الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne Démocratique et Populaire

Ministère de l'Enseignement Supérieur
et de la Recherche Scientifique

Ecole Nationale Supérieure de Management
Koléa

وزارة التعليم العالي و البحث العلمي

المدرسة الوطنية العليا للمناجمنت
القليعة

DISSERTATION

Submitted in partial fulfillment for the requirements of
« Masters in Strategic Management & Information System »

An Exploratory Study on How Energy Utilities in Algeria Can Approach Blockchain Technology

Case: Algeria's Energy Sector

Submitted by:

TOBBECHE Rayane Hamida

Under the Supervision of:

Pr. TOUMI AMARA Djamila

Academic Year: 2023 /2024

Abstract

This study examines key blockchain use cases for Algerian energy utilities. As blockchain is an emerging technology perceived as a critical uncertainty, its implementation presents both challenges and opportunities that are still largely unknown. Therefore, a broad initial scope was applied, inventorying and grouping a wide range of blockchain-based use cases within the energy market into clusters based on their overall area of use. Each cluster was analyzed and evaluated to best fit both the strategy of the commissioning company and the criteria for using blockchain technology. two clusters most suited to the specified selection criteria were selected. A final evaluation prioritized these clusters based on their overall maturity and high market relevance, selecting them for further detailed analysis. The findings indicate that blockchain technology can significantly contribute to decentralized energy management, improved energy trading, and transaction security, while also highlighting adoption barriers such as market maturity and regulatory challenges.

Keywords: Blockchain technology, energy, use case, strategic .

Résume

L'Algérie, comme beaucoup d'autres pays, vise à améliorer la durabilité et l'efficacité de son secteur énergétique pour atteindre les objectifs de la Vision 2030. Cette étude examine les principaux cas d'utilisation de la blockchain pour les services publics d'énergie en Algérie. Étant donné que la blockchain est une technologie émergente perçue comme une incertitude critique, son implémentation présente à la fois des défis et des opportunités encore largement inconnus. Par conséquent, une approche initiale large a été appliquée, répertoriant et regroupant un large éventail de cas d'utilisation basés sur la blockchain dans le marché de l'énergie en clusters en fonction de leur domaine d'utilisation global. Chaque cluster a été analysé et évalué pour correspondre au mieux à la stratégie de l'entreprise commanditaire et aux critères d'utilisation de la technologie blockchain. Deux clusters répondant le mieux aux critères de sélection spécifiés ont été sélectionnés. Une évaluation finale a priorisé ces clusters en fonction de leur maturité globale et de leur forte pertinence sur le marché, les sélectionnant pour une analyse plus détaillée. Les résultats indiquent que la technologie blockchain peut contribuer de manière significative à la gestion décentralisée de l'énergie, à l'amélioration des échanges énergétiques et à la sécurisation des transactions, tout en soulignant les obstacles à son adoption, tels que la maturité du marché et les défis réglementaires.

Mots clés : Technologie Blockchain, énergie, cas d'utilisation, stratégique.

ملخص

تهدف الجزائر، مثل العديد من البلدان الأخرى، إلى تعزيز استدامة قطاع الطاقة وكفاءته لتحقيق أهداف رؤية 2030. تتناول هذه الدراسة حالات استخدام البلوكتشين الرئيسية لمرافق الطاقة الجزائرية. نظرًا لأن تقنية البلوكتشين هي تقنية ناشئة يُنظر إليها على أنها حالة عدم يقين حرجة، فإن تنفيذها يمثل تحديات وفرصًا لا تزال مجهولة إلى حد كبير. لذلك، تم تطبيق نطاق أولي واسع، حيث تم جرد وتجميع مجموعة واسعة من حالات الاستخدام المستندة إلى البلوكتشين داخل سوق الطاقة في مجموعات بناءً على مجال استخدامها الإجمالي. تم تحليل كل مجموعة وتقييمها لتناسب بشكل أفضل استراتيجية الشركة المكلفة ومعايير استخدام تقنية البلوكتشين .تم اختيار مجموعتين الأكثر ملاءمة لمعايير الاختيار المحددة. وقد أعطى التقييم النهائي الأولوية لهذه المجموعات بناءً على نضجها العام وأهميتها العالية في السوق، واختيارها لمزيد من التحليل التفصيلي. تشير النتائج إلى أن تقنية البلوكتشين يمكن أن تساهم بشكل كبير في إدارة الطاقة اللامركزية، وتحسين تداول الطاقة، وأمن المعاملات، مع تسليط الضوء أيضًا على عوائق الاعتماد مثل نضج السوق والتحديات التنظيمية.

الكلمات المفتاحية: تقنية البلوكشين ، الطاقة، حالة الاستخدام، الإستراتيجية.

Contents

List of Abbreviations

ERP - Enterprise Resource Planning

BI - Business Intelligence

CPM - Corporate Performance Management

ELIT - El Djazayer Information Technology

HISSAB - Financial Management ERP System

NOVA - Human Resources ERP System

ATTAD - Stock Management ERP System

DC DSI - Direction Centrale Digitalisation et Système d'Information

TRL - Technological Readiness Level

MRL - Market Readiness Level

RRL - Regulatory Readiness Level

ARL - Acceptance Readiness Level

ORL - Organizational Readiness Level

P2P - Peer-to-Peer

GWh - Gigawatt Hours

PV - Photovoltaic

IoT - Internet of Things

EV - Electric Vehicle

ISO - International Organization for Standardization

NLP - Natural Language Processing

AI - Artificial Intelligence

ICT - Information and Communication Technology

Lists of figures

Lists of Tables

Introduction

1. Study Context

The global energy sector is undergoing rapid transformation towards more sustainable and efficient systems, driven by the imperative to reduce carbon emissions and improve energy efficiency. This shift necessitates the exploration of alternative energy sources and a fundamental rethinking of how we generate, distribute, and utilize power. The urgency of these changes raises critical questions about the allocation of power, energy availability, and usage across various contexts.

Within Algeria, the government is actively addressing these challenges through comprehensive policy frameworks and strategic management initiatives aimed at fostering a sustainable energy future. The country's Vision 2030 outlines ambitious goals to diversify energy production by increasing the share of renewable energy, which requires the integration of advanced technologies to enhance efficiency, transparency, and transaction management.

Furthermore, the digital realm is experiencing a rapid transformation across multiple sectors, significantly impacting how energy systems are managed and optimized. Blockchain technology, with its decentralized, transparent, and secure attributes, presents a promising solution to revolutionize energy management and transactions. This technology has the potential to enhance transparency and reliability in energy data, streamline energy trading, and enable more efficient and resilient energy systems *(Mengelkamp et al., 2018; Wang & Su, 2020)*.

In this context, blockchain can address several pressing issues in the energy sector. By facilitating peer-to-peer energy trading, blockchain reduces transaction costs and empowers consumers to become active participants in the energy market. Additionally, it provides a robust framework for tracking renewable energy credits and carbon emissions, ensuring compliance with regulatory standards and promoting sustainability. The adoption of blockchain in the energy sector can thus play a crucial role in achieving Algeria's Vision 2030 goals, aligning technological advancements with strategic energy objectives.

The motivation for this study is multifaceted. First, Algeria's heavy reliance on hydrocarbon resources presents significant environmental and economic challenges. Diversifying the energy mix to include a larger proportion of renewable energy is essential for sustainable development. Blockchain technology, with its potential to enhance energy efficiency and transparency, offers a viable pathway to achieving these goals.

Second, there is a notable gap in the literature regarding the application of blockchain technology in the Algerian energy sector. While global interest in blockchain is rising, its specific potential and challenges within the Algerian context remain largely unexplored. This study aims to fill this gap by providing a comprehensive analysis of blockchain use cases that align with Algeria's strategic energy objectives.

Finally, the study seeks to provide practical recommendations for key stakeholders in the Algerian energy sector. By identifying and evaluating relevant blockchain use cases, the research aims to guide these organizations in leveraging blockchain technology to enhance their operations and achieve their strategic goals.

Given the nascent state of blockchain technology in Algeria and the absence of similar studies in the local context, this research aims to fill a significant gap. By providing a detailed analysis of relevant blockchain use cases and evaluating their strategic alignment with Algeria's energy goals, this study offers valuable insights and practical recommendations for stakeholders. This research is crucial for advancing the understanding and implementation of blockchain technology in Algeria's energy sector, supporting the country's transition towards a more sustainable and efficient energy future.

2. Objective of the Study

The goal of this study is to explore the potential of blockchain technology to reorganize the energy ecosystem in Algeria, aligning with the country's Vision 2030 for sustainable development. Given the significant uncertainties and the nascent state of blockchain technology in the Algerian context, a qualitative and exploratory approach is essential.

The study aims to investigate future scenarios for ecosystem configuration within the Algerian energy sector, focusing on the disruptive potential of blockchain technology.

To achieve this, the research will gain a deeper understanding of blockchain-based use cases by conducting a thorough review of global applications. It will also assess the maturity and relevance of these use cases, ensuring alignment with Algeria's strategic energy goals.

By addressing these objectives, the study aims to support Algeria's transition towards a more sustainable and technologically advanced energy sector by prioritizing use cases, leveraging blockchain technology to meet long-term strategic goals, and providing valuable insights and recommendations for stakeholders.

3. Problematic of the Study

Main Research Question:

"How can energy utilities in Algeria approach blockchain technology to achieve the sustainability and efficiency goals of Vision 2030?"

This research question seeks to connect the transformative potential of blockchain technology with the strategic goals outlined in Algeria's 2030 Vision for the energy sector. The primary aim is to identify innovative blockchain solutions that can support long-term national energy plans, particularly in the context of renewable energy integration and energy efficiency improvements.

To thoroughly address this main research question, the study will answer several sub-questions:

- Which blockchain use cases are currently operational globally?
- How do these blockchain use cases align with Algeria's strategic energy goals outlined in the 2030 Vision and fit the criteria for blockchain adoption?
- What are the maturity levels of these blockchain use cases, and what barriers prevent the adoption within the Algerian energy sector?

By addressing these questions, the study aims to provide a comprehensive understanding of how blockchain technology can be harnessed to transform the Algerian energy sector.

The findings will offer valuable insights for policymakers, energy utilities, and other stakeholders, guiding them in implementing blockchain solutions that align with Algeria's strategic energy goals and enhance the sector's technological capabilities.

4. Key Entities

The focus of this study is on the Algerian energy sector, specifically examining how blockchain technology can be leveraged to meet the strategic goals outlined in Algeria's Vision 2030.

The study primarily involves three key entities: SDG Group, Sonatrach, and Sonelgaz, which play pivotal roles in Algeria's energy landscape.

While the study Conducted at SDG Group, a leading IT consulting firm specializing in digital transformation and information systems, the research utilized valuable data and insights obtained from their clients, including Sonatrach.

The involved companies provided documented processes and participated in stakeholder interviews, contributing significantly to the study’s findings.

5. Research Framework

This dissertation is structured into several key chapters, each addressing different aspects of the study.

- **Introduction:** provides an overview of the study's background and motivation, outlines the research problem and objectives, and introduces the key questions guiding the research.

- **Literature Review:** reviews existing literature on blockchain technology and its applications in the energy sector, identifies gaps in the current research that this study aims to fill, and discusses the theoretical framework underpinning the study.

- **Study Context and Key Entities:** provides an overview of the Algerian energy sector, introduces SDG Group, Sonatrach, and Sonelgaz, highlighting their roles in the study, and discusses the strategic goals of Algeria's Vision 2030 and how they relate to the study.

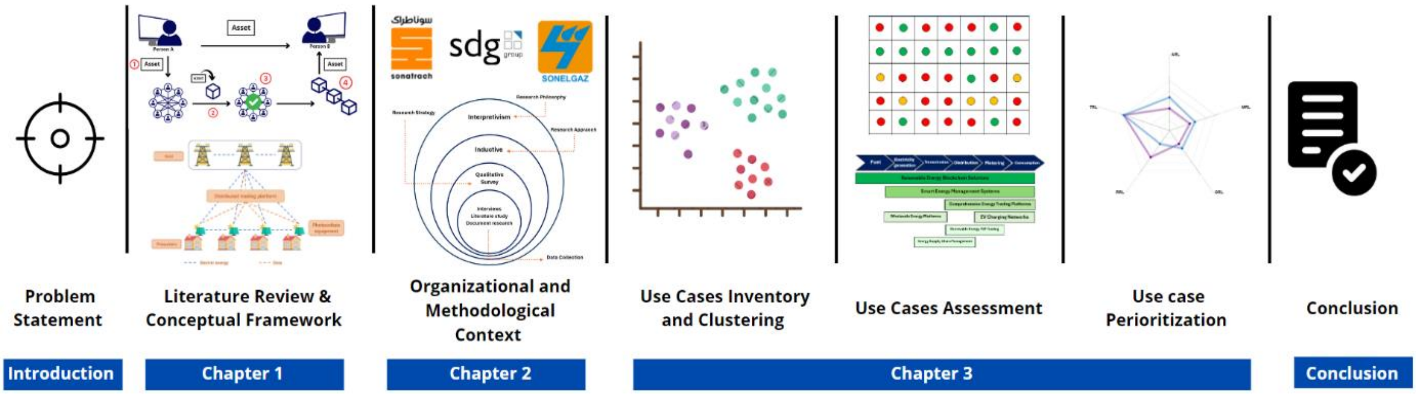
- **Methodology:** describes the qualitative and exploratory approach adopted for the study, detailing the data collection methods, including interviews and document analysis, and explaining the analytical framework used to evaluate blockchain use cases.

- **Results:** chapter presents the findings from the data collection and analysis, discussing the identified blockchain use cases and their relevance to the Algerian energy sector, and evaluating the maturity and strategic alignment of these use cases with Algeria's Vision 2030.

- **Discussion:** chapter interprets the results in the context of the research questions and objectives, compares the findings with existing literature and other case studies, and addresses the implications of the findings for the Algerian energy sector and potential barriers to adoption.

- **Conclusion:** summarizes the key findings and their significance, provides practical recommendations for implementing blockchain technology in Algeria's energy sector, and suggests areas for future research to further explore the potential of blockchain in energy management.

Figure 1: The outline of the thesis presented with the research process and the expected outcomes.



Chapter I: Literature Review & Conceptual Frame

Section 01: Literature Review:

A literature review was carried to gain a broader and more in-depth understanding of the research subject. The subject of blockchain adoption within the energy sector is a relatively new area of research, but it is gaining attention both within academia and in practice. However, the vast majority of the academic literature focuses on theoretical applications, most of which were blockchain and clean energy or solely on P2P electricity trading (Ma et al., 2024), which additionally required the use of non-academic sources of information. The literature reviewed thus intentionally consists also of grey literature, i.e. white papers produced by start-ups and management consultancy firms, governmental reports, and posts on platforms such as UN.

Initially, the literature review was conducted as a preliminary research method to gain a general understand on blockchain evolution and implementations within the energy sector. The second part of the literature review was more focused, critically targeting the results on the ground and the interest of various countries to adopt this technology. The aim of the second part was to superficially evaluate the possibility of applying these projects in the Algerian landscape

The literature was found using Web of Science portal, this is because the focus was on selecting articles from well-established academic journals and Web of Science is the most authoritative database for them. The main purpose of the literature review was to get a deeper understanding on how blockchain could be applied within the energy sector, which is why the following keywords were used for searches: "Blockchain + Energy sector", "Blockchain + Energy Internet", "Blockchain + power system", "Blockchain use case", "Blockchain applications", "Blockchain energy trading", "Blockchain + P2P trading", "Blockchain + clean energy".

1. Evolution of different versions of Blockchain technologies

The evolution of blockchain technology has been a remarkable journey of innovation and expansion, transcending its initial role as a ledger for cryptocurrency transactions to become a foundational element in the paradigm shift towards Industry 4.0.

Emerging in 2008 as a cornerstone of Bitcoin, blockchain served primarily to facilitate decentralized financial exchanges *(Nakamoto, 2008)*. At this point, four years after the appearance of Bitcoin, the most of the investigations were focused on the financial sector. This created the wrong impression that blockchain, as a technology, is only applicable to the financial sector.

However, Ethereum's emergence in 2015 marked the beginning of Blockchain 2.0, It was the first cryptocurrency presented as a Turing complete system, allowing for participants to create parts of the code that are linked to the blockchain and invoice them by establishing a transaction on this chain. These parts of the code are known as smart contracts *(Buterin, 2013)*.

This new feature was very different from the existing cryptocurrency and, for this reason, Ethereum became the reference system since its launch, changing the perception that blockchain technology was only for financial purposes, transforming the blockchain from a transactional platform into a comprehensive solution capable of integration at strategic and operational levels across organizations.

(López-Sorribes et al., 2023) Conducted an examination of research publications containing the term "blockchain", A substantial increase in publications was noted from 310 papers in 2016 to 19,305 in 2022, it was observed that the initial financial focus of blockchain research has diversified, with topics such as security, IoT, management, application, and privacy emerging as prevalent themes.

The collective research, underscores blockchain's significant evolution and its strategic integration within the framework of Industry 4.0. *(Siqin et al., 2022)* delved into platform-based operations, exploring through literature reviews and case studies how various Industry 4.0 technologies enhance business operations. Their findings illustrate the practical applications of blockchain in real-world scenarios, such as product authentication, information identification, and cryptocurrency payments, highlighting its role in driving economic and societal benefits.

This resonates with the broader narrative of blockchain's journey, showcasing its transformation from a novel technology to a cornerstone of Industry 4.0, essential for the digital and industrial advancements that characterize this new era.

Further advancement came with Blockchain 3.0, which began to take shape around 2018. This generation of blockchain technology transcended the financial focus, broadening its reach to a plethora of applications such as decentralized apps (dApps), cloud computing, web apps, and the improvement of messaging and system security protocols *(Kameshwaran et al., 2023)*.

By 2020, Another upcoming propitious progression in the evolution of Blockchain is the Blockchain 4.0. It aims to deliver Blockchain Technology as a business-usable platform to create and run applications thus converting the technology to fully mainstream. It has the possibility of inculcating other prosperous technologies such as Artificial Intelligence with Blockchain *(Mukherjee & Pradhan, 2021)*. Innovations like Deep Brain Chain and SingularityNET introduced AI algorithms into blockchain networks, optimizing efficiency and creating a synergy between AI and blockchain technologies.

Looking toward the future, *(Choi & Siqin, 2022)* pointed out that the promise of Blockchain 5.0 envisions a seamless integration into societal structures, potentially leading to a cashless society, smarter city planning, and enhanced governance models that could help combat corruption.

Features like decentralized web and Hash graph-enabled blockchain systems represent the next frontier in blockchain's evolution, aiming to deliver even greater efficiencies, security, and scalability.

Table 1: Comparison between different generations of blockchain

Parameter	Blockchain 1.0	Blockchain 2.0	Blockchain 3.0	Blockchain 4.0
Underlying principle	Distributed Ledger Technology (DLT)	Smart contracts	Decentralized Apps (dApps)	Blockchain with AI
Consensus mechanism	Proof of work	Delegated proof of work	Proof of stake Proof of authority	Proof of integrity
Verification	By miners	Through smart contracts and miners	In-built verification mechanism via dApps	verification via Sharding
Interoperability	Not interoperable	Not interoperable	Interoperable	Highly interoperable
Intercommunication	Not allowed	Not allowed	Allowed	Allowed
Speed	7 TPS	15 TPS	1000 of TPS	1 M TPS
Cost	Expensive	Cheaper	More Cheaper	Cost effective
Energy Consumption	Highest	Moderate	Energy efficient	Highly efficient
Example	Financial sector	Non-financial sector	Business platforms	Industry 4.0

Source :(Mukherjee & Pradhan, 2021)

The evolution of blockchain has been not just a technological advancement but a strategic revolution, morphing from a simple transactional tool to a sophisticated decision-support solution, embracing the surge of new technologies such as data analytics, mobile and social technologies, artificial intelligence, and machine learning.

2. Application and improvement timeline of blockchain technology in the energy sector

Jeremy Rifkin, an American scholar, predicted in his book "The Third Industrial Revolution: how lateral power is transforming energy, the economy, and the world" in 2011 that a new energy utilization system is about to emerge, which is characterized by the deep integration of new energy technology and information technology. He named the new energy system he envisioned as the Energy Internet *(Rifkin, 2011)*.

(Hussain et al., 2019) defined the Energy Internet as the integration of the existing power system with distributed energy resources for energy delivery and management. Energy Internet can serve as the foundation of smart cities and smart buildings. Compared with traditional energy technologies, applying blockchain into energy field has these technical advantages which drawn the attention of more and more researchers.

(Mihaylov et al.2014) conducted a study on the application of blockchain technology in the energy field, in which a virtual currency was introduced to energy markets based on information provided by smart meters.

Energy trading processes began to be redefined in 2015 with the deployment of blockchain, which enabled more transparent, efficient, and decentralized energy marketplaces (Mengelkamp et al., 2018). Blockchain facilitated peer-to-peer energy trading, allowing producers and consumers to transact directly, thereby bypassing traditional energy suppliers and reducing costs associated with energy distribution.

The subsequent year, witnessed the introduction of blockchain deployment in the electric vehicle (EV) industry, revolutionizing how EVs interact with charging stations and grid operators *(Uddin et al., 2023)*. Most of Germany's electric vehicle owners have their own charging stations, and 9 out of 10 families charge their electric cars at home. However, there are not enough public charging stations in Germany, which affects the market development of electric vehicles. To address this issue, Share & Charge built a sharing platform by connecting the owner of a charging station and the owner of an electric vehicle based on blockchain technology *(Plenter et al., 2018)*.

By 2018, blockchain found its use in microgrid operations and control, offering a decentralized framework for managing energy distribution and consumption within localized grids *(Huang et al., 2018)*. A new perspective is presented by *(Thomas et al., 2019)* where decentralization of medium-voltage direct-current (MVDC) link control is implemented via Blockchain. This control strategy gives the grid operators shared responsibilities within the energy system. This utilization marked a shift towards more sustainable and autonomous energy systems, capable of integrating renewable energy sources and responding dynamically to changes in energy demand.

The transformative journey of blockchain technology in the energy sector has not only redefined energy trading but has also paved the way for innovations beyond traditional frameworks. This technology heralds a new era of intelligent regulation, connecting smart devices and Internet information through an immutable, distributed ledger system.

(Baashar et al., 2021) pointed out that the application of blockchain technology in the energy sector is multifaceted, addressing both the challenges of existing power infrastructure inefficiencies and spearheading advancements in renewable energy distribution and carbon emission reduction.

Blockchain technology introduces a novel approach to building and managing power grids, especially in regions plagued by inefficient power facilities and frequent power outages. The smart grid concept was proposed to ensure efficient electricity distribution, maintain low losses, and high quality and electricity supply *(Agung and Handayani, 2022)*.

Using a blockchain-based registry by their needs, intermediaries of generators and buyers can organize, value, and enter into an exchange through power agreements in the smart contract *(Alam and Jain, 2020)*. By leveraging blockchain smart contracts, a new grid infrastructure can be envisioned—one that is more resilient, efficient, and capable of real-time energy demand-side management. According to *(Wang et al., 2019)* this is achieved through a layered framework for peer-to-peer information and energy exchanges that implements market mechanisms in the form of smart contracts for transactions, thus facilitating the market-clearing price effectively.

Startups and established power companies alike are exploring blockchain to automate and streamline energy distribution processes. This involves tracking renewable energy production and distribution, thereby ensuring transparency and efficiency in the energy market. The electricity sector, in particular, shows promise for blockchain applications due to the fungible and distributable nature of electric energy, much like digital currency *(Di Silvestre et al., 2020)*.

Blockchain technology is at the forefront of addressing global challenges such as climate change mitigation and enhancing electricity access. It enables the creation of smart contracts, supports microgrid applications, ancillary services, energy storage systems, and demand-side management *(Kirchhoff and Strunz, 2019; Singla et al., 2019)*.

Specifically, the deployment of blockchain in microgrids facilitates decentralized energy production and distribution, empowering communities to manage renewable energy sources effectively and sustainably.

Otherwise, several blockchain approaches have been investigated widely for increasing the grid immunity toward cyber-physical attacks *(Uddin et al., 2023)*. *(Liang et al., 2019)* presents an inclusive conversation on the blockchain technology adoption in enhancing the security, privacy, and robustness of the power grid, via utilizing the meters as nodes in a distributed network which encapsulates the meter's measurements as blocks in the chain.

Blockchain technology offers a solution to the complexities and challenges of carbon emission trading—a market mechanism designed to reduce global carbon emissions and combat climate change *(Teng et al., 2021)*.

By providing a transparent, immutable ledger for recording carbon emission quotas, blockchain facilitates the accurate tracking of real emissions, trading rules, and prices, thus ensuring the authenticity and traceability of emission permits *(Bao et al., 2021)*. As an illustrative case *(Teng et al., 2021)* highlighted the potential of blockchain technology in revolutionizing the management of decentralized energy systems, particularly through the administration of green certificates and emissions tracking.

Emphasizing the significance of registries in energy markets, it underscores the blockchain's role in ensuring secure, transparent, and traceable transactions for CO2 emissions and green certificates. This approach mirrors the mechanisms of carbon emissions trading, aiming to standardize and simplify the process of certifying electricity generated from renewable sources such as wind and solar energy.

The integration of blockchain technology into the energy sector represents a paradigm shift towards more sustainable, efficient, and secure energy systems. From revolutionizing energy trading and grid management to facilitating renewable energy distribution and enhancing carbon emission trading, blockchain stands as a pivotal technology in addressing the pressing challenges of our times. Its potential to transform the energy sector is not only promising but also imperative for a sustainable future.

Table 2: Summary of blockchain applications in the field of energy

Application scenarios	References	Contribution
P2P Energy Trading	(Mengelkamp et al., 2018)	Presented a model of electricity trading based on the production of photovoltaic systems.
	(Han et al., 2020)	A framework to bring together producer resources and consumer requirements in blockchain-based renewable energy trading.
Grid Management and Optimization	(Wu et al., 2018)	Presented the blockchain to record data derived from the energy flow calculation model and the customization of the electricity price
	(Alam and Jain, 2020)	Described a series of innovative solutions in smart cities and the emerging Blockchain technology and the potential that it could have in Smart Grid.
	(Alessandra et al., 2018)	Proposed a synergy between Smart Energy Grid and Blockchain technology for smart cities, especially on buying and selling energy.
Information security and privacy	(Narbayeva et al., 2020)	Proposed using blockchain to increase the cybersecurity of autonomous vehicles.
Electric Vehicle (EV)	(Fu et al., 2020)	Proposed companies connected with electric mobility customers through smart contracts with the help of blockchain technology.
	(Sharma et al., 2020)	It featured a secure transaction approach to charging station identification and fast charging or standard charging and considering charging costs remotely.
Renewable energy	(Li et al., 2019)	Presented the management of a system for distributed energy in a multisectoral and renewable demand mode.
	(Han et al., 2020)	It proposed a conceptual framework in which it allows us to contemplate the creation of renewable energy prosumers between neighbors autonomously with their neighbors based on blockchain techniques.
	(Duchenne, 2018)	Development of real and executable renewable energy projects despite climatic changes.

Electricity market	(Zhang et al., 2017)	A model for the implementation of computer systems in the field of urban electricity transmission and distribution.
	(Adeyemi et al., 2020)	Multiple scenarios where blockchain has been used for the energy distribution service, helping to understand the difficulties that this change may face
	(Chen et al., 2019)	Presented a decentralized electrical model without a central coordinator understanding the use of blockchain for computer-based transactions

Source: Own Work

3. How different countries have adopted blockchain in their energy sectors:

The following investigation aims to explore the diverse landscape of blockchain adoption in the energy sectors of different countries. By delving into successful case studies.

For instance, In the United States, the Brooklyn Microgrid exemplifies the innovative application of blockchain in energy trading. This peer-to-peer (P2P) platform, run by Transactive Grid which represents a collaboration between LO3 Energy, Consensus, Siemens, and Centrica, allows prosumers in Brooklyn, New York, to sell excess energy directly to their neighbors. Utilizing Ethereum-based smart contracts, this project marked the first energy transaction recorded in blockchains worldwide. Beyond facilitating transactions, the Brooklyn microgrids envisions a future where community members can select energy sources based on price or shared environmental and social values, heralding a new era of consumer engagement in energy distribution *(Mengelkamp et al., 2018)*, so Microgrid members will be able in the future not only to decide from whom to buy/sell energy based on their price preferences, but also on other criteria that reflect their environmental or social values.

In the Netherlands, BAS Nederland's acceptance of Bitcoin for energy bill payments pioneered the intersection of cryptocurrency and energy services *(Alladi et al., 2019)*, this was quickly followed by other utility companies such as Enercity and Elegant. With Enercity, customers can execute payments via the Internet and use automatically exchange Bitcoins to Euros. Elegant introduced cryptocurrency payments for energy services provision, including gas and electricity payments *(Andoni et al., 2019).*

A part of a broader exploration of blockchain's potential In the Netherlands, a project in Rotterdam that utilized blockchain for data management in one of the country's largest heat networks. By storing data on a shared ledger, the project anticipated significant savings in administrative costs and laid the groundwork for a reliable heat trading system *(Andoni et al., 2019)*. In the future, project partners plan to apply this to a larger network that supplies with heat up to half a million homes in the Netherlands.

Austria's largest utility company, Wien Energy, embarked on a blockchain trial for gas trading, highlighting the technology's utility in automating and streamlining trade processes. Supported by blockchain startup BTL, the trial showed there can be significant gains in costs and efficiency by the automation of trade processes such as confirmations, actualizations, invoice generation, settlement, audit, reporting and regulatory compliance. *(CoinGeek, 2017)*, This initiative reflects the broader European interest in blockchain as a tool for enhancing the energy sector's efficiency and transparency.

France and Spain have also made significant strides in integrating blockchain into their energy sectors. Bouygues Immobilier's collaboration with Lyon for direct energy exchanges between solar producers and consumers exemplifies this trend, using blockchain to ensure the authenticity of energy transactions, at different locations in the system, as energy is exchanged between different flats in a building. Smart contracts are used to derive geolocation of nodes in the system that enable accurate calculations of power losses as energy is being transmitted *(Loukil, 2016)*.

Similarly, Spanish renewable energy giant Iberdrola utilized blockchain to track renewable energy sources, improving transparency and reducing operational costs, as evidenced by the trial *(Wang & Su, 2020)*, Iberdrola's technological framework tracked the movement of renewable energy from two wind farms and a power station to bank offices located in the Basque Country and Cordoba in the south. The firm utilized an open-source blockchain platform developed by the Energy Web Foundation, designed to satisfy the regulatory, operational, and market demands of the energy sector in experimental projects. Iberdrola is of the opinion that blockchain technology will enhance the issuance of certificates verifying the origin of energy, thereby allowing consumers to be informed about the sources of their energy consumption. This decentralized approach removes the intermediary's role, potentially leading to enhanced transparency within the energy sector and a reduction in operational costs. The mentioned pilot projects are expected to refine the certification process for petrochemical products and bolster the quality of safety certifications for these products, potentially yielding savings of up to 400,000 euros annually.

Germany's Share & Charge project, leveraging the Ethereum network, offers a decentralized platform connecting electric car owners with charging stations. Launched in 2017 by a subsidiary of German energy and gas supplier RWE *(Plenter et al., 2018)*, it relies on the Ethereum network to handle its operations and is the world's first electric transportation community platform to use blockchain technology. This project addresses the critical issue of charging infrastructure for electric vehicles, because there are not enough public charging stations in Germany, which affects the market development of electric vehicles. showcasing blockchain's potential to facilitate shared energy resources.

The Poseidon Foundation in London has introduced a novel approach by integrating the carbon market into retail transactions, allowing consumers to offset their carbon footprint through everyday purchases, this allows them to understand the carbon emissions of each purchase at the point of sale so can provide the opportunity to make up for the impact of carbon emissions in real time. This initiative, exemplified by a pilot project at BEN & JERRY'S, demonstrates blockchain's versatility in supporting global forest conservation efforts alongside commercial activities. Poseidon also cooperates with the Liverpool City Council to participate in the construction of a blockchain-based Carbon Credits System, with the aim of making up 110% of the city's carbon emissions by 2020 *(Wang & Su, 2020).*

Despite the enthusiasm and the evident benefits, the adoption of blockchain in the energy sector is not without its challenges. *(Chan et al., 2023)* addressed Issues such as technological maturity, regulatory hurdles, security concerns, and the need for substantial investment in infrastructure have emerged as common themes across these pioneering initiatives.

(Zhu et al., 2020) explored the potential of blockchain technology to reform China's energy industry amidst growing demands for sustainable and intelligent energy solutions. By examining the progress of blockchain applications globally, the research identifies opportunities and challenges specific to China's unique market conditions. The methodology includes a comprehensive survey of blockchain technology advancements and the analysis of typical international use cases to extract valuable insights. Key findings indicate that while China's monopolistic energy market structure and stringent regulations hinder blockchain adoption, the increasing prevalence of clean energy provides significant opportunities. The study highlights the need for policy reforms to support blockchain integration, suggesting that technological barriers are less daunting than regulatory ones. It concludes with recommendations for loosening regulatory constraints, fostering innovation through research collaboration, and encouraging the development

of distributed power generation to fully realize blockchain's potential in transforming China's energy sector.

Additionally, the importance of stakeholder engagement, both from the public and private sectors, has been repeatedly emphasized in many studies as critical for the successful integration of blockchain technology into existing energy systems.

4. The future trends of energy blockchain:

The domain of energy blockchain is poised at a critical juncture, with predictions suggesting it could generate an annual business value exceeding $175 billion by 2025 and surpassing $3 trillion by 2030 *(Teng et al., 2021)*.

From the perspective of academic research and pilot projects, energy blockchain is still in the growth stage as the application is also in its early stage *(Uddin et al., 2023)*. The consensus among experts suggests that achieving mainstream adoption of blockchain technology within the energy sector could span a timeline of 5 to 10 years.

(Di Silvestre et al., 2020) in his investigation about blockchain mentioned that the electrical energy sector, in particular, emerges as the most promising arena for blockchain technology application. This can be attributed to the inherent similarities between electrical energy and electronic money—both are fungible, convertible, distributable via networks, and immune to duplication through simple means.

Despite successfully navigating the proof-of-concept phase, the challenge now lies in scaling up the technology to achieve cost efficiency and widespread implementation.

The future direction of energy blockchain is being shaped by two main avenues of research: engineering-oriented and management-oriented. *(Ma et al., 2024)* conducted an analysis of 622 selected articles on blockchain in the energy field, the results showed that engineering research focuses on creating system architectures that integrate smart contracts and trading platforms with blockchain and IoT technologies, aiming to enhance the efficiency, security, and reliability of energy transactions and improve distribution networks.

The authors also pointed that management research is refining energy provisioning and trading models to suit the digital and decentralized nature of blockchain. This involves exploring new trading approaches in distributed energy systems, assessing digitalization's effects on supply and demand, and formulating strategies for microgrid and peer-to-peer transaction management.

Both streams of research address market risks and regulatory challenges to facilitate a smooth shift towards more sustainable and resilient energy systems, marking the pivotal areas for future exploration and development in the energy blockchain domain (Ma et al., 2024).

The future direction of energy blockchain research embodies a comprehensive approach that harmonizes technological innovation with strategic management (Alladi et al., 2019). This equilibrium is crucial for unlocking the full potential of blockchain in transforming the energy sector, propelling it toward heightened efficiency, sustainability, and resilience. The path forward is marked by the challenge of scaling technological advancements while navigating the intricacies of market dynamics and regulatory frameworks, setting the stage for a revolutionary shift in how energy is produced, distributed, and consumed.

The existing literature reveals a significant potential for blockchain technology to transform the energy sector through enhanced transparency, efficiency, and sustainability. Studies have shown that blockchain can facilitate decentralized energy trading, improve grid management, and ensure secure and transparent transactions. However, despite these promising prospects, the adoption of blockchain in the energy sector, particularly in developing countries like Algeria, remains underexplored. This study aims to fill this gap by investigating the specific applications and implications of blockchain technology within the Algerian energy ecosystem. By aligning with Algeria's Vision 2030, which emphasizes sustainable development and technological innovation, this research seeks to provide strategic insights that can drive policy decisions and practical implementations. The results of this study are expected to offer a comprehensive understanding of the barriers and enablers of blockchain adoption, thereby contributing valuable knowledge to both academic discourse and industry practices. Ultimately, this research will position blockchain as a pivotal tool in achieving a more efficient, transparent, and sustainable energy future for Algeria.

Section 2: Conceptual Framework

This section outlines the conceptual framework that underpins our study, detailing the key theories, models, and concepts that guide the analysis and interpretation of our research findings. By establishing a robust theoretical foundation, we aim to provide a clear context for understanding the implications of blockchain technology within the Algerian energy sector. The conceptual framework integrates insights from existing literature, theoretical models, and practical applications, offering a comprehensive overview of the potential and challenges of blockchain adoption in this field.

1. Blockchain technology

In recent years, blockchain technology has emerged as a revolutionary force across various industries, offering a new paradigm for managing transactions and data securely and transparently. Initially developed as the underlying technology for cryptocurrencies like Bitcoin, blockchain has proven its potential far beyond digital currencies. Its decentralized nature, coupled with attributes such as immutability, transparency, and enhanced security, makes it an ideal solution for many complex systems, including the energy sector. Understanding the basics of blockchain, can better appreciate its applications and the significant impact it holds for enhancing efficiency, transparency, and sustainability in energy markets.

1.1. Definition and overview:

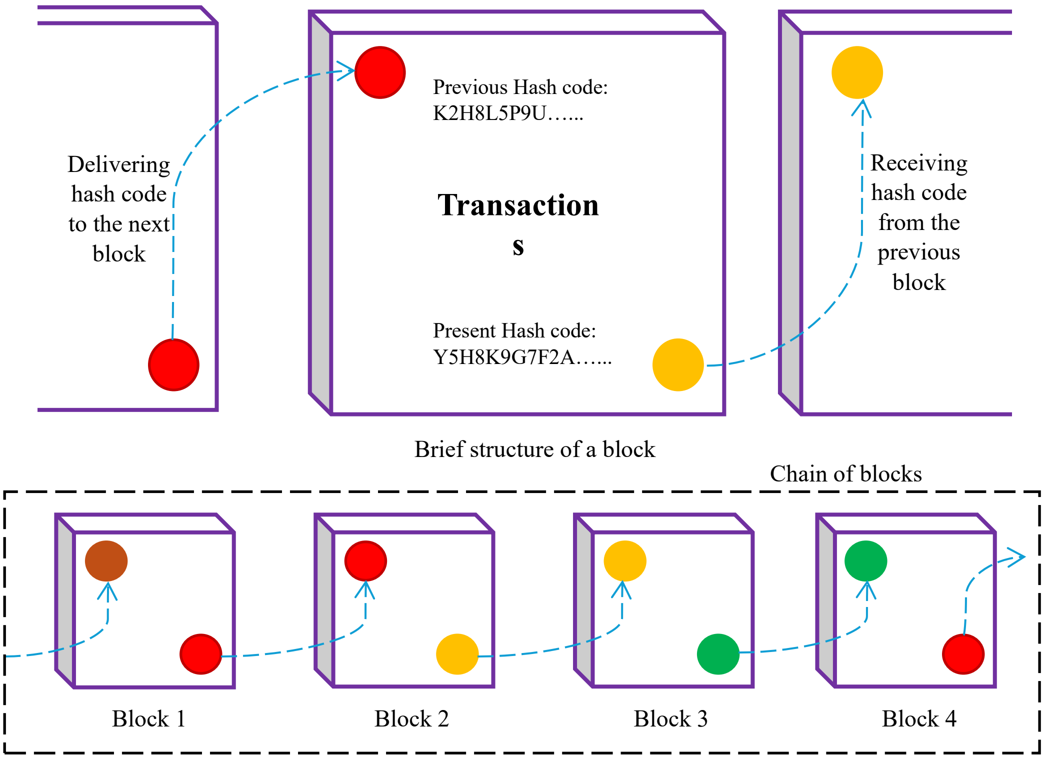
Blockchain is a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible — a house, a car, cash, land — or intangible like intellectual property, such as patents, copyrights, or branding. Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved *(Gupta, 2017)*.

As the foundational technology behind Bitcoin, blockchain serves as a decentralized database, storing information about transactions within blocks that are cryptographically connected to each other, thereby securing the veracity and continuity of the data. Beyond its application in cryptocurrency, blockchain represents a distributed system framework, equipped with consensus protocols to maintain network reliability *(Ghiro et al., 2021)*.

At its core, blockchain is structured around three principal concepts: transactions, blocks, and chains. A transaction refers to the operation that causes the state of the ledger to change, such as adding a transfer record. Block records all transactions that occur within a period of time and is a consensus on the current state of the ledger. Chain refers to the blocks connected in chronological order, which is a log of the state change of the entire ledger.

If the blockchain is regarded as a state machine, then each transaction is trying to change the state. The block generated by each consensus is that the participant confirms the result of the state change caused by the transaction in the block (Wang & Su, 2020).

Figure 2: General structure of blockchain



Source: (Uddin et al., 2023)

Blockchains run on digital networks. Data transmission in such networks is equivalent to copying data from one place to the other, e.g. in the cryptocurrency domain this is equivalent to copying digital coins from one user's electronic wallet to another's.

The principal challenge resides in the fact that the system needs to ensure that coins are only spent once and there is no double-spending. Typically, a central authority, like a central bank, oversees these transactions, ensuring the records are accurate and secure.

However, having one central point can be costly, require trust in this authority, and pose risks because if this central system fails or is attacked, the entire system is vulnerable.

The primary purpose of blockchain technologies is to remove the need for such intermediaries and replace them with a distributed network of digital users who work in partnership to verify transactions and safeguard the integrity of the ledger *(Andoni et al., 2019)*.

Contrary to centralized systems, every member of the blockchain network holds his own copy of the ledger or can access it in the open cloud. As a result, anyone in the network can have access to the historic log of the system transactions and verify their validity, enabling a high level of transparency.

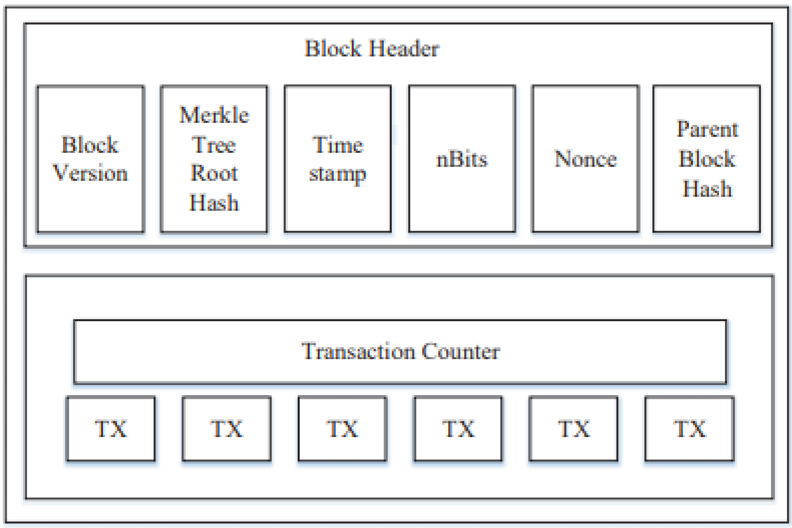
1.2.Blockchain core technology:

Blockchain technology is a comprehensive technical system that integrates multiple technologies. Blockchain technology mainly includes essential core technologies, With the continuous evolution of demand and the development of blockchain technology, the key technology of smart contracts has also been introduced to blockchain technology. The following is a detailed introduction to these technical principles.

1.2.1. Data storage structure

In blockchain, data is stored permanently in blocks. Blocks are sequentially generated and connected in a time order, forming a chain. Each block writes down every transaction that happened while it was being created. A block generally consists of a block header and a block body (Zheng et al., 2017).

Figure 3: Structure of Block



Source: (Zheng et al., 2017)

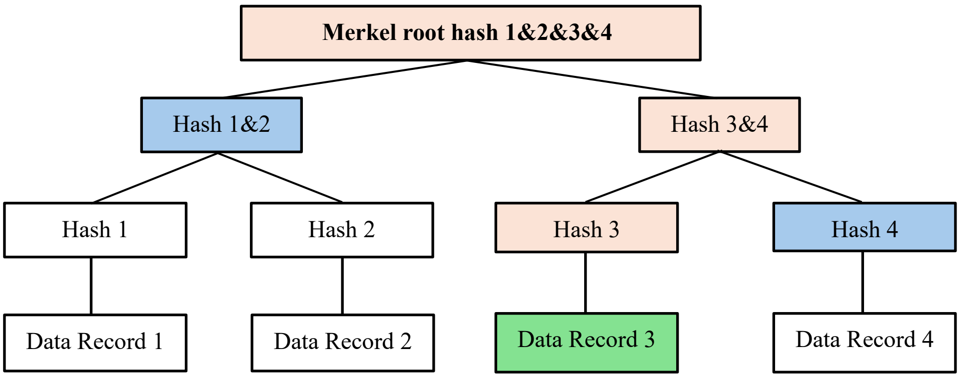
The block header includes:

- **Block version:** Indicates the version of the block structure being used. This can help with software upgrades and ensuring that nodes in the network understand the block.

- **Merkle tree root hash:** a special code that represents all the transactions in the block. Merkle trees are then used to structure the records in blocks, and support efficient verification of the chain's data authenticity.

In a simple Merkle tree, all data is at the bottom. Each piece of data is turned into a hash - a kind of digital fingerprint, and then these hashes are combined in pairs to create new hashes, step by step, until there's one top hash. This top hash is called the Merkle root and is stored in a block along with all the transactions *(Chitchyan & Murkin, 2018)*.

Figure 4: A simple Merkle tree



Source: Own Work

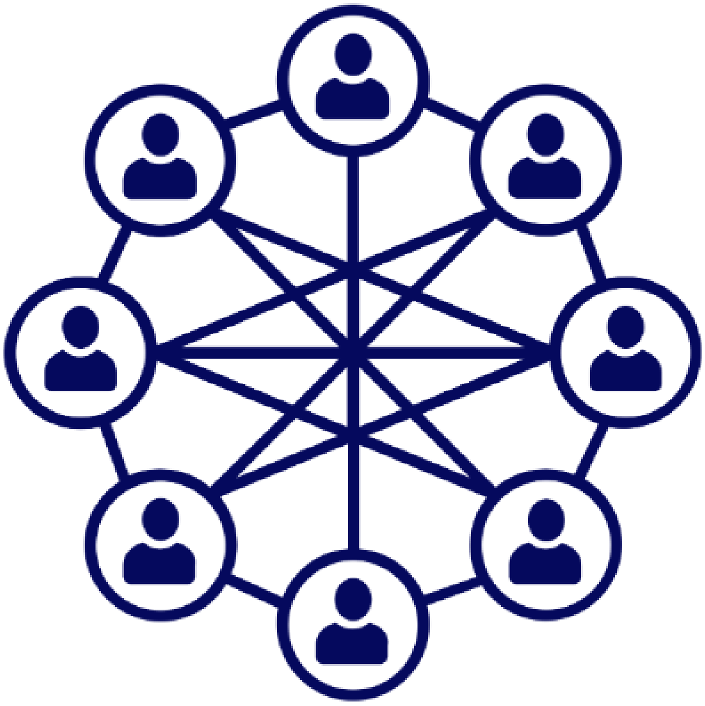
- **Timestamp:** Records when the block was created.
- **nBits:** the goal number that a block's hash code must meet to be considered valid.
- **Nonce**: This is a number that blockchain miners are constantly changing to try to solve a complex mathematical problem. The nonce is part of what goes into creating a hash for a block.
- **Parent block hash:** This is a unique code that connects to the block before it.

The block body is composed of a transaction counter and transactions. How many transactions a block can hold depends on the block's size and the size of each individual transaction. Blockchain uses an asymmetric cryptography mechanism to validate the authentication of transactions *(Zheng et al., 2017)*.

1.2.2. Network protocol

Blockchain networks usually use a peer-to-peer (P2P) protocol, which means every computer in the network is equal and there aren't any special or controlling computers. Because there's no central server, it's tough for attackers to take down the network, making it very reliable even if something goes wrong. Every computer (or node) in this network is on the same level, and the network's tasks are spread out across these nodes. This setup means that attacking a few nodes doesn't really affect the whole network. Different blockchain systems might create their own versions of P2P protocols to meet their specific needs. Block chain network nodes have the characteristics of equality, autonomy and distribution, presenting a flat topology without any centralized authority nodes or hierarchical structure *(Wang & Su, 2020)*.

Figure 5: P2P network typology



Source: (Wang et al., 2020)

1.2.3. Distributed Ledger Technology (DLT)

Is a decentralized method of storing data across multiple locations or organizations without central control, also defined as a linked list of sets of transactions between the peers of a network, ordered by time, and where each peer holds a local copy (Suvarna, 2018).

Unlike traditional storage systems that depend on a central point for data management, DLT operates on consensus rules and collective decision-making, making it more reliable and less dependent on large, centralized data centers prone to issues. Furthermore, every node in a DLT network maintains a complete copy of the data, enhancing security and trustworthiness since no single node can unilaterally alter the data.

This approach addresses the challenges of traditional systems by improving data management's reliability and efficiency, offering a secure way to handle data without the need for central oversight.

1.2.4. Consensus mechanism:

The most innovative breakthrough of the blockchain is the establishment of trust based on a large amount of trust usually untrusted nodes. This is achieved through a complex consensus mechanism; The process of the Consensus mechanisms is used in blockchain to manage all the nodes that process transactions on the network. It makes sure that all the nodes on the network are synchronized with each other and agree on one consensus in which transaction is legitimate and then added to the blockchain.

These mechanisms are a crucial part of the blockchain network. When everyone can take part in the blockchain and submit data to the network, then with the help of the consensus mechanism transactions are continuously checked and verified by all the nodes (Aggarwal & Kumar, 2021).

Without this agreement, blockchain is at risk of various types of attacks. Consensus algorithms with variable properties have been developed and utilized in the industry nowadays. The four well-known consensus algorithms are:

1.2.4.1. Proof of work

The origins of PoW, used by Bitcoin. The PoW is known as mining and the participated nodes in the process are known as miners. In this. Miners compete to find a special number called a nonce that, when used in a cryptographic hash function with other block data, produces a hash that meets certain criteria. This process, known as "brute-forcing," requires significant computational effort. The successful miner's block is then verified by others in the network; if valid, it's added to the blockchain, and the miner earns a reward.

This Proof of Work (PoW) system encourages miners to pool their resources in "mining pools" to increase their chances of earning rewards, leading to concerns about centralization. While PoW has enabled Bitcoin to handle a large number of transactions, it faces limitations in transaction speed and finality compared to traditional payment systems like Visa.

Solutions to improve scalability and speed include increasing block sizes, pruning the blockchain, and innovations like sharding and sidechains (Andoni et al., 2019). A major criticism of PoW is its significant environmental impact due to the vast amounts of electricity consumed by mining operations.

This has prompted discussions about more sustainable consensus mechanisms, such as Proof of Stake (PoS), as potential alternatives to reduce the environmental footprint of cryptocurrencies.

1.2.4.2. Proof of stake

Proof of Stake (PoS) is an alternative to the Proof of Work (PoW) consensus mechanism and is designed to be more energy-efficient, faster, and cheaper, requiring less computational power.

In PoS, the process of creating a new block in the blockchain is handled by validators instead of miners. Participants can become validators by staking their own cryptocurrency tokens, which involves locking up a certain amount of their coins as a form of security deposit for a set period of time (Aggarwal & Kumar, 2021).

The chance of being chosen to create the next block depends on the size of one's stake and, in some cases, how long the tokens have been staked. The more you stake and the longer your tokens have been staked, the higher your chances of being selected as a validator (Aggarwal & Kumar, 2021).

This method is energy-saving because only selected few validators are needed to create a block, reducing the overall energy consumption of the network.

One key aspect of PoS is that validators are incentivized to act honestly. If a validator tries to manipulate the process or acts maliciously, they risk losing their staked tokens.

Honest validators are rewarded for their contributions, usually through transaction fees, as there is no block reward like in PoW. This system is currently used by the Ethereum network, among others, and is considered a more sustainable and efficient approach to achieving consensus in blockchain networks.

1.2.4.3. Delegated Proof of Stake (DPoS)

In the context of a Delegated Proof of Stake (DPoS) blockchain system, a "delegate" is someone who has the authority to create blocks in the network. This delegate is chosen based on receiving the highest number of votes from all participating nodes in the network.

In return for their role in maintaining the blockchain, delegates are rewarded. This reward can come from transaction fees collected from the transactions included in the blocks they produce, or from new coins that are generated as part of the network's inflation process.

The DPoS consensus mechanism operates by allowing network participants, or nodes, to use their coins to vote for who they want to act as delegates. The more coins a node stakes (locks up as a form of security deposit to support a delegate), the more weight their vote carries.

For instance, if one user (A) stakes 5 coins on a delegate, and another user (B) stakes just 1 coin, then A's vote is considered 5 times more powerful than B's vote. This system incentivizes the participation in the governance of the blockchain, with the stake amount determining the influence a node has over the selection of delegates *(Aggarwal & Kumar, 2021)*.

However, there are concerns about DPoS, especially regarding centralization risks if not many people participate in the voting process. Despite these concerns, DPoS is considered robust, capable of handling up to 49% of faulty or malicious nodes in a network without failing, making it a promising technology for managing blockchain systems efficiently.

1.2.4.4. Practical Byzantine Fault Tolerance (PBFT)

Byzantine Fault Tolerance (BFT) helps a computer network stay reliable even if some parts fail or act maliciously. It's like having a system that can still agree on decisions and work correctly even if some computers try to cause problems. NEO, a blockchain platform, uses BFT to agree on new blocks of transactions.

To make BFT practical for real-world use, a method called Practical Byzantine Fault Tolerance (PBFT) was developed. PBFT lets computers in the network agree on new information (like transactions in a block) through a process similar to an election (Aggarwal & Kumar, 2021).

Here's a simplified explanation of how it works:

1. A "speaker" is randomly picked from all the network's computers (nodes). This is like choosing someone to propose what to do next.
2. This speaker checks transactions, puts them into a new block, and works out a hash value (a unique digital fingerprint for the block).
3. The new block is then sent to the other nodes, acting as "delegates," who review everything in the block to make sure it's correct.
4. These delegates share and compare their reviews. If more than two-thirds of them agree, the block is validated and added to the blockchain.

This process ensures that, even if some nodes are faulty or dishonest, the network can still function correctly and reach agreement on new blocks.

The following table provides an overview of other consensus mechanisms, each with unique methods and goals for achieving agreement on the blockchain.

Figure 6: Other Consensus Mechanisms

#	Mechanism	Description
1	Proof of Capacity (PoC)	Miners use available storage space to store possible solutions, increasing the chance of creating a new block.
2	Proof of Elapsed Time (PoET)	Miners are chosen based on a random wart time, with the first to finish waiting getting to produce a new block.
3	Proof of Activity (PoA)	A hybrid of PoW and PoS, starting with solving a puzzle and then switching to a staking phase for block validation.
4	Proof of Publication (PoP)	Used to verify if certain information has been published on the blockchain at a specific time and date.
5	Proof of Retrievability (PoR)	Ensures a file has been completely downloaded and retrieved, useful in distributed storage systems.

6	Proof of Importance (PoI)	Considers an entity's overall contribution and involvement in the network for the privilege of validating transactions.
7	Proof of Ownership (PoO)	Verifies the ownership of certain information, useful for certifying intellectual property rights on the blockchain.
8	Proof of Burn (PoB)	Miners 'burn' cryptocurrency by sending it to an unusable address to obtain the right to mine and validate transactions.

Source: Own Work

1.2.5. Smart contracts

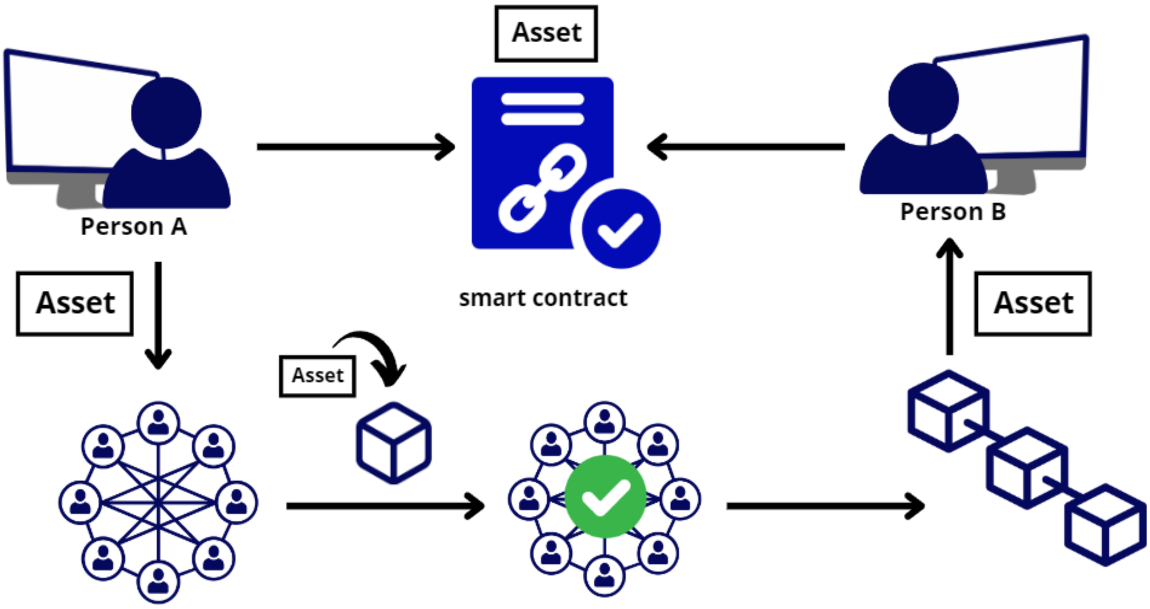
The concept of smart contracts was first introduced by cryptographer Nick Szabo in 1994, around the same time the Internet was becoming widely used. Smart contracts are digital agreements where the terms are written in code and executed automatically by the computer system when certain conditions are met. Unlike traditional contracts, which require trust between parties to fulfill obligations, smart contracts operate on a trustless basis because their execution is entirely controlled by the code, making the process automatic and tamper-proof.

Smart contracts work by following these steps:

1. **Construction:** Users on the blockchain collaborate to create a smart contract.
2. **Storage:** The smart contract is distributed to every node in the network via a peer-to-peer (P2P) network and saved on the blockchain.
3. **Execution:** The smart contract continuously monitors for conditions that trigger its execution. When these conditions are met, it automatically carries out the agreed actions and notifies the users involved.

Smart contracts enable transactions and agreements to be executed without the need for a third party. They are trackable, irreversible, and ensure high efficiency, low maintenance costs, and accurate execution of contracts. However, despite their advantages over traditional contracts, smart contracts are still a developing technology with ongoing research to explore their full potential and address any emerging risks.

Figure 7: Smart contracts working mechanism



Source: Own Work

1.3. Types of blockchain

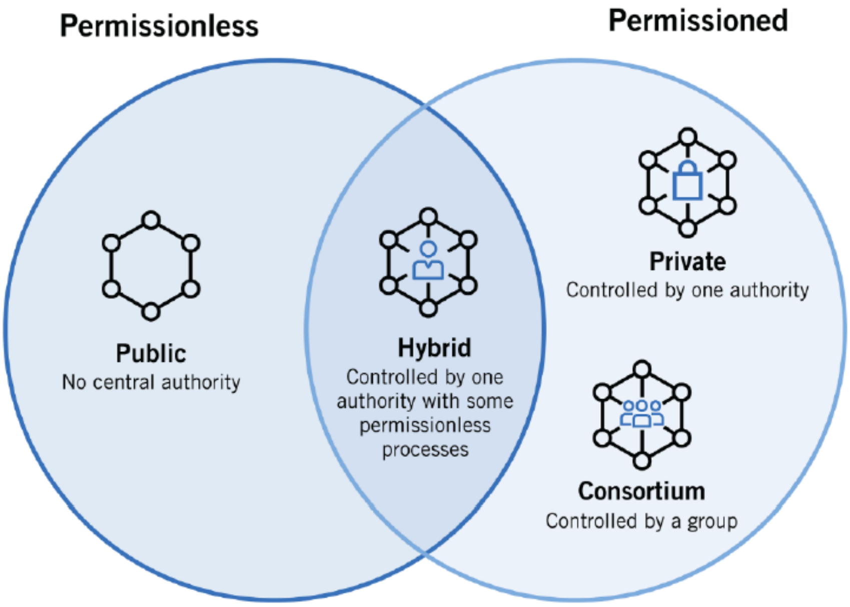
1.3.1. Public blockchains are permissionless and fully decentralized platforms where anyone can participate, access data, and validate transactions, making them ideal for cryptocurrency activities with examples including Bitcoin, Ethereum, and Litecoin.

1.3.2. Private blockchains are permissioned and controlled by single organizations, offering restricted access and selective participation rights, suited for specific business applications like Ripple and Hyperledger, but are more centralized and susceptible to fraud.

1.3.3. Consortium blockchains offer a middle ground with governance by a group of organizations, enhancing security and decentralization, suitable for collaborative industry efforts like R3 and the Global Shipping Business Network Consortium.

1.3.4. Hybrid blockchains combine elements of both private and public blockchains, controlled by an organization but with certain processes overseen by public validation, exemplified by IBM Food Trust, aiming to bring efficiency and transparency to specific sectors like the food supply chain.

Figure 8: Types of blockchains

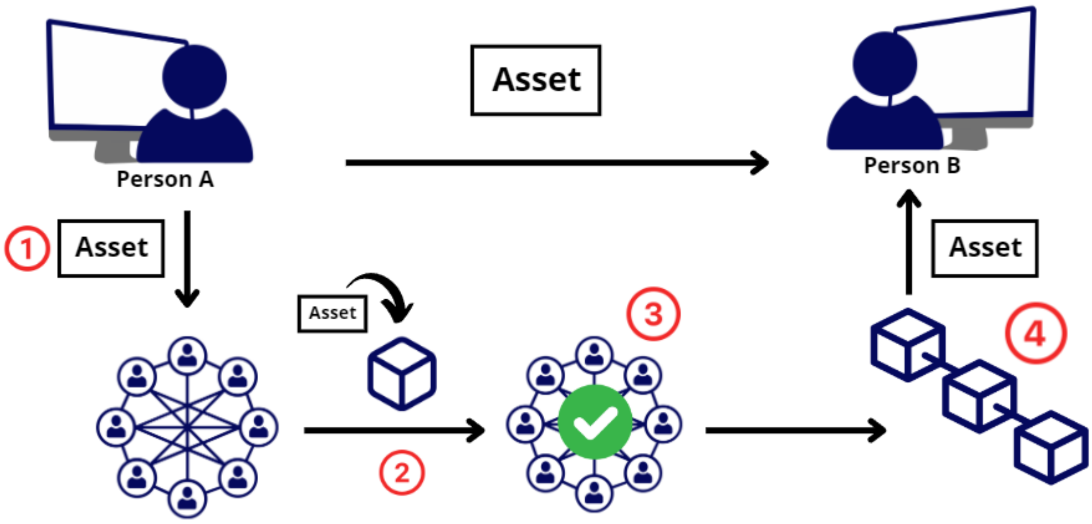


Source: (Sharad Mangrulkar & Vijay Chavan, 2024)

1.4. Blockchain technology working mechanism:

A transaction using the BCn technology is occurred by enabling the four secured steps upon the request of the consumer as shown in Fig. (Wang et al., 2021)

Figure 9: Working mechanism of blockchain



Source: Own Work

- **Step 1: Broadcast Mechanism –** A transaction is initiated by a node and broadcasted to other nodes; The node that generates the transaction information broadcasts the information to the connected nodes. If the information passes verification by these nodes, they will rebroadcast it. A transaction is considered valid if over 51% of the nodes receive and approve it.
- **Step 2: Create Blocks –** Once verified, the transaction data, processed through hashing and structured in a Merkle tree, is placed into a new block. This ensures that transaction records are securely and efficiently stored.
- **Step 3: Verify the Transaction –** There are two issues that need to be addressed at this stage. The first is to use asymmetric encryption algorithms to solve the problem of trust among blockchain network users. The second is to use a consensus algorithm to prevent users' coins from being used twice.
- **Step 4: Chain Formation –** Blocks are linked in an ordered fashion, creating a chain of transaction records that are secure and verifiable, thanks to timestamps and the immutable nature of blockchain.

1.5. Key characteristics:

- **Distributed and Sustainable**: The shared ledger's existence doesn't rely on a single entity, being collectively maintained by its users.
- **Secure and Private**: Access to the network is guarded by permissions and cryptography, ensuring participant authenticity and privacy.
- **Indelible**: Once a transaction is recorded, it cannot be altered except by adding a new transaction to reverse an error.
- **Transparent and Auditable**: All participants have access to the same records, allowing for easy validation and near real-time verification without third parties.
- **Consensus-Based**: Transaction validity relies on the agreement of network participants, often through consensus algorithms.
- **Orchestrated and Flexible**: The platform can be programmed with business rules and smart contracts, enabling the network to support comprehensive business processes and various activities as it grows.

2. Current trends in the energy sector

In recent years, the energy sector has been undergoing significant transformation driven by three critical trends: electrification, decentralization, and digitalization. Electrification, the shift towards using electricity as a primary energy source in traditionally fossil fuel-dominated sectors like transportation and heating, is propelled by the need to reduce greenhouse gas emissions and meet increasing electricity demand. This trend is evident in the rapid growth of electric vehicles and the integration of renewable energy sources into the grid *(World Economic Forum, 2017)*. Decentralization, facilitated by the rise of distributed energy resources such as solar and wind power, is reducing reliance on centralized power generation. This shift enables consumers to become "prosumers," generating and consuming their own energy, thereby creating a more resilient and efficient energy system *(Mengelkamp et al., 2018)*. Digitalization stands at the forefront of this transformation, incorporating advanced technologies like the Internet of Things (IoT), smart meters, and data analytics to enhance grid management and operational efficiency. These technologies support real-time monitoring, demand response, and the integration of renewable energy, promoting a more flexible and adaptive energy infrastructure *(Wang & Su, 2020)*. Together, these trends are driving the energy sector towards a more sustainable, efficient, and resilient future.

This subsection, will focus specifically on the electricity market, examining how these trends are shaping the future of electricity generation, distribution, and consumption, and exploring the role of blockchain technology in this evolving landscape.

2.1. Electric power industry trends

Historically, the electric power industry has largely depended on centralized generation facilities, heavily reliant on fossil fuels, notably coal, which remains responsible for worldwide electricity production. This centralized approach facilitated a straightforward, one-way flow of electricity from power plants, through voltage conversion substations, to the end users. However, this model has encountered several significant challenges:

- **Limited Control for Consumers and Insufficient Grid Insights**

  In the conventional setup, end users had negligible control over their energy environments, leading to a passive approach to electricity consumption. Concurrently, the operators of these grids were hampered by a lack of instantaneous data regarding the state and performance of the network, a problem compounded by the system's inherent design limitations and the linear nature of power flows.

- **Infrastructural and Environmental Impediments**
  Characterized by frequent disruptions, high infrastructure maintenance expenses, inefficient long-haul transmission, and, critically, elevated levels of greenhouse gas emissions, the traditional system underscored operational and environmental inefficiencies.

The World Economic Forum has identified three critical technological trends that enhance the transformation of the industry (The World Economic Forum, 2017). This transformation is characterized by three key trends. These three trends in particular are converging to produce game-changing disruptions:

2.1.1. Electrification

Electrification reflects the shift towards using electricity as a primary energy source in sectors traditionally dominated by fossil fuels, such as transportation and heating. This transition is propelled by the goal of reducing greenhouse gas emissions and is characterized by rapid growth in electricity demand.

While this presents an opportunity for environmental improvements, especially in countries where transportation is a major energy consumer, it also poses challenges. These include managing regional transmission bottlenecks and adapting market designs to encourage smarter energy use.

The success of electrification in lowering overall emissions hinges on the sustainability of the primary energy sources used for electricity generation.

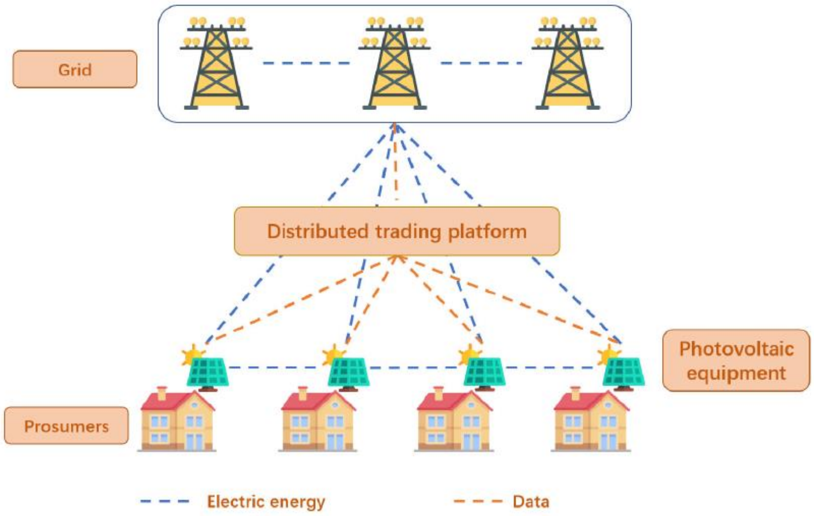
2.1.2. Decentralization

Decentralization follows, driven by the increased adoption of renewable and distributed energy resources like solar PVs and wind power. This trend is reducing reliance on centralized power generation, thereby minimizing transmission losses and mitigating environmental impacts.

However, it introduces complexities in grid management due to the bidirectional flow of electricity and the variability of renewable sources.

The role of Distribution System Operators is becoming increasingly akin to that of Transmission System Operators, as they navigate the challenges of integrating a growing number of prosumers—consumers who also produce energy—into the grid.

Figure 10: Distributed trading platform



Source: (Bao et al., 2021)

As mentioned, this trend, and because of it the dynamics of electricity flow have changed. This model enable consumers to not only consume electricity but also to produce it, turning them into "prosumers" — producers and consumers. When prosumers generate more electricity than they need, the surplus can be fed back into the grid, creating a bidirectional flow.

2.1.3. Digitalization

Digitalization stands at the forefront of this transformation, catalyzing changes across the entire energy value chain. By incorporating digital technologies such as the Internet of Things (IoT), smart meters, and advanced data analytics, the sector is enhancing grid management and operational efficiency.

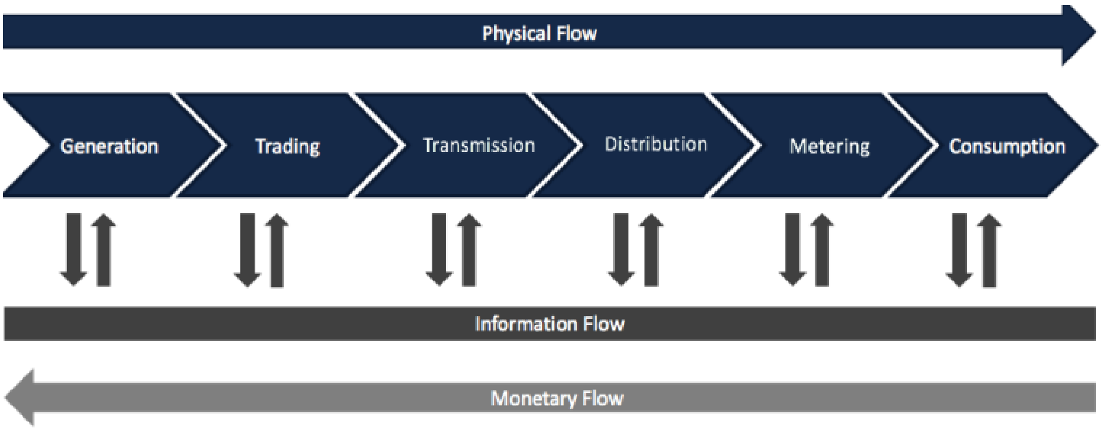
These technologies enable real-time monitoring and control of energy systems, facilitating the integration of renewable sources through virtual power plants and optimizing electricity transmission.

Despite the potential for significant efficiency gains, the digital shift presents challenges including adapting regulatory frameworks to support innovation, addressing data privacy, and safeguarding against security vulnerabilities.

A mid these shifts away from the traditional, centralized energy system, innovative technologies like blockchain are poised to play a pivotal role. Blockchain, with its decentralized and digital framework, is well-suited to enhance data flows and simplify transactions within the energy sector. Its application could significantly bolster the efficiency and transparency of interactions among various entities and devices within the energy landscape.

2.2. The Electricity Value Chain

Figure 11: Electricity Value Chain



Source: (Künneke & Fens, 2007)

The electricity value chain represents the full lifecycle of electricity, from generation to consumption, and includes the trading of energy along with transmission and distribution processes. As can be seen from Figure 11, three main exchange processes take place within the value chain; the physical flow of power, the flow of information and the monetary flow from the users to the generators and grid operators.

The value chain and the physical flow of electricity start with the generation of electricity where Electricity Generators feed electricity into the grid.

- **Generation**: Energy production is initiated by electricity producers, the owners of power plants where electricity is generated. These producers might sell electricity to suppliers or directly to consumers. When they supply directly, they assume the role of both producer and supplier.
- **Trading**: Electricity markets facilitate the trading of electricity. Various markets exist, including long-term, day-ahead, intraday, and balance markets. Trade involves notifying the Transmission System Operator (TSO) of planned supply or demand, with the TSO intervening to balance the grid as needed.

- **Transmission**: The TSO, is responsible for the national high-voltage grid. They maintain a balanced supply of electricity and manage the transmission process, ensuring continuous supply.
- **Distribution**: Regional grids, managed by Distribution System Operators (DSOs), transport electricity from the transmission network to end-consumers. DSOs ensure that electricity reaches consumers and may also handle metering if no third party is assigned.
- **Metering**: Metering involves recording electricity usage at the consumer's end, which could be managed by DSOs if not outsourced.
- **Consumption**: The end-users of electricity, consumers, can be categorized as small (households and SMEs) or large (industrial firms). Large consumers may engage in energy markets directly, while small consumers typically interact with suppliers.

ICT in Smart Grid Value Chain: Below is the use of ICT tools in various components of the electricity value chain (Krishnamoorthi et al., 2023).

- **Generation**: Integration of smart meters and technologies related to Internet of things .
- **Transport**: Utilization of sensor-based networks, embedded systems, machine-to-machine communication, and various communication protocols.
- **Retail**: Deployment of smart meters and development of end-user interfaces.
- **Consumption**: Adoption of smart buildings and devices, with an emphasis on data centers, cloud computing, data analytics, and intelligence to optimize usage and efficiency.

3. Blockchain in the Energy Industry

There is a debate that blockchain is a promising technology to convert all existing business models. In addition, several research highlights that blockchain has potential to optimize numerous processes, reduce the intermediaries and lower costs.

There exist various studies about blockchain business models, suggest that business processes can be affected and improved by blockchain technology. This includes automation increasing, reduction of intermediaries and administration, opportunities for data tracking and audits, minimizing the risk of errors, frauds, transactions, and processing time, implementation of innovative payment solutions and supporting democratic decision-making.

In the energy sector, several pilot projects across the globe are exploring the use of blockchain to facilitate a more decentralized, efficient, and sustainable energy market, particularly for renewable energy

3.1. Energy Business Models Adapted to Blockchain

Blockchain technology is revolutionizing the energy sector by enabling new, innovative business models that enhance efficiency, transparency, and decentralization. By integrating blockchain, the sector can move towards more sustainable and resilient energy systems, facilitating peer-to-peer energy trading, transparent tracking of renewable energy credits, and the development of microgrids. This section explores how blockchain supports these advancements and the transformative potential it holds for the energy industry.

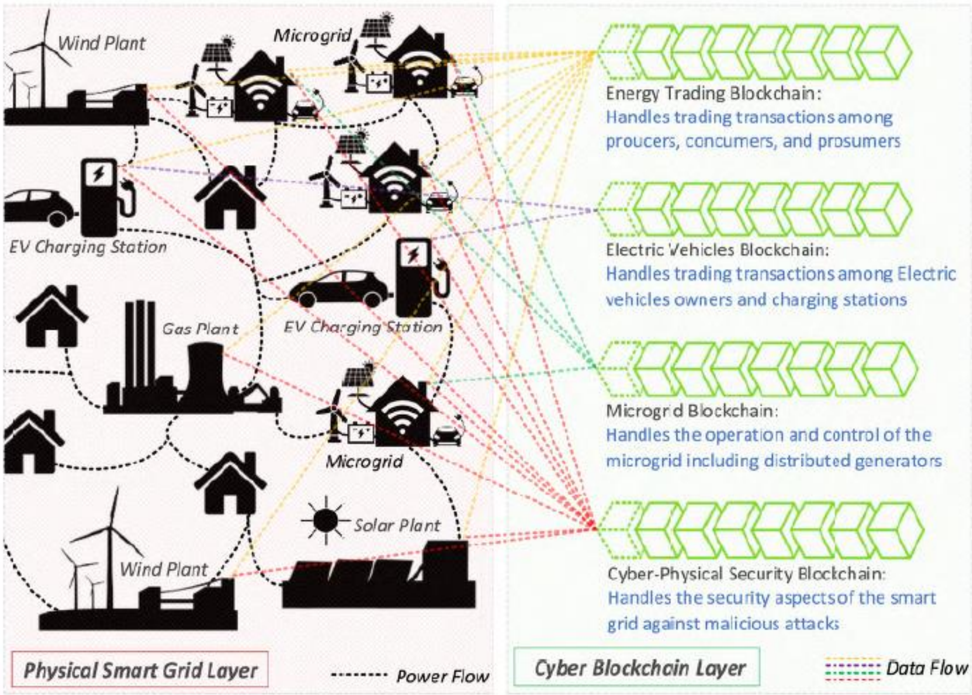
3.1.1. Blockchain in Decentralization and Electrification:

The convergence of electrification and decentralization in the energy sector represents a paradigm shift toward more sustainable and efficient energy systems. Blockchain technology stands as a significant enabler in this transition by providing a secure and transparent way to manage the increasingly complex network of transactions that decentralization brings.

With electrification, sectors like transportation and heating are moving away from fossil fuels and adopting electric solutions, such as electric vehicles (EVs), which contribute to carbon reduction goals.

Blockchain can support this transition by facilitating secure and transparent energy trading platforms that enable EV owners to engage in vehicle-to-grid interactions and monetize their investment, potentially increasing grid stability and energy efficiency.

Figure 12: Blockchain as a new cyber layer of smart grids.



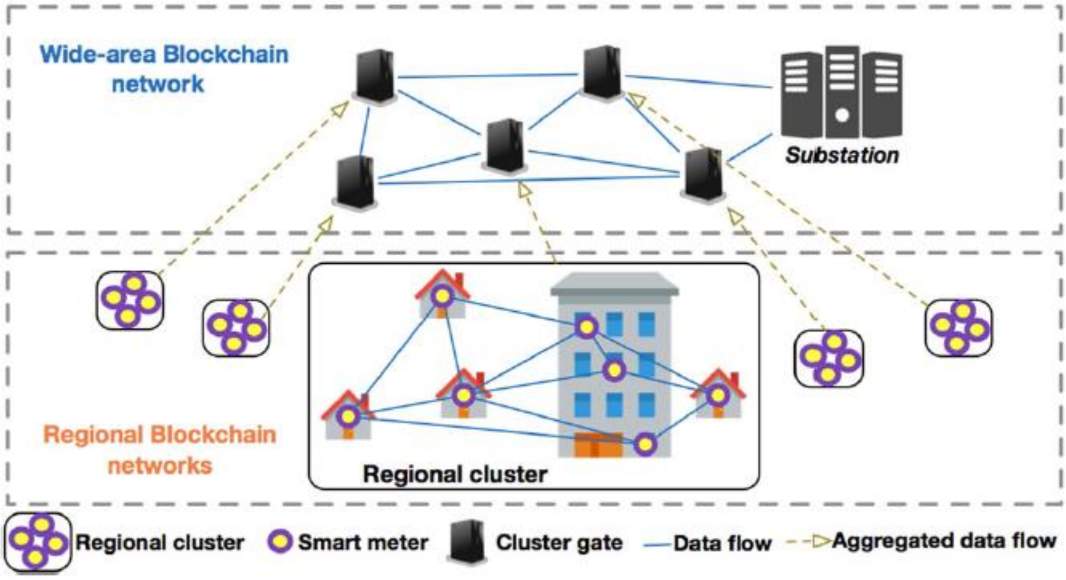
Source: (Musleh et al., 2019)

Decentralization introduces distributed energy resources (DERs), such as solar photovoltaics and wind power, reducing reliance on centralized power plants. Blockchain enhances this trend by allowing local energy production to be securely traded and efficiently distributed within the community, lowering transaction costs and optimizing asset utilization. As DERs proliferate, blockchain provides the necessary architecture to manage peer-to-peer transactions, fostering a system where customers become proactive participants.

3.1.2. Digitalization:

Blockchain is integral to the digitalization of the energy sector, supporting the real-time, automated communication necessary for advanced grid management. The digitization of the grid with smart metering, sensors, and IoT devices creates vast data streams that can be transparently and immutably recorded on a blockchain, facilitating improved operations and enabling innovative business models.

Figure 13: Schematic of the Blockchain based meter data aggregation framework



Source: (Dong et al., 2018)

Blockchain's inherent characteristics—decentralized control, secure data handling, and transparency—are instrumental in unlocking the potential of smart grid technologies.

With blockchain, smart meters not only record consumption data but also become active elements in a larger energy trading system, allowing consumers to engage in real-time energy transactions.

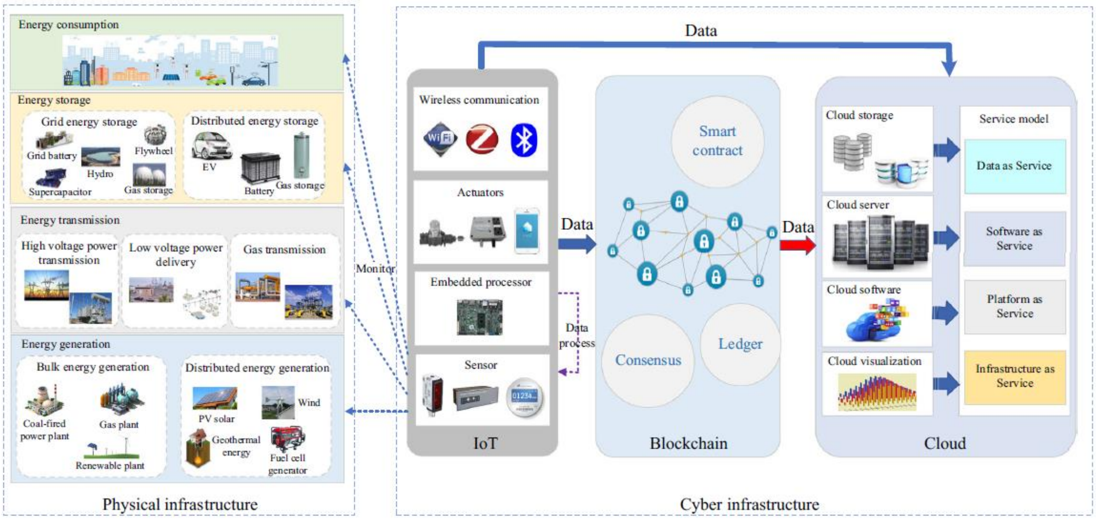
Moreover, blockchain-based platforms can aggregate data from various sources, enhancing demand response programs and grid balancing efforts. By leveraging blockchain, utilities and service providers can offer personalized energy solutions, improve system reliability, and ensure fair compensation for energy generation and storage.

3.2. Energy Value Chain and Blockchain Integration:

The advent of blockchain technology has ushered in a transformative era for the electricity value chain, promising enhanced efficiency, security, and transparency from generation to consumption.

The integration of blockchain within the electricity value chain is a leap towards a decentralized, resilient, and user-empowered system.

Figure 14: Cyber-physical infrastructure of future energy systems



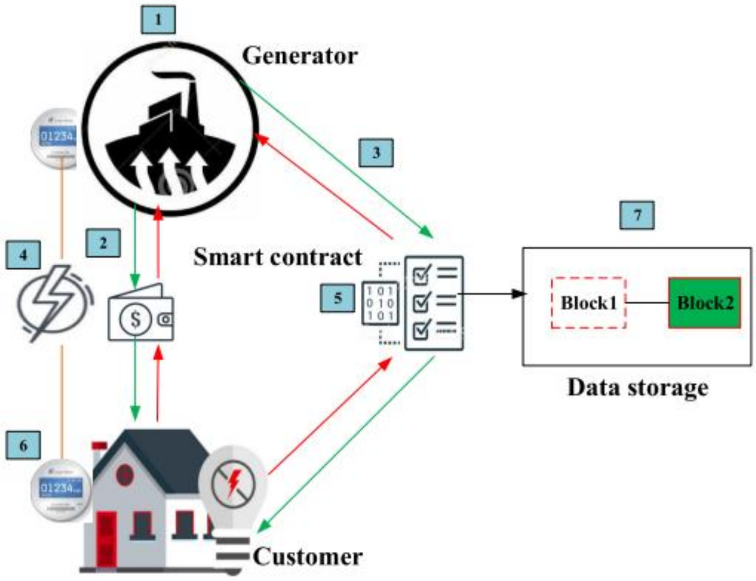
Source: (Dong et al., 2018)

The traditional model of energy distribution is being revolutionized by blockchain. In the past, centralized authorities managed the generation and distribution of energy. However, blockchain enables a more decentralized approach, where distributed generation resources such as rooftop solar panels and local wind turbines can contribute to the grid. Through smart contracts on a blockchain, producers can automatically sell excess energy to neighbors or back to the grid, optimizing the use of renewable resources and reducing waste (Dong et al., 2018).

Blockchain technology ensures that each transaction within the electricity value chain is securely logged and transparent. This level of transparency builds trust among stakeholders and facilitates the accurate tracking of energy flows. Moreover, the inherent security of blockchain with its immutable ledger prevents tampering, fraud, and unauthorized access, ensuring the integrity of the electricity market.

The use of smart contracts is a game-changer in automating the operational aspects of the electricity value chain. Smart contracts can execute transactions automatically when certain conditions are met, such as releasing payment upon delivery of energy. This automation reduces administrative overhead, eliminates the need for intermediaries, and speeds up processes, resulting in cost savings for both providers and consumers.

Figure 15: Proposed architecture for contract trading with smart contract.



Source: (Tesfamicael et al., 2020)

Blockchain enables more sophisticated demand-response management by allowing devices to participate in the grid's balancing act. IoT devices can communicate in real-time with the blockchain to adjust consumption based on grid needs, contributing to the stability and efficiency of the power system.

One of the most groundbreaking implications of blockchain is the facilitation of peer-to-peer (P2P) energy trading. Consumers with energy-producing capabilities can directly sell their surplus to others in a decentralized marketplace. This not only empowers consumers to become prosumers but also leads to more competitive energy prices and encourages the adoption of renewable energy sources *(Tesfamicael et al., 2020)*.

Blockchain technology plays a vital role in the management of energy storage and distribution. By recording the storage, release, and distribution of energy across various storage solutions, blockchain can optimize the energy flow, minimize losses, and ensure that energy is available where and when it is most needed.

Chapter II: Organizational Context and Methodology

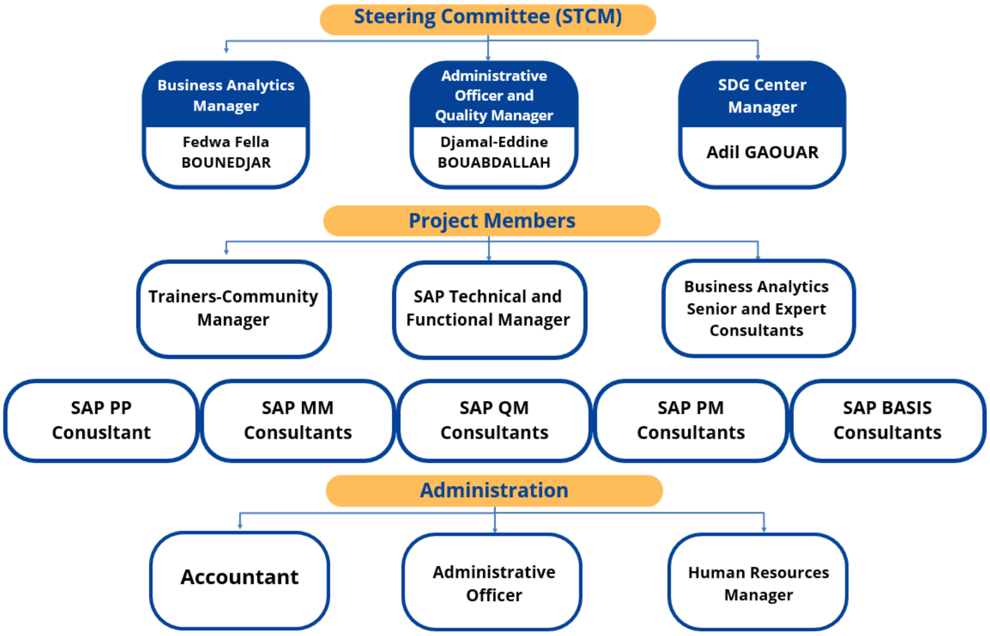
Section 1: Organizational Context

This section presents detailed insights into Sonatrach and Sonelgaz, two pivotal companies in Algeria's energy sector. The analysis and findings in this study are based on interviews and document analysis conducted within these organizations. These companies play a significant role in the nation's hydrocarbon and renewable energy industries, respectively, providing a comprehensive context for understanding the current technological and operational landscape. The internship was conducted at SDG Group, a prominent IT consulting firm specializing in digital transformation and information systems. Clients of SDG Group such as Sonatrach, provided valuable data and insights through their documented processes and stakeholder interviews. This collaboration enabled a thorough examination of their strategies, challenges, and innovations in the adoption of advanced technologies, particularly in the fields of oil, gas, and renewable energy. This section aims to provide a comprehensive overview of the organizations involved in our study.

1. Presentation of SDG Group

Founded in 2013, SDG Consulting (SARL) is a leading IT consulting firm affiliated with the international SDG Group. The company specializes in developing information systems and providing strategic consultancy services in various domains, including Enterprise Resource Planning (ERP), Business Intelligence (BI), and Corporate Performance Management (CPM). SDG Group operates in multiple regions, including North Africa, the Middle East, Europe, and the USA

Figure 16: SDG's Group Organization



Source: Internal Document

SDG Group aims to be a center of excellence in modelling, implementation, consultancy, and support for information systems. The company focuses on delivering high-quality, client-centric solutions that enhance business performance and drive innovation.

SDG Group has a significant presence in the oil and gas sector, providing advanced IT solutions to key players such as Sonatrach. These companies benefit from SDG's expertise in ERP systems, business analytics, and performance management, which are crucial for optimizing their operations and enhancing decision-making processes.

By implementing cutting-edge technologies and innovative solutions, SDG Group helps oil and gas companies improve operational efficiency, reduce costs, and achieve their strategic goals.

SDG Group missions:

- **Developing and Implementing Information Systems:** design, develop, and implement efficient information systems tailored to the specific needs of their clients. This includes ERP systems, business intelligence, and performance management solutions.
- **Consultancy and Support Services:** by helping organizations optimize their IT infrastructure and business processes. SDG Group provides continuous support to ensure the seamless operation of the implemented systems.
- **Driving Innovation and Digital Transformation:** focuses on driving innovation and digital transformation across various industries. This involves leveraging cutting-edge technologies to improve operational efficiency, decision-making processes, and overall business performance.

2. Presentation of the Sonelgaz Group

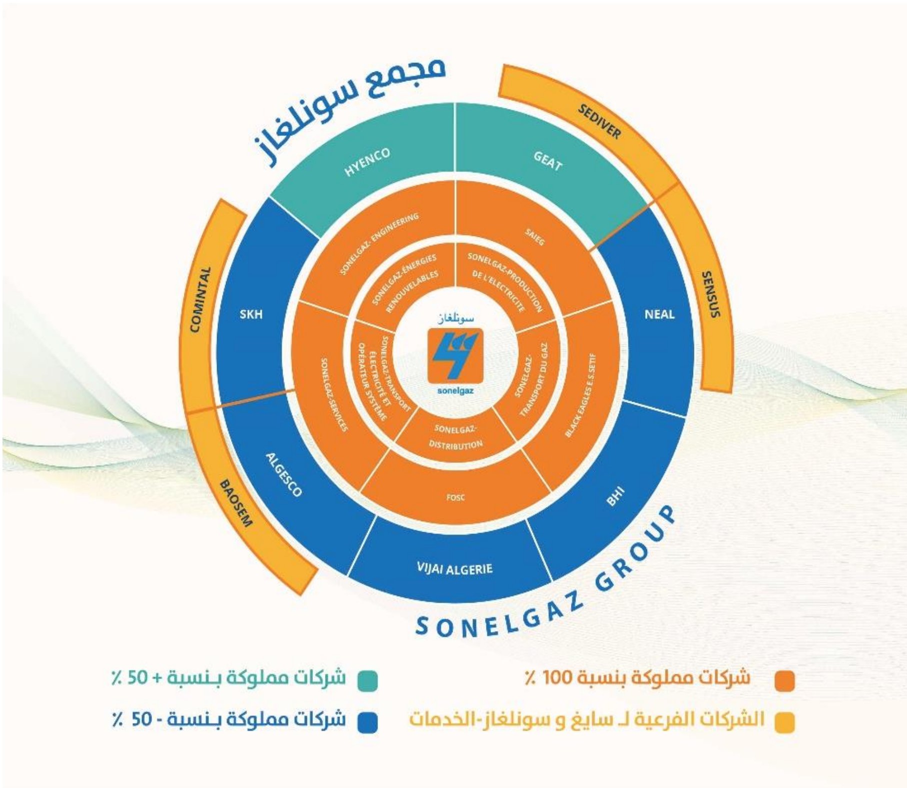
Sonelgaz, established in 1969, is a state-owned enterprise headquartered in Algeria. As the principal operator in Algeria's energy sector, Sonelgaz is responsible for the generation, transmission, and distribution of electricity and natural gas. It plays a critical role in the country's economic and social development, providing essential energy services to millions of Algerians.

The company manages a variety of power plants, including hydroelectric, conventional thermal, combined cycle, and cogeneration facilities, with total electricity production of 70,904 GWh in 2017. Sonelgaz distributed energy to more than 10 million customers, achieving a 99% electricity coverage rate.

Sonelgaz, as the principal operator in Algeria's energy sector, engages in both regulated and non-regulated activities. The company's operations reflect a blend of government oversight and market-driven initiatives, highlighting its pivotal role in the country's energy landscape.

- **Non-Regulated Activities**: Sonelgaz operates in the deregulated sectors of electricity production and the supply of natural gas and electricity. The company manages various installations with a significant total installed capacity, including hydroelectric, conventional thermal, combined cycle, and cogeneration power plants. These diverse power generation methods enable Sonelgaz to maintain a robust and flexible energy production portfolio.
- **Regulated Activities**: Sonelgaz distributes energy to a large customer base across Algeria. The company provides electricity and natural gas to millions of subscribers, ensuring widespread energy access and contributing to national energy security.

Figure 17: Presentation of the Sonelgaz Group



Source: Sonelgaz website

Sonelgaz established El Djazayer Information Technology (ELIT) in 2009 to develop and manage its information systems internally rather than relying on foreign solutions. This strategy has allowed Sonelgaz to create value while ensuring data security and avoiding dependency on external software providers.

ELIT's initial focus was on developing ERP systems, such as HISSAB project for financial management, NOVA project for human resources, and ATTAD project for stock management. These systems have improved operational efficiency, real-time data access, and decision-making processes.

Despite integration challenges and the need for organizational adaptation, the long-term benefits of these systems highlight the importance of sustained digital transformation efforts. Sonelgaz's commitment to digital transformation and innovative technologies positions it well to meet future energy demands and support Algeria's sustainable development goals.

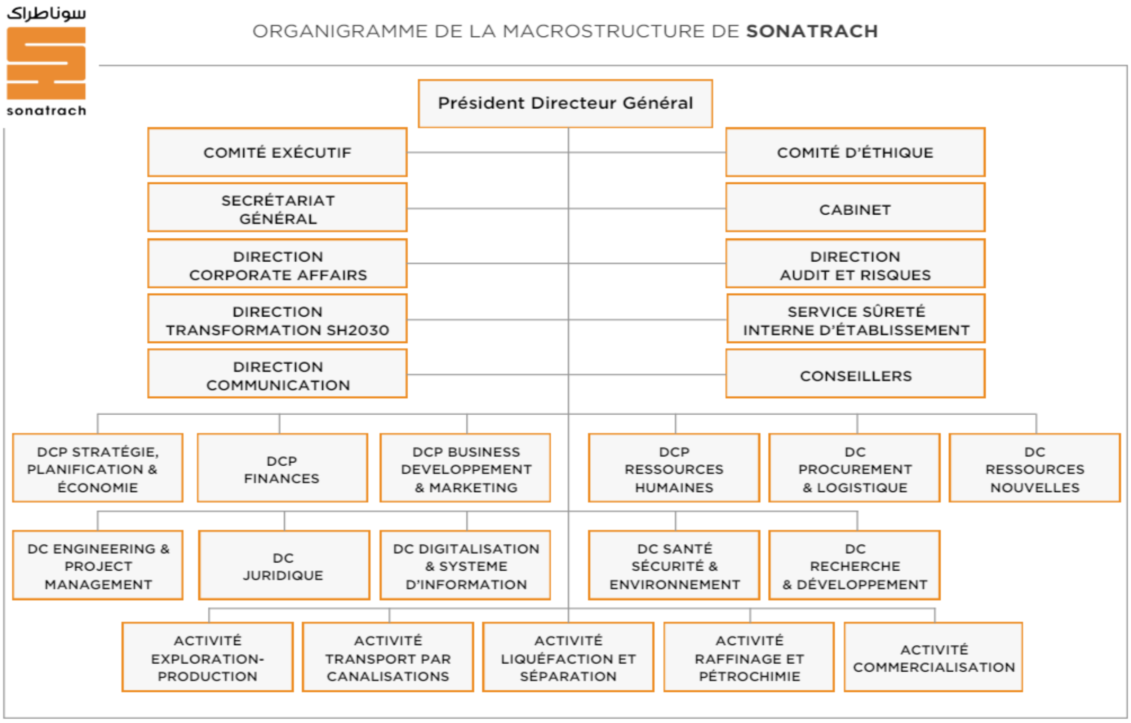
3. Presentation of the Sonatrach Group

Sonatrach, Algeria's national oil and gas company, commands a prominent position in the nation's hydrocarbon sector, boasting extensive assets and operational capabilities. With proven reserves exceeding 12 billion barrels of oil equivalent (BOE), Sonatrach is a major player in the global energy market, contributing significantly to Algeria's economic growth and energy security. The company's activities encompass exploration, production, transportation, refining, and marketing, supported by a workforce of over 120,000 employees.

As a key driver of Algeria's hydrocarbon industry, Sonatrach is guided by a strategic vision of excellence, sustainability, and leadership. The company prioritizes operational efficiency, safety, and environmental stewardship in all its endeavors, adhering to international best practices and standards.

Sonatrach continually invests in technology and innovation to optimize its operations, maximize resource recovery, and minimize environmental impact. For the improvement of its performance and the modernization of its management, Sonatrach increasingly considers the interests of its stakeholders, particularly through the growing use of information systems to enhance service quality.

Figure 18: Sonatrach's Organization Chart



Source: Internal Document

Sonatrach continually invests in technology and innovation to optimize its operations, maximize resource recovery, and minimize environmental impact. For the improvement of its performance and the modernization of its management, Sonatrach increasingly considers the interests of its stakeholders, particularly through the growing use of information systems to enhance service quality.

In this context, Sonatrach has embarked on significant digital transformation projects to modernize its operations and improve efficiency. Starting with creation of the DC DSI on 2020, Sonatrach established the Direction Centrale Digitalisation et Système d'Information (DC DSI) to oversee its digital transformation efforts. This decision was driven by the need to better manage information systems and enhance overall operational efficiency.

- **ERP Systems:** The DC DSI focuses on developing and implementing ERP (Enterprise Resource Planning) systems to streamline operations across various departments. These systems are crucial for integrating different functions and ensuring smooth data flow.
- **Advanced Technologies:** Sonatrach has adopted advanced technologies such as big data analytics to improve decision-making processes and operational efficiency. These technologies help in predicting maintenance needs, optimizing resource allocation, and enhancing overall productivity.

Section 2: Methodological framework

This section will present and explain the methodology used in this study. Initially, the research process will be outlined, followed by a discussion on the research methods and the chosen tools, the various methods for data collection and analysis will be covered. Lastly, a detailed step-by-step description of the methodology will be provided.

1. Research Philosophy

The research philosophy adopted for this study is interpretivism. Interpretivism is a well-established and elaborated research paradigm particularly suited for research in information systems *(Goldkuhl, 2012)*, which make it ideal for understanding the evolving and context-sensitive nature of blockchain technology. Interpretivism is well-suited for exploring the subjective realities and nuanced perceptions of stakeholders in the Algerian energy sector, including policymakers, utility companies, and technology providers.

Ontological Perspective

Ontology concerns the nature of reality and what can be known about it. In the context of this research, the ontological stance is **constructivist**, which asserts that reality is constructed through human experiences and interactions. This perspective is appropriate for studying how blockchain technology can be adopted in the energy sector, as it involves understanding the complex interactions between technology, organizations, and regulatory frameworks.

Epistemological Perspective

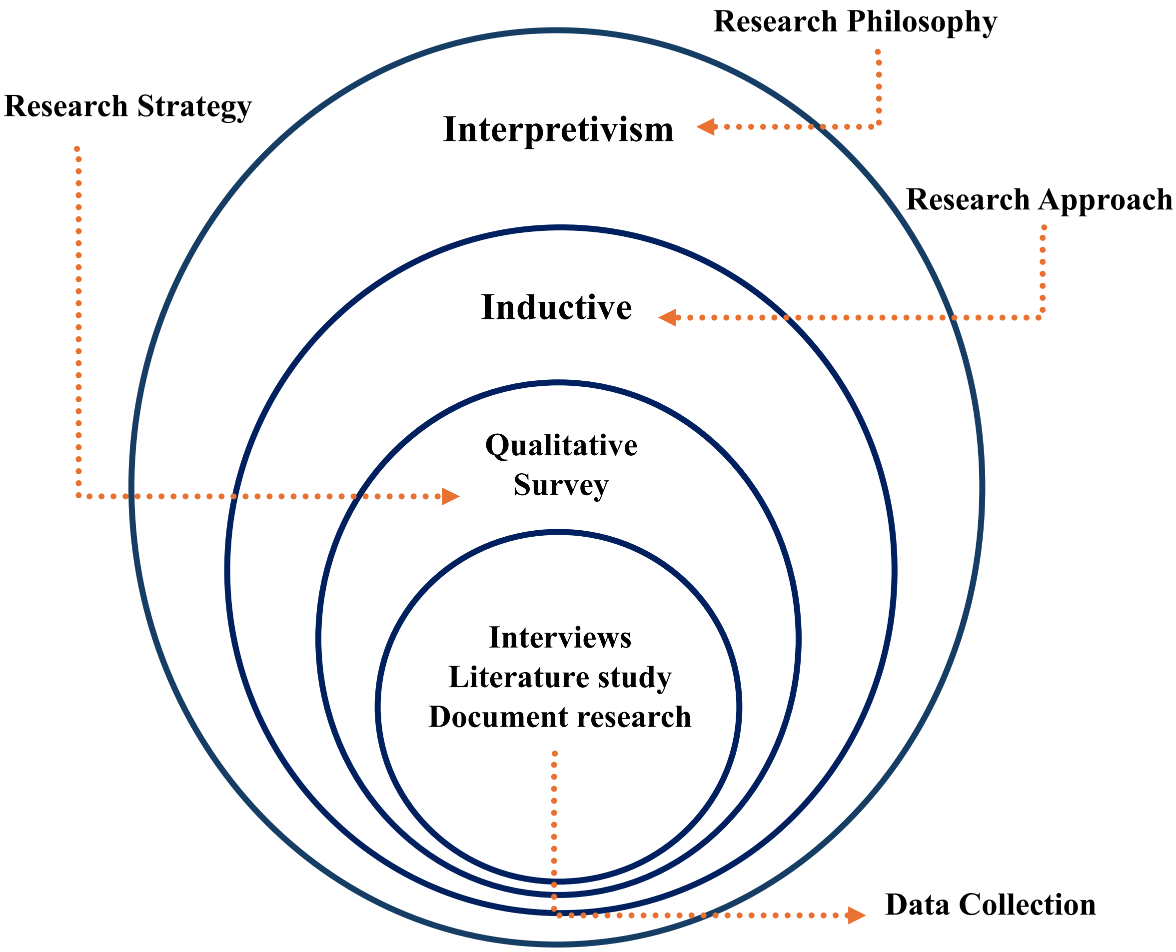
Epistemology deals with the nature and scope of knowledge. The epistemological stance of this research is **interpretivist**, which emphasizes understanding phenomena through the meanings that people assign to them. This approach is suitable for exploring the adoption of blockchain technology in Algeria's energy sector, as it involves interpreting the perceptions, motivations, and actions of various stakeholders (e.g., policymakers, energy companies, consumers).

2. Research Approach

An inductive approach is employed because no initial hypotheses were established, and the nature of the findings was unknown at the start of the study. This approach is appropriate as it facilitates the discovery of patterns, themes, and theories emerging from the collected data, leading to conclusions grounded in empirical evidence (El-Badawy, 2022).

This method is often used in qualitative studies with open-ended research questions, focusing on understanding dynamics, emergence, or constructing alternative futures which ensures a structured and comprehensive approach to exploring the adoption of blockchain technology in the Algerian energy sector.

Figure 19: Saunders' Research Onion



Source: Own work

3. Research Strategy

This study employs a qualitative survey strategy, this is due to the exploratory nature of study which used because there is limited prior research on the adoption of blockchain technology in the Algerian energy sector. This approach allows for an in-depth exploration of new concepts and issues, facilitating the development of a more comprehensive theoretical perspective.

The qualitative survey method offers the flexibility to adapt the research process as new information emerges (Jansen, 2010). This adaptability is crucial in exploratory studies, allowing the researcher to modify the approach based on ongoing findings.

4. Data collection methods

An exploratory method with qualitative data was used, relying on both primary and secondary sources. The data collection methods employed in this study are designed to capture a comprehensive and nuanced understanding of blockchain technology adoption in the Algerian energy sector.

By combining semi-structured interviews with a thorough review of literature and document analysis, this study ensures a robust and contextually relevant dataset that informs the research findings and supports the study's exploratory objectives.

4.1.Primary Data Collection

Semi-Structured Interviews:

semi-structured interviews were conducted with 5 experts in both the Information technology and energy domains details can be found in appendix C. Participants included utility managers, and technology providers who are directly involved or have a significant interest in the adoption of blockchain technology in the Algerian energy sector. Some experts were interviewed multiple times throughout each phase of our study to gather comprehensive insights.

Interviews were conducted both in person and electronically, with sessions held in English and French based on the interviewees' language preferences. Notes were taken during the interviews to facilitate the transcription process and serve as a backup.

The questions focused on understanding stakeholders' perceptions, expectations, challenges, and experiences. They covered areas such as the current state of art, regulatory environment, and strategic Algeria's 2030 Vision. The complete interview protocol can be found in appendix.

Generally seen, the questions to gather feedback (validation of each phase of our study, gain strategic insights such as identifying strategic axes and answering the model's questions, etc.) were somehow similar for each of the experts that were interviewed. These questions included:

- Questions Regarding the Use Cases**:** In this part of the interview, experts were asked to evaluate the described use case. Specifically, they were asked whether they agreed with how the use cases were presented and if they believed these narratives could be feasibly integrated within Algeria's energy sector.

- Questions Regarding the Implications for Scenarios**:** Experts were asked to assess the implications derived for each cluster of use cases. For each cluster, various implications for the energy landscape were identified. Experts were asked whether they agreed with these implications and if they found them comprehensive.

- Questions Regarding Obstacles for the Application of Use Case Clusters**:** This segment focused on identifying the most significant obstacles to the implementation of each use case cluster. Experts provided insights on the primary challenges that could hinder the realization of these use cases, offering valuable information for interpreting each cluster's feasibility.

- Questions on Specific Topics**:** Experts were asked to validate specific aspects of the study's interpretation and results. They were also invited to elaborate on certain assumptions or provide deeper insights based on their field of expertise. This allowed for a detailed examination of particular topics relevant to the research.

- Questions Regarding the Assessment Model**:** Experts were asked to evaluate the maturity levels of the use cases. Questions focused on the technological readiness, market readiness, and organizational readiness also experts were asked to assess the relevance of blockchain technology in the context of the use cases.

The number of interviews was not predefined upfront. Instead, the interviews were planned until saturation was reached.

4.2.Secondary Data Collection

Literature study: A comprehensive review of existing literature was conducted to gather secondary data. This included academic journals, industry reports, white papers, and case studies related to blockchain technology as well as Key databases such as Crunchbase which used to identify relevant blockchain use cases. Industry reports and white papers were sourced from reputable organizations and industry bodies.

The literature study focused on identifying global trends, successful implementations, technological advancements This provided a contextual background and informed the development of interview questions.

Document Analysis: Official documents, regulatory guidelines, strategic plans, and reports from Algerian energy authorities and companies were analyzed. This included materials from organizations such as Sonatrach and Sonelgaz.

The document analysis aimed to understand the regulatory framework, strategic priorities, and existing initiatives related to digitalization in Algeria. This helped contextualize the primary data and ensured a comprehensive understanding of the research problem.

5. Data analysis methods:

The data analysis methods employed in this study were designed to systematically process and interpret the qualitative data collected from both primary and secondary sources. These methods aim to uncover patterns, themes, and insights that are crucial for understanding the integration of blockchain technology in the Algerian energy sector.

When using qualitative data collection methods, the data collected is often characterized by a lack of standardization and thoroughness of descriptions and explanations *(Tümen Akyildiz & Ahmed, 2021)*, Therefore, we employed multiple methods to ensure the reliability and robustness of results. Concretely,

5.1.Natural Language Processing (NLP) for Text Cluster Analysis

NLP methods were employed for text cluster analysis. Machine learning methods can automate clustering based on specific computational logic without requiring human intervention (Ezugwu et al., 2022).

This is a novel analytical methodology in the context of existing literature reviews on energy and blockchain. NLP methods were used to perform semantic analysis on the summary parts of the dataset to trace and categorize information effectively.

5.2.Thematic Analysis

Thematic analysis was the primary method used for analyzing interview data. This involved identifying recurring patterns and themes within the interview transcripts. Each transcript was carefully reviewed, and key phrases or ideas were highlighted. broader themes were then developed to capture the essence of the stakeholders' perceptions, experiences, and expectations regarding blockchain technology. These themes were refined through iterative reviews to ensure they accurately reflected the data.

A decision tree model was integrated into the thematic analysis. During the interviews, questions derived from these models were posed to validate the results and assess the applicability of blockchain technology. This helped evaluate factors such as the role of intermediaries, management of digital assets, and other operational considerations.

The interviews thus contributed significantly to the evaluation process by gathering stakeholders' opinions and answers to the model's questions, ensuring that the thematic analysis was both comprehensive and grounded in real-world insights.

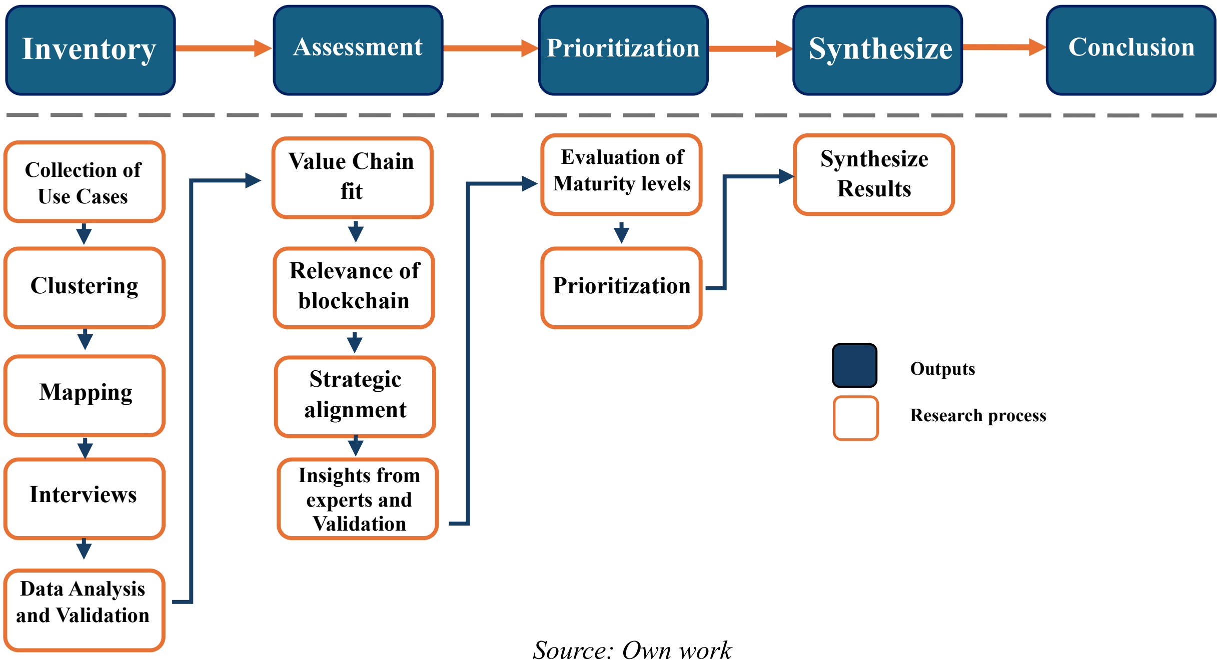
5.3.Document and Literature Analysis

Which was used to extract insights and aid in the evaluation by analyzing the companies and the energy sector in Algeria. This involved examining official documents, regulatory guidelines, strategic plans, and reports from Algerian energy authorities and companies. The analysis aimed to understand the regulatory framework, strategic priorities, and existing initiatives related to blockchain technology in Algeria. This helped assess the potential of adopting the technology strategically within the Algerian context.

6. Detailed Description of the Research Design

This part provides a comprehensive overview of the research design employed in this study. It outlines the systematic approach taken to address the research questions, including the methodologies and strategies used for data collection and analysis. By detailing each step of the research process, this section aims to give a clear understanding of how the study was structured, ensuring transparency and rigor in the investigation. The subsequent pages will elaborate on the specific research methods, tools, and techniques applied, offering a step-by-step description to guide the reader through the study's design and implementation.

Figure 20: Research Process



Source: Own work

6.1. Inventory

The initial stage of our research approach is focused on the inventory of blockchain-based energy use cases. This foundational stage involves the comprehensive collection, mapping, and clustering of use cases. The specific sub-activities involved in this stage include:

6.1.1. Use cases Collection

The primary objective of the data collection phase was to compile an exhaustive list of blockchain-based use cases within the energy sector, aiming to analyze their objectives, technologies used, and the broader implications for energy management. This was achieved through a dual approach:

- **Databases**: The main database utilized was Crunchbase, which offers extensive data on companies, including startups in the blockchain arena. This database was instrumental in identifying use cases that are actively being developed and deployed in the market.

- **Literature**: Key academic and industry reports were reviewed, with a particular focus on the work of (Andoni et al, 2019). This seminal paper provided a foundational framework for understanding the challenges and opportunities of blockchain technology in the energy sector, guiding the selection and evaluation of pertinent use cases.

6.1.2. Use cases clustering

After completing an extensive data collection, the subsequent phase involved clustering the blockchain use cases to uncover common themes and operational similarities. This critical step aids in transforming the collected data into actionable insights and provides a deeper understanding of the diverse applications of blockchain technologies in the energy sector.

To facilitate effective text-based cluster analysis, we employed Natural Language Processing (NLP) techniques. Machine learning methods were utilized to automate the clustering process, relying on specific computational algorithms. This approach eliminates the need for manual intervention, significantly reducing the labor-intensive elements traditionally associated with such analyses *(Ezugwu et al., 2022)*.

For the clustering task, we opted for the K-means algorithm, renowned for its simplicity and efficacy in organizing data into a predetermined number of clusters based on feature similarities. The selection of the K-means algorithm is bolstered by its documented success in handling large datasets and streamlining complex data analyses, as discussed in various academic and methodological studies, including those presented by *(Korobova et al. 2020)*.

This choice is in line with the overarching methodological objectives of our study, which seek to deliver precise and actionable insights into how blockchain technologies can be deployed and optimized within the realm of energy management.

The optimal number of clusters, denoted as K, was determined using the silhouette score—a method that assists in identifying the most statistically appropriate number of clusters by evaluating the improvement in explained variance through the clustering process *(Shahapure & Nicholas, 2020)*.

6.1.3. Mapping of use cases

The activity of mapping the use case clusters is essential for presenting complex data in an accessible and comprehensible manner. To visualize the flow of blockchain applications from foundational sources (e.g., oil and gas, renewable energy) to the outcomes in terms of operational excellence. Sankey diagrams was used to help depict how different energy sources are linked to specific blockchain applications and their subsequent attributes. It aims to illustrate the relationships, distributions, and patterns within the clustered blockchain use cases in the energy sector, making the insights gleaned from the data analysis tangible and actionable.

6.2. Assessment

6.2.1. The electricity value chain fit

All of the use case clusters are evaluated based on their fit with the business operations of an electric utility. By placing the clusters into the electricity value chain, the use cases deemed not to fit into the current or possible future, should remove from further analysis. This is an important step given the selected scope and delimitations.

6.2.2. Blockchain Relevance

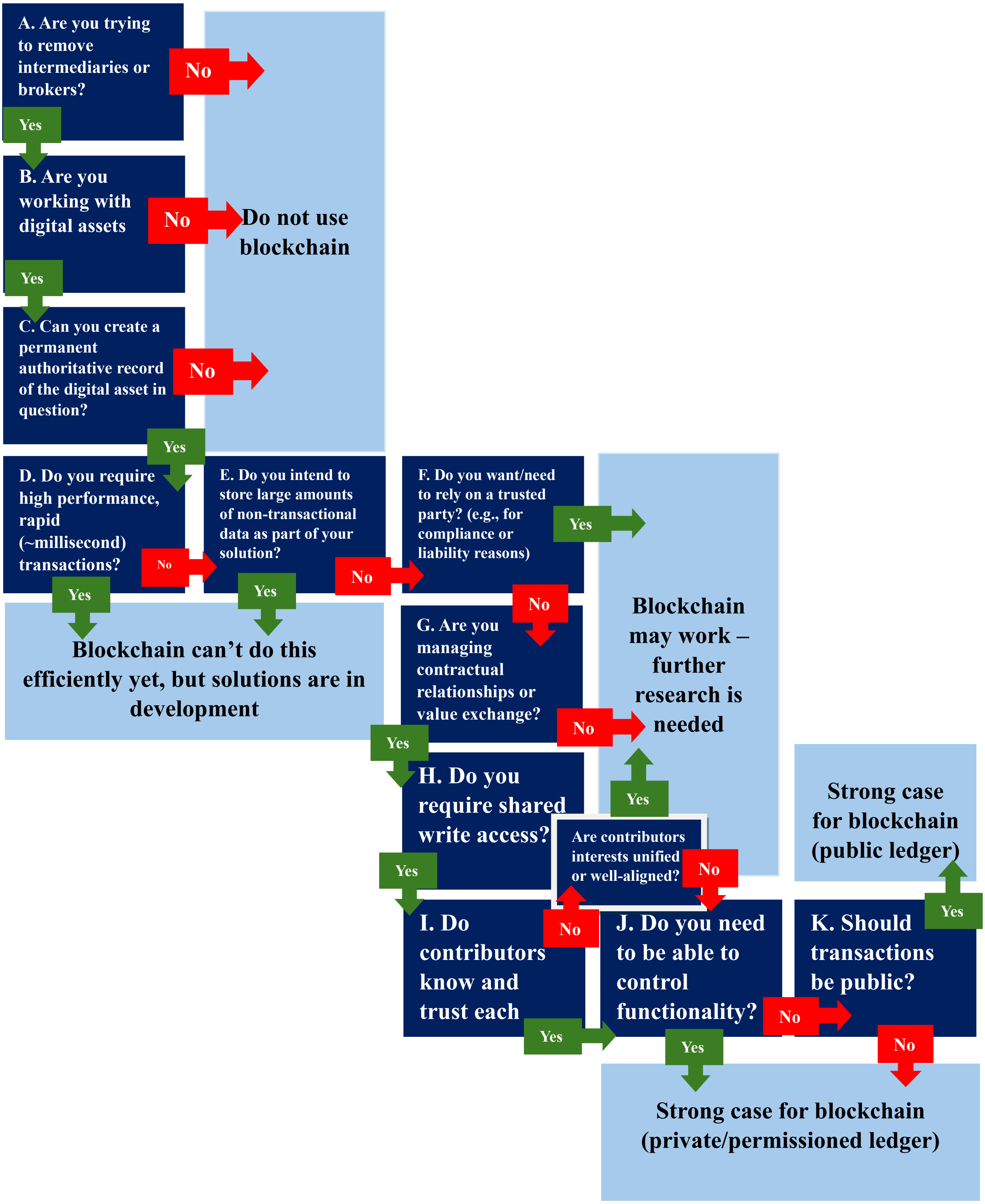
Blockchain technology, while innovative, is not universally applicable across all potential use cases or business scenarios. Its successful deployment relies heavily on the ability to meet specific operational demands and strategic goals, making the preliminary assessment of its relevance critical. This assessment is guided by various established criteria developed by academia, industry experts, and governmental bodies to determine when and where blockchain technology is best suited.

To methodically evaluate blockchain's applicability, we draw upon several decision tree models that offer structured frameworks for analysis. One such model, developed by *(Mulligan et al,2018)*, is designed to define whether blockchain is an appropriate solution for specific business challenges. This model poses a series of questions that help in assessing whether removing intermediaries, managing digitally native assets, creating permanent records, and addressing other critical operational considerations align with blockchain capabilities.

Several models, such as those by *(Hunhevicz & Hall, 2020)*, were investigated. However, *(Mulligan et al, 2018)* is particularly straightforward and user-friendly, making it ideal for quick preliminary assessments where the goal is to rapidly determine the basic suitability of blockchain for simpler use cases. This model is best suited for organizations that are beginning to explore blockchain possibilities and need a clear, concise framework to quickly rule out unsuitable applications.

We chose this decision tree model because our priority is to achieve speed and simplicity in the evaluation process, without the necessity for an in-depth integration into complex business strategies. Additional constraints and considerations will be addressed in the subsequent sections.

Figure 21: Decision tree model



Source: (Mulligan et al,2018)

6.2.3. Strategic Alignment

Following the evaluation of blockchain relevance, we shift our focus to strategic alignment. While the decision tree model offers speed and simplicity in assessing blockchain relevance, it is crucial to examine how well it aligns with the strategic goals of the organizations. This analysis will help us determine whether the use case clusters support long-term goals, facilitate potential synergies, and identify any strategic misalignments that could impact the effective adoption of blockchain technology.

Our evaluation aims to ensure that the adoption of blockchain technology is not only technologically feasible but also strategically beneficial. By aligning blockchain implementation with overarching strategic objectives, we can enhance its integration into the organizational framework. Thus it's important to consider the strategic landscape outlined in key documentation from prominent players in Algeria's energy sector, such as Sonatrach and Sonelgaz. These entities dominate the sector and set the strategic tone for technological adoption.

This phase of the evaluation will provide insights into the strategic implications of decisions and guide the optimal integration of blockchain within operations. Through a comprehensive review of strategic alignment, we seek to bridge the gap between technological implementation and strategic vision, ensuring that our adoption of blockchain technology aligns seamlessly with organizational objectives.

The clusters of use cases will be rigorously assessed to determine their alignment with the strategic objectives. This evaluation will utilize a nuanced three-level scale designed to reflect the depth and nature of alignment:

- Score 0 (No Alignment): The use case has no relevance or connection to the strategic objectives of the organization. Implementing this use case would likely provide no benefit towards achieving strategic goals.

- Score 1 (Partial Alignment): The use case aligns with certain aspects of the organization’s strategy. While not directly central to strategic objectives, its implementation could indirectly support broader goals or address secondary objectives that contribute to the overall strategy.

- Score 2 (Full Alignment): The use case is highly aligned with the organization’s strategic objectives. Implementation would directly contribute to and accelerate the realization of these goals, potentially delivering significant strategic benefits.

By meticulously assessing the strategic alignment of blockchain use cases, we can ensure that technological adoption not only meets operational demands but also enhances strategic initiatives, leading to a more integrated and effective implementation of blockchain within our organizational framework.

6.3. Prioritization

This study embarked on evaluating the maturity of various blockchain use cases within the energy sector, employing a methodical framework known as the Balanced Readiness Level assessment (BRLa).

This approach extends beyond traditional technology readiness assessments to include market, regulatory, acceptance, and organizational readiness, offering a comprehensive view of each use case's potential for successful implementation.

Two foundational studies *(Vik et al., 2021)*, *(Richter et al., 2018)* were investigated to conduct this evaluation which provided a theoretical backbone for developing an assessment methodology tailored to blockchain applications in energy.

The Balanced Readiness Level model was adopted as a refined tool to capture the multifaceted challenges and requirements of integrating blockchain technologies into the highly regulated and technically complex landscape of energy systems.

- **Technological Readiness Level (TRL)**

Assesses the maturity of the technology itself. It evaluates the progression from conceptualization and design through to development and final operational deployment. TRL considers whether the technology is still at the proof-of-concept stage, if it has been tested in a lab, or if it is already in full-scale commercial use.

Table 3: Dimension of Technological Readiness Level assessments

Level	TRL
1	Specific technological idea is formulated
2	The technology idea is explicitly described
3	Experimental proof of concept
4	Technological elements are tested and validated in lab or simulated environment
5	Integrated technology tested and validated in lab or simulated environment
6	Technology demonstrated in relevant environment
7	System prototype demonstrated in natural environment
8	Product tested and validated, and the functionality is being optimized
9	Actual system proven functional in natural environment

Source: (Vik et al., 2021)

- **Market Readiness Level (MRL)**

Focuses on the readiness of the market to adopt and integrate the new technology. MRL evaluates market demand, competitive environment, customer acceptance, and the overall business model's viability. It looks at whether there is a market identified, if the product has been introduced to potential users, and the level of market acceptance.

Table 4: Dimension of Market Readiness Level assessments

Level	MRL
1	Hunch of a market need
2	Market and product are described
3	Market need and market supply are explicated.
4	Validation of market/small pilot campaign
5	Business model described
6	Products are being launched in limited scope
7	Customers confirm progress/improvement
8	Stable sale makes income predictions possible
9	Market confirms stability/growth

Source: (Vik et al., 2021)

- **Regulatory Readiness Level (RRL)**:

Measures the state of regulatory support or compliance required for the technology. RRL assesses if existing regulations support the use of the technology, the need for new regulations, or if the technology must adapt to current regulatory frameworks to facilitate deployment.

Table 5: Dimension of Regulatory Readiness Level assessments

Level	RRL
1	The legal and/or regulatory aspects of the technology is unpredictable or unknown
2	Use or production will require changes of laws.
3	Use and/or production will require change or reinterpretations of regulatory framework
4	Use and/or production will require demanding permissions or approvals
5	Use and/or production will presuppose accessible permissions or approvals
6	Necessary approvals are likely
7	Necessary approvals for use or production are' just
8	Use or production fulfill general conditions
9	Use and production are regulatory unproblematic

Source: (Vik et al., 2021)

- **Acceptance Readiness Level (ARL)**:

Examines the societal acceptance and ethical considerations of the technology. ARL determines how well the technology is received by potential users and the broader community, considering social, cultural, and ethical implications.

Table 6: Dimension of Acceptance Readiness Level assessments

Level	ARL
1	The technology is or will be seen as illegitimate or unacceptable
2	The technology will be seen as controversial in large parts of the population
3	The technology is seen as unwanted or inappropriate among groups of the population
4	The technology is seen as controversial among groups of the population
5	Use of the technology is seen as unwanted or inappropriate among key actors in the sector

6	Use of the technology is seen as unwanted or inappropriate among a few actors in the sector
7	The technology is seen as controversial in parts of the sector
8	The technology is seen as controversial among marginal interest groups
9	The technology is generally accepted/applauded

Source: (Vik et al., 2021)

- **Organizational Readiness Level (ORL)**:

Looks at how well the technology can be integrated into existing systems and processes within organizations. ORL assesses the need for changes in organizational structures or processes, training requirements, and the overall impact on current operational workflows.

Table 7: Dimension of Acceptance Readiness Level assessments

Level	ORL
1	The technology represents a fundamental break with existing work processes
2	Unclear how the technology might be adapted to existing work processes/organization
3	An idea about integration domestication exists
4	Integration with work processes/organization is formulated
5	A concrete plan for integration with existing work processes is formulated
6	Large/fundamental organizational changes are needed in order to use the technology
7	Small organizational changes are needed in order to use the technology
8	Technology is adapted to work processes and/or existing technology
9	The technology works seamlessly with existing technology

Source: (Vik et al., 2021)

In summary, this chapter has detailed the comprehensive methodology employed in our study, providing a clear and structured framework for evaluating the integration of blockchain technology within the Algerian energy sector. By systematically outlining each step of the research process, we have laid a robust foundation for the subsequent analysis. This thorough approach ensures that our findings are not only grounded in empirical evidence but also strategically relevant, paving the way for the effective adoption of blockchain solutions in Algeria's energy landscape.

Chapter III: Results and Discussion

Section 01: Results

In this section, the empirical findings will be analyzed following the consecutive steps of the use case evaluation approach introduced in the previous chapter. The presentation of results consists of three parts: an overview of the inventory step, an analysis of the use case clusters in the assessment step, and the prioritization step. The purpose of this chapter is to answer the research question: "What are the key blockchain scenarios that Algerian energy utilities should focus on to align with the country's 2030 Vision and enhance their technological capabilities?" This question connects the potential of blockchain technology with the strategic goals outlined in Algeria's 2030 Vision for the energy sector, emphasizing the need for innovative solutions that support long-term national energy plans. Specifically, this section addresses which blockchain scenarios are currently operational globally, how these scenarios align with Algeria's strategic energy goals in terms of renewable energy integration and energy efficiency improvements, and what the maturity levels of these blockchain applications are, along with the barriers preventing their widespread adoption within the energy sector.

1. Contextual Analysis of the Algerian Energy Sector

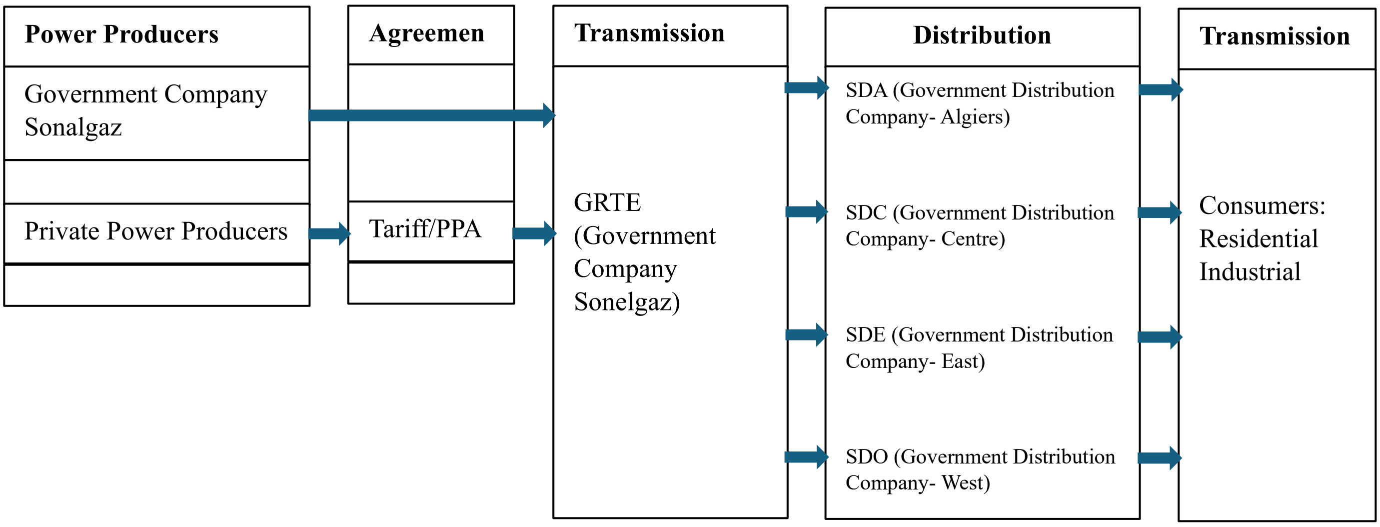
In recent years, Algeria has embarked on significant legal and institutional reforms aimed at adapting its energy sector to the demands of a competitive, open economy. This transition encompasses both fossil fuels and renewable energy sources, seeking to attract private sector participation in energy investments, technology acquisition, and market expansion. The enactment of the Electricity Law N°02-01 on February 5, 2002, marks a cornerstone in these efforts, advocating for the liberalization of the electricity sector, competitive market access, and the maintenance of public service standards.

Similarly, the hydrocarbons bill aligns with objectives to enhance the diversity, quality, and competitiveness of energy products and services (Stambouli, 2010). These reforms underscore Algeria's commitment to fostering a regulatory environment conducive to innovation and competition.

To move towards a more sustainable energy model, Algeria recognizes the insufficiency and environmental cost of its fossil fuel dependency. The country has planned a set of actions across the energy sector to remain committed to an energetic model based on fossil energies, due to its significant endowment of these resources. However, the focus on renewable energy is evident in the government's program to promote significant investments in this area, particularly between 2020 and 2030. This strategic shift acknowledges the abundant solar energy potential within Algeria.

Despite these initiatives, the transition to a sustainable energy model presents considerable challenges. The government faces obstacles such as inadequate grid infrastructure, high investment costs, and low public awareness. The integration of smart technology into the electricity grid represents a forward-thinking approach to enhancing energy efficiency and incorporating renewable sources.

Figure 22: Structure of the Algerian electricity market



Source: (Bouznit et al., 2020)

Additionally, the legal and policy frameworks represent a significant challenge for the government. Effective translation of these frameworks into actionable regulations is crucial for overcoming the barriers to increased renewable energy use. This includes creating a comprehensive regulatory framework that supports innovation and market expansion.

Algeria's energy sector is at a pivotal point, necessitating a delicate balance between leveraging its hydrocarbon resources and accelerating the transition to renewable energy. The success of this transition hinges on strategic investments, policy reforms, and the integration of smart technologies.

By prioritizing renewable energy and efficiency, Algeria can forge a path towards sustainable development that not only mitigates the impacts of climate change but also catalyzes economic growth and energy security. The journey is complex and fraught with challenges, but the potential rewards for Algeria and the global community are immense.

2. Inventory of Use Cases

The results presented in this phase provide valuable insights into blockchain-based energy use cases. This foundational effort involved a thorough collection and assessment of use cases, enabling us to map and categorize them into distinct clusters. By analyzing these clusters, we can better understand their potential impact on the sector.

2.1. Collection of use cases

The data collection phase was meticulously designed to compile an extensive list of blockchain applications across the energy sector. This segment outlines the significant insights derived from the gathered data, demonstrating the diverse applications and strategic potential of blockchain technology in this field, an exhaustive list was compiled, which incorporated over 130 use cases publicly available in the market.

This compilation was derived from an extensive review of the Crunchbase database, and consulting the seminal work of (Andoni et al., 2019), the review served as a foundational resource in identifying key projects and initiatives relevant to the scope of this research. This process provides a broad coverage of current applications of blockchain technology in the field. Each use case was meticulously documented with respect to its primary objectives, the technologies employed, and a detailed description of its implementation. This documentation facilitated a thorough understanding of the diverse applications of blockchain technologies and their specific functions within the energy sector.

Throughout the research process, the analysis of blockchain use cases in the energy sector revealed a strong focus on enhancing transactional efficiencies and supply chain transparency, particularly through peer-to-peer energy.

A significant trend was the integration of blockchain with IoT technologies, which are used to secure and manage data from smart meters and sensors, thereby supporting sophisticated strategies in grid management and energy distribution.

Many projects were found to align with key industry objectives, including improving operational efficiency, maintaining supply chain integrity, and fostering sustainable energy practices.

Geographically, blockchain technology has been widely adopted, with notable activities in Europe and North America and across various energy sector segments, demonstrating its broad potential to innovate traditional systems and emerging areas like electric vehicle charging networks.

This comprehensive understanding and documentation of blockchain applications underscore their transformative impact and strategic value in the energy sector, highlighting areas ripe for future innovation and investment. The complete and final list of inventoried use cases is provided in Appendix A for further reference.

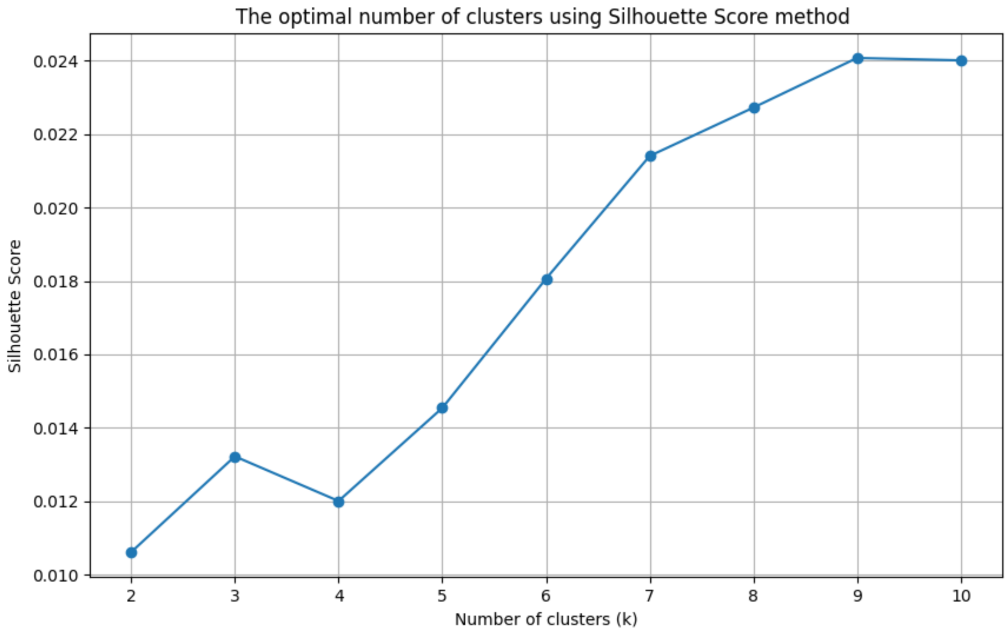
2.2.Clustering of use cases

Following the inventory phase, the next step involved clustering these cases to identify distinct groups based on similarities in their objectives and functionalities.

The clustering process was executed using the K-means algorithm, a well-established method in data science for grouping data into k number of clusters, where k is predetermined through analytical methods. To determine the optimal number of clusters, the silhouette score method was employed.

The Python programming language and its associated libraries were utilized to perform the clustering and silhouette score calculation. The specific code and algorithms used are detailed in Appendix B.

Figure 23: The optimal number of clusters using silhouette score method



Source: Own Work

The results of the silhouette score analysis, starts at a lower value when the number of clusters (k) is 2. There's a noticeable increase in silhouette score as the number of clusters rises, with the score improving significantly from k=2 to k=5. This indicates that the data points are progressively better matched to their own clusters and more distinct from other clusters as k increases within this range. From k=5 to k=7, the silhouette score continues to increase, albeit at a slower pace, suggesting that further gains in cluster definition are being made. The score plateaus between k=7 and k=9, with the silhouette score slightly decreasing at k=8 before increasing again at k=9.

The highest silhouette score is observed at k=9, suggesting that 9 clusters provide the best average separation and cohesion for this dataset. There is a slight dip in the score at k=10, which could indicate that having more clusters might start to degrade the quality of the clustering in terms of inter-cluster separation and intra-cluster cohesion.

Based on figure, choosing 9 clusters seems to be the most appropriate for the dataset because it yields the highest silhouette score, suggesting a good balance between the clusters' separation and the cohesion within them.

Table 8: Result of Clustering Process.

Clusters	Use cases numbers	Title
Cluster 0	4	Energy Supply Chain Management
Cluster 1	19	Renewable Energy P2P Trading Platforms
Cluster 2	13	Environmental Carbon Credits Blockchain Platform
Cluster 3	15	Smart Energy Management Systems
Cluster 4	12	EV Charging Networks
Cluster 5	17	Wholesale Energy Blockchain Platforms
Cluster 6	22	Renewable Energy Blockchain Solutions
Cluster 7	10	Sustainable Cryptocurrency Mining Operations
Cluster 8	19	Comprehensive Energy Trading Platforms

Source: Own Work

In the intricate landscape of blockchain applications within the energy sector, our analysis has distilled the diversity of initiatives into 9 distinct clusters. These clusters were identified based on textual similarities in the objectives and descriptions of the use cases, providing a structured overview of the blockchain landscape in the energy domain.

Cluster 0, Energy Supply Chain Management, featuring 4 use cases, not only champions the streamlining of supply chains but also focuses on optimizing energy procurement at wholesale prices, fostering dynamic pricing models that enhance efficiency and reduce costs.

Cluster 1, Renewable Energy P2P Trading Platforms, with its 19 use cases, elevates the ecosystem by facilitating access to renewable energy markets, allowing a broader range of participants to engage in the trading of solar and other renewable resources, thereby increasing accessibility and market reach.

Cluster 2, Environmental Carbon Credits Blockchain Platform, consisting of 13 use cases, is the confluence of environmental consciousness and technological innovation, with platforms intricately designed for the nuanced trading of carbon credits.

Cluster 3, Smart Energy Management Systems, incorporates 15 use cases that interweave IoT with blockchain to forge intelligent, responsive solutions for managing energy usage.

Cluster 4's EV Charging Networks, encompassing 12 use cases, not only accentuates the expanding support system for electric vehicles but also underscores the role of blockchain in ensuring the security and reliability of this critical infrastructure.

Cluster 5, Wholesale Energy Blockchain Platforms, presents 17 use cases that demonstrate blockchain's scalability in wholesale energy markets, aiming to streamline large-volume transactions and elevate market fluidity.

Cluster 6, Renewable Energy Blockchain Solutions, with 22 use cases, exhibits a broad spectrum of blockchain applications that are reshaping renewable energy systems, aligning electricity generation with sustainable practices.

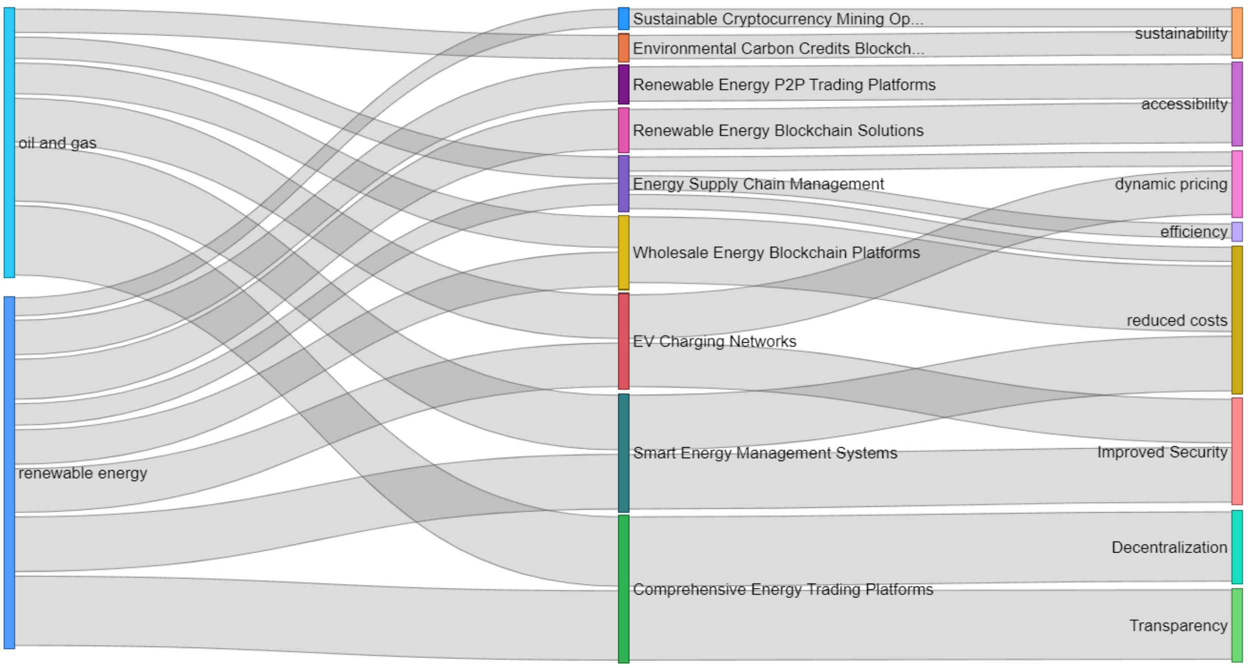
Cluster 7, Sustainable Cryptocurrency Mining Operations, with 10 use cases, signals a conscientious approach to cryptocurrency mining, harnessing solar power to mitigate the environmental impact.

Cluster 8, Comprehensive Energy Trading Platforms, shares the forefront with Cluster 1 by comprising 19 use cases, characterized by their robust trading solutions that utilize blockchain to refine and safeguard transactional processes. embodying the decentralized ethos that is central to blockchain technology and transformative for energy trading dynamics.

2.3. Visual representation:

In order to display the progress and focus within the domain of blockchain applications in the energy sector, we constructed a Sankey diagram. The purpose of this visualization is to demonstrate not only the distribution and prevalence of use cases across various clusters but also the dynamic flow of innovation from foundational energy sources towards key attributes sought in blockchain applications.

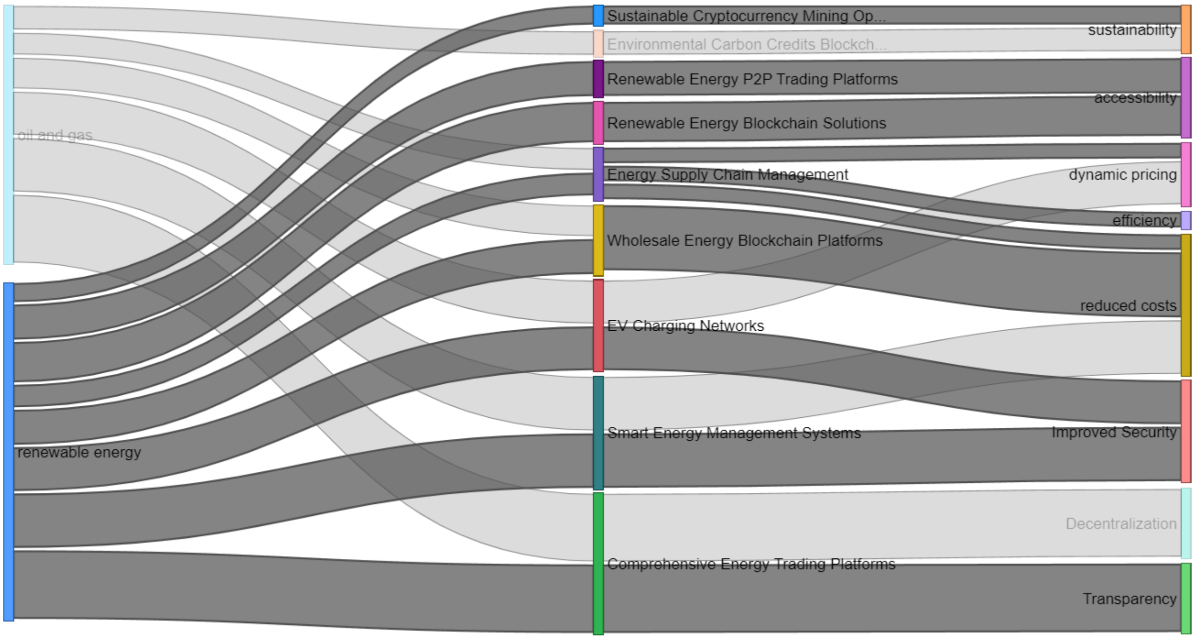
Figure 24: The Sankey diagram displaying the deployment of clusters in the energy sector



Source: Own Work

In our examination of the Sankey diagram, we discern the distribution of blockchain use cases emerging from two foundational energy sources: oil and gas, and renewable energy towards various applications characterized by attributes such as sustainability, accessibility, dynamic pricing, efficiency, reduced costs, improved security, decentralization, and transparency. The diagram's flows, whose lengths are indicative of the number of documented use cases, portray a compelling narrative of blockchain adoption and its intersection with energy sector priorities.

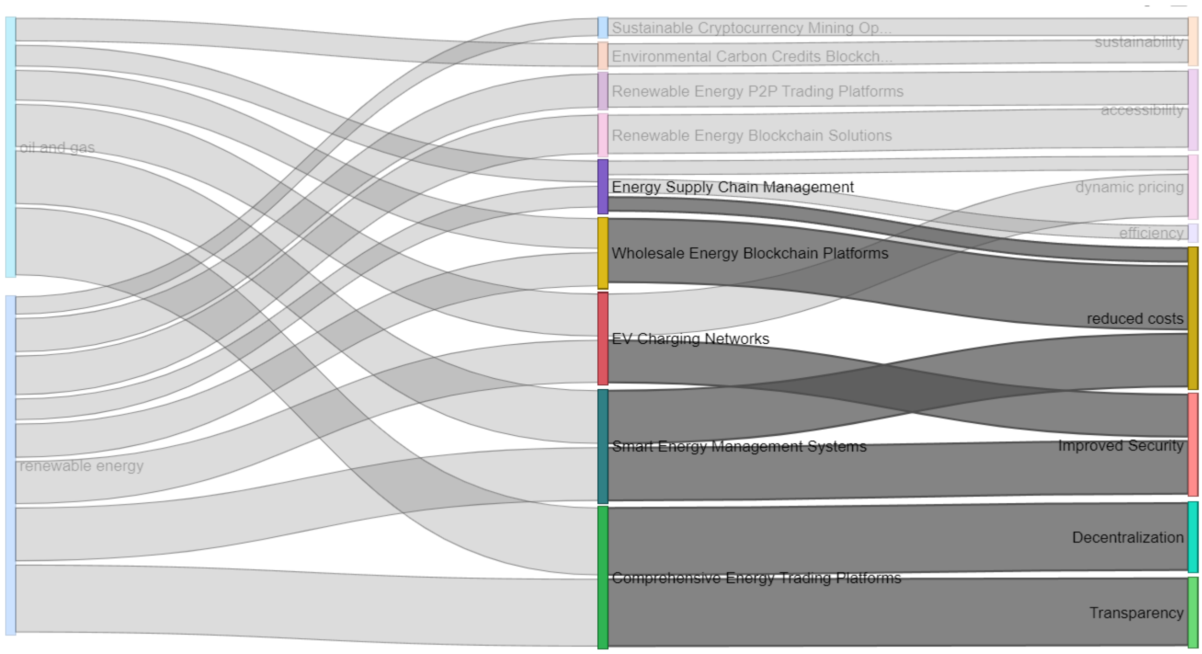
Figure 25: The Sankey diagram displaying the deployment of clusters related to renewable energy resources



Source: Own Work

The diagram shows that blockchain applications in the energy sector extend far beyond the traditional fossil fuels, branching into innovative areas that exploit **renewable resources**. It's clear from the diagram that the renewable energy sector harnesses blockchain for a variety of applications, more so than the oil and gas sector, which implies a significant shift towards cleaner energy use in blockchain development.

Figure 26: The Sankey diagram displaying the deployment of clusters based on attributes

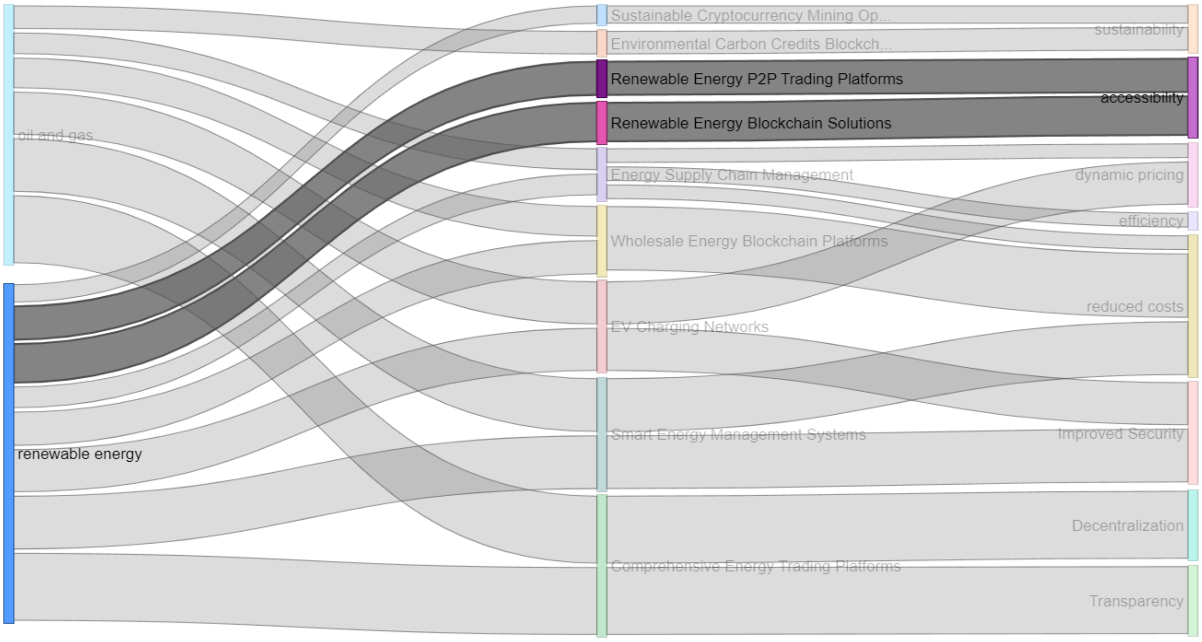


Source: Own Work

Otherwise, the diagram clearly demonstrates that the attributes of **decentralization** and **transparency** are paramount in these blockchain applications, resonating with the sector's current market trends that emphasize efficiency and consumer empowerment. Moreover, we note that attributes such as dynamic pricing in Energy Supply Chain Management and **improved security** in EV Charging Networks are especially prominent. These are pivotal areas where blockchain's impact on **cost reduction** and system resilience becomes evident.

Also, the flow toward **Renewable Energy P2P Trading Platforms and solutions** is notable for its highlighting the sector's move towards democratizing energy distribution and enabling greater consumer accessibility.

Figure 27: The Sankey diagram displaying the deployment of renewable energy clusters



Source: Own Work

Our interpretation of the Sankey diagram leads us to conclude that the energy sector's foray into blockchain is marked by a deliberate pivot towards systems that support dynamic market interactions, prioritize consumer agency, and foster sustainable practices.

In our pursuit to identify and prioritize blockchain-based use cases for an electric utility, it is clear that those which enhance user accessibility, promote energy independence, and contribute to environmental sustainability hold considerable strategic value. These use cases not only align with immediate market imperatives but are also foundational to the utility's long-term technological advancement and sectoral leadership.

So far, the results of the inventory stage, have successfully mapped out a varied landscape of applications. The utilization of blockchain technology is evidently more prevalent and diverse in the renewable energy domain than in oil and gas, showcasing an industry trend towards sustainable and efficient energy solutions, which demonstrates a clear alignment with current market trends favoring decentralization, transparency, and consumer empowerment.

These interpretations reveal a sector that is not only ripe for innovation but also actively pursuing transformative blockchain applications that correspond with a global shift towards cleaner energy and more decentralized, efficient, and consumer-centric energy models.

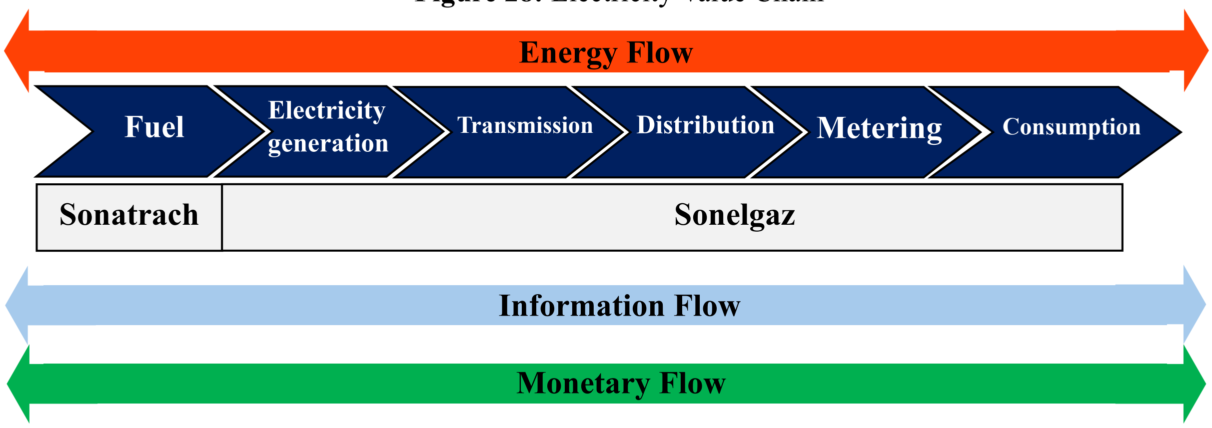
3. Assessment:

As outlined, the evaluation of the use case clusters within this phase of the funnel involves a two-stage assessment process. The first stage assesses the general alignment of the clusters with the electricity value chain. This initial evaluation is critical to identifying and eliminating any use cases that do not correspond to the operational context of an electric utility. In the subsequent stage, the remaining clusters are assessed for their relevance to blockchain applications and their strategic alignment with objectives. This methodical approach ensures that only the most relevant and strategically aligned use cases are considered for further development and implementation.

3.1.The electricity value chain fit

The initial phase of the evaluation focuses on assessing the applicability of blockchain technology clusters within the electricity value chain, specifically adapted to the Algerian energy context as derived from conducted interviews.

Figure 28: Electricity Value Chain

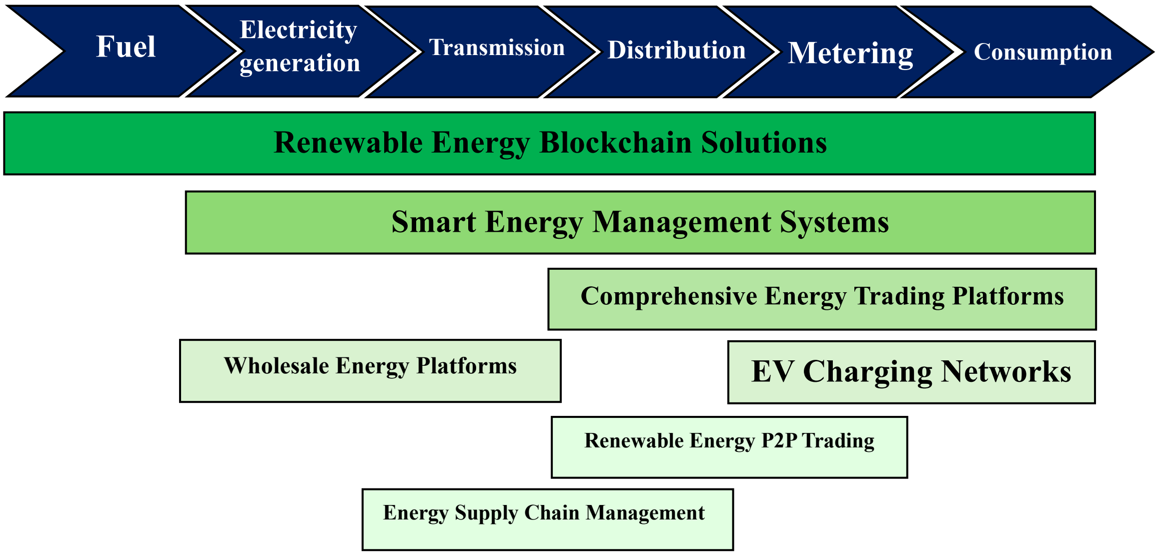


Source: Own Work

The responses from these interviews indicate that the electricity value chain encompasses all essential activities for producing, distributing, and consuming electrical energy. This chain is segmented into six key areas: fuel procurement, electricity generation, transmission, distribution, metering, and consumption.

Moreover, emphasizing the crucial roles of Sonatrach and Sonelgaz, these companies are not only key players in managing the physical flow of energy but also in handling the associated information and financial transactions across the value chain. This highlights their comprehensive control over the sector.

Figure 29: Assessment based on cluster fit in the electricity value



Source: Own Work

The value chain effectively conveys the interconnected nature of modern energy systems, where technology plays a central role in enhancing each stage of the electricity value chain. The focus on the placement of Renewable Energy Blockchain Solutions underscores the growing importance of renewable energies and the need for systems to ensure their efficient integration and management.

Blockchain technology likely aids in certifying the origin and sustainability of these energy sources. Across Transmission to Consumption, Smart Energy Management Systems spanning multiple stages indicate a holistic approach to energy management, capable of optimizing energy use in real-time across the entire grid. The inclusion of Wholesale and Comprehensive Energy Trading Platforms in the transmission stage suggests a focus on enhancing the efficiency and transparency of energy transactions.

This is crucial for maintaining system balance and supporting the financial stability of energy markets. EV Charging Networks and Renewable Energy P2P Trading are pivotal in modernizing energy distribution systems to support the growing number of electric vehicles and to facilitate a more consumer-driven, peer-to-peer energy market. This aligns with trends towards greater consumer empowerment and energy decentralization.

Overall Supply Chain Management: the extensive span of Energy Supply Chain Management across all stages emphasizes a strategic approach to overseeing and refining the entire energy process.

In this thorough examination, two clusters were deemed not to fit into the electricity value chain and were subsequently removed. These clusters are Environmental Carbon Credits Blockchain Platform and Sustainable Cryptocurrency Mining Operations.

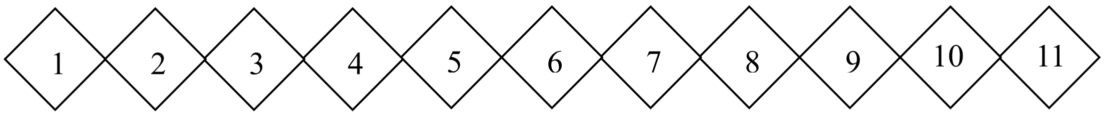
3.2.Blockchain relevance

This section evaluates the suitability of blockchain across seven key use case clusters within the energy sector, each representing unique applications and challenges. The evaluation utilizes a specific model (mentioned in the previous chapter) to assess blockchain's fit against various operational and strategic dimensions.

Each cluster is briefly defined to clarify its role and importance. Insights from industry experts are integrated to provide real-world perspectives on the potential and limitations of blockchain applications.

This structured analysis aims to identify the most effective blockchain applications, guiding strategic decisions on technology adoption in the energy sector.

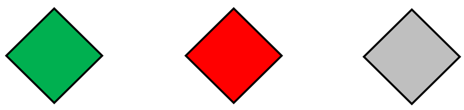
Figure 30: Representation of the used decision tree model, each diamond stands for the respective question



Source: Own Work

This visual serves as a decision-aid tool, each of the 11 diamonds represents a question in the decision-making process regarding the implementation of blockchain technology. The diamond shape is commonly used in flowcharts to denote a decision point *(Schousek, 2018)*, making it an appropriate choice for the visual.

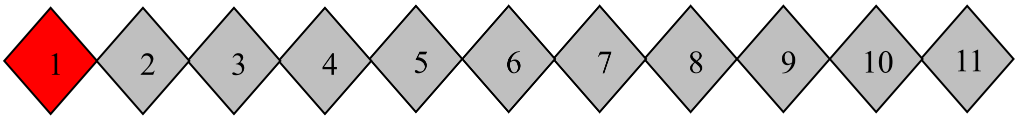
- **Green Diamond**: Represents a "Yes" answer,
- **Red Diamond**: Represents a "No" answer,
- **Grey Diamond**: Indicates that the answer to the question does not influence or is irrelevant to the decision about using blockchain.



3.2.1. Energy Supply Chain Management

This cluster focuses on enhancing the efficiency and reducing the costs of energy procurement and distribution by employing blockchain to create dynamic pricing models and streamline supply chain operations.

Figure 31: Results of applying decision tree model



Source: Own Work

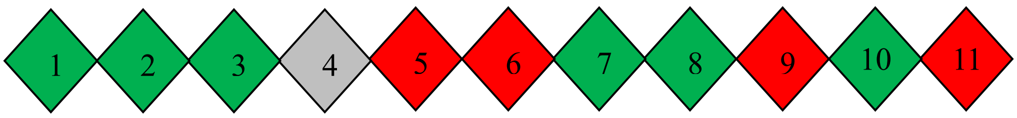
While blockchain offers benefits in terms of security, immutability, and reducing reliance on intermediaries, the specific requirements for high-speed transactions, large data storage, centralized control, and regulatory compliance might be better addressed with alternative technologies. These alternatives can provide the necessary performance, ease of regulatory alignment, and cost-effectiveness without the complexities associated with blockchain implementation.

Experts highlight the modality of Algerian landscape, where the infrastructure and market dynamics involve significant regulatory oversight and rapid transaction needs, using a combination of advanced centralized databases for operational management and blockchain for specific applications like contract management or certain aspects of supply chain tracking could be a more practical approach.

3.2.2. Renewable Energy P2P Trading Platforms:

These platforms facilitate access to renewable energy markets by enabling peer-to-peer trading of solar and other renewable resources, which traditional electricity consumers also act as generators and suppliers, allowing electricity to be traded directly within a network. Which increases market accessibility and reach for a broader range of participants.

Figure 32: Results of applying decision tree model



Source: Own Work

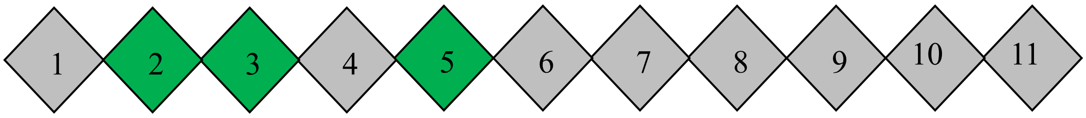
The implementation of blockchain technology in the renewable energy trading sector reveals a strong alignment with the technology's capabilities and the sector's needs. While interviewees predict the possibility to eliminates the need for intermediaries, which is theoretically plausible, the practical elimination of intermediaries in Algeria's renewable energy sector hinges on comprehensive regulatory reforms, substantial infrastructural enhancements, and a shift in market dynamics.

Achieving this would also require overcoming significant resistance from entrenched interests, however these changes align with the political and economic objectives of the Algerian government. Highlighting the support of digital representation of energy assets, and accommodates the need for high-performance, real-time trading something that (Mukherjee & Pradhan, 2021) emphasized its possibility within blockchain 3.0 and 4.0. Additionally, blockchain's ability to manage smart contracts and provide shared write access aligns well with the collaborative nature of the energy trading market. Privat and control over functionalities adaptations further bolster the case for blockchain, making it an ideal solution to meet the operational goals of renewable energy trading.

3.2.3. Smart Energy Management Systems:

Integrating IoT with blockchain, this cluster aims to develop intelligent solutions for energy usage management, enhancing the effectiveness of energy distribution and consumption monitoring.

Figure 33: Results of applying decision tree model



Source: Own Work

In the Algerian energy sector, the application of Smart Energy Management Systems (SEMS) represents a sophisticated approach that leverages blockchain technology not to replace but to augment the functionalities of existing intermediaries. The integration of blockchain enhances data management, transaction processing, and the enforcement of contracts, contributing significantly to operational efficiency and security.

By utilizing blockchain's immutable and transparent properties, SEMS can streamline operations, reduce administrative overhead, and improve compliance and data security across the board. This optimized interaction with established intermediaries, such as utility companies and regulatory bodies, ensures higher transaction accuracy and reliability in energy management.

Importantly, the utilization of digital assets, high-performance computing, and the management of large non-transactional datasets further equip the SEMS to handle real-time data processing and make swift adjustments necessary for maintaining grid stability and optimizing energy usage.

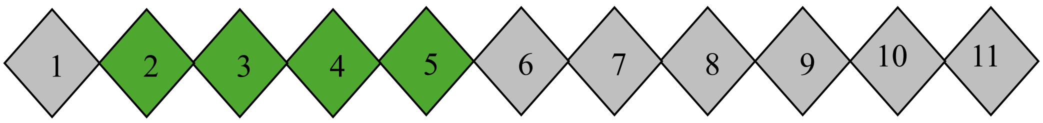
However, the requirement to store large amounts of recording data poses a challenge, as blockchain may not be the most appropriate solution in its current form. This area requires further development to optimize the technology for large-scale data handling while maintaining grid stability and optimizing energy usage.

3.2.4. EV Charging Networks:

Blockchain technology can significantly enhance EV charging and management by streamlining the identification of EV users and simplifying the exchange of charge detail records across charging networks. It can efficiently handle numerous low-value payments, potentially lowering transaction fees and reducing the time required for user authentication.

This efficiency could reduce the operational costs of charging stations, making it feasible for both companies and individuals to manage them. Furthermore, blockchain acts as a secure and transparent ledger for various stakeholders in the EV charging market and enables automated, autonomous payments.

Figure 34: Results of applying decision tree



Source: Own Work

The first question doesn't influence the use of blockchain. The obtained responses lack of how EV charging networks in Algeria are designed to integrate with existing infrastructures and digital technologies, this is due to the difficulty of reaching the top management, and the implementation still in progress.

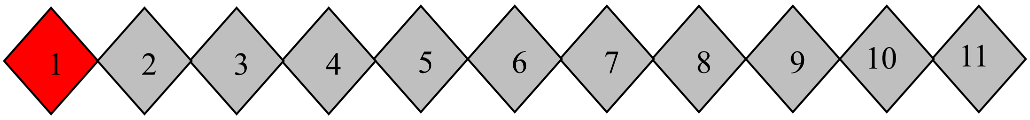
However, results showed that blockchain could be implemented, however High-performance computing and rapid transaction capabilities are vital for real-time energy management and customer service interactions in EV charging networks and storing extensive data related to energy consumption, customer interaction, and operational efficiency is essential for strategic planning and network expansion.

As a result, the decision tree model appears that blockchain **can't** do this efficiently yet, but solutions are in development.

3.2.5. Wholesale Energy Blockchain Platforms:

This cluster utilizes blockchain to improve transaction fluidity and transparency in wholesale energy markets.

Figure 35: Results of applying decision tree model



Source: Own Work

Wholesale energy trading in Algeria involves the transaction of primary energy commodities like electricity and gas. The trading process is traditionally segmented into three stages: pre-trade, trade and post-trade differ from trade execution, confirmations, settlements and payments *(Dick & Praktiknjo, 2019)*.

The current system heavily relies on manual processes for data exchange among participants and external financial transactions facilitated by banks or clearing houses.

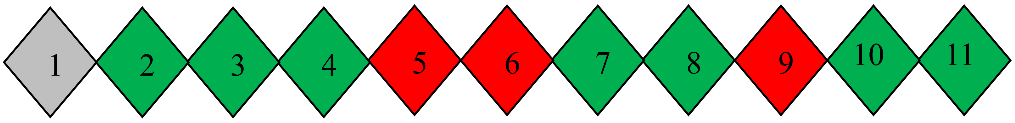
In light of blockchain use cases in such activities ensure transaction without a middleman, there is a strong consensus against eliminating intermediaries in the Algerian market context, intermediaries like banks, clearing houses and government play crucial roles, not just in transaction processing but also in regulatory compliance and market stabilization.

So blockchain is not seen as a fully appropriate solution for the wholesale energy market in Algeria under the current conditions.

3.2.6. Renewable Energy Blockchain Solutions:

This cluster is broader and can include various projects aimed at enhancing the renewable energy sector through blockchain applications designed to integrate renewable energy into the grid effectively such as managing energy flows within microgrids, tracking and enhancing the transparency in renewable energy distribution and usage, promoting sustainability and aligning generation with environmental goals.

Figure 36: Results of applying decision tree model



Source: Own Work

Applying blockchain within the cluster doesn't aim to remove intermediaries instead, they enhance the coordination between existing systems, which leads to ignore the answer of the first question.

So, the first phase indicates the possibility of the implementation of blockchain energy, in the following phase the intervention of expert plays a crucial role which indicates how quickly a blockchain network can process high speed transactions in light of development we are witnessed, a higher TPS means faster confirmation and lower fees for users.

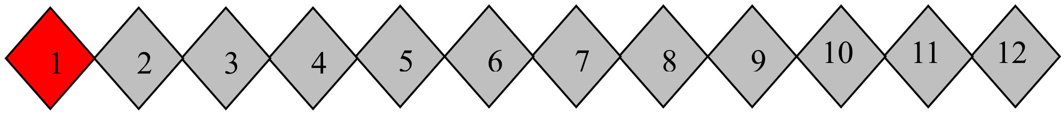
Key factors influencing transaction speed include the consensus mechanism, block size, network congestion, layer 2 solutions, technology upgrades, and the quality of hardware and infrastructure.

Another crucial metric for evaluating a blockchain's performance and relevance is avoid using blockchain to record large volumes of operational data the rest of answer related to the evaluation indicate that this cluster thus presents a compelling case for the application of private or permissioned blockchain networks in the renewable energy sector.

3.2.7. Comprehensive Energy Trading Platforms:

Similar to wholesale energy cluster but more extensive in scope, this cluster includes robust platforms that utilize blockchain for secure and efficient energy trading, embodying the decentralized ethos of blockchain technology.

Figure 37: Results of applying decision tree *model*



Source: Own Work

Decentralized energy trading is the direct trading of energy between prosumers or small-scale producers of energy without the use of a third-party intermediary. While the typical application of blockchain technology is to eliminate intermediaries it is clearly appear that does not align with the current trends of Algeria's energy trading sector. However, blockchain could still play a supportive role, enhancing the infrastructure around the intermediaries, rather than replacing them.

The evaluation given previously is summarized in the following Table:

- Cluster 1: Energy Supply Chain Management
- Cluster 2: Renewable Energy P2P Trading Platforms
- Cluster 3: Smart Energy Management Systems
- Cluster 4: EV Charging Networks
- Cluster 5: Wholesale Energy Blockchain Platforms
- Cluster 6: Renewable Energy Blockchain Solutions
- Cluster 7: Comprehensive Energy Trading Platforms

Table 9: Blockchain Relevance results for the 7 use case clusters.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Eliminate Intermediaries?	Red	Green	Grey	Grey	Red	Grey	Red
Work with Digital Assets?	Grey	Green	Green	Green	Grey	Green	Grey
Need Permanent Data Solution? (Yes/No)	Grey	Green	Green	Green	Grey	Green	Grey
Need High Performance & Fast Transactions?	Grey	Grey	Grey	Green	Grey	Green	Grey
Store Large Non-Transactional Data?	Grey	Red	Green	Green	Grey	Red	Grey
Rely on Trusted Parties?	Grey	Red	Grey	Grey	Grey	Red	Grey
Manage Contracts or Value Exchanges?	Grey	Green	Grey	Grey	Grey	Green	Grey
Need Shared Write Access?	Grey	Green	Grey	Grey	Grey	Green	Grey
Contributors Know & Trust Each Other?	Grey	Red	Grey	Grey	Grey	Red	Grey
Need Control Over Tech Solutions?	Grey	Green	Grey	Grey	Grey	Green	Grey
Transactions Public?	Grey	Red	Grey	Grey	Grey	Green	Grey

Source: Own Work

The visualization demonstrates a systematic approach to evaluating the suitability of blockchain technology across different use case clusters. The pattern of responses in the decision-making process indicates that clusters related to Renewable Energy P2P Trading, and Renewable Energy Blockchain Solutions are strong case for the implementation of blockchain, which generally exhibit positive alignment with the operational requirements necessary for the implementations.

3.3. Strategic alignment

The visualization demonstrates a systematic approach to evaluating the suitability of blockchain technology across different use case clusters. The pattern of responses in the decision-making process indicates that clusters related to Renewable Energy P2P Trading, and Renewable Energy Blockchain Solutions are strong case for the implementation of blockchain, which generally exhibit positive alignment with the operational requirements necessary for the implementations.

As we continue our assessment, by looking to the strategic landscape outlined in key documentation from prominent players in Algeria's energy sector. Through an in-depth review of internal documents from both Sonatrach and Sonelgaz, as well as publications from the Algerian government, we have identified the following strategic axes and objectives as follow:

Strategic Axis 1: Expansion of Renewable Energy Capacity

- Achieve a renewable energy output of 27% of total electricity production by 2035, with a major focus on solar and wind energy.
- Implement the one-gigawatt solar project and further develop wind energy sites along the 1,300-kilometer Mediterranean coastline and in the Sahel region.
- Enhance and optimize existing hydroelectric and biomass energy production facilities.

Strategic Axis 2: Technological Advancement and Innovation

- Foster the development and deployment of cutting-edge technologies in photovoltaic modules, solar tracking, and wind turbines.
- Integrate advanced energy storage solutions to stabilize and increase the efficiency of the energy grid.
- Promote the application of smart grid technologies to improve grid management and resilience.

Strategic Axis 3: Strengthening International Partnerships and Investment

- Establish strategic partnerships with leading global entities in the renewable energy sector to leverage their expertise and technology.
- Attract foreign direct investment by offering competitive incentives such as long-term PPAs and favorable terms in reverse tender processes for renewable projects.

- Enhance collaboration with international certification bodies to ensure compliance and quality standards in renewable technologies.

Strategic Axis 4: Regulatory and Policy Support

- Update and streamline regulatory frameworks to facilitate the rapid deployment of renewable energy projects.
- Continue to develop policies that incentivize both local and international investments in renewable energy.

Strategic Axis 5: Sustainability and Environmental Integration

- Implement projects in a manner that minimizes environmental impact, particularly in ecologically sensitive areas.
- Develop and promote the use of off-grid renewable energy solutions for rural electrification to reduce disparities in energy access.
- Commit to international environmental standards and practices to reduce carbon emissions and promote sustainability.

As we mentioned in the previous chapter this evaluation utilizes a nuanced three-level scale designed to reflect the depth and nature of alignment:

- 🔴 No alignment: Score 1
- 🟡 Partial alignment: Score 1
- 🟢 full alignment: Score

Table 10: Strategic Alignment evaluation of Blockchain Use Case Clusters

Strategic goals	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Expansion of Renewable Energy Capacity	🔴	🟢	🔴	🔴	🔴	🟢	🔴
Technological Advancement and Innovation	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Strengthening International Partnerships and Investment	🟡	🔴	🔴	🔴	🟢	🔴	🟡
Regulatory and Policy Support	🔴	🟡	🔴	🔴	🟡	🟡	🔴
Sustainability and Environmental Integration	🔴	🟢	🔴	🔴	🔴	🟢	🔴
Totale	3	7	3	3	5	7	3

Source: Own Work

The visualization clearly delineates the alignment of blockchain use case clusters with specific strategic goals in the energy sector. It is evident that Clusters 2 and 6 show the highest total scores, indicating robust alignment with the strategic goals outlined. These clusters, focusing on to Renewable Energy P2P Trading, and Renewable Energy Blockchain Solutions respectively, align well across most strategic goals, including Expansion of Renewable Energy Capacity, Technological Advancement, and Sustainability.

In summary of the assessment stage, two use case clusters demonstrate both high strategic relevance and strong alignment with blockchain capabilities. These clusters are "Renewable Energy P2P Trading Platforms" and "Renewable Energy Blockchain Solutions." Each of these clusters not only aligns with key strategic objectives like the expansion of renewable energy capacity and enhancement of technological innovation but also leverages blockchain's strengths in ensuring transparency, efficiency, and decentralization.

The remaining use case clusters, while valuable, do not exhibit the same level of comprehensive alignment and are therefore not prioritized for further detailed analysis at this stage. The focus will now shift to a deeper evaluation of the "Renewable Energy P2P Trading Platforms" and "Renewable Energy Blockchain Solutions" clusters, examining their readiness for implementation.

4. Prioritization

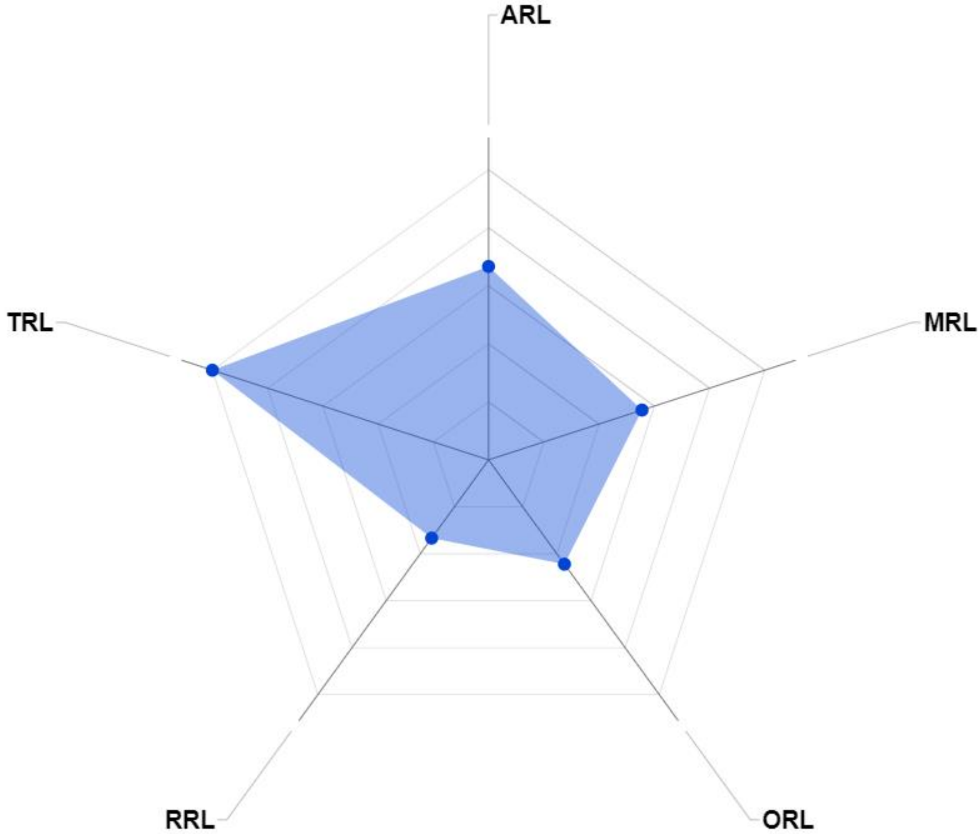
In this section, we conduct a detailed analysis of the two selected blockchain use case clusters within the energy sector, employing the Balanced Readiness Level assessment (BRLa) framework as outlined in Chapter 2 of the study.

The BRLa model incorporates multiple dimensions—Technological Readiness Level (TRL), Market Readiness Level (MRL), Regulatory Readiness Level (RRL), Acceptance Readiness Level (ARL), and Organizational Readiness Level (ORL)—to evaluate each use case.

The tables of the questionnaires used to assess the maturity level are provided in Appendix C , with each answer indicating the level of maturity related to each dimension.

- **Renewable Energy P2P Trading**

Figure 38: Maturity Assessment of Renewable Energy P2P Trading.



Source: Own Work

The **Technological Readiness Level (TRL)** is notably high, evidenced by several blockchain applications moving into late-stage development and commercial deployment. For example, Powerledger's xGrid platform demonstrates that blockchain technology has been effectively developed and validated in real-world settings, being fully operational and servicing over 30 clients across 10 countries. This broad-scale validation, including platforms like Verv's, which facilitates energy trading among neighbors with solar panels, showcases the robust development and practical utility of the technology. These implementations not only enhance the efficiency of renewable energy distribution but also confirm the technology's readiness for larger markets.

Market Readiness Level (MRL) reflects substantial interest and engagement from both consumers and providers, driven by the visible benefits and potential of blockchain to revolutionize energy trading. The ongoing pilot projects globally and early commercial activities indicate a vibrant but still maturing market. However, despite the promising deployment of business models like those discussed by *(Parag & Sovacool, 2016)*, the lack of widespread commercial penetration and coherent business models suggests that while the market is prepared for expanded blockchain integration, further development and strategic marketing efforts are necessary and broader evidence about customer satisfaction will be needed as more extensive implementations occur to achieve full market readiness.

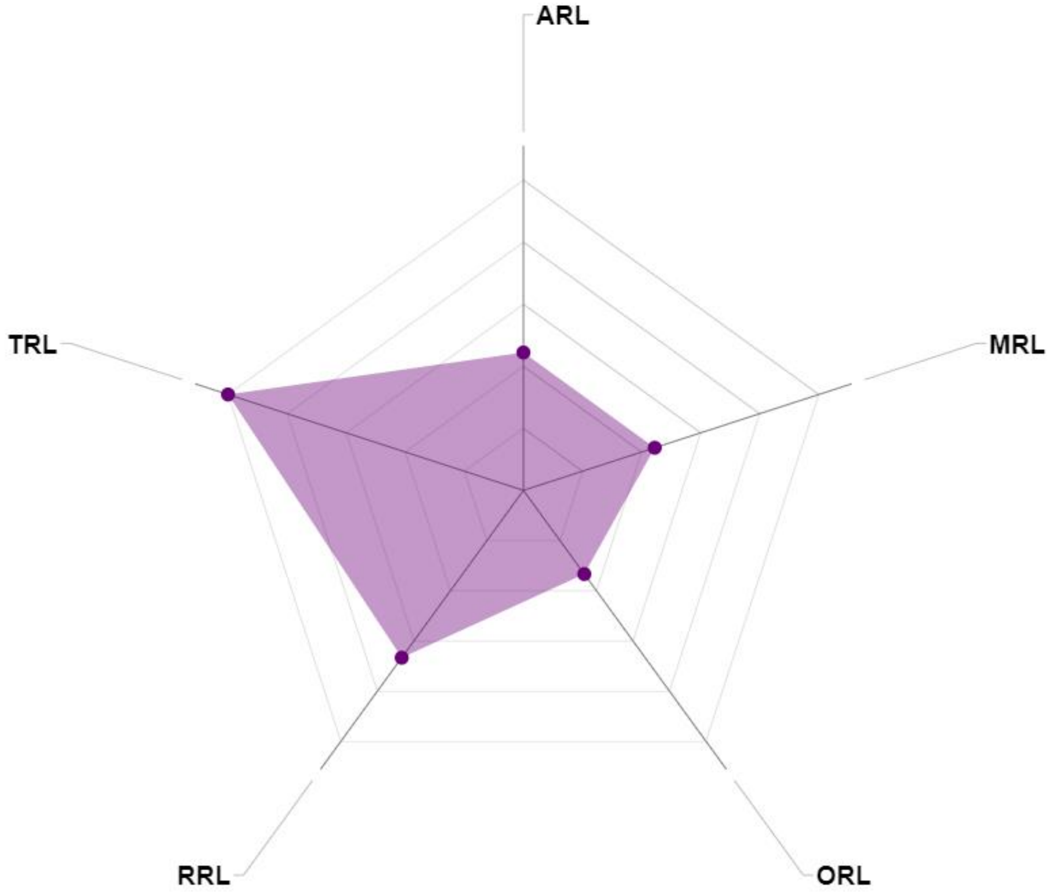
Regulatory Readiness Level (RRL), remains low. The complex regulatory environment, with significant barriers highlighted by key industry figures like directors at LO3 Energy, underscores the challenges. The existing regulations are often inadequate to address the nuances of decentralized energy systems facilitated by blockchain, leading to uncertainties that could stymie broader adoption. The need for a coherent policy mix and substantial legal adaptations to support decentralized technologies is critical for advancing regulatory readiness.

Acceptance Readiness Level (ARL) is moderately high, supported by positive responses from communities involved in pilot projects, such as those utilizing residential PV systems. The growing interest in sustainable and decentralized energy solutions indicates that societal acceptance is on the rise, which should propel further technology adoption.

Organizational Readiness Level (ORL) appears to be in a developmental phase, rated around Level 3 to 4. Although there are clear plans and some initial implementations of blockchain within organizational structures, significant work remains. The integration of such a transformative technology requires not only technical adjustments but also major shifts in operational processes and organizational culture *(Brilliantova & Thurner, 2019)*. As companies continue to navigate these changes, the organizational readiness will need to evolve to fully leverage the benefits of blockchain in energy trading.

- **Renewable Energy Blockchain Solutions**

Figure 39: Maturity Assessment of Renewable Energy blockchain solutions .



Source: Own Work

The **Technological Readiness Level (TRL)** is high, reflecting significant advancements in blockchain applications. Notable implementations, such as Nasdaq's pilot for trading green certificates and Vision's integration with smart meters, underscore that the technology is not only undergoing rigorous testing but is also seeing early adoption in operational settings. This progression suggests a higher level of technological readiness, moving closer to commercial maturity.

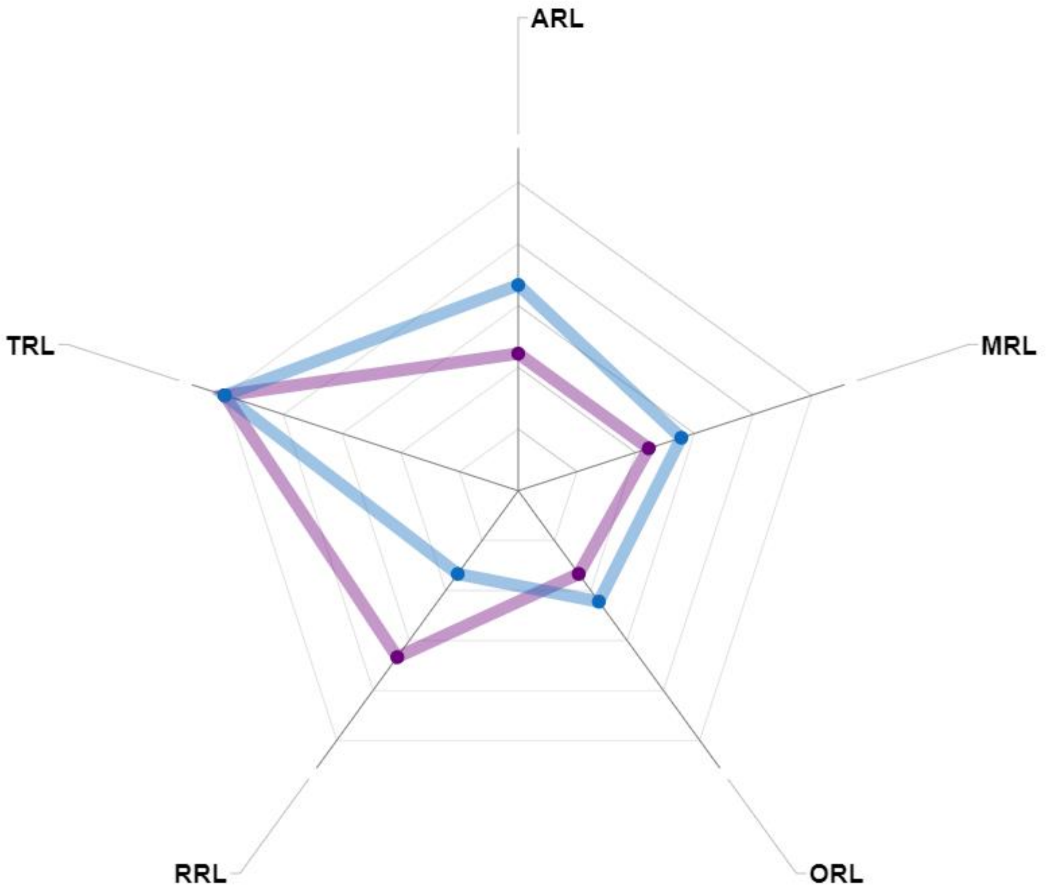
Similarly, the **Market Readiness Level (MRL)** mirrors the TRL with its moderate status, indicative of a market that is both receptive and gradually adopting blockchain innovations. Initiatives like Sun Exchange, which uses blockchain for solar asset trading, and Vision's

customizable energy products, are emerging examples of market adoption. Although these projects are in early stages, they are starting to attract attention, demonstrating potential business models and initial market interest that promise expansion yet hint at the need for broader market penetration.
conversely, the **Regulatory Readiness Level (RRL)** lags behind, marking a significant challenge particularly in a sector as regulated as energy. While there are instances of regulatory accommodation—as seen with Nasdaq's successful pilot—the overall regulatory landscape remains a complex field with substantial barriers that must be navigated to realize the full potential of blockchain technologies in this domain.

The **Acceptance Readiness Level (ARL)**, nearly as high as the TRL and MRL, indicates strong societal and consumer acceptance. Projects that promote tangible benefits, such as enhanced transparency in energy tracking and direct benefits to users through initiatives like those of Sun Exchange, foster public trust and acceptance, thus supporting the broader integration of these technologies into society.

However, the **Organizational Readiness Level (ORL)** is relatively lower, suggesting that while there is some movement towards adapting organizational structures to accommodate new technologies, significant changes are still required. The integration of blockchain into existing business models, as seen with ekWateur and Vision, indicates active efforts but also highlights the extensive organizational adaptations that are necessary to fully harness the capabilities of blockchain.

Figure 40: Maturity Assessment of the use cases clusters



Source: Own Work

Renewable Energy P2P Trading cluster emerges with notable strengths, particularly in Organizational Readiness Level (ORL), where it leads significantly, indicating superior internal preparation and adaptation to integrate and leverage blockchain technology effectively. Although the Technological Readiness Level (TRL) and Acceptance Readiness Level (ARL) are robust across all assessments, the cluster shows competitive technological development and exceptionally high societal acceptance, which are critical for successful implementation. While it does face challenges with lower Regulatory Readiness Level (RRL) and not the highest Market Readiness Level (MRL), the overall strong organizational foundation and societal support make Renewable Energy P2P Trading cluster a compelling use case. This suggests that while regulatory and market strategies may require further enhancement, the strong internal capabilities and public favorability position the cluster favorably for overcoming these barriers and leading successful blockchain integration in renewable energy.

Section 2: Discussion

This section aims to synthesize and interpret the key findings from our research, contextualizing them within the broader landscape of blockchain technology and the energy sector. It will provide a detailed analysis of how these findings address our main research question and sub-questions, discuss the implications of our results, compare them with existing literature, and acknowledge the limitations encountered during the research process.

In our study, we identified over 130 blockchain use cases within the energy sector, which were subsequently clustered into nine distinct groups. These findings highlight the extensive range of blockchain applications, from enhancing energy trading platforms to managing renewable energy resources more efficiently. The clustering of use cases underscores the high expectations for blockchain technology in the energy sector and the active experimentation by both start-ups and established companies. This broad spectrum of activity indicates that stakeholders across the electricity value chain are keen to explore what blockchain can offer.

Our evaluation process involved assessing the relevance of blockchain technology to the identified use cases and evaluating their strategic alignment with the objectives of key stakeholders in the Algerian energy sector. This approach ensured that the selected use cases were not only operationally feasible but also strategically beneficial.

The expert interviews conducted validated our findings and provided qualitative insights that helped refine our understanding of the practical challenges and opportunities associated with implementing blockchain technology in Algeria. These interviews highlighted several critical factors, including the regulatory frameworks and organizational adaptability needed for the successful adoption of blockchain technology. The feedback emphasized that while blockchain has significant potential, its implementation must be carefully aligned with both operational needs and strategic objectives.

Blockchain should not just be applied as a solution to any problem but carefully considered as one possible technology among many others. decisions should be based on evaluations that address several factors. Due to the findings of the study which have provided significant implications for the Algerian energy sector, Renewable Energy P2P Trading cluster was identified as the most suitable area to initiate blockchain implementation. The use case evaluation framework developed for this study addresses these parameters and can serve as a foundation for future decision-making.

Our study's findings align with global trends observed in previous studies, such as those identified by The World Economic Forum which emphasized the critical technological trends of decentralization, electrification, and digitalization (The World Economic Forum, 2017). The market development towards increased decentralization, electrification, and digitalization is occurring in parallel with blockchain development, and it is affecting the scope of use cases. Renewable energy and distributed energy resources form the core of the majority of the use cases, creating opportunities for new business models to emerge, where Consumers will play a more active role as owners of distributed energy resources, energy suppliers, and traders, as well as providers of flexible capacity, as blockchain can lower the barriers to entry in these markets. This shift in customer preferences and overall macro development should be an essential aspect to consider when prioritizing use cases. However, our maturity assessment revealed that the regulation of businesses using blockchain technology in the energy sector is underdeveloped, particularly for use cases targeting customer solutions.

Another observation with previous studies, the energy landscapes of Algeria and China share several similarities impacting blockchain technology implementation, particularly in Renewable Energy P2P Trading. Both countries have heavily regulated energy markets, the monopolistic structure and stringent regulations have hindered blockchain adoption.

In China, efforts to reform the electricity system are underway to accommodate new business models enabled by blockchain (Zhu et al., 2020). Algeria should show similar interest for market reforms to support decentralized energy trading and enhance the integration of renewable energy sources. So, requiring substantial policy reforms to accommodate innovative technologies. The centralized nature of both energy markets necessitates a shift towards more flexible and decentralized systems to fully leverage blockchain benefits.

While both countries are investing in renewable energy and digital technologies, the maturity of blockchain solutions varies. In China, there has been significant progress in pilot projects and research collaborations, which has helped overcome some technological barriers (Zhu et al., 2020). In Algeria, the technology is still in its nascent stages, and there is a greater need for hands-on experience and pilot projects to build technical expertise and demonstrate feasibility. The implementation of Renewable Energy P2P Trading in Algeria can drive significant advancements in the energy sector by promoting sustainable practices, enhancing energy access, and reducing operational costs. The comparison with China underscores the importance of regulatory support and market reforms for successful blockchain technology adoption.

Our research contributes to the growing body of knowledge on blockchain technology, particularly its application in the energy sector. By identifying over 130 blockchain use cases and clustering them into nine distinct groups, we provide a comprehensive overview of how blockchain can be leveraged to enhance energy sector operations. This detailed analysis aids both academic researchers and industry professionals in understanding the potential and limitations of blockchain applications in a critical sector. Also, the study aligns its findings with Algeria's strategic energy goals outlined in the 2030 Vision, emphasizing the need for innovative solutions that support long-term national energy plans. By focusing on use cases like Renewable Energy P2P Trading, which was identified as the most suitable area for blockchain implementation, the study provides actionable insights that can help Algeria achieve its renewable energy targets and improve energy efficiency.

Our study provides valuable insights into the potential of blockchain in the Algerian energy sector but faces several limitations. The nascent stage of blockchain technology in Algeria and the accompanying regulatory and policy challenges hinder its adoption. Data collection proved difficult due to the limited availability of documented use cases and technical information. Engaging experts from both blockchain technology and the energy sector was challenging, as many were unavailable or unwilling to participate, which impacted the depth of insights gathered. The semi-structured interviews, while providing qualitative insights, were constrained by the interviewees' limited understanding of blockchain, leading to less detailed responses and scheduling difficulties. Additionally, the scarcity of local expertise in blockchain technology posed a significant constraint, making it harder to address the specific context and challenges of the Algerian market. The study also relied heavily on theoretical models and global case studies due to the lack of operational blockchain projects in Algeria, which may limit the applicability of the findings to the local context. These limitations underscore the need for continued research and the development of localized expertise and data to better implement blockchain technology in the Algerian energy sector.

To address these limitations, future research should aim to expand the pool of expert interviewees, perhaps by leveraging broader networks or collaborating with international organizations. Additionally, further studies could focus on longitudinal case studies to assess the practical implementation of blockchain solutions over time. Enhanced efforts to build local expertise and document emerging use cases within Algeria would also contribute to a more robust and context-specific understanding of blockchain's potential in the energy sector.

Conclusion

The rapid transformation of the global energy sector, driven by the imperative to reduce carbon emissions and improve energy efficiency, necessitates the adoption of advanced technologies. Blockchain technology, with its decentralized, transparent, and secure attributes, presents a promising solution to revolutionize energy management and transactions.

Presently, Algeria's energy market is dominated by large enterprises like Sonatrach and Sonelgaz, which presents both opportunities and challenges for the implementation of blockchain technology. The decreasing costs of renewable energy sources such as solar and wind provide significant opportunities for blockchain applications. However, the adoption of blockchain technology in Algeria's energy sector is still in its nascent stages, facing both technical and policy challenges.

This study sought to answer the key research question: "What are the key blockchain use cases that Algerian energy utilities should focus on to align with the country's 2030 Vision and enhance their technological capabilities?"

In addressing this question, the study conducted a thorough review of global blockchain applications in the energy sector, assessing their maturity and relevance to Algeria's strategic energy goals. The study identified that blockchain use cases, particularly Renewable Energy P2P Trading Platforms align well with Algeria's strategic energy goals. These applications can significantly contribute in achieving the targets outlined in Vision 2030, promoting sustainability, energy efficiency, and the development of a circular economy.

Despite the potential benefits, the adoption of blockchain technology in Algeria's energy sector is still in its early stages and faces several challenges. The technology is maturing, but significant regulatory and policy barriers remain. The existing regulatory framework is not fully adaptable to the new business models enabled by blockchain, and the energy market is heavily dominated by large state-owned enterprises like Sonelgaz, which can hinder the rapid implementation of innovative technologies.

To overcome these challenges and foster the adoption of blockchain technology, several policy recommendations have been proposed. First, it is crucial to support research and development initiatives focused on blockchain technology, particularly in areas such as encryption technologies, distributed algorithms, and risk assessment. Establishing relevant research platforms involving enterprises, universities, and research institutes can drive innovation and address specific problems in the Algerian context.

Second, promoting household distributed power generation can accelerate the application of blockchain technology. Smart meters connected to blockchain can facilitate the recording and trading of energy, encouraging active participation from consumers in clean energy production and carbon emission reduction. This approach aligns with the global trend of increasing consumer empowerment and decentralization in the energy sector.

Third, regulatory reforms are essential to create a conducive environment for blockchain innovations. The existing regulations need to be updated to accommodate the new business models enabled by blockchain. Simplifying the approval processes for energy projects and amending outdated laws can help to remove barriers to entry for energy blockchain companies. Additionally, regulators should consider using blockchain technology itself to promote smart supervision and enhance the efficiency of regulatory processes.

In summary, this research underscores the significant potential of blockchain technology to transform Algeria's energy sector. By addressing the current challenges and leveraging the opportunities presented by renewable energy, Algeria can enhance its energy efficiency, promote sustainability, and achieve its Vision 2030 goals. Future studies should focus on longitudinal analyses to monitor the implementation and impact of blockchain projects, ensuring that the technology’s adoption aligns with Algeria’s strategic energy objectives. The strategic implementation of blockchain can drive the country's transition towards a more resilient and innovative energy ecosystem.

Bibliography

Adeyemi, A., Yan, M., Shahidehpour, M., Botero, C., Guerra, A. V., Gurung, N., Zhang, L. (Calvin), & Paaso, A. (2020). Blockchain technology applications in power distribution systems. *The Electricity Journal*, *33*(8), 106817. https://doi.org/10.1016/j.tej.2020.106817

Aggarwal, S., & Kumar, N. (2021). Cryptographic consensus mechanisms. In *Advances in Computers* (Vol. 121, pp. 211–226). Elsevier. https://doi.org/10.1016/bs.adcom.2020.08.011

Agung, A. A. G., & Handayani, R. (2022). Blockchain for smart grid. *Journal of King Saud University - Computer and Information Sciences*, *34*(3), 666–675. https://doi.org/10.1016/j.jksuci.2020.01.002

Alam, M. A., & Jain, S. (2020). Blockchain Implementation Using Smart Grid-Based Smart City. In *Handbook of Research on Blockchain Technology* (pp. 133–169). Elsevier. https://doi.org/10.1016/B978-0-12-819816-2.00006-X

Alladi, T., Chamola, V., Rodrigues, J. J. P. C., & Kozlov, S. A. (2019). Blockchain in Smart Grids: A Review on Different Use Cases. *Sensors*, *19*(22), 4862. https://doi.org/10.3390/s19224862

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. https://doi.org/10.1016/j.rser.2018.10.014

Baashar, Y., Alkawsi, G., Alkahtani, A. A., Hashim, W., Razali, R. A., & Tiong, S. K. (2021). Toward Blockchain Technology in the Energy Environment. *Sustainability*, *13*(16), 9008. https://doi.org/10.3390/su13169008

Bao, J., He, D., Luo, M., & Choo, K.-K. R. (2021). A Survey of Blockchain Applications in the Energy Sector. *IEEE Systems Journal*, *15*(3), 3370–3381. https://doi.org/10.1109/JSYST.2020.2998791

Bouznit, M., Pablo-Romero, M. D. P., & Sánchez-Braza, A. (2020). Measures to Promote Renewable Energy for Electricity Generation in Algeria. *Sustainability*, *12*(4), 1468. https://doi.org/10.3390/su12041468

Brilliantova, V., & Thurner, T. W. (2019). Blockchain and the future of energy. *Technology in Society*, *57*, 38–45. https://doi.org/10.1016/j.techsoc.2018.11.001

Buterin, V. (2014). *Ethereum Whitepaper*.

Chan, H.-L., Choi, T.-M., & Mendez De La Torre, D. (2023). The "SMARTER" framework and real application cases of blockchain. *Technological Forecasting and Social Change*, *196*, 122798. https://doi.org/10.1016/j.techfore.2023.122798

Chen, S., Bai, Y., Zhang, Y., Liu, X., Zhang, J., Gao, T., Fang, Z., & Dai, Y. (2019). A Framework of Decentralized Electricity Market Based on The Collaborative Mechanism of Blockchain and Edge Computing. *2019 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI)*, 219–223. https://doi.org/10.1109/SOLI48380.2019.8955023

Chitchyan, R., & Murkin, J. (2018). *Review of Blockchain Technology and its Expectations: Case of the Energy Sector* (Issue arXiv:1803.03567). arXiv. http://arxiv.org/abs/1803.03567

Choi, T.-M., & Siqin, T. (2022). Blockchain in logistics and production from Blockchain 1.0 to Blockchain 5.0: An intra-inter-organizational framework. *Transportation Research Part E: Logistics and Transportation Review*, *160*, 102653. https://doi.org/10.1016/j.tre.2022.102653

CoinGeek. (2017). *Energy Firms Complete Successful BTL Group Blockchain Trial*. https://coingeek.com/energy-firms-complete-successful-btl-group-blockchain-trial/

Daniel, S. S., Bowe, E. T., Lallemand, R., Yeh, M. N., & James, L. S. (1975). Renal response to acid loading in the developing lamb fetus, intact in utero. *Journal of Perinatal Medicine*, *3*(1), 34–43. https://doi.org/10.1515/jpme.1975.3.1.34

Di Silvestre, M. L., Gallo, P., Guerrero, J. M., Musca, R., Riva Sanseverino, E., Sciumè, G., Vásquez, J. C., & Zizzo, G. (2020). Blockchain for power systems: Current trends and future applications. *Renewable and Sustainable Energy Reviews*, *119*, 109585. https://doi.org/10.1016/j.rser.2019.109585

Dick, C., & Praktiknjo, A. (2019). Blockchain Technology and Electricity Wholesale Markets: Expert Insights on Potentials and Challenges for OTC Trading in Europe. *Energies*, *12*(5), 832. https://doi.org/10.3390/en12050832

Dong, Z., Luo, F., & Liang, G. (2018). Blockchain: A secure, decentralized, trusted cyber infrastructure solution for future energy systems. *Journal of Modern Power Systems and Clean Energy*, *6*(5), 958–967. https://doi.org/10.1007/s40565-018-0418-0

Duchenne, J. (2018). Blockchain and Smart Contracts. In *Transforming Climate Finance and Green Investment with Blockchains* (pp. 303–317). Elsevier. https://doi.org/10.1016/B978-0-12-814447-3.00022-7

El-Badawy, S. (2022). *The Importance of Inductive Reasoning in Science: A Critical Analysis*. https://doi.org/10.13140/RG.2.2.18728.14087

Essaaidi, M. (Ed.). (2014). *2014 International Renewable and Sustainable Energy Conference (IRSEC 2014): Quarzazate, Morocco, 17 - 19 October 2014*. IEEE.

Ezugwu, A. E., Ikotun, A. M., Oyelade, O. O., Abualigah, L., Agushaka, J. O., Eke, C. I., & Akinyelu, A. A. (2022). A comprehensive survey of clustering algorithms: State-of-the-art machine learning applications, taxonomy, challenges, and future research prospects. *Engineering Applications of Artificial Intelligence*, *110*, 104743. https://doi.org/10.1016/j.engappai.2022.104743

Fu, Z., Dong, P., & Ju, Y. (2020). An intelligent electric vehicle charging system for new energy companies based on consortium blockchain. *Journal of Cleaner Production*, *261*, 121219. https://doi.org/10.1016/j.jclepro.2020.121219

Ghiro, L., Restuccia, F., D'Oro, S., Basagni, S., Melodia, T., Maccari, L., & Cigno, R. L. (2021). A Blockchain Definition to Clarify its Role for the Internet of Things. *2021 19th Mediterranean Communication and Computer Networking Conference (MedComNet)*, 1–8. https://doi.org/10.1109/MedComNet52149.2021.9501280

Goldkuhl, G. (2012). Pragmatism *vs* interpretivism in qualitative information systems research. *European Journal of Information Systems*, *21*(2), 135–146. https://doi.org/10.1057/ejis.2011.54

Gupta, manav. (2017). *Blockchain for dummies*. IBM. https://gunkelweb.com/coms465/texts/ibm_blockchain.pdf

Han, D., Zhang, C., Ping, J., & Yan, Z. (2020). Smart contract architecture for decentralized energy trading and management based on blockchains. *Energy*, *199*, 117417. https://doi.org/10.1016/j.energy.2020.117417

Hunhevicz, J. J., & Hall, D. M. (2020). Do you need a blockchain in construction? Use case categories and decision framework for DLT design options. *Advanced Engineering Informatics*, *45*, 101094. https://doi.org/10.1016/j.aei.2020.101094

Hussain, S. M. S., Nadeem, F., Aftab, M. A., Ali, I., & Ustun, T. S. (2019). The Emerging Energy Internet: Architecture, Benefits, Challenges, and Future Prospects. *Electronics*, *8*(9), 1037. https://doi.org/10.3390/electronics8091037

Jansen, H. (2010). The Logic of Qualitative Survey Research and its Position in the Field of Social Research Methods. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *Vol 11*, No 2 (2010): Visualising Migration and Social Division: Insights From Social Sciences and the Visual Arts. https://doi.org/10.17169/FQS-11.2.1450

Joshi, K., Trivedi, G., & Maru, P. (2020). Research-ready, Technology-set, Deployment-go: The role of blockchain in peer-to-peer energy trading. *2020 IEEE Bombay Section Signature Conference (IBSSC)*, 140–145. https://doi.org/10.1109/IBSSC51096.2020.9332220

Kameshwaran, A., Sam, D., Rashika, R. S., Kanya, N., Narayanan, P. L., & Hariharan, R. (2023). Introduction—Blockchain and smart grid. In *Blockchain-Based Systems for the Modern Energy Grid* (pp. 1–17). Elsevier. https://doi.org/10.1016/B978-0-323-91850-3.00001-9

Khan, M. A., & Salah, K. (2018). IoT security: Review, blockchain solutions, and open challenges. *Future Generation Computer Systems*, *82*, 395–411. https://doi.org/10.1016/j.future.2017.11.022

Kirchhoff, H., & Strunz, K. (2019). Key drivers for successful development of peer-to-peer microgrids for swarm electrification. *Applied Energy*, *244*, 46–62. https://doi.org/10.1016/j.apenergy.2019.03.016

Knirsch, F., Unterweger, A., & Engel, D. (2019). Implementing a blockchain from scratch: Why, how, and what we learned. *EURASIP Journal on Information Security*, *2019*(1), 2. https://doi.org/10.1186/s13635-019-0085-3

Korobova, L. A., Gladkikh, T. V., Savvina, E. A., Kovaleva, E. N., Lukina, O. O., & Tolstova, I. S. (2020). Application of Cluster Analysis for Business Processes in the Implementation of Integrated Economic and Management Systems. *Proceedings of the Russian Conference on Digital Economy and Knowledge Management (RuDEcK 2020)*. Russian Conference on Digital Economy and Knowledge Management (RuDEcK 2020). https://doi.org/10.2991/aebmr.k.200730.059

Krishnamoorthi, S., Rajasekar, V., & Balusamy, B. (2023). Blockchain for energy transactions. In *Blockchain-Based Systems for the Modern Energy Grid* (pp. 51–69). Elsevier. https://doi.org/10.1016/B978-0-323-91850-3.00013-5

Künneke, R., & Fens, T. (2007). Ownership unbundling in electricity distribution: The case of The Netherlands. *Energy Policy*, *35*(3), 1920–1930. https://doi.org/10.1016/j.enpol.2006.05.008

Lance, V. (1976). Studies on the annual reproductive cycle of the female cobra, Naja naja. Seasonal variation in plasma inorganic ions. *Comparative Biochemistry and Physiology. A, Comparative Physiology*, *53*(3), 285–289. https://doi.org/10.1016/s0300-9629(76)80037-0

Li, Y., Yang, W., He, P., Chen, C., & Wang, X. (2019). Design and management of a distributed hybrid energy system through smart contract and blockchain. *Applied Energy*, *248*, 390–405. https://doi.org/10.1016/j.apenergy.2019.04.132

Liang, G., Weller, S. R., Luo, F., Zhao, J., & Dong, Z. Y. (2019). Distributed Blockchain-Based Data Protection Framework for Modern Power Systems Against Cyber Attacks. *IEEE Transactions on Smart Grid*, *10*(3), 3162–3173. https://doi.org/10.1109/TSG.2018.2819663

López-Sorribes, S., Rius-Torrentó, J., & Solsona-Tehàs, F. (2023). A Bibliometric Review of the Evolution of Blockchain Technologies. *Sensors*, *23*(6), 3167. https://doi.org/10.3390/s23063167

Loukil, R. (2016). *Bouygues Immobilier mise sur la Blockchain pour tracer les échanges d'énergie solaire*. https://www.usine-digitale.fr/article/bouygues-immobilier-mise-sur-la-blockchain-pour-tracer-les-echanges-d-energie-solaire.N449427

Ma, C.-Q., Lei, Y.-T., Ren, Y.-S., Chen, X.-Q., Wang, Y.-R., & Narayan, S. (2024). Systematic analysis of the blockchain in the energy sector: Trends, issues, and future directions. *Telecommunications Policy*, *48*(2), 102677. https://doi.org/10.1016/j.telpol.2023.102677

Martin, Starace, & Tricoire. (2017, March). *The Future of Electricity New Technologies Transforming the Grid Edge*. World Economic Forum. https://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf

Mengelkamp, E., Gärttner, J., Rock, K., Kessler, S., Orsini, L., & Weinhardt, C. (2018). Designing microgrid energy markets. *Applied Energy*, *210*, 870–880. https://doi.org/10.1016/j.apenergy.2017.06.054

Mengelkamp, E., Notheisen, B., Beer, C., Dauer, D., & Weinhardt, C. (2018). A blockchain-based smart grid: Towards sustainable local energy markets. *Computer Science - Research and Development*, *33*(1), 207–214. https://doi.org/10.1007/s00450-017-0360-9

Mentsiev, A. U., Guzueva, E. R., Yunaeva, S. M., Engel, M. V., & Abubakarov, M. V. (2019). Blockchain as a technology for the transition to a new digital economy. *Journal of Physics: Conference Series*, *1399*(3), 033113. https://doi.org/10.1088/1742-6596/1399/3/033113

Mihaylov, M., Jurado, S., Avellana, N., Van Moffaert, K., De Abril, I. M., & Nowe, A. (2014). NRGcoin: Virtual currency for trading of renewable energy in smart grids. *11th International Conference on the European Energy Market (EEM14)*, 1–6. https://doi.org/10.1109/EEM.2014.6861213

Mukherjee, P., & Pradhan, C. (2021). Blockchain 1.0 to Blockchain 4.0—The Evolutionary Transformation of Blockchain Technology. In S. K. Panda, A. K. Jena, S. K. Swain, & S. C. Satapathy (Eds.), *Blockchain Technology: Applications and Challenges* (Vol. 203, pp. 29–49). Springer International Publishing. https://doi.org/10.1007/978-3-030-69395-4_3

Mulligan, C., Zhu Scott, J., Warren, S., & Rangaswami, J. (2018). *Blockchain Beyond the Hype A Practical Framework for Business Leaders*. 12.

Musleh, A. S., Yao, G., & Muyeen, S. M. (2019). Blockchain Applications in Smart Grid–Review and Frameworks. *IEEE Access*, *7*, 86746–86757. https://doi.org/10.1109/ACCESS.2019.2920682

Nakamoto, S. (2008). *Bitcoin*.

Narbayeva, S., Bakibayev, T., Abeshev, K., Makarova, I., Shubenkova, K., & Pashkevich, A. (2020). Blockchain Technology on the Way of Autonomous Vehicles Development. *Transportation Research Procedia*, *44*, 168–175. https://doi.org/10.1016/j.trpro.2020.02.024

Nguyen, B., Jaber, F., & Simkin, L. (2022). A systematic review of the dark side of CRM: The need for a new research agenda. *Journal of Strategic Marketing*, *30*(1), 93–111. https://doi.org/10.1080/0965254X.2019.1642939

Our Ecological Footprint: Reducing Human Impact on the Earth. New society publishers. (2020). [Annuelle]. UNITED NATION.

Parag, Y., & Sovacool, B. K. (2016). Electricity market design for the prosumer era. *Nature Energy*, *1*(4), 16032. https://doi.org/10.1038/nenergy.2016.32

Parmentola, A., Petrillo, A., Tutore, I., & De Felice, F. (2022). Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). *Business Strategy and the Environment*, *31*(1), 194–217. https://doi.org/10.1002/bse.2882

Pieroni, A., Scarpato, N., Di Nunzio, L., Fallucchi, F., & Raso, M. (2018). Smarter City: Smart Energy Grid based on Blockchain Technology. *International Journal on Advanced Science, Engineering and Information Technology*, *8*(1), 298. https://doi.org/10.18517/ijaseit.8.1.4954

Richter, B., Mengelkamp, E., & Weinhardt, C. (2018). Maturity of Blockchain Technology in Local Electricity Markets. *2018 15th International Conference on the European Energy Market (EEM)*, 1–6. https://doi.org/10.1109/EEM.2018.8469955

Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. Palgrave Macmillan.

Schousek, T. (2018). Fundamentals of good practice. In *The Art of Assembly Language Programming Using PIC© Technology* (pp. 83–108). Elsevier. https://doi.org/10.1016/B978-0-12-812617-2.00007-9

Shahapure, K. R., & Nicholas, C. (2020). Cluster Quality Analysis Using Silhouette Score. *2020 IEEE 7th International Conference on Data Science and Advanced Analytics (DSAA)*, 747–748. https://doi.org/10.1109/DSAA49011.2020.00096

Sharad Mangrulkar, R., & Vijay Chavan, P. (2024). Introduction to Blockchain. In *Blockchain Essentials* (pp. 1–46). Apress. https://doi.org/10.1007/978-1-4842-9975-3_1

Sharma, S., Mathur, A., Choudhary, K., & Singh, P. (2020). Blockchain Enabled Electric Vehicle Charging Infrastructure. *2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA)*, 975–979. https://doi.org/10.1109/ICIRCA48905.2020.9183298

Singla, V., Malav, I. K., Kaur, J., & Kalra, S. (2019). Develop Leave Application using Blockchain Smart Contract. *2019 11th International Conference on Communication Systems & Networks (COMSNETS)*, 547–549. https://doi.org/10.1109/COMSNETS.2019.8711422

Siqin, T., Choi, T.-M., Chung, S.-H., & Wen, X. (2024). Platform Operations in the Industry 4.0 Era: Recent Advances and the 3As Framework. *IEEE Transactions on Engineering Management*, *71*, 1145–1162. https://doi.org/10.1109/TEM.2021.3138745

Stambouli, A. (2010). *An overview of different energy sources in Algeria*. https://www.jeaconf.org/UploadedFiles/Document/db8b44dd-8036-47ef-a62a-080f35315daa.pdf

Suvarna, K. (2018). *Review of Distributed Ledgers: The technological Advances behind cryptocurrency*.

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

Teng, F., Zhang, Q., Wang, G., Liu, J., & Li, H. (2021). A comprehensive review of energy blockchain: Application scenarios and development trends. *International Journal of Energy Research*, *45*(12), 17515–17531. https://doi.org/10.1002/er.7109

Tesfamicael, A. D., Liu, V., Mckague, M., Caelli, W., & Foo, E. (2020). A Design for a Secure Energy Market Trading System in a National Wholesale Electricity Market. *IEEE Access*, *8*, 132424–132445. https://doi.org/10.1109/ACCESS.2020.3009356

The 6th IEEE International Conference on Renewable Energy Research and Applications (ICRERA 2017): San Diego, CA, USA, 05-08 November 2017. (2017). IEEE.

The "SMARTER" framework and real application cases of blockchain. (n.d.). https://doi.org/10.1016/j.techfore.2023.122798

Thomas, L., Zhou, Y., Long, C., Wu, J., & Jenkins, N. (2019). A general form of smart contract for decentralized energy systems management. *Nature Energy*, *4*(2), 140–149. https://doi.org/10.1038/s41560-018-0317-7

Tümen Akyildiz, S., & Ahmed, K. H. (2021). An Overview of Qualitative Research and Focus Group Discussion. *International Journal of Academic Research in Education*, *7*(1), 1–15. https://doi.org/10.17985/ijare.866762

Uddin, S. S., Joysoyal, R., Sarker, S. K., Muyeen, S. M., Ali, Md. F., Hasan, Md. M., Abhi, S. H., Islam, Md. R., Ahamed, Md. H., Islam, Md. M., Das, S. K., Badal, Md. F. R., Das, P., & Tasneem, Z. (2023). Next-generation blockchain enabled smart grid: Conceptual framework, key technologies and industry practices review. *Energy and AI*, *12*, 100228. https://doi.org/10.1016/j.egyai.2022.100228

Vik, J., Melås, A. M., Stræte, E. P., & Søraa, R. A. (2021). Balanced readiness level assessment (BRLa): A tool for exploring new and emerging technologies. *Technological Forecasting and Social Change*, *169*, 120854. https://doi.org/10.1016/j.techfore.2021.120854

Wang, N., Zhou, X., Lu, X., Guan, Z., Wu, L., Du, X., & Guizani, M. (2019). When Energy Trading Meets Blockchain in Electrical Power System: The State of the Art. *Applied Sciences*, *9*(8), 1561. https://doi.org/10.3390/app9081561

Wang, Q., Li, R., & Zhan, L. (2021). Blockchain technology in the energy sector: From basic research to real world applications. *Computer Science Review*, *39*, 100362. https://doi.org/10.1016/j.cosrev.2021.100362

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. https://doi.org/10.1016/j.cosrev.2020.100275

Wang, Z., Fu, Y., Zhong, L., & Dai, F. (2020). Research on Blockchain Availability Modeling in P2P Network. *International Journal of Advanced Network, Monitoring and Controls*, *5*(1), 36–43. https://doi.org/10.21307/ijanmc-2020-006

Wegrzyn, k & wang. (2021). *BLOCKCAHIAIN IN SUPPLY CHAIN*. https://www.foley.com/insights/publications/2021/08/types-of-blockchain-public-private-between/

Wu, X., Duan, B., Yan, Y., & Zhong, Y. (2017). M2M Blockchain: The Case of Demand Side Management of Smart Grid. *2017 IEEE 23rd International Conference on Parallel and Distributed Systems (ICPADS)*, 810–813. https://doi.org/10.1109/ICPADS.2017.00113

Wu, Y., Wu, Y., Guerrero, J. M., & Vasquez, J. C. (2021). A comprehensive overview of framework for developing sustainable energy internet: From things-based energy network to services-based management system. *Renewable and Sustainable Energy Reviews*, *150*, 111409. https://doi.org/10.1016/j.rser.2021.111409

Zhang, C., Romagnoli, A., Zhou, L., & Kraft, M. (2017). From Numerical Model to Computational Intelligence: The Digital Transition of Urban Energy System. *Energy Procedia*, *143*, 884–890. https://doi.org/10.1016/j.egypro.2017.12.778

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. *2017 IEEE International Congress on Big Data (BigData Congress)*, 557–564. https://doi.org/10.1109/BigDataCongress.2017.85

Zhu, S., Song, M., Lim, M. K., Wang, J., & Zhao, J. (2020). The development of energy blockchain and its implications for China's energy sector. *Resources Policy*, *66*, 101595. https://doi.org/10.1016/j.resourpol.2020.101595

Appendix

Appendix A

Use case ID	Project	Company	Objective	Technology used	Location	Description
UC001	Jouliette	Alliander & Spectral Energy	P2P energy sharing platform	MultiChain, AI	Netherlands	Development of Jouliette, a P2P energy sharing platform in Amsterdam, focused on a behind-the-meter smart grid
UC002	SolarMente	SolarMente	Solar energy management and trading platform	Blockchain, Solar Energy, IoT	Spain	SolarMente is innovating at the intersection of blockchain and solar energy, allowing users to control energy storage and consumption. Their platform enables the purchase and sale of surplus energy within a community.
UC003	Conjoule	Conjoule GmbH	P2P energy markets for renewable energy	Blockchain, P2P Platform	Germany	Conjoule, is developing a P2P marketplace for renewable energy. This platform enables direct transactions between prosumers with solar PV and local consumers, eliminating the need for intermediaries. Currently piloted in two German cities.
UC004	uGrid	Power Ledger	Energy tracking and trading within microgrids	Blockchain	Global	uGrid facilitates energy trading within embedded networks like apartment complexes, shopping centers, and office buildings. It enables residents to trade solar energy, enhancing local energy efficiency and investment in renewables within the community.
UC005	xGrid	Power Ledger	Facilitate solar power trading across the grid	Blockchain	Global	xGrid allows customers to trade solar energy across the electricity grid, leveraging blockchain for transaction tracking and dynamic pricing. It supports energy trading among consumers within the same or different utilities, offering cost benefits and revenue opportunities. The platform includes innovative programs like Loyalty Solar Swap and Gifted P2P, enhancing brand engagement and providing renewable energy solutions for

						commercial customers and their communities.
UC006	Vision	Power Ledger	Energy traceability and retailer revenue optimization	Blockchain, Smart Meters	Global	Vision integrates with smart meters to automatically track and trace energy from its source, enhancing transparency and accountability. The platform helps energy retailers create new revenue streams and retain customers. In partnership with ekWateur, it's transforming the French electricity market by enabling customizable energy mixes for consumers.
UC007	TraceX	Power Ledger	Trading of Energy Attribute Certificates (EACs)	Blockchain	Global	TraceX is a blockchain-based digital marketplace for trading various environmental commodities, including Renewable Energy Certificates (RECs), Guarantees of Origin (GOs), and carbon credits. It provides real-time price discovery, an immutable audit trail, and streamlined payment processes, catering to generators, utilities, and traders in the EAC market.
UC008	PPA Vision	Power Ledger	Enhance visibility and management of Power Purchase Agreements (PPAs)	Blockchain	Global	PPA Vision provides a comprehensive solution for tracking and trading energy within PPAs, integrating seamlessly with existing systems. It offers generators the ability to meet regulatory and renewable energy targets while providing cost savings on energy for commercial users.
UC009	EcoWatt Green Energy Investment	EcoWatt	Tokenization of green assets and carbon credits	Blockchain, Tokenization, Web 3	Global, The Bahamas	EcoWatt, in partnership with GEM Digital Limited, has secured a $110 million investment to expand its blockchain-powered renewable energy projects, including wind, solar, hydrogen, and geothermal power, as well as reforestation efforts aimed at planting 100 million trees by 2025. The initiative utilizes the EcoWatt Token (EWT), backed by these green assets, to facilitate carbon-

						neutral goals for companies and incentivize sustainable practices among consumers.
UC010	Carbonable	Carbonable	Manage carbon contributions using blockchain and NFTs	Blockchain, NFTs	Global	Carbonable offers a blockchain-based platform for transparent and secure financing of carbon credit projects through NFT sales. In 2023, the startup raised €1.2 million to expand its team and enhance R&D, focusing on reducing the ecological impact and greenwashing in carbon investments.
UC011	React Energy Network	React	Decentralize and monetize energy assets through an open network	Blockchain, IoT	Global, starting in the USA	React is building a next-generation energy cooperative aimed at decarbonizing power grids through a decentralized network. It facilitates an open, permissionless platform for resource owners to monetize assets and provides the energy market with granular, flexible energy access. React leverages tokens to incentivize community participation and asset deployment.
UC012	eXmarket Platform	Fohat eTech Global	Develop a blockchain network for energy asset trading in Brazil	Blockchain (Corda Enterprise), CordApp	Brazil, Latin America	Fohat eTech Global, leveraging Corda Enterprise technology, has developed the eXmarket platform to enhance transparency, visibility, and scalability in Brazil's Free Energy Market. This platform intelligently manages asset dispatch and trading, ensuring efficient contractual and financial flows within the energy sector.

UC013	Integrated Grid Services	Power Transition	Optimize grid and microgrid operations with advanced technology	AI, Machine Learning, Distributed Ledger Technology (DLT), Open Integration Bus (OIB)	Global	This initiative leverages AI and machine learning to optimize distributed energy resources (DERs) across networks, enhancing grid balance and generating new revenue streams. The development of an Open Integration Bus (OIB) and a 3rd generation DLT platform facilitates rapid integration of energy assets from microgrids to electric vehicle infrastructure, creating a neural network for precise data aggregation. This leads to more efficient forecasting, lower infrastructure costs, and reduced consumer bills.
UC014	Omega Grid Local Energy Market	Omega Grid	Develop an efficient local energy market system using blockchain	Blockchain (Proof of Authority), Integration with Proof of Stake Networks	USA	Omega Grid's platform revolutionizes local energy markets by leveraging a blockchain-based architecture to optimize generation and load mixes without the need for central clearinghouses or extensive communication infrastructure. Designed for energy efficiency, it interfaces with existing markets and supports Proof of Authority and Proof of Stake models to minimize energy use.
UC015	Green Energy Mining (GEM) System	Perpetual Industries	Develop a sustainable and energy-efficient cryptocurrency mining system	Green Energy (Solar, Wind, Hydro), Blockchain, Masternodes, Proof of Stake, Proof of Work, Dapps	Indiana, USA	Perpetual Industries is developing the GEM System, a revolutionary cryptomining farm that utilizes a combination of solar, wind, and hydro power to sustain its operations, significantly reducing the environmental impact and power costs associated with blockchain and cryptocurrency mining.
UC016	Solar Micro-Investing	PowerErn	Finance solar energy solutions through a buy-to-lease model	Blockchain	Dubai	PowerErn leverages blockchain for a micro-investing platform that allows global investors to buy solar cells and lease them, generating passive income and funding solar plants in emerging markets. This model provides solar energy at zero

						capital cost to high-impact communities, offering a sustainable financial return to investors.
UC017	Enercity Bitcoin Payment	Enercity	Implement Bitcoin as a payment method for energy bills	Blockchain, Cryptocurrency (Bitcoin)	Germany	Enercity, under the leadership of Chairwoman Susanna Zapreva, has introduced Bitcoin as a payment option for household energy bills, pioneering the adoption of cryptocurrency in the energy sector. This service facilitates decentralized, secure transactions, with automatic exchange from Bitcoin to Euro handled by Pey GmbH. Enercity aims to set a standard in digitalized and decentralized options for the energy sector.
UC018	Smart Community	Enervalis	Develop a fully smart energy community with Blockchain technology	Blockchain, NRGcoin, Smartpower Suite	Eemnes, Netherlands	Enervalis has initiated a pioneering project in Eemnes, Netherlands, to transform a small township into a future-ready energy community. This community will leverage the Smartpower Suite and NRGcoin to create a local energy market that enables sustainable energy practices and self-sufficiency.
UC019	ENGIE Energy Access Electrification	ENGIE Energy Access	Accelerate sustainable electrification in Sub-Saharan Africa	Blockchain, Cryptocurrency (Energy Web Tokens)	Sub-Saharan Africa	ENGIE Energy Access, in collaboration with Energy Web, is using blockchain technology and Energy Web Tokens (EWT) to innovate financing for sustainable electrification projects. The project focuses on providing PAYGo solar solutions to improve energy access in African communities.
UC020	Volt Markets EnergyChain	Volt Markets	Manage environmental commodities and decentralized energy services	Blockchain, Energy Efficiency Coin	Global	Volt Markets developed EnergyChain, a blockchain platform with its own cryptocurrency, Energy Efficiency Coin. The platform supports decentralized energy grid services and a smart property and land titles registry.

UC021	Climatecoin	Climatecoin	Trade carbon credits as cryptocurrency	Blockchain, Cryptocurrency	Global	Climatecoin offers a cryptocurrency where each token represents one carbon credit, allowing buyers to invest in or offset carbon credits, contributing to environmental sustainability.
UC022	Energo Labs	Energo Labs	Facilitate P2P energy and EV charging trading	Blockchain	Global	Energo Labs created a platform for peer-to-peer energy trading and smart EV charging, enabling transactions not just between households but also between machines.
UC023	Everty P2P EV Charging	Everty	Develop a peer-to-peer network for EV charging	Blockchain	Global	Everty is developing a peer-to-peer system for EV charging, allowing individuals with home charging stations to connect to the network and offer charging services to others.
UC024	Kepco EV Charging	Kepco	Build blockchain-powered EV charging stations	Blockchain	Global	Kepco plans to construct the world's first blockchain-based EV charging stations, using the technology to manage charging data and support customers at the stations, aiming for enhanced operational efficiency and customer service.
UC025	Oslo2Rome	Fortum, Innogy, and other partners	Enhance the EV charging experience across borders	Blockchain	Sweden, Norway, Germany, Austria, Netherlands, France	The Oslo2Rome project, involving multiple European partners, explores blockchain's potential to improve cross-border electric vehicle (EV) charging. This initiative aims to provide seamless payment and roaming services for EV users traveling through multiple countries.
UC026	AdptEVE	Freeelio	Develop decentralized digital intelligence for energy systems	AI, Blockchain	Munich, Germany	Freeelio is developing AdptEVE, a decentralized AI designed to understand and optimize energy systems. Initially deployed in solar buildings, AdptEVE uses data to advise on and adapt energy usage, aiming to enhance efficiency and sustainability within the energy sector.

UC027	Green Energy Wallet	Green Energy Wallet	Use electric vehicle batteries as a large buffer store for renewable energy	Blockchain, Bi-directional Charging Stations, Mobile App	Global	GEW connects batteries from electric vehicles and home energy systems to store and manage renewable energy. It utilizes bi-directional charging stations to manage the flow of electricity, ensuring efficient energy storage and supply. The GEW app facilitates interaction between vehicles, home systems, and the power grid, leveraging blockchain for energy trading and rewards.
UC028	Verv Energy Trading	Verv	Enable peer-to-peer renewable energy trading within communities	Blockchain, AI, High-speed Data Acquisition	Hackney, UK	Verv's platform allows households with solar panels to sell excess energy directly to neighbors, enhancing ROI and promoting renewable uptake. The platform was tested in Hackney, enabling residents to directly benefit from community-generated solar energy, reducing bills and carbon emissions.
UC029	Local Energy Marketplace	FEDECOM	Develop a blockchain-based marketplace for local energy trading	Blockchain, Cloud Computing, Smart Billing, Energy Certificate Issuance	Global	FEDECOM introduces a scalable cloud platform featuring an open marketplace for energy and flexibility trading. It supports both intra and inter-community peer-to-peer trading, utilizing blockchain for transparency and security. The platform includes smart billing and the issuance of energy certificates, enhancing the management and supervision of local energy systems.
UC030	4New Waste-to-Energy	4New	Implement blockchain in waste-to-fuel power plants	Blockchain, Cryptocurrency	Global	4New utilizes blockchain to manage the entire supply chain for waste-to-fuel power plants, from waste collection to electricity generation and sales, funded by their own token.
UC031	PetroBloq Oil & Gas Supply	PetroBloq	Develop a blockchain platform for oil & gas supply chain	Blockchain	Global	PetroBloq is creating a blockchain platform to enhance time and cost efficiency while increasing transparency in the oil & gas product supply chain.

UC032	DAO IPCI Environmental Trading	DAO IPCI	Support environmental initiatives with blockchain	Blockchain	Global	DAO IPCI provides an open-source blockchain platform to allocate and manage environmental assets like carbon credits, with the first carbon credit trade occurring in March 2017.
UC033	Energy Blockchain Green Marketplace	Energy Blockchain Labs	Develop a green energy marketplace with IBM	Blockchain	China	In partnership with IBM, Energy Blockchain Labs is creating an efficient marketplace for green energy in China, focusing on a platform to assist organizations with government-mandated CER quotas.
UC034	Evolution Energie Traceability	Evolution Energie	Enable tracking of renewable energy through the grid	Blockchain	Global	Evolution Energie develops a system to track the origin and flow of renewable energy on the electric grid, allowing customers to verify the source of their energy.
UC035	Blockchain for Direct Energy Commerce	Hive Power	Enhance direct consumer engagement and transaction efficiency	Blockchain, Smart Contracts	Global	Using blockchain technology to facilitate direct energy transactions between suppliers and consumers, eliminating intermediaries and enhancing transaction transparency and efficiency.
UC036	Enerchain Ponton	Ponton	Decentralize wholesale energy trading and settlement	Blockchain	Europe	Ponton developed Enerchain, a decentralized platform for OTC wholesale energy trading, supported by over 30 leading European energy trading companies. This platform aims to enhance transparency and efficiency in energy trading operations.
UC037	Interbit Platform	BTL	Enhance wholesale energy trading and settlement	Blockchain	Europe	Interbit is a blockchain platform used by 9 leading energy and oil & gas companies in Europe, focusing on improving the efficiency of gas trading from reconciliation through to settlement and delivery of trades.
UC038	ImpactPPA	ImpactPPA	Transform the global energy market with blockchain-based pre-paid electricity	Blockchain, Mobile Technology	Global	ImpactPPA leverages blockchain technology to allow consumers worldwide to pre-pay for electricity via mobile devices. It aims to democratize energy access, especially for the unbanked population, by providing a secure, transparent payment

						rail that connects investors, service providers, and consumers in the energy sector.
UC039	Share&Charge	MotionWerk	Develop a decentralized, blockchain-based EV charging network	Blockchain	Global	Share&Charge Foundation aims to overcome market fragmentation in EV charging infrastructure using blockchain technology. It focuses on enabling peer-to-peer charging and ensuring interoperability across different charging networks and operators. This initiative promotes universal access to EV charging, reducing dependency on centralized network operators and fostering a competitive, user-centric EV charging market.
UC040	Carboncoin Initiative	Carboncoin	Provide a sustainable cryptocurrency for value storage and transactions while funding global reforestation efforts	Blockchain, Cryptocurrency (Carboncoin)	Global	Carboncoin offers a cryptocurrency solution that minimizes environmental impact by eliminating profit-driven mining and directing transaction fees towards reforestation and climate change initiatives. It operates a decentralized network independent of banks, facilitating secure and automatic transactions via digital wallets and CarbonShopper.com.
UC041	Bankymoon Blockchain Meters	Bankymoon	Implement blockchain-enabled smart meters for energy payments	Blockchain, Smart Meters	South Africa	Bankymoon has introduced blockchain-enabled smart meters in Africa, designed to improve the efficiency of energy suppliers in collecting payments. Additionally, these smart meters allow humanitarian aid to be directly converted into energy credits, which can be sent to schools and other institutions in need.
UC042	Drift Energy Management	Drift	Utilize blockchain for better pricing and green energy promotion	Blockchain, Machine Learning, High-Frequency Trading	New York, USA	Drift employs blockchain, machine learning, and high-frequency trading strategies to offer better energy prices and support green energy consumption among retail

						customers in New York.
UC043	Greeneum Network	Greeneum	Incentivize renewable energy generation with P2P trading	Blockchain, AI, GREEN Tokens	Cyprus, UK, Israel, Germany, Guinea, Argentina, USA, India, Australia	Greeneum provides a global P2P energy trading platform that uses blockchain and AI to optimize the energy industry, promoting the generation and consumption of renewable energy through GREEN tokens. The platform aims to collect and process data for energy industry optimization.
UC044	Grid+ Energy Trading	Grid+	Offer energy at wholesale prices and enable P2P trading among customers	Blockchain	Texas, USA	Grid+ operates as a retail provider buying energy at wholesale prices and facilitates peer-to-peer energy trading among its customers using blockchain technology, enhancing energy market efficiency and reducing costs for participants.
UC045	Grid Singularity	Grid Singularity	Develop core blockchain technology for B2B energy sector provision	Blockchain	International	Grid Singularity is focused on creating a blockchain-based core technology platform for the energy sector. This platform is designed to support business-to-business provisions and underpin the Energy Web Foundation, aiming to revolutionize how energy markets operate globally with increased efficiency.
UC046	SolarCoin	SolarCoin Foundation	Incentivize solar energy production	Blockchain, Cryptocurrency	Global (13+ countries)	SolarCoin awards crypto-coins to verified solar energy producers, with each coin representing 1 MWh of solar energy.
UC047	Sun Exchange	Sun Exchange	Fund solar PV installations via P2P investment	Blockchain, Cryptocurrency	Southern Africa	Enables P2P funding of solar installations for schools and hospitals in Southern Africa, offering returns on investment.
UC048	Veridium Labs	Veridium Labs	Tokenize natural capital for environmental impact	Blockchain, Cryptocurrency	Borneo, Indonesia	Creates tokens representing natural capital, such as greenhouse gas removal or forest conservation, for trading and regulatory compliance.
UC049	WePower	WePower	Enable P2P trading and funding of renewable energy	Blockchain, Cryptocurrency	Lithuania, Spain	A platform for trading renewable energy P2P and funding renewable projects by pre-selling future energy generation.

UC050	Electron	Electron	Automated energy supplier switching and support P2P energy trading	Blockchain	UK	Automates energy supplier switching; supports P2P energy trading and grid-balancing.
UC051	Energy Web Foundation	Energy Web Foundation	Accelerate blockchain technology across energy markets	Blockchain	Somaliland, Haiti, India, Argentina	Non-profit alliance between major energy players to build a blockchain ecosystem for energy.
UC052	LO3 Energy (Exergy)	LO3 Energy	P2P energy trading and grid-level service provision	Blockchain	NY, USA	P2P energy trading platform also aimed at grid-level services such as DER aggregation and balancing.
UC053	MyBit	MyBit	P2P investment into IoT hardware like solar panels	Blockchain, IoT	Global	Allows investors to own and earn returns from tokenized IoT hardware, focusing on connected solar panels.
UC054	Clean Energy Certificate	Siemens Energy	Certify products as manufactured from renewable energy sources	Blockchain	Global	Siemens Energy has developed the Clean Energy Certificate to connect physical assets to a digital decentralized infrastructure. Using blockchain, this certificate tags products with details about their renewable energy origin, enhancing transparency and verifying low carbon intensity throughout the supply chain.
UC055	Pebbles	Siemens	Develop a blockchain-based platform for local energy trading	Blockchain	Wildpoldsried, Germany	Pebbles, initiated by Siemens alongside Allgäuer Überlandwerk and AllgäuNetz, is a blockchain-based energy trading platform designed to optimize electricity trading. It enables local energy producers to sell directly to consumers without traditional operators, integrating battery storage for electric vehicles and ensuring transaction transparency and security.

UC056	Brooklyn MicroGrid	Transactive Grid	Implement blockchain-based P2P energy trading	Blockchain, Ethereum, Smart Contracts, PBFT, Tendermint	Brooklyn, New York, USA	Brooklyn MicroGrid, run by Transactive Grid—a partnership between LO3 Energy, Consensys, Siemens, and Centrica—is a pioneering blockchain-based platform for P2P energy trading in the Gowanus and Park Slope communities of Brooklyn. It enables prosumers to sell excess energy from solar panels directly to neighbors using Ethereum-based smart contracts and PBFT consensus implemented by Tendermint. The platform allows for real-time price setting and automatic transaction recording on the blockchain, enhancing transparency and reducing reliance on traditional energy distribution methods. Over 300 households and businesses are engaged in its ongoing development.
UC057	BAS Nederland Bitcoin Billing	BAS Nederland	Accept Bitcoin for energy payments	Blockchain, Cryptocurrency	Netherlands	BAS Nederland was the first energy company to accept Bitcoin for energy bill payments, promoting the use of cryptocurrencies in traditional billing systems to enhance payment flexibility and accessibility.
UC058	Recycle to Coin	BCDC	Reward recycling of materials with cryptocurrency tokens	Blockchain, Cryptocurrency	Global	The Recycle to Coin project by BCDC incentivizes sustainable behavior by rewarding individuals with tokens for recycling bottles and cans.
UC059	Elegant Energy Crypto Payments	Elegant	Enable cryptocurrency payments for energy services	Blockchain, Cryptocurrency	Germany	Elegant introduced cryptocurrency payments for energy services, including gas and electricity, providing customers with modern payment options that enhance convenience and transaction efficiency.
UC060	Disaggregated Billing	Enexis	Develop a solution to separate EV charging costs	Blockchain, Collaboration with IBM	Global	Enexis, in collaboration with IBM, is developing a blockchain-based solution to disaggregate electricity costs associated with EV charging from the rest of the household electricity bill. This

						system is particularly designed for individuals with company cars where the employer covers the fuel costs.
UC061	SunChain Energy Trading	TECSOL, Enedis	Certify and execute energy transactions via blockchain	Blockchain, Smart Meters	France	SunChain collaborates with Enedis to use blockchain for certifying and automatically executing transactions between consumers and energy producers, with smart meter data ensuring traceable and green energy generation.
UC062	PROSUME Energy Platform	PROSUME	Decentralize energy trading and management	Blockchain, Data Science		PROSUME develops a multi-solution decentralized blockchain platform that integrates power producers, consumers, and utilities, facilitating a variety of applications including smart metering and energy billing.
UC063	Pylon Network Metering	Pylon Network	Implement blockchain-integrated smart metering solutions	Blockchain, Smart Meters		Pylon Network offers Klenergy Metron, a smart meter integrated with blockchain technology that tracks and records energy production and consumption, promoting efficient energy management and billing.
UC064	M-PAYG Solar Services	M-PAYG	Provide blockchain-based pay-as-you-go solar services	Blockchain, Mobile Payments	Denmark	M-PAYG offers solar services in developing countries, enabling customers to pay for rooftop PV systems in mobile payment increments until ownership is transferred, with plans to implement blockchain for enhanced transparency and control.
UC065	Engie Blockchain Water Meters	Engie	Implement blockchain for water metering and management	Blockchain, Smart Water Meters	France	Engie is setting up blockchain infrastructure on a network of connected water meters to trace water flows and automatically manage repair actions, expanding applications to other utilities like gas and electricity.
UC066	CGI and Eneco Heat Metering	CGI, Eneco	Explore blockchain applications for heat meter data collection	Blockchain, Heat Meters	Netherlands	CGI and Eneco developed a pilot project that uses blockchain for heat meter data collection and billing in one of the largest heat networks in the Netherlands, aiming to

						reduce administrative costs and improve data management.
UC067	PRTI	PRTI	Build a waste-to-energy plant that mines cryptocurrencies	Blockchain, Cryptocurrency	USA	Similar to 4NEW, PRTI focuses on integrating waste-to-energy solutions with cryptocurrency mining, promoting sustainable energy use.
UC068	Envion	Envion	Use solar energy for cryptocurrency mining	Blockchain, Cryptocurrency	Germany	Envion uses excess solar energy, which would otherwise be curtailed, to power cryptocurrency mining operations, enhancing energy efficiency and sustainability.
UC069	HydroMiner	HydroMiner	Cryptocurrency mining using hydroelectric power	Blockchain, Cryptocurrency	Austria	HydroMiner utilizes low-cost hydroelectric power for environmentally friendly cryptocurrency mining.
UC070	Sun Exchange	Sun Exchange	Crowdsale of solar projects using blockchain	Blockchain, Cryptocurrency	South Africa	Sun Exchange uses blockchain to facilitate the buying of solar assets which are then leased to users in the developing world, generating returns for investors in the form of solar-produced energy.
UC071	Inuk	Inuk	App-based real-time carbon footprint monitoring and offsetting	Blockchain, Cryptocurrency	France	Inuk uses an app to link everyday activities to carbon credits, proposing actions such as investing in solar projects to counteract carbon production, with blockchain ensuring the transparency and validity of transactions.
UC072	Co-Tricity	Innogy	Develop a P2P energy trading platform	Blockchain	Global	Co-Tricity by Innogy aims to develop a market platform that connects homeowners who produce solar energy with local businesses to facilitate P2P energy transactions.
UC073	CoSol	CoSol	Enable P2P energy trading using blockchain	Blockchain, Ethereum	Global	CoSol utilizes Ethereum blockchain to create the IoRE (Internet of Renewable Energy) software, enabling P2P energy trading between small producers and consumers.
UC074	Greeneum	Greeneum	Provide tokens for granting carbon credits and green certificates	Blockchain, Cryptocurrency	Global	Greeneum issues GREEN tokens to facilitate carbon credit transactions and promote investments in green energy projects.

UC075	Wien Energie Gas Trading	Wien Energie	Pilot blockchain for gas trading	Blockchain, with support from BTL	Austria	Wien Energie, in collaboration with blockchain startup BTL, successfully completed a 12-week pilot for blockchain-based gas trading in Europe, aiming to enhance efficiencies and reduce costs through automated trading processes.
UC076	VAKT Global Trading	VAKT	Develop a digital platform for energy commodities trading	Blockchain	Global	A collaborative project with major energy corporations like BP, Shell, and Statoil, VAKT aims to develop a blockchain-based platform for energy commodities trading to enhance the security, transparency, and efficiency of global energy transactions.
UC077	Wholesale Energy Trading	BP, Shell, Statoil, BTL	Develop blockchain-based platform for wholesale trading of oil and gas	Blockchain	Global	Collaborative effort by major energy companies and software developer BTL to streamline wholesale energy trading and settlement processes.
UC078	EnergiToken	Energi Mine	Reward sustainable behaviour	Blockchain	Global	Decentralized platform to incentivize energy-efficient behaviors, using tokens that can pay for electricity or EV charging.
UC079	Bittwatt	Bittwatt	Develop a digital platform for energy stakeholders	Blockchain, AI	Global	Bittwatt's platform uses Ethereum blockchain to enable near real-time information sharing among stakeholders (TSOs, DSOs, energy suppliers, producers, consumers) for decentralized energy delivery, balancing, metering, and billing.
UC080	Clearwatts	Clearwatts with BigchainDB and Spherity	Develop a platform for real-time energy trading and settlements	Blockchain	Global	Clearwatts is developing a platform that allows various energy stakeholders to share reliable information in real-time for energy trading and the settlement of power purchase agreements.
UC081	Green Running (VLUX)	Green Running	Develop a decentralized platform for P2P energy trading	Blockchain, Ethereum, Smart Contracts	Global	Green Running is working on a decentralized platform to facilitate P2P energy trading, emphasizing transactions between energy suppliers and local aggregators. VLUX tokens support transactions within the ecosystem.

UC082	Nasdaq Green Certificates	Nasdaq with Filament	Pilot blockchain-based green certificates trading	Blockchain, DLT	Global	Nasdaq conducted a successful pilot in trading green certificates using blockchain technology, enabling solar producers to trade certificates online through Nasdaq's Linq platform.
UC083	Volts Markets	Volts Markets	Automate issuance and tracking of renewable energy certificates	Blockchain, Smart Contracts	Global	Volts Markets uses smart contracts on its energy assets exchange platform to automatically issue and track renewable energy certificates, facilitating a more streamlined market for these assets.
UC084	Veridium	Veridium	Trading carbon credits and natural capital assets	Ethereum-based blockchain	Global	Veridium has launched a platform for trading carbon credits using an Ethereum-based blockchain, offering enhanced transparency and efficiency in the carbon credits market.
UC085	DAO IPCI	DAO IPCI	Provide integrated services for carbon and environmental assets	Blockchain, Smart Contracts	Russia	DAO IPCI is developing an open-source blockchain solution to create a unified, decentralized platform for trading carbon credits and managing environmental assets, aiming to reduce fragmentation in current carbon markets.
UC086	CarbonX	CarbonX with ConsenSys	P2P carbon trading and incentivizing eco-friendly consumer behavior	Blockchain	Global	CarbonX assesses products and services for carbon footprints and incentivizes consumers to purchase carbon-neutral products, using blockchain to facilitate P2P carbon trading.
UC087	Energy Blockchain Labs	Energy Blockchain Labs with IBM	Create a carbon credit management platform	Hyperledger Fabric	China	In partnership with IBM, Energy Blockchain Labs is developing a platform to manage carbon credits in China's national carbon market, aiming to reduce operational costs and improve efficiency by utilizing blockchain technology.
UC088	Filament	Filament	IoT, smart devices, automation, asset management	Blockchain	USA	Provides blockchain IoT solutions such as smart metering, real-time monitoring, asset tracking, and asset management.
UC089	Slock.it	Slock.it	IoT, smart devices, automation, sharing economy platform	Ethereum, Blockchain	Germany	Develops IoT applications and the Universal Sharing Network for sharing economy, partnering with major companies like Siemens.

UC090	Dajie	Dajie	IoT, smart devices, asset management	Blockchain	Italy	Offers an IoT solution that allows energy generated by prosumers to create coins stored in a digital wallet.
UC091	ElectriCChain	ElectriCChain	IoT, smart devices, solar data integration	Blockchain	Global	Collects live solar data into a single blockchain, rewarding solar producers with SolarCoins.
UC092	Fortum	Fortum	IoT, smart home, energy optimization	Blockchain	Finland	Offers a blockchain-based solution for consumer control over connected home appliances to optimize energy use.
UC093	AdptEVE	Freeelio	IoT, smart devices, energy management	Blockchain, AI	USA	Aims to optimize energy management in solar buildings and homes with the help of data-driven techniques and smart contracts.
UC094	Green Running	Green Running	IoT, AI, P2P energy trading	Blockchain, AI	UK	Develops AI solutions to predict home energy demands and pricing, enabling optimized P2P energy trading via blockchain.
UC095	Tavrida Electric	Tavrida Electric	IoT, energy transactions traceability	Blockchain	Russia	Uses blockchain for energy transactions traceability between electrical equipment suppliers and operators.
UC096	Wanxiang	Wanxiang	IoT, smart city projects, asset management	Blockchain	China	Invests in blockchain initiatives for smart city projects, focusing on IoT and asset management.
UC097	Eurelectric Platform	Eurelectric	Explore blockchain potential across the electricity value chain	Blockchain	European Union	Comprises 24 energy companies investigating blockchain across generation, trading, supply, and networks. Published a significant industry report.
UC098	Swytch	Swytch	Tokenization of Renewable Energy	Blockchain	Global	A cryptocurrency incentivizing renewable energy production by verifying and rewarding production, with tokens that can be traded.
UC099	Hyperledger	Linux Foundation	Provide scalable, energy-efficient blockchain solutions for enterprises	Blockchain	Global	Open-source collaborative effort researching different consensus algorithms, including PBFT and PoET. Developed platforms like Hyperledger Fabric and Hyperledger Sawtooth.
UC100	Blockchain Research Lab	Blockchain Research Lab	Explore blockchain's potential for developing integrated energy systems	Blockchain	Global	Aims to integrate smart meters, blockchain technology, and real-time auctions to create an integrated energy market, reducing power system imbalance costs and

						improving system efficiency.
UC101	Blockchain Futures Lab	Blockchain Futures Lab	Study blockchains' social, economic, and political effects	Blockchain	Global	Research initiative examining the broader impacts of blockchain on societies and economies.
UC102	Alastria	Alastria	Develop a semi-public DLT infrastructure across sectors compliant with Spanish and EU regulations	Blockchain	Spain	National blockchain initiative including major Spanish banks, communication firms, and energy companies, focused on creating a multi-partner digital platform.
UC103	BlockLab	BlockLab	Examine blockchain feasibility for logistics and energy	Blockchain	Netherlands	Funded by the City and Port of Rotterdam, supporting pilot projects in logistics and energy.
UC104	EU Blockchain Observatory	European Commission	Facilitate blockchain adoption across the EU	Blockchain	European Union	A forum to accelerate blockchain dialogue and development within the EU, supporting wide-ranging blockchain adoption and regulatory discussions.
UC105	Divvi	Divvi	P2P Trading	Blockchain	Global	P2P energy trading platform designed specifically for prosumers.
UC106	Electrify.Asia	Electrify.Asia	P2P Trading	Blockchain	Global	Platform to connect consumers with small electricity producers, with plans to add a P2P trading feature. Includes a smart meter called powerpod to track and audit energy production.
UC107	TenneT, Sonnen	TenneT, Sonnen	Grid stabilization & Management	Blockchain	Germany	Consortium focusing on integrating residential solar panels as a balancing factor for the grid during periods of insufficient transport capacity.
UC108	TenneT, Vandebron	TenneT, Vandebron, IBM	Grid stabilization & Management	Blockchain	Netherlands	Collaboration to develop solutions using the capacity of EV batteries to balance the grid, involving innovative blockchain management strategies.
UC109	Charg	Charg	EV Charging & Management	Blockchain	Global	The Charg app enables drivers to connect with EV charging stations, both private and public, facilitating an increase in charging station availability and potentially reducing costs.
UC110	PRTI & Standard American Mining	PRTI & Standard American Mining	Cryptocurrency Mining	Waste-to-Energy	USA	The first waste-to-energy power plant dedicated to producing energy for cryptocurrency

						mining, leveraging waste processing as a power source.
UC111	Hydrominer	Hydrominer	Cryptocurrency Mining	Hydropower		Utilizes excess capacity of hydropower plants for energy-intensive cryptocurrency mining, accessing lower costs and renewable energy.
UC112	QIWI, Tavrida Electric	QIWI, Tavrida Electric	Energy Data Exchange Platform	Blockchain	Global	Partnership to utilize blockchain for recording energy transactions, improving grid capacity planning and transparency for regulatory bodies.
UC113	Totaro & Associates	Totaro & Associates	Energy Data Exchange Platform	Blockchain		Developing a platform for the energy industry to share data, with royalties paid to data providers generating revenue from shared data.
UC114	WaveX	WaveX	Crowdfunding for Renewable Energy	Blockchain	Not Specified	Connects investors with people who have space for solar panels to facilitate the financing of solar energy, allowing investors to earn from generated electricity.
UC115	Assetron Energy	Assetron Energy	Crowdfunding for Renewable Energy	Blockchain	Australia	Aims to develop a blockchain-based P2P platform for financing large-scale solar power projects in Australia.
UC116	Dooak	Dooak	Crowdfunding for Renewable Energy	Ethereum Blockchain	Latin America	An investment platform for distributed energy projects using smart contracts to boost business competitiveness.
UC117	Local-E	Local-E	Tokenization of Renewable Energy	Blockchain	Not Specified	Supports local solar production by allowing customers to buy tokens that guarantee them solar power at a fixed rate.
UC118	NRG Coin (Scanergy)	Enervalis, Vrije Universiteit Brussel	Tokenization of Renewable Energy	Blockchain	Not Specified	Provides NRG coins to renewable energy producers for each kWh of electricity they produce, potentially replacing traditional renewable energy certificates.
UC119	GrünStromJeton	GrünStromJeton	Tokenization of Renewable Energy	Blockchain	Not Specified	Offers tokens to consumers to track the proportion of renewable energy in their consumption, enhancing transparency.
UC120	Platinum Energy Recovery Corporation	Platinum Energy Recovery Corporation	Wholesale Energy Trading and Settlement	Blockchain	Asia	Develops a blockchain-based platform for the trading of wholesale energy commodities,

						focusing on the Asian market.
UC121	Daisee	Daisee	Platform	Blockchain	Not Specified	Aims to create the "Internet of Energy," building an infrastructure to support various energy applications.
UC122	PowerToShare	ToBlockChain	Platform	Blockchain	Not Specified	Software platform capable of hosting various applications, including P2P trading and certificates of origin, currently featuring five decentralized applications.
UC123	EnLedger	EnLedger	Platform	Blockchain	Not Specified	Provides a blockchain-based platform called EnergyChain and its associated currency, Energy Efficiency Coin. Supports decentralized energy grid services and smart property titles.
UC124	Oursolargrid	Oursolargrid	P2P Trading	Blockchain	Not Specified	Establishes a community for solar energy producers to trade or share electricity locally, aiming to enhance incentives for investing in solar power.
UC125	Positive Energy Community	SPREAD	P2P Trading	Blockchain	Not Specified	P2P energy trading platform that also supports crowdsourcing and crowdfunding for renewable energy assets like solar PVs and wind turbines.
UC126	Open Energy Network	Intrinsic ID, Guardtime	Metering Reliability	Blockchain	Not Specified	Develops a secure solution focusing on the authenticity of measurement data and sender in blockchain applications.
UC127	Bovlabs	Bovlabs	P2P Trading	Blockchain	Not Specified	Creates a community marketplace for trading locally generated energy through P2P methods.
UC128	AGL Energy Project	AGL Energy, Marchment Hill Consulting	P2P Trading	Blockchain	Melbourne, Australia	Develops a P2P platform allowing households and businesses to trade/share power locally, with a pilot project in Melbourne.
UC129	Elblox	Axpo, Wuppertaler Stadtwerke	P2P Trading	Blockchain	Not Specified	Platform enabling prosumers and small-scale renewable producers to buy and sell electricity locally.
UC130	BCPG, Power Ledger	BCPG, Power Ledger	P2P Trading	Blockchain	Thailand	Facilitates electricity trading between institutions such as malls, schools, and service apartments in

						Thailand through a pilot project.
UC131	Restart Energy	Restart Energy	Cryptocurrency Bill Payments	Blockchain	Romania	Romanian energy supplier accepting Bitcoin for bill payments and developing a P2P platform to connect energy producers with customers. Introduced RED MWAT token for transactions within its platform.

Appendix B

```
import numpy as np
import pandas as pd
from sklearn.feature_extraction.text import TfidfVectorizer, CountVectorizer
from sklearn.cluster import KMeans
from sklearn.metrics import silhouette_score
from sklearn.feature_extraction.text import CountVectorizer


# Load your dataset
file_path = 'C:/Users/fateh/OneDrive/Bureau/use cases list .xlsx'  # Update the file path
data = pd.read_excel(file_path)

# Combine the 'Objective' and 'Description' for clustering
data['text_data'] = data['Objective '] + " " + data['Description']

# Function to preprocess text
def preprocess_text(text):
    text = text.lower()
    text = ''.join([char for char in text if char.isalnum() or char.isspace()])
    return text

# Apply text preprocessing
data['processed_text'] = data['text_data'].apply(preprocess_text)

# Vectorize the text data using TF-IDF
tfidf_vectorizer = TfidfVectorizer(max_features=5000)
tfidf_matrix = tfidf_vectorizer.fit_transform(data['processed_text'])

# Determine the optimal number of clusters using silhouette scores
silhouette_scores = []
K = range(2, 11)  # Adjust range as needed

for k in K:
    kmeans = KMeans(n_clusters=k, random_state=42)
    kmeans.fit(tfidf_matrix)
    cluster_labels = kmeans.labels_
    silhouette_avg = silhouette_score(tfidf_matrix, cluster_labels)
    silhouette_scores.append(silhouette_avg)

optimal_k = K[np.argmax(silhouette_scores)]

# Clustering with the optimal number of clusters
kmeans_optimal = KMeans(n_clusters=9, random_state=42)
data['cluster'] = kmeans_optimal.fit_predict(tfidf_matrix)
```

```
# Function to find most common words in each cluster
def most_common_words(data, cluster_number):
    cluster_data = data[data['cluster'] == cluster_number]['processed_text']
    count_vectorizer = CountVectorizer(stop_words='english')
    word_count = count_vectorizer.fit_transform(cluster_data)
    sum_words = word_count.sum(axis=0)
    words_freq = [(word, sum_words[0, idx]) for word, idx in
count_vectorizer.vocabulary_.items()]
    most_common = sorted(words_freq, key=lambda x: x[1], reverse=True)[:5]
    return most_common

# Gather most common words for each cluster and generate cluster names
cluster_names = {}
for i in range(9):
    common_words = most_common_words(data, i)
    cluster_names[i] = ', '.join([word for word, freq in common_words])

# Output the cluster names and a preview of the clustered data
print("Cluster Names:", cluster_names)
print(data[['Use case ID', 'cluster']])
# Show the first few rows with cluster labels and find the most frequent terms in each cluster
data['cluster'].value_counts(), data.head()
print(data['cluster'].value_counts(), data.head())

# Group by cluster and list use case IDs
clustered_use_cases = data.groupby('cluster')['Use case ID'].apply(list)

# Print the use case IDs for each cluster
for cluster_id, use_case_ids in clustered_use_cases.items():
    print(f"Cluster {cluster_id}: {len(use_case_ids)} use cases")
    print(f"Use case IDs: {use_case_ids}\n")
```

Appendix C

Guide for Semi-Structured Interview Questions

1. **Background Information**
   - Please provide your name, role, and the organization you are affiliated with.
   - How long have you been involved in the energy sector and in what capacities?
2. **Questions Regarding the Use Cases**
   - Could you evaluate the described blockchain use cases?
   - Do you agree with how they have been presented?
   - Do you believe these use cases could be feasibly integrated within Algeria's energy sector? Why or why not?
   - Are there any specific aspects of these use cases that you find particularly promising or concerning?
3. **Questions Regarding the Implications for Scenarios**
   - For each cluster of use cases, various implications for the energy landscape have been identified. Do you agree with these implications?
   - Do you find the implications comprehensive and reflective of the current and future state of the energy sector in Algeria?
   - Are there any additional implications or considerations that you think should be included?
4. **Questions Regarding Obstacles for the Application of Use Case Clusters**
   - What do you perceive as the most significant obstacles to the implementation of each use case cluster?
   - Could you provide insights into the primary challenges that could hinder the realization of these use cases?
   - How might these obstacles be overcome, and what measures could be taken to facilitate the implementation of these use cases?
5. **Questions Regarding the Assessment Model**

   (decision tree model)

6. **Questions on Specific aspects**
   - Can you validate specific aspects of the study's interpretation and results? For instance, do you agree with the assessment of technological readiness for these use cases?
   - Are there certain assumptions in the study that you would like to elaborate on or challenge?
   - Based on your field of expertise, can you provide deeper insights into any particular topics relevant to this research?
7. **Additional Questions**
   - What areas of blockchain technology research do you think are most critical for Algeria's energy sector?
   - How can partnerships between enterprises, universities, and research institutes be strengthened to support blockchain development?
   - What role do you see for government support in advancing blockchain research and adoption?
8. **Closing Remarks**
   - Is there anything else you would like to add regarding the use of blockchain in the energy sector?
   - Do you have any additional recommendations or insights that could help advance this research?
   -

Questionnaire for maturity level assessment

Table 11: Questionnaire for the dimension of technology readiness level assessment.

Level	TRL
1	Is a specific technological idea formulated?
2	Is the idea explicitly described?
3	Is a concept clearly demonstrated and described?
4	Are the core technological elements tested and validated one by one?
5	Are core components tested together and validated in lab/simulated environment?
6	Is a prototype tested and validated in a relevant environment?
7	Is the technology tested and validated in natural environment?
8	Is the technology tested and validated in a broad scale?
9	Is the technology fully developed and ready to use?

Source: (Richter et al., 2018)

Table 12 Questionnaire for the dimension of market readiness level assessment.

Level	MRL
1	Does an idea regarding a market need exist?
2	Has an idea regarding a need and a technological solution been formulated?
3	Has a market demand and a service been explicated?
4	Is the market demand and the idea confirmed by customers and market actors?
5	Is there a described business model?
6	Has the service been sold?
7	Is there evidence of customer satisfaction in the market?
8	Are there stable and growing figures demonstrating market acceptance?
9	Is the technology available in a market through a defined business model?

Source: (Richter et al., 2018)

Table 13: Questionnaire for the dimension of regulatory readiness level assessment.

Level	RRL
1	Are the legal and regulatory aspects of the technology unpredictable/unknown?
2	Will use of the technology demand legal changes?
3	Will use of the technology require regulatory changes?
4	Will use of the technology require demanding permissions/approvals?
5	Will use of the technology require easily accessible permissions?
6	Are needed approvals/ permissions likely?
7	Are the necessary approvals/ permissions close to be given?
8	Does use and production of the technology fulfill general requirements?
9	Is use and production of the technology regulatory unproblematic?

Source: (Richter et al., 2018)

Table 14: Questionnaire for the dimension of acceptance readiness level assessment.

Level	ARL
1	Will the technology be seen as illegitimate or socially unacceptable?
2	Is the technology controversial among large part of the population?
3	Is the technology seen as very questionable among groups of the population?
4	Is the technology seen as questionable among groups of the population?
5	Is the technology seen as questionable among key actors in the sector?
6	Is the technology seen as questionable by a few actors in the sector?
7	Is the technology seen as questionable in parts of the sector?
8	Is use of the technology seen as questionable within marginal interest groups?
9	Is use and production of the technology socially accepted in general?

Source: (Richter et al., 2018)

Table 15: Questionnaire for the dimension of organizational readiness level assessment.

Level	ORL
1	Will the technology represent a fundamental break with existing work processes?
2	Is the integration with existing work processes unclear or problematic?
3	Has an idea regarding integration/domestication been formulated?
4	Has a potential integration and domestication of the technology been described?
5	Is there a plan for integration of the technology with existing work-processes?
6	Are major organizational changes needed for the technology to be used?
7	Are only minor organizational changes needed?
8	Is the technology adapted to work processes and/or other technologies?
9	Can the technology be used seamlessly together with existing technologies?

Source: (Richter et al., 2018)