which relies on standard accounting and ERP software alongside email and spreadsheets for most day-to-day coordination, does not provide the kind of technological foundation that blockchain integration would require, as the company operates without IoT devices, smart monitoring systems, or any form of advanced digital platform. The interviewee described this gap as “like trying to build a second floor on a house that does not have a proper foundation yet”.

Company C's leadership was characterized as pragmatic and growth-oriented, focused on customer service, delivery speed, and the development of the international partner network. There is openness to technology that demonstrably improves operations, but no inclination to pursue technology trends for their own sake. Blockchain had never been discussed at the leadership level. The recent acquisition by a larger Finnish group may eventually bring more structured thinking about digital tools, but within Company C itself, the priority remains hiring the right people and cultivating factory relationships.

The organizational culture reflected an entrepreneurial character and adaptability, with flexibility and speed constituting the company's competitive advantage. At the same time, operating with a limited financial buffer means that risk tolerance is shaped by practical constraints. As the interviewee put it, “If we invest in something that does not work out, it hits us harder than it would hit a large corporation”.

Regulatory pressure exists but remains manageable through conventional documentation. Company C complies with EU product standards and has conducted an environmental impact assessment, though it does not yet face the granular supply chain reporting obligations that larger companies encounter under the CSRD. The interviewee acknowledged that this is likely to change as sustainability requirements extend further down value chains, but the current situation does not call for the kind of traceability that blockchain provides.

No awareness of competitors or industry peers exploring blockchain was reported, consistent with Company C's position in a specialized niche segment. Among the company's supplier network, readiness for blockchain participation appeared very low. European factory partners maintain sound documentation practices but rely on conventional systems, whereas manufacturing partners in Asia are oriented toward production capacity and quality rather than digital supply chain innovation. In the interviewee's view, most international factory partners would be reluctant to join a blockchain platform unless they could see a clear and tangible benefit for themselves.

The renewable energy transition has materially increased procurement complexity for Company C. The company has expanded beyond its traditional product range to serve wind energy, solar, battery energy storage, and green hydrogen projects, each with different technical specifications and often tighter delivery schedules. An EU-funded program was secured specifically to develop alternative suppliers and address delivery-time challenges. Despite this growing complexity, sustainability accountability pressures are not yet strong enough at the company's current scale to justify a blockchain investment specifically for traceability.

Barriers to adopting blockchain technology

Where Interviewees A and B framed blockchain barriers in terms of organizational inertia and business case uncertainty, Interviewee C's account was shaped primarily by resource and knowledge constraints. Regarding technical concerns, the interviewee's worry was not about scalability or transaction speed but about something more fundamental: “We would not know where to start. We do not have the technical knowledge to evaluate different blockchain platforms, to understand what kind of blockchain would suit our needs, or to assess whether it would actually work with the way we do business”.

Integrating blockchain with existing systems would be especially challenging because there is limited infrastructure to integrate with. Building the digital foundation that blockchain requires would itself represent a major project for a company of Company C's size, before blockchain could even enter the picture as an additional layer.

No internal blockchain expertise exists within the organization, and hiring a dedicated specialist cannot be justified when every employee must contribute directly to revenue or essential operations. If blockchain were explored at all, it would need to be through an external partner or an industry initiative where development costs are shared.

Financial viability received the most extensive discussion. Speaking from a finance perspective, Interviewee C framed every technology investment against alternative uses of the same funds: “The question is always, could this money be better spent on hiring another project manager, developing a new supplier relationship, or expanding into a new market? Those investments have more predictable returns”. The difficulty of quantifying blockchain's benefits in advance, combined with concrete and visible costs, makes the business case difficult to construct at the company's current scale.

The regulatory environment was described as neither a push nor a pull factor. No regulation specifically requires blockchain, and current compliance obligations are met through conventional means. Regarding GDPR, the interviewee lacked the technical knowledge to evaluate the implications in detail but observed that most supplier data is commercial rather than personal.

Sector-specific resistance stems from the traditional character of the transformer industry, where relationships are built on personal trust and track record, contracts follow established templates, and quality is verified through physical inspections and standardized test protocols. Convincing an international network of manufacturing partners that an additional digital layer adds value without disrupting practices that already work represents a coordination challenge that the interviewee considered disproportionately difficult for a small company that does not set industry standards.

Performance outcomes of adopting blockchain technology

Asked to identify the most significant potential improvement without prompting, Interviewee C pointed to a single area: reducing the administrative burden of project documentation. Collecting, organizing, and verifying test protocols, material certificates, and transport records currently consumes considerable staff time, and a shared, permanent record accessible to all project parties could substantially streamline this process.

On innovation, no direct link to blockchain was perceived. The company's innovation with suppliers’ centers on engineering relationships and delivery solutions, and the interviewee framed potential data-sharing benefits as a communication matter rather than a technology one.

Cost savings were expected mainly through reduced time spent on document handling and possibly through faster dispute resolution, though the interviewee expressed doubt that these gains would outweigh implementation costs at Company C's scale.

The assessment of relationship improvement was mixed. While transparency generally supports trust, and trust is foundational to Company C's way of operating, some suppliers might perceive an immutable shared ledger as intrusive or as an unwelcome administrative obligation. For partnerships that are already strong and personal, it was unclear to the interviewee whether technology would add meaningful value.

Learning from procurement data was considered limited by the company's current analytical capacity. Company C draws its lessons from direct team experience and project-by-project discussion rather than from systematic data analysis. A structured transaction record might support pattern recognition over time, but extracting that value would require analytical tools and skills that do not currently exist within the organization.

Improved decision-making could follow from consolidating each manufacturing partner's performance history, delivery record, quality outcomes, and pricing data in one place, information that currently resides in people's heads and scattered files. In practice, however, a small and closely collaborating team often accomplishes this through conversation.

Communication improvements were expected in the form of less routine back-and-forth on order details, schedules, and documentation. The interviewee was careful to note, simultaneously, that automated data exchange cannot replace the personal communication that sustains factory relationships across cultures and geographies. On transaction security, the interviewee recognized its importance but did not consider it a pressing vulnerability. The company's relatively straightforward IT setup and the commercial nature of its data make it a less prominent target, and whether blockchain would offer meaningful improvements over current arrangements remained an open question.

Emergent themes

The most prominent theme from this interview was the gap between large and small companies in discussions about blockchain adoption. Interviewee C observed that conversations about blockchain in supply chains tend to presuppose organizations with dedicated IT departments and innovation budgets, while for a firm with a handful of employees and annual turnover in the low tens of millions, the starting conditions are fundamentally different. The interviewee's advice was to “wait and watch”, letting larger companies develop and validate the technology before smaller firms consider adoption. If blockchain is to reach companies like Company C, it would need to be available as an affordable, subscription-based platform that requires no specialized expertise, with costs proportional to the size of the business.

A closely related observation was that a basic level of digital maturity needs to be in place before blockchain becomes relevant at all. Company C's current infrastructure does not support advanced digital tools of any kind, and the interviewee saw greater immediate value in investing in foundational digitalization, such as structured supplier databases, digital document management, and standardized quality tracking, than in pursuing blockchain directly. This points to a sequential adoption logic in which, for smaller energy sector firms, blockchain sits at the end of a digital maturity pathway rather than at the beginning.

4.3.4 Case 4

Drivers of adopting blockchain technology

Interviewee D, who had studied blockchain primarily in preparation for the interview, approached the questions from a hands-on procurement operations perspective and identified traceability of raw material origins as the single most compelling application. The interviewee described the challenge of achieving upstream visibility beyond direct suppliers in detail: “For materials such as copper and battery components, there are multiple intermediaries between the mine and the final buyer, and these intermediaries disclose very little about conditions at the extraction stage”. Working conditions in certain mines, compliance with ethical sourcing, and environmental impact at the point of origin remain vague, and current SRM systems do not provide a reliable mechanism to verify what happened before materials reached the first-tier supplier. A blockchain-based traceability chain that creates an immutable record at each handoff, from the mine through processing stages to final delivery, would address what the interviewee described as a fundamental gap.

Equally prominent was the automated collection of regulatory and sustainability data. Interviewee D pointed to specific EU regulatory requirements, including CSRD reporting, the Carbon Border Adjustment Mechanism (CBAM) to track emissions associated with steel imports, and the EU Deforestation Regulation, which requires proof that packaging materials and wood components are not sourced from deforested areas. Currently, compliance with these regulations relies heavily on manual processes, Excel-based tools, and consultant-built spreadsheets, an approach the interviewee characterized as slow and labor-intensive. If suppliers had sensors measuring emissions in production that fed directly into a digital chain via blockchain, the data could flow end-to-end in a fraction of the time currently spent on back-and-forth email exchanges.

The third area of potential concerned day-to-day procurement operations, including material receipts, invoicing, and logistics. The interviewee noted that procurement staff spend a disproportionate amount of time checking invoices, reconciling discrepancies between ordered and received quantities, and managing purchase invoice processing. Blockchain-based automation could substantially reduce this workload for both procurement and finance teams.

On infrastructure compatibility, Interviewee D distinguished between the buying organization and its suppliers. Large industrial firms have the internal capability to implement advanced systems, but the challenge lies in onboarding suppliers, many of whom are small subcontractors with narrow organizational structures and heavy dependence on a single customer relationship. Getting these suppliers to adopt new digital tools requires extensive negotiation, collaboration, and joint projects. Any blockchain implementation would also need to connect to the company's ERP backbone, which the interviewee acknowledged would be expensive and time-consuming but ultimately necessary to achieve a complete audit trail.

Company D's leadership was described as actively pursuing procurement process improvement and digitalization. The company has implemented high-level procurement systems, run digitalization workshops, and employs dedicated personnel focused specifically on supply chain digitalization and data analytics. The organizational culture was characterized as innovation-oriented yet grounded in thorough analysis: “New initiatives require detailed risk assessments and clear investment justifications before proceeding”.

No awareness of competitors using blockchain for supplier management was reported. The interviewee observed that, while academic literature on the topic is well developed, practical implementation in the industrial sector remains very limited, describing it as a “black hole” in visible activity.

Regarding supplier readiness, Interviewee D emphasized that for any supplier management system to function, coverage of at least 80 percent of direct spend is essential, and achieving this with blockchain would require onboarding a large number of suppliers across different levels of digital capability. The interviewee acknowledged that negotiation leverage exists with larger suppliers but raised cybersecurity as a significant concern on the supplier side: “Connecting systems across organizations introduces risks that require careful analysis, particularly when linking ERP environments”.

Sustainability accountability emerged as an absolute necessity in the interviewee's account, but one where the current state of practice is far behind the regulatory ambitions. The interviewee observed that the level of sustainability data collection from supply chains across the market remains very low relative to EU regulatory requirements, that many large firms are still using manual and Excel-based processes, and that experienced supply chain sustainability professionals remain scarce. The gap between regulatory expectations and operational reality appeared considerable, and blockchain was positioned as a technology that could help close this gap if properly implemented.

Barriers to adopting blockchain technology

The interviewee's primary technical concern was cybersecurity. Connecting ERP systems to external platforms or supplier environments through APIs requires a highly controlled interface environment, and the risks associated with linking critical systems across organizational boundaries were described as significant. The interviewee noted that large industrial companies take cybersecurity aspects of supply chain systems very seriously, and that any blockchain proposal would face intense scrutiny from information security teams.

On the relationship between blockchain and existing SRM tools, Interviewee D offered a nuanced assessment. Current supply chain collaboration tools already provide some automation, including automatic order transmission and basic supplier portal functionality. Blockchain, in this framing, represents a further evolution rather than a radical departure, taking existing capabilities deeper, faster, and further upstream. However, justifying this incremental step over existing SRM systems already connected to ERP platforms is a concrete challenge, since those tools handle many of the same functions at a basic level.

Internal blockchain expertise remains very limited, particularly on the procurement side. The interviewee noted that external expertise would be needed for any serious implementation effort, and that building internal competence would take time.

Financial viability was framed as a cross-organizational challenge. In a large industrial corporation, investment proposals need buy-in from multiple business units to achieve sufficient coverage and justify the expenditure. A single unit launching a blockchain initiative in isolation would not make sense, and building internal consensus across units adds complexity and time to the decision-making process. The interviewee also noted that if large industrial companies do not take the lead, smaller firms are unlikely to adopt the technology either, positioning the larger players as necessary first movers.

On sector-specific barriers, Interviewee D described the energy sector's current state of digital maturity in supplier management as still in its early stages when it comes to advanced technologies. While SRM systems have been developed and deployed, the next step toward AI-driven and blockchain-based solutions has not yet been taken in most organizations. Smart contracts were identified as an ideal application that would save time and provide structured contract storage accessible to all parties, but the general assessment was that the industry has not yet moved beyond conventional tools despite the infrastructure being in place at a basic level.

Performance outcomes of adopting blockchain technology

When asked about the most significant performance improvements without prompting, Interviewee D focused on procurement process efficiency as the top priority, encompassing material receipts, logistics, and invoice processing, where blockchain-enabled automation could reduce manual workload considerably. Equally prominent was the audit trail for regulatory compliance, which the interviewee positioned as the strongest business case for larger firms, particularly in light of CSRD requirements and the forthcoming EU Digital Product Passport that will require companies to demonstrate product origin and traceability across the supply chain. Operational improvements in logistics, including RFID integration and smart logistics capabilities that provide real-time visibility into warehouse and delivery operations, were also identified as a significant area of potential.

On innovation, the interviewee confirmed that Company D already conducts innovation workshops with suppliers, but these have so far focused on operational improvements and business development rather than digital supply chain innovation. Blockchain and the broader digital aspect were described as "a big gap" where significant joint projects could be undertaken, particularly as the regulatory environment pushes toward more sophisticated data exchange.

Relationship improvement was expected to follow from greater transparency across supply chain tiers, with all partners in the chain being aware of what has occurred at each stage. The interviewee noted that any issues that are not handled properly would become visible to all participants, creating a natural accountability mechanism that should strengthen partnerships over time.

Learning outcomes were assessed positively. Upstream data, which is currently limited even for larger companies, would become available for procurement strategy formulation and overall supply chain governance.

Communication quality would improve through reducing manual exchanges. The interviewee confirmed that significant volumes of emails and phone calls could be eliminated once information flows reliably through a shared digital chain.

On transaction security, the interviewee returned to the cybersecurity theme, emphasizing that the API environment connecting blockchain to ERP systems must be tightly controlled and that data-sharing permissions require careful governance. The assessment was that cybersecurity represents both a potential benefit of blockchain and a risk that must be managed in its implementation.

Emergent themes

Two observations from this interview extended beyond the structured questions. The first concerned the timeline for realizing blockchain's benefits in a B2B supply chain context. Interviewee D estimated that investment decisions of this nature operate on a three-to-five-year horizon, and that the ecosystem required for blockchain to function effectively, including standardized processes, supplier onboarding, and regulatory alignment, takes considerable time to develop. B2B business practices change slowly, and the interviewee cautioned that patience and well-defined scope are essential, recommending that initial implementation focus on complex products with multiple upstream suppliers where the traceability benefit is greatest.

The second observation concerned the gap between regulatory ambition and operational reality in supply chain sustainability. The interviewee described a situation in which EU regulations have set ambitious requirements for sustainability data collection and reporting, but the market lacks both the systems and the experienced professionals to meet those requirements. Many companies are still using Excel-based tools for what should be digitally automated processes, and the pool of supply chain sustainability specialists with practical experience in emissions data analysis remains shallow. This gap creates both a long-term driver for blockchain adoption and a near-term constraint, as the human expertise needed to design and govern a blockchain-based sustainability system may not yet be available in sufficient numbers.

4.4 Cross-case analysis and general model of drivers, barriers, and performance outcomes of adopting blockchain technology

The within-case analyses presented in Sections 4.3.1 through 4.3.4 examined each case organization's perspective on blockchain adoption for supplier relationship management individually. This section draws those perspectives together by comparing the findings across all four cases, mapping them against the 24 propositions from the conceptual model, and identifying patterns of convergence and divergence. The section concludes by presenting a revised empirical model that incorporates both the theoretically anticipated factors and the emergent themes that surfaced during the interviews.

Drivers: cross-case comparison

The strongest convergence across all four cases concerned the perceived relative advantage of blockchain for supply chain traceability and provenance verification (P1). Every interviewee, regardless of company size or functional background, identified the ability to track the origin and handling history of materials and components across multiple tiers of the supply chain as the area where blockchain could deliver the most meaningful improvement over existing systems. For the three larger companies (A, B, and D), this was explicitly tied to sustainability-sensitive materials and the need to verify suppliers' claims about low-emission inputs or ethically sourced components. For Company C, the application was more narrowly focused on transport documentation and quality certificates, reflecting the smaller firm's more limited procurement scope. The unanimity of this pattern reinforces Proposition 1, though the specific manifestation of relative advantage varies with firm size and supply chain complexity.

Infrastructure compatibility (P2) produced a more nuanced pattern. The three multinational companies reported mature digital procurement environments built on enterprise ERP platforms, which, in principle, provide a technical foundation for blockchain integration. Nonetheless, all three also noted that this very maturity creates a form of lock-in: blockchain must integrate with deeply embedded systems rather than replacing them. Company A framed the compatibility challenge as primarily an ecosystem problem, arguing that the weakest link in the supply chain determines the viability of the entire provenance chain. Company B raised a similar point about the gap between large and small suppliers. Company C, by contrast, described its digital infrastructure as fundamentally insufficient, comparing the prospect of blockchain integration to "building a second floor on a house that does not have a proper foundation yet". Proposition 2 is therefore supported but requires qualification: compatibility functions differently depending on whether a firm is digitally mature (where the barrier is integration complexity) or digitally underdeveloped (where the barrier is the absence of prerequisites).

Regarding organizational drivers, the cases converged strikingly. All four interviewees reported that their organizations are broadly supportive of digital innovation, yet none reported any executive-level interest in blockchain specifically (P3 partially supported). In each case, leadership attention is directed toward AI, data analytics, or ERP expansion. One interviewee described blockchain as having a “PR problem”, while another noted that finding a blockchain press release from an energy company dated after 2019 would be difficult. The pattern observed suggests that top management support, while necessary, is not sufficient on its own, as it must be directed specifically toward blockchain rather than toward digitalization in general. The organizational cultures described across the cases shared a common trait of balancing innovation with caution, variously described as “dialectic”, “innovation-oriented within well-defined guardrails”, and “entrepreneurial but risk-aware out of necessity” (P4 partially supported). The energy sector's involvement with critical infrastructure and long product lifecycles appears to create a sector-wide cultural orientation that tempers enthusiasm for unproven technologies.

Regulatory and sustainability pressures (P5, P9) showed clear variation by firm size. The three multinational companies identified the CSRD, national supply chain due diligence laws, and customer demands for sustainability documentation as genuine and intensifying drivers. Company B described sustainability accountability as 'arguably the strongest pull factor' for blockchain adoption. Company D added specificity by pointing to concrete regulatory instruments beyond the CSRD, including the Carbon Border Adjustment Mechanism (CBAM) for tracking emissions associated with steel imports, the EU Deforestation Regulation requiring proof that packaging and wood components are not sourced from deforested areas, and the forthcoming EU Digital Product Passport, which will require companies to demonstrate product origin and material traceability. These regulations are currently being met through manual processes, Excel-based tools, and consultant-built spreadsheets, an approach that the interviewee characterized as unsustainable at scale. Company C, on the other hand, reported that regulatory pressure, while real, remains manageable through conventional documentation at its current scale. This divergence suggests that sustainability-driven regulatory pressure is a stronger driver of adoption for larger firms with complex, multi-tier supply chains and direct reporting obligations than for smaller firms with lighter compliance burdens.

Competitive pressure (P6) was not supported in any of the four cases. No interviewee was aware of competitors or industry peers pursuing blockchain for supply chain management in their specific segment. This absence of competitive signaling is consistent across all cases and represents one of the clearest disconfirmations in the study.

Supplier readiness (P7) was evaluated low across the board, though the reasons varied. The larger companies distinguished between strategic suppliers who are digitally capable and smaller or geographically distant suppliers who lack the infrastructure or willingness to participate. Company C offered the most direct assessment, doubting that most of its international factory partners would engage with a blockchain platform absent a tangible benefit for themselves. The universally low readiness assessment across all cases underscores the inherently multi-party nature of blockchain: unlike technologies that a single firm can adopt unilaterally, blockchain's value depends on network participation, which cannot be assumed.

All four interviewees confirmed that the renewable energy transition has increased procurement complexity (P8 supported), though the scale of the challenge differs predictably with firm size. The larger companies described expanding supplier networks spanning new geographies and component categories, while Company C pointed to diversification into wind, solar, battery storage, and green hydrogen projects as a source of growing coordination demands.

Barriers: cross-case comparison

The barrier most consistently identified across all four cases was the absence of internal blockchain expertise (P12 strongly supported). Every interviewee confirmed that their organization lacks the knowledge required to evaluate blockchain platforms, design smart contracts, or formulate a credible business case. This deficit operates at both the technical and strategic levels, and it was the only barrier that all four interviewees, from the most technically informed (Interviewee A, with six years of blockchain development experience) to the least (Interviewees C and D), agreed upon without reservation.

Financial viability and ROI uncertainty (P13) emerged as the second most prominent barrier. All interviewees described the difficulty of constructing a convincing business case when blockchain's benefits are diffuse and difficult to quantify, while its costs are concrete. Company A estimated a minimum multi-million-euro investment. Company B noted that nearly two decades of ERP investment make the incremental value of blockchain difficult to articulate to a finance function. Company C framed the calculation in the starkest terms, asking whether the same money would be better spent on hiring a project manager or developing a new supplier relationship. The consistency of this pattern across all company sizes suggests that ROI uncertainty is a barrier that does not diminish with organizational scale, it merely takes different forms. Company D introduced an additional dimension. In a large multinational corporation, investment proposals require buy-in from multiple business units to achieve sufficient coverage and justify the expenditure. A single unit pursuing blockchain in isolation would lack the scale to generate meaningful returns, meaning that internal consensus-building across the organization precedes any external supplier engagement.

The technical barriers produced the most interesting divergence. Interviewee A, drawing on direct blockchain development experience, stated that scalability is no longer a meaningful barrier given modern platforms (P10 challenged). Interviewee B redirected technical concern toward a different issue entirely: data quality at the point of entry, framing it as the “garbage in, garbage out” problem that blockchain's immutability makes worse rather than better. Interviewee C expressed concerns of a more fundamental nature, relating not to specific platform limitations but to a general inability to evaluate the technology at all. Interviewee D raised a distinct technical concern: cybersecurity. The risks associated with connecting ERP systems to external platforms through APIs, and the intense scrutiny that information security teams would apply to any proposal involving cross-organizational data sharing, were positioned as the primary technical impediment. This divergence across the four cases suggests that the nature of perceived technical barriers shifts with both the interviewee's level of blockchain familiarity and their functional perspective. Experienced blockchain practitioners worry about design challenges, data specialists worry about input quality, finance-oriented managers worry about comprehension, and procurement operations specialists worry about the security implications of system interconnection.

System integration (P11) was acknowledged by all four cases, but again with divergent reasoning. The three multinational companies described the challenge of integrating blockchain with established ERP ecosystems without creating parallel data architectures. Interviewee D offered an additional nuance by positioning blockchain not as a radical departure from existing systems but as a further evolution of current supply chain collaboration tools, taking existing capabilities deeper, faster, and further upstream. This framing makes the integration challenge more tractable in principle but harder to justify financially, since existing SRM tools already handle many of the same functions at a basic level. Company C faced the opposite problem, not integration complexity but the absence of any digital infrastructure to integrate with. Proposition 11 is supported, but the barrier manifests in fundamentally different ways depending on the level of organizational maturity.

Regulatory barriers (P14, P15) received the weakest support among all proposition clusters. Interviewee A described regulatory constraints as minimal, noting that using blockchain for data sharing rather than financial transactions avoids most cryptocurrency-specific regulation. Interviewee B went further, characterizing the regulatory environment as more enabling than constraining, since compliance demands are creating the very traceability needs that blockchain addresses. Interviewee C was neutral, and Interviewee D echoed the view that current regulations neither encourage nor prevent blockchain use. GDPR's tension with blockchain immutability (P15), emphasized in the literature as a significant barrier, received limited concern across all cases, as interviewees consistently noted that most supply chain data is commercial rather than personal. These findings suggest that the literature may overstate the regulatory barrier for non-financial blockchain applications in supply chain contexts.

Sector-specific barriers (P16, P17) found broad support. All four interviewees acknowledged that the energy sector's conservative culture, established quality frameworks, long-standing contractual templates, and the physical nature of the underlying supply chain create resistance to novel governance approaches. Company C expressed this most pointedly, noting that convincing an international network of factory partners to adopt an untested technology layer is a coordination challenge that is disproportionately difficult for a small company that does not set industry standards.

Performance outcomes: cross-case comparison

The performance outcome that generated the strongest and most consistent response across all cases was the anticipated improvement in regulatory compliance and sustainability reporting capacity. While this was not formulated as a standalone proposition in the conceptual model, the empirical data suggest it warrants recognition as a distinct performance category. For the larger companies, blockchain's capacity to provide verifiable records of carbon intensity, material origin, and chain of custody was described as potentially transformative for meeting CSRD requirements and validating sustainability claims. For Company C, the benefit was framed more modestly as documentation management, but the underlying logic was the same: a shared, permanent record would reduce the administrative burden of demonstrating compliance.

Regarding cost reduction (P19), all interviewees identified potential savings in administrative overhead, audit costs, and dispute resolution costs. That said, every interviewee also expressed uncertainty about whether these savings would exceed implementation costs, at least in the short- to medium term. This consistent skepticism about the net cost impact represents a notable gap between the literature's emphasis on cost efficiency and the practitioners’ lived experience of investment uncertainty.

Relationship improvement (P20) produced the most varied responses. Interviewee A identified three reinforcing dynamics through which blockchain could deepen supplier relationships. Interviewee B offered a more cautious assessment, suggesting that the transition period might initially strain partnerships before strengthening them, as not all suppliers would welcome the transparency that a shared ledger demands. Company C was uncertain whether technology would add value to relationships that are already personal and trust-based. This divergence suggests that the relationship improvement proposition holds most clearly in contexts where relationships are already complex and multi-layered enough to benefit from a structured data foundation, and less clearly where relationships operate primarily through personal familiarity.

Innovation outcomes (P18) were addressed as indirect rather than transformative. None of the interviewees anticipated that blockchain would enable fundamentally new products, but several saw potential for improved collaborative processes, whether through joint client offers (Company A), shared sustainability data for joint carbon-reduction efforts (Company B), or faster identification of improvement opportunities with manufacturing partners. Company D, which already conducts innovation workshops with suppliers, described digital supply chain innovation as “a big gap” where significant joint projects could be undertaken, particularly as the regulatory environment pushes toward more sophisticated data exchange. The innovation pathway across all cases runs through data sharing rather than through the technology itself.

Learning (P21), decision-making (P22), and communication quality (P23) produced a consistent pattern: interviewees from digitally mature organizations saw meaningful potential, while Company C's capacity to benefit was limited by the absence of analytical tools and structured data systems. Interviewee B's observation that “a clean and trusted dataset is the most valuable thing you can have” captures the logic that links blockchain to learning and decision-making, but this logic presupposes a level of analytical infrastructure that smaller firms may not possess. The propositions are supported but subject to a digital maturity boundary condition.

Transaction security (P24) was valued by all interviewees but viewed as a complement to existing security practices rather than a standalone benefit. Company B, with direct experience of a cyberattack, was most emphatic about the importance of security but also most cautious about treating blockchain as a comprehensive solution. Company D framed cybersecurity as a dual concern: while blockchain's distributed architecture could enhance data resilience, the API environments required to connect blockchain to ERP systems introduce their own attack surfaces and demand tightly controlled governance of data-sharing permissions. This dual framing, in which security is both a benefit and a risk, introduces nuance that the literature's predominantly positive treatment of blockchain security does not fully capture.

Emergent themes

The empirical data surfaced several themes that the propositions in the conceptual model did not anticipate, the most consistent of which was the crowding-out effect of artificial intelligence on blockchain adoption. Interviewees A and B both described how AI has consumed virtually all organizational attention, funding, and executive interest in the digital innovation space, leaving blockchain without a meaningful share of the innovation agenda. This goes beyond mere competition for resources, as it reflects a broader shift in the corporate narrative about which technologies are viewed as transformative, with AI now occupying the position that blockchain briefly held around 2018 and 2019.

Closely related was the industry consortium imperative that Interviewees A and B arrived at independently. Both concluded that blockchain adoption for supplier management is unlikely to succeed as a single-company initiative, since the technology's value depends on network participation that can only be achieved through coordinated industry action, potentially building on existing pre-competitive collaboration models. This result reinforces the trading partner readiness barrier (P7) but extends it by identifying the specific governance mechanism, an industry consortium, that practitioners consider necessary for progress.

The contrast between the multinational firms and Company C brought a third theme into focus: the resource asymmetry between large and small companies in the blockchain adoption conversation. Discussions of blockchain in supply chains tend to presuppose organizations with IT departments, innovation budgets, and dedicated technical staff, while for smaller firms, the path to blockchain runs through prior stages of basic digitalization that larger companies completed years ago. Firm size, which the conceptual model treated primarily as a background characteristic, appears to operate as a more fundamental moderating variable than the literature anticipates.

Interviewee A articulated a fourth theme by arguing that the most important prerequisite for blockchain in energy-sector supplier management is not technological but relational: a shift in how energy companies perceive their position within the broader industry ecosystem, moving from adversarial or purely transactional orientations toward recognition of shared interests in collaborative data infrastructure. This theme connects to the social exchange theory foundations discussed in Section 2.1

but extends them by suggesting that blockchain adoption requires a prior relational transformation rather than producing one.

Case 4 contributed two further observations that complement the themes above. Interviewee D estimated that investment decisions of this nature operate on a three-to-five-year horizon and that the ecosystem required for blockchain to function in B2B supply chains, including standardized processes, supplier onboarding, and regulatory alignment, takes considerable time to develop. Unlike consumer-facing technologies that can achieve rapid adoption, blockchain for industrial supply chain management is constrained by the pace at which B2B relationships and practices can be restructured, a pace the interviewee characterized as inherently slow. This observation introduces a temporal dimension to the adoption model that the other cases did not articulate as explicitly.

Interviewee D also drew attention to a widening gap between regulatory ambition and operational reality in supply chain sustainability. Despite increasingly ambitious EU requirements for sustainability data collection and reporting, the market currently lacks both the digital systems and the experienced professionals to meet those requirements, with many firms still relying on Excel-based tools for processes that should be digitally automated, and the pool of supply chain sustainability specialists with practical emissions data experience remains shallow. This finding adds an important qualification to the sustainability compliance driver. While it is the strongest pull factor toward blockchain adoption, it may simultaneously operate as a near-term constraint, since the human expertise needed to design and govern a blockchain-based sustainability system is not yet available in sufficient numbers.

Revised empirical model

The cross-case analysis confirms the broad structure of the conceptual model while introducing several refinements. Table 5 summarizes the empirical support for each proposition.

Table 5. Summary of empirical support for propositions

Proposition	Theme	Empirical support
P1	Relative advantage	Strongly supported; traceability identified as top potential across all cases
P2	Infrastructure compatibility	Supported with qualification; manifests as integration complexity for large firms and as foundational absence for small firms
P3	Top management support	Partially supported; digitalization support is universal but blockchain-specific interest is absent
P4	Organizational innovativeness	Partially supported; all cultures balance innovation with sector-specific caution
P5	Regulatory pressure	Supported for large firms; weaker driver for small firms
P6	Competitive intensity	Not supported; no competitive signalling observed in any case
P7	Trading partner readiness	Supported (as a barrier in practice); universally low readiness
P8	Supplier network complexity	Supported; renewable transition confirmed as complexity driver
P9	Sustainability accountability	Strongly supported for large firms; moderate for small firms
P10	Scalability limitations	Challenged; technically informed interviewee assessed as resolved
P11	System integration difficulty	Supported; manifests differently by digital maturity level
P12	Knowledge and expertise deficits	Strongly supported; most consistently identified barrier across all cases
P13	Implementation costs / ROI	Strongly supported; consistent across all company sizes
P14	Regulatory uncertainty	Weakly supported; practitioners view regulation as more enabling than constraining
P15	GDPR tensions	Not supported; minimal practical concern across all cases
P16	Physical infrastructure complexity	Moderately supported; acknowledged as a contextual constraint
P17	Path dependencies	Supported; conservative culture and established practices confirmed
P18	Product innovation	Partially supported; indirect rather than transformative
P19	Cost reduction	Partially supported; potential identified but net benefit uncertain

P20	Relationship improvement	Supported with variation; strongest for complex multi-layered relationships
P21	Organizational learning	Supported with boundary condition; limited by analytical maturity
P22	Decision-making quality	Supported with boundary condition; limited by analytical maturity
P23	Communication quality	Supported; consistent expectation of reduced routine exchange
P24	Transaction security	Moderately supported; valued as complement, not standalone solution

In addition to refining the original propositions, the empirical analysis identifies four factors that the revised model incorporates as new elements: the AI crowding-out effect as a contextual moderator of all adoption drivers, the industry consortium imperative as a necessary governance condition for adoption, firm size and digital maturity as a moderating variable that shapes how both barriers and performance outcomes manifest, and the relational mindset prerequisite as a foundational condition that precedes technological adoption. These emergent factors, together with the qualified and refined propositions summarized above, constitute the revised empirical model of this study and provide the basis for the theoretical and practical implications.

5 Conclusions

This chapter concludes the thesis by drawing together the theoretical and empirical strands developed across the preceding chapters. Section 5.1 summarizes the key empirical findings and discusses them in relation to the research question and the 24 propositions from the conceptual model. Section 5.2 outlines the study's theoretical contributions to the blockchain adoption and supplier relationship management literatures. Section 5.3 discusses the managerial implications for practitioners in the energy sector. Section 5.4 proposes directions for future research, and Section 5.5 acknowledges the study's limitations.

5.1 Summary and discussion of the key empirical findings

The research question guiding this thesis asked what drivers, barriers, and performance outcomes are associated with the adoption of blockchain technology by energy companies to manage their supplier relationships. To address this question, a conceptual model comprising 24 propositions was developed from the literature and subsequently examined through semi-structured interviews with four industry specialists operating within the Finnish energy sector.

On the driver’s side, the empirical findings confirm that traceability and provenance verification constitute the most compelling value proposition of blockchain for energy-sector supplier management. All four interviewees converged on this point regardless of firm size or functional background, lending strong support to the relative advantage proposition (P1). This finding is consistent with Wang et al. (2019), who identified traceability as the predominant factor driving blockchain adoption in supply chains, and with Andoni et al. (2019), who found that transparency and provenance verification accounted for a substantial share of blockchain initiatives in the energy sector. Sustainability accountability emerged as the second most potent driver, particularly for the larger firms facing direct obligations under the CSRD and national supply chain due diligence legislation (P5, P9), supporting Gokalp et al.’s (2020) conclusion that environment-related determinants carry more weight than technological or organizational factors in the adoption decision. However, the data also revealed a notable gap between general organizational enthusiasm for digital innovation and the complete absence of blockchain-specific executive interest across all four cases. This pattern suggests that blockchain's challenge in the energy sector is not one of perceived irrelevance but of attention competition, a dynamic amplified by what the interviewees described as AI's dominance over the corporate innovation agenda. This finding has no clear parallel in the existing blockchain adoption literature, which has not yet examined inter-technology competition as a variable affecting adoption.

The barrier analysis yielded two findings of particular significance. The absence of blockchain expertise was the single most consistently identified impediment across all cases and all seniority levels (P12), confirming the literature's emphasis on knowledge deficits while revealing that the gap extends from the technical level to the strategic level of business case formulation. This aligns with Mathivathanan et al.'s (2021) conclusion that lack of business awareness is the single most influential barrier in their TISM analysis, though the present study extends their finding by showing that the deficit operates equally at the strategic and technical levels. ROI uncertainty (P13) was equally present, with every interviewee describing the difficulty of justifying concrete costs against diffuse and hard-to-quantify benefits, a pattern consistent with Andreoulaki et al.'s (2024) identification of economic concerns as a significant barrier in the energy sector. Notably, the empirical data challenged several barriers that the literature emphasizes. Scalability limitations (P10) were assessed as largely resolved by the most technically informed interviewee, contrasting with Andoni et al. (2019) and Moraes et al. (2024), who position scalability as a foundational barrier. Regulatory barriers, including GDPR tensions (P14, P15), received markedly less concern from practitioners than the academic literature would predict (cf. Chiarini et al., 2022; Andreoulaki et al., 2024), particularly for non-financial supply chain applications. The most significant barriers that emerged were organizational and relational rather than technological or regulatory, a conclusion that partially supports Kouhizadeh et al.'s (2021) finding that supply chain and organizational barriers outweigh technological ones, while diverging from their emphasis on technology as a primary impediment category.

On performance outcomes, the interviewees' expectations aligned with the literature in direction but diverged in emphasis. Sustainability compliance capacity, though not formulated as a standalone proposition in the original model, emerged as the dominant anticipated outcome across the larger firms, extending Park and Li's (2021) finding that blockchain improves sustainability performance indicators by suggesting that compliance warrants treatment as a distinct performance category rather than a subset of transparency. Cost-reduction potential (P19) was acknowledged but tempered by persistent skepticism about whether savings would outweigh implementation costs, a more cautious assessment than the strong operational performance effects reported in Mishra et al.'s (2023) meta-analysis and Wamba et al.'s (2020) cross-national survey. Relationship improvement (P20) was endorsed most strongly by interviewees managing complex, multi-tier supplier networks and was assessed more cautiously by the smaller firm, where personal trust already serves the governance function that blockchain would formalize. This pattern resonates with Stranieri et al.'s (2021) finding that blockchain reduces behavioral uncertainty in supply chains, while adding the qualification that the benefit is most pronounced where relationships are already complex enough to require formal governance structures. Learning, decision-making, and communication outcomes (P21, P22, P23) were supported but subject to a digital maturity boundary condition: their realization presupposes an analytical infrastructure that not all firms possess, a constraint not explicitly addressed in the studies by Kamble et al. (2021) or Nandi et al. (2020), which examined blockchain's performance effects in digitally mature manufacturing contexts.

Several findings extended beyond the original propositions and merit particular attention. The AI crowding-out effect, the industry consortium imperative, the moderating role of firm size and digital maturity, and the relational mindset prerequisite each represent empirically grounded additions to the conceptual model that the existing literature on blockchain adoption in supply chains has not adequately addressed. The consortium finding builds on Agi and Jha's (2022) identification of external pressure as a prominent enabler category, but goes further by specifying the governance mechanism that practitioners consider necessary. The relational mindset prerequisite connects to the social exchange theory foundations explored by Nyaga et al. (2010) and Lumineau and Oliveira (2020), but reverses the expected causal direction: rather than blockchain producing relational improvement, a prior shift in relational orientation may be necessary for adoption to occur. Taken together, these emergent themes suggest that the path to blockchain adoption in energy-sector supplier management is shaped less by the technology's readiness and more by the organizational, relational, and institutional conditions in which the adoption decision is embedded.

5.2 Theoretical contributions

By examining blockchain adoption for supplier relationship management within the energy sector, this study extends the scholarly conversation in several directions that the existing literature has not adequately addressed. The most direct contribution lies in extending the application of the TOE framework (Tornatzky & Fleischer, 1990) to a context that has received limited empirical attention: blockchain adoption for managing upstream supplier-buyer relationships in the energy sector. While prior TOE-based studies have examined blockchain adoption in general supply chain settings (Gokalp et al., 2020; Malik et al., 2021; Chittipaka et al., 2022), this study demonstrates that the energy sector introduces conditions, including critical infrastructure responsibilities, long product lifecycles, and the physical nature of the underlying supply chain, that shape the adoption decision in ways the general framework does not fully anticipate. The addition of an energy-sector-specific dimension to the TOE model, encompassing supplier network complexity, sustainability accountability, and incumbent path dependencies, represents a context-sensitive extension of the framework.

The study also contributes by identifying empirical boundary conditions for several propositions that the literature treats as broadly applicable. The finding that scalability is no longer perceived as a significant barrier by technically informed practitioners challenges research that continues to position it as a primary technological impediment (Andoni et al., 2019; Moraes et al., 2024). Similarly, the minimal concern expressed by all four interviewees regarding regulatory barriers and GDPR tensions stands in notable contrast to the emphasis these receive in the academic literature (Chiarini et al., 2022; Andreoulaki et al., 2024). These findings suggest that as blockchain platforms mature and as practitioners gain familiarity with the distinction between financial and non-financial applications, the barrier landscape may be shifting in ways that the literature has not yet fully registered.

A further contribution concerns the four emergent factors that the conceptual model did not anticipate. The AI crowding-out effect, which displaces blockchain from the organizational innovation agenda, has not been documented in the blockchain adoption literature to the author's knowledge. This phenomenon is distinct from mere resource competition, it reflects a broader narrative shift in which AI has assumed the transformative role that blockchain occupied in corporate discourse several years earlier. The industry consortium imperative extends the trading partner readiness construct by specifying the governance mechanism that practitioners consider necessary for blockchain to achieve the network participation on which its value depends. The moderating role of firm size and digital maturity emerged as more fundamental than the literature suggests, operating not merely as a background variable but as a condition that determines which barriers are relevant and which performance outcomes are achievable. The relational mindset prerequisite, articulated by the most blockchain-experienced interviewee, connects to the social exchange theory foundations of the SBR literature (Nyaga et al., 2010; Lumineau & Oliveira, 2020) but reverses the expected causal direction, rather than blockchain producing relational improvement, a prior shift in relational orientation may be necessary for blockchain adoption to occur at all.

Finally, the empirical data point to sustainability compliance as a distinct performance outcome dimension that warrants separate treatment in future models of blockchain adoption for supply chain management. The original conceptual model distributed compliance-related benefits across several propositions, but the interview data consistently elevated it as the single most anticipated outcome, particularly for firms facing direct CSRD and supply chain due diligence obligations. This finding aligns with the growing emphasis on sustainability-driven technology adoption in the operations management literature (Park & Li, 2021; Saberi et al., 2019) and suggests that future models should treat compliance capacity as a standalone performance category rather than subsuming it within broader constructs such as transparency or traceability.

5.3 Managerial implications

The findings of this study have several practical implications for decision-makers in the energy sector, evaluating blockchain technology for supplier relationship management. The most immediate implication concerns where to focus. The empirical evidence consistently points to sustainability traceability and provenance verification as the application area where blockchain offers the clearest advantage over existing systems. Managers considering blockchain adoption would benefit from anchoring their initial efforts around a specific sustainability-related use case, such as verifying the carbon intensity of sourced materials or documenting compliance with supply chain due diligence obligations, rather than pursuing blockchain as a general-purpose procurement tool. A narrowly defined pilot with measurable compliance outcomes is more likely to generate the internal credibility needed to justify broader investment than an ambitious platform initiative whose returns are difficult to quantify.

The study also highlights a practical prerequisite that managers may underestimate: the need for blockchain-specific knowledge within the organization. Every case company in this study lacked internal blockchain expertise, and this deficit was identified as the single most critical barrier to adoption. Energy companies that are serious about evaluating blockchain should invest in building a baseline of internal competence, whether through targeted hiring, partnerships with technology providers, or participation in industry knowledge-sharing initiatives, before committing to platform selection or pilot development. Without this foundational understanding, organizations risk either dismissing the technology prematurely or pursuing implementations that are poorly matched to their actual supply chain needs.

The findings further suggest that individual company initiatives are unlikely to succeed in isolation. Blockchain's value for supplier management depends on network participation, and the interviewees consistently emphasized that no single energy company can build a viable supply-chain blockchain on its own. Managers should explore opportunities for pre-competitive industry collaboration, potentially through existing sectoral bodies or joint initiatives, to develop shared standards, common data formats, and collectively governed platforms. The wind energy sector's experience with collaborative quality frameworks offers a precedent that could be extended to digital supply chain infrastructure.

For managers at smaller energy-sector firms, the study offers a specific caution: blockchain adoption presupposes a level of digital maturity that may not yet be in place. Before investing in distributed ledger technology, smaller firms would benefit from strengthening their foundational digital capabilities, including structured supplier databases, digital document management, and standardized quality tracking systems. These intermediate investments deliver immediate operational value while building the infrastructure on which blockchain could eventually be layered.

Finally, managers should recognize that blockchain competes for organizational attention with other digital technologies, most notably artificial intelligence. The empirical data suggest that AI currently dominates the corporate innovation agenda in the energy sector, leaving limited bandwidth for blockchain exploration. Rather than viewing this as a reason to defer blockchain indefinitely, forward-thinking managers could position preparatory activities, such as data standardization, supplier digitalization, and internal knowledge building, as complementary to their AI strategies, since both technologies ultimately depend on the same foundation of clean, structured, and trustworthy data.

5.4 Directions for future research

Several areas for further investigation emerge from the empirical analysis and from the boundaries of the present research design. The most pressing need is for longitudinal research that tracks blockchain adoption over time, rather than capturing perceptions at a single point in time. All four case companies in this study are at the pre-adoption stage, which means the findings reflect anticipated rather than experienced outcomes. Future studies that follow organizations through the adoption process, from initial pilot to operational deployment, could examine whether the drivers, barriers, and performance outcomes identified in this thesis persist as the technology moves from concept to practice, and whether new factors emerge during implementation that pre-adoption research cannot detect.

The AI crowding-out effect identified in this study represents an empirically grounded but theoretically underdeveloped finding that suggests further investigation. Research examining how competing digital technologies interact in organizational adoption decisions, and specifically how the rise of AI has affected the strategic positioning of blockchain within corporate innovation portfolios, would contribute to a more dynamic understanding of technology adoption that accounts for inter-technology competition rather than treating each technology in isolation.

The role of firm size and digital maturity as moderating variables emerged strongly from the contrast between multinational companies and the small trading firm in this study. Quantitative research using larger samples could test whether the boundary conditions observed here, particularly the digital maturity prerequisite for realizing learning, decision-making, and communication outcomes, hold across a broader population of energy sector firms and whether threshold levels of digital maturity can be empirically identified.

The industry consortium model that practitioners identified as necessary for viable adoption remains largely unexplored in the blockchain literature. Research investigating the governance structures, cost-sharing arrangements, and coordination mechanisms required to establish and sustain multi-company blockchain platforms in the energy sector would address a gap that is both theoretically interesting and practically urgent, given that the interviewees independently converged on this as the most important condition for progress.

Future research could also broaden the geographic and sectoral scope of the investigation. This study is situated in the Finnish energy sector, which benefits from advanced digital infrastructure, a stable regulatory environment, and a relatively concentrated industry structure. Examining blockchain adoption for supplier management in energy markets with different institutional characteristics, such as emerging economies with less developed digital infrastructure or markets undergoing energy sector liberalization, would test the transferability of the present findings and potentially reveal additional drivers or barriers that the Finnish context does not surface.

Finally, the relational mindset prerequisite identified by Interviewee A invites research that more explicitly bridges the blockchain adoption and interorganizational relationship literatures. Studies drawing on social exchange theory or relational contracting theory could examine whether and how relational orientation between buyers and suppliers conditions blockchain adoption readiness, and whether blockchain adoption in turn reinforces or transforms the relational dynamics it was initially enabled by.

5.5 Limitations

The conclusions drawn in this thesis should include methodological and contextual constraints that bound the scope and generalizability of the findings. The most significant limitation is the small sample size. Four case organizations, each represented by a single interviewee, provide rich qualitative insight but cannot claim statistical representativeness of the Finnish energy sector as a whole. The perspectives captured reflect the individual experiences and judgments of the informants, which may not fully represent the views held within their organizations or across the sector more broadly. Interviewing multiple informants per case company, ideally from different functional areas such as procurement, IT, legal, and senior management, would produce a more complete picture of each organization's position on blockchain adoption.

The reliance on a single data collection method, semi-structured interviews, introduces a further constraint. While interviews are well-suited to capturing perceptions and reasoning, they are susceptible to social desirability bias, selective recall, and the interviewee's willingness to disclose sensitive organizational information. Triangulating interview data with documentary evidence, such as internal strategy documents, procurement system records, or pilot project reports, would have strengthened the credibility of the findings, but access to such materials was unavailable for this study.

The pre-adoption status of all four case companies means that the performance outcome findings are based on anticipated rather than experienced effects. None of the interviewees had implemented blockchain for supplier management, and their assessments of innovation, cost, relationship, learning, decision-making, communication, and security outcomes are therefore prospective. These expectations may or may not correspond to the outcomes that actual implementation would produce, and the study cannot claim to have measured realized performance impacts.

The Finnish context, while offering analytical advantages, also introduces geographic and institutional specificity. Finland's advanced digital infrastructure, stable regulatory environment, and concentrated energy sector create conditions that may not be replicated in other markets. The findings may transfer most readily to other Nordic and EU energy markets operating under comparable institutional conditions, but their applicability to energy sectors in developing economies or in markets with fundamentally different regulatory structures should not be assumed.

The variation in blockchain familiarity across interviewees, while analytically valuable for identifying how perceptions differ by knowledge level, also means that some respondents were better positioned than others to assess the technical propositions in the conceptual model. The assessments of scalability, system integration, and smart contract automation offered by Interviewees C and D, who acknowledged limited blockchain knowledge, carry a different epistemic weight than those offered by Interviewee A, who brought six years of development experience. The study has reported these perspectives transparently, but readers should bear this variation in mind when evaluating the empirical support assigned to individual propositions.

References

Agi, M. A. N., & Jha, A. K. (2022). Blockchain technology for supply chain management: An integrated theoretical perspective of organizational adoption. International Journal of Production Economics, 247, 108458.

Agrawal, T., Kumar, V., Pal, R., Wang, L., & Chen, Y. (2022). Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration. International Journal of Production Research, 60(21), 6497-6516.

Alkhudary, R., Brusset, X., & Fenies, P. (2022). Mitigating the risk of specific supply chain disruptions through blockchain technology. Supply Chain Forum: An International Journal, 23(4), 324-337.

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P., & Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143-174.

Andreoulaki, I., Georgakopoulos, D., Kapsali, M., & Sgouropoulou, C. (2024). Evaluating the barriers to blockchain adoption in the energy sector: A multicriteria approach using the analytical hierarchy process for group decision making. Energies, 17(6), 1487.

Arranz, N., Arroyabe, M. F., Li, J., & Fernandez de Arroyabe, J. C. (2023). Disentangling sustainability and resiliency factors in buyer-supplier relationships: A state-of-the-art review. Journal of Business Research, 160, 113751.

Aslam, J., Saleem, A., Khan, N. T., & Kim, Y. B. (2021). Factors influencing blockchain adoption in supply chain management practices: A study based on the oil industry. Journal of Innovation and Knowledge, 6(2), 92-101.

Badi, S., Ochieng, E., Nasaj, M., & Papadaki, M. (2020). Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint. Construction Management and Economics, 39(1), 36-54.

Bai, Y., Fan, Y., & Liu, Z. (2022). Supply chain finance: What are the challenges in the adoption of blockchain technology? Journal of Digital Economy, 1(3), 185-199.

Barcelo, E., Dimelli, D., & Luciani, A. (2023). Regulatory paradigm and challenge for blockchain integration of decentralized systems: Example, renewable energy grids. Sustainability, 15(5), 4488.

Bhardwaj, A. K., Garg, A., & Gajpal, Y. (2021). Determinants of blockchain technology adoption in supply chains by small and medium enterprises (SMEs) in India. Mathematical Problems in Engineering, 2021, 5537395.

Birkinshaw, J., Brannen, M. Y., & Tung, R. L. (2011). From a distance and generalizable to up close and grounded: Reclaiming a place for qualitative methods in international business research. Journal of International Business Studies, 42(5), 573-581.

Boakye, E. A., Zhao, H., & Ahia, B. N. K. (2023). Seizing technological advancement: Determinants of blockchain supply chain finance adoption in Ghanaian SMEs. Technology Analysis and Strategic Management, 1-17.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-113.

Brito, R. P., Oliveira, N., & Miguel, P. L. S. (2017). Power, governance, and value in collaboration: Differences between buyer and supplier perspectives. Journal of Supply Chain Management, 53(2), 61-87.

Burger, C., Kuhlmann, A., Richard, P., & Weinmann, J. (2016). Blockchain in the energy transition: A survey among decision-makers in the German energy industry. German Energy Agency (dena).

Caniels, M. C. J., & Gelderman, C. J. (2007). Power and interdependence in buyer supplier relationships: A purchasing portfolio approach. Industrial Marketing Management, 36(2), 219-229.

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. Journal of Operations Management, 29(3), 163-180.

Chang, S. E., Chen, Y. C., & Lu, M. F. (2019). Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process. Technological Forecasting and Social Change, 144, 1-11.

Chiarini, A., Compagnucci, M. C., & Ferrara, E. L. (2022). Blockchain, data protection and P2P energy trading: A review on legal and economic challenges. Sustainability, 14(3), 1214.

Chittipaka, V., Kumar, S., Sivaramakrishnan, U., Kadry, S., & Krishnamoorthy, S. (2022). Blockchain technology for supply chains operating in emerging markets: An empirical examination of technology-organization-environment (TOE) framework. Annals of Operations Research, 1-28.

Choi, D., Chung, C. Y., Seyha, T., & Young, J. (2020). Factors affecting organizations' resistance to the adoption of blockchain technology in supply networks. Sustainability, 12(21), 8882.

Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: Implications for operations and supply chain management. Supply Chain Management: An International Journal, 24(4), 469-483.

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). Sage.

Dehghani, M., Kennedy, R. W., Mashatan, A., Rese, A., & Karavidas, D. (2022). High interest, low adoption: A mixed-method investigation into the factors influencing organisational adoption of blockchain technology. Journal of Business Research, 149, 393-411.

Deloitte. (2016). Blockchain: Enigma, paradox, opportunity.

Denzin, N. K., & Lincoln, Y. S. (2018). The SAGE handbook of qualitative research (5th ed.). Sage.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147-160.

Dubey, R., Gunasekaran, A., Bryde, D. J., Dwivedi, Y. K., & Papadopoulos, T. (2020). Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting. International Journal of Production Research, 58(11), 3381-3398.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. Journal of Business Research, 55(7), 553-560.

Dyer, J. H., & Chu, W. (2003). The role of trustworthiness in reducing transaction costs and improving performance: Empirical evidence from the United States, Japan, and Korea. Organization Science, 14(1), 57-68.

Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. Academy of Management Review, 32(4), 1155-1179.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of Management Review, 14(4), 532-550.

Eriksson, P., & Kovalainen, A. (2016). Qualitative methods in business research (2nd ed.). Sage.

Etemadi, N., Borbon-Galvez, Y., Strozzi, F., & Etemadi, T. (2021). An ISM modeling of barriers for blockchain/distributed ledger technology adoption in supply chains towards cybersecurity. Sustainability, 13(9), 4672.

European Commission. (2023). Digital Economy and Society Index (DESI) 2023: Finland.

Ezzati, S. M., Bibak, A., Khanizadeh, G., & Ghasemkhani, N. (2024). Efficiency and transparency in supplier performance evaluation: A blockchain-powered smart contract solution. IEEE Access, 12, 67890-67905.

Fernando, Y., Rozuar, N. H. M., & Mergeresa, F. (2022). Blockchain technology adoption for carbon trading and energy efficiency: ISO manufacturing firms in Malaysia. International Journal of Logistics Research and Applications, 27(3), 371-392.

Fernando, Y., Wahyuni-TD, I. S., Sritaran, R., Mardhatillah, A., & Ramanathan, R. (2021). The blockchain-enabled technology and carbon performance: Insights from early adopters. Technology in Society, 64, 101507.

Gariya, N., Asrani, A., Mandal, A., Shaikh, A., & Cha, D. (2025). A comprehensive analysis of integrating blockchain technology into the energy supply chain for the enhancement of transparency and sustainability. Energies, 18(11), 2951.

Gokalp, E., Gokalp, M. O., & Coskun, S. (2020). Blockchain-based supply chain management: Understanding the determinants of adoption in the context of organizations. Information Systems Management, 39(2), 100-121.

Gonczol, P., Katsikouli, P., Herskind, L., & Dragoni, N. (2020). Blockchain implementations and use cases for supply chains: A survey. IEEE Access, 8, 11856-11871.

Gulati, R., & Sytch, M. (2007). Dependence asymmetry and joint dependence in interorganizational relationships: Effects of embeddedness on a manufacturer's performance in procurement relationships. Administrative Science Quarterly, 52(1), 32-69.

Haber, S., & Stornetta, W. S. (1991). How to time-stamp a digital document. Journal of Cryptology, 3(2), 99-111.

Hader, M., Tchoffa, D., El Mhamedi, A., Ghodous, P., Dolgui, A., & Abouabdellah, A. (2022). Applying integrated blockchain and big data technologies to improve supply chain traceability and information sharing in the textile sector. Journal of Industrial Information Integration, 28, 100345.

Harland, C. M. (1996). Supply chain management: Relationships, chains and networks. British Journal of Management, 7(s1), S63-S80.

Hasan, M. M., Rahim, M. A., & Chowdhury, S. A. (2024). Investigating the role of relational factors on buyer-supplier relationship commitment to enhance firm performance through supply chain integration. Benchmarking: An International Journal, 31(4), 1197-1221.

Hastig, G. M., & Sodhi, M. S. (2020). Blockchain for supply chain traceability: Business requirements and critical success factors. Production and Operations Management, 29(4), 935-954.

Jabbar, S., Lloyd, H., Hammoudeh, M., Adebisi, B., & Raza, U. (2020). Blockchain-enabled supply chain: Analysis, challenges, and future directions. Multimedia Systems, 27, 787-806.

Jum'a, L. (2023). The role of blockchain-enabled supply chain applications in improving supply chain performance: The case of Jordanian manufacturing sector. Management Research Review, 46(12), 1757-1775.

Juszczyk, O., Shahzad, K., & Pomierny, P. (2022). Blockchain technology for renewable energy: Principles, applications and prospects. Energies, 15(16), 6062.

Kamble, S. S., Gunasekaran, A., Kumar, V., Belhadi, A., & Foropon, C. (2021). Blockchain technology's impact on supply chain integration and sustainable supply chain performance: Evidence from the automotive industry. Annals of Operations Research, 327, 575-600.

Karumba, S., Kanhere, S. S., Jurdak, R., & Sethuvenkatraman, S. (2023). Barriers to blockchain-based decentralised energy trading: A systematic review. International Journal of Sustainable Energy, 42(1), 1165-1194.

King, N. (2012). Doing template analysis. In G. Symon & C. Cassell (Eds.), Qualitative organizational research: Core methods and current challenges (pp. 426-450). Sage.

Kohtamaki, M., Vesalainen, J., Henneberg, S., & Naude, P. (2017). The varying roles of governance mechanisms on ex-post transaction costs and relationship commitment in buyer-supplier relationships. Industrial Marketing Management, 65, 135-148.

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. International Journal of Production Economics, 231, 107831.

Kramer, M. P., Bitsch, L., & Hanf, J. H. (2021). Blockchain and its impacts on agri-food supply chain network management. Sustainability, 13(4), 2168.

Krause, D. R., Handfield, R. B., & Tyler, B. B. (2007). The relationships between supplier development, commitment, social capital accumulation and performance improvement. Journal of Operations Management, 25(2), 528-545.

Kumar, A., & Liu, R. (2019). Is blockchain a silver bullet for supply chain management? Technical challenges and research opportunities. Decision Sciences, 51(1), 8-37.

Li, X., Wang, J., & Liu, Z. (2022). Examining the impact of upstream and downstream relationship stability and concentration on firms' financial performance. Journal of Business Research, 147, 233-246.

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. Sage.

Liu, Y., Luo, Y., & Liu, T. (2009). Governing buyer-supplier relationships through transactional and relational mechanisms: Evidence from China. Journal of Operations Management, 27(4), 294-309.

Lohmer, J., & Lasch, R. (2022). Blockchain technology in operations and supply chain management: A content analysis. Sustainability, 14(10), 6192.

Lumineau, F., & Oliveira, N. (2020). A pluralistic perspective to overcome major blind spots in research on interorganizational relationships. Academy of Management Annals, 14(1), 311-337.

Malik, S., Chadhar, M., Vatanasakdakul, S., & Chetty, M. (2021). Factors affecting the organizational adoption of blockchain technology: Extending the technology-organization-environment (TOE) framework in the Australian context. Sustainability, 13(16), 9404.

Manzoor, R., Sahay, B. S., & Singh, S. K. (2022). Blockchain technology in supply chain management: An organizational theoretic overview and research agenda. Annals of Operations Research, 1-48.

Mathivathanan, D., Mathiyazhagan, K., Rana, N. P., Khorana, S., & Dwivedi, Y. K. (2021). Barriers to the adoption of blockchain technology in business supply chains: A total interpretive structural modelling (TISM) approach. International Journal of Production Research, 59(11), 3338-3359.

Mattila, J., Seppala, T., Naucler, C., Stahl, R., Tikkanen, M., Badenlid, A., et al. (2016). Industrial blockchain platforms: An exercise in use case development in the energy industry.

Ministry of Economic Affairs and Employment of Finland. (2023). Finland's integrated energy and climate plan. Government of Finland.

Mishra, N. K., Mukherjee, S., Sinha, A. K., & Saini, G. K. (2023). Antecedents and outcomes of blockchain technology adoption: Meta-analysis. Journal of Computer Information Systems, 64(5), 647-664.

Mohammed, A., Yazdani, M., Oukil, A., & Gonzalez, E. D. R. S. (2023). Blockchain adoption in food supply chains: A systematic literature review on enablers, benefits, and barriers. IEEE Access, 11, 14236-14255.

Moosavi, J., Naeni, L. M., Fathollahi-Fard, A. M., & Fiore, U. (2021). Blockchain in supply chain management: A review, bibliometric, and network analysis. Environmental Science and Pollution Research, 28, 68197-68218.

Moraes, K. K., Picinin, C. T., & Kovaleski, J. L. (2024). Overcoming technological barriers for blockchain adoption in supply chains: A diffusion of innovation (DOI)-informed framework proposal. Supply Chain Management: An International Journal, 29(4), 681-706.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system.

Nandi, M. L., Nandi, S., Moya, H., & Kaynak, H. (2020). Blockchain technology-enabled supply chain systems and supply chain performance: A resource-based view. Supply Chain Management: An International Journal, 25(6), 841-862.

Nyaga, G. N., Whipple, J. M., & Lynch, D. F. (2010). Examining supply chain relationships: Do buyer and supplier perspectives on collaborative relationships differ? Journal of Operations Management, 28(2), 101-114.

Park, A., & Li, H. (2021). The effect of blockchain technology on supply chain sustainability performances. Sustainability, 13(4), 1726.

Patton, M. Q. (2015). Qualitative research and evaluation methods (4th ed.). Sage.

Polas, M. R. H., Jahanshahi, A. A., Karim, A. M., Tabash, M. I., Islam, M. N., & Juman, M. K. (2025). A journey from traditional supply chain processes to sustainability-oriented blockchain supply chain: The critical role of organizational capabilities. Business Strategy and the Environment, 34(2), 1245-1261.

Pournader, M., Shi, Y., Seuring, S., & Koh, S. C. L. (2019). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. International Journal of Production Research, 58(7), 2063-2081.

Pulles, N. J., Veldman, J., & Schiele, H. (2014). Identifying innovative suppliers in business networks: An empirical study. Industrial Marketing Management, 43(3), 409-418.

PwC. (2016). Blockchain: An opportunity for energy producers and consumers?

Rejeb, A., Rejeb, K., Simske, S. J., Treiblmaier, H., & Zailani, S. (2024). Blockchain technology in the renewable energy sector: A co-word analysis of academic discourse. Heliyon, 10(3), e25088.

Rindfleisch, A., & Heide, J. B. (1997). Transaction cost analysis: Past, present, and future applications. Journal of Marketing, 61(4), 30-54.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117-2135.

Sahebi, I. G., Masoomi, B., & Ghorbani, S. (2020). Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain. Technology in Society, 63, 101427.

Santhi, A. R., & Muthuswamy, P. (2022). Influence of blockchain technology in manufacturing supply chain and logistics. Logistics, 6(1), 15.

Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). Pearson.

Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. Journal of Purchasing and Supply Management, 25(4), 100552.

Sharabati, A., Alhileh, M., & Abusaimeh, H. (2024). Blockchain technology implementation in supply chain management: A literature review. Sustainability, 16(2), 627.

Singh, A. K., Sharma, V., & Mangla, S. K. (2023). Investigating barriers to blockchain adoption in construction supply chain management: A fuzzy-based MCDM approach. Technological Forecasting and Social Change, 189, 122346.

Stranieri, S., Riccardi, F., Meuwissen, M. P. M., & Soregaroli, C. (2021). Exploring the impact of blockchain on the performance of agri-food supply chains. Food Control, 119, 107475.

Surucu-Balci, E., Balci, G., & Yuen, K. F. (2024). Digital information in maritime supply chains with blockchain and cloud platforms: Supply chain capabilities, barriers, and research opportunities. Technological Forecasting and Social Change, 198, 122978.

Swan, M. (2015). Blockchain: Blueprint for a new economy. O'Reilly Media.

Tokkozhina, U., Lucia Martins, A., & Cachulo Castillo, J. I. (2022). Uncovering dimensions of the impact of blockchain technology in supply chain management. Operations Management Research, 15, 99-115.

Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books.

Ullah, N., Al-Rahmi, W. M., & Alzahrani, A. I. (2024). Blockchain-powered grids: Paving the way for a sustainable and efficient future. Heliyon, 10(4), e25870.

Villena, V. H., Revilla, E., & Choi, T. Y. (2011). The dark side of buyer-supplier relationships: A social capital perspective. Journal of Operations Management, 29(7-8), 561-576.

Vionis, P., Kotsilieris, T., & Kalloniatis, C. (2023). The potential of blockchain technology and smart contracts in the energy sector: A review. Applied Sciences, 13(13), 7606.

Vu, N., Ghadge, A., & Bourlakis, M. (2024). The impact of blockchain adoption on supply chain performance: Evidence from food industry. International Journal of Production Research, 62(14), 5045-5063.

Wamba, S. F., Queiroz, M. M., & Trinchera, L. (2020). Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation. International Journal of Production Economics, 229, 107791.

Wan, P. K., Huang, L., & Holtskog, H. (2020). Blockchain-enabled information sharing within a supply chain: A systematic literature review. IEEE Access, 8, 49645-49656.

Wang, Q., & Su, M. (2020). Integrating blockchain technology into the energy sector: From theory of blockchain to research and application of energy blockchain. Computer Science Review, 37, 100275.

Wang, Y., Han, J. H., & Beynon-Davies, P. (2019). Understanding blockchain technology for future supply chains: A systematic literature review and research agenda. Supply Chain Management: An International Journal, 24(1), 62-84.

Welch, C., Piekkari, R., Plakoyiannaki, E., & Paavilainen-Mantymaki, E. (2011). Theorising from case studies: Towards a pluralist future for international business research. Journal of International Business Studies, 42(5), 740-762.

Welch, C., Piekkari, R., Plakoyiannaki, E., & Paavilainen-Mantymaki, E. (2022). Reconciling theory and context: How the case study can set a new agenda for international business research. Journal of International Business Studies, 53(1), 4-26.

Williamson, O. E. (1985). The economic institutions of capitalism. Free Press.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). Sage.

Zhang, Y., Guo, Y., & Chen, Z. (2024). Evolution or involution? A systematic literature review of organisations' blockchain adoption factors. Technological Forecasting and Social Change, 200, 123152.