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Sectoral Analysis of Block chain and Smart Contract Innovation in the European Union

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- Definition of blockchain and smart contracts
- Regulatory framework influencing the blockchain adoption in the EU
- Sectoral analysis of blockchain adoption in the EU
- Critical evaluation of blockchain adoption in the EU

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HARZ, Dominik; KNOTTENBELT, William, 2018. Towards safer smart contracts: A survey of languages and verification methods. arXiv preprint arXiv:1809.09805.
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Date: _____________________________

GRATITUDE

To God, the Divine Creator and Sustainer of all things, I humbly dedicate this thesis. With deep reverence, I acknowledge your boundless wisdom, grace, and guidance that have been instrumental in every step of this academic pursuit. Your unwavering presence has been the beacon of hope during moments of uncertainty, and your infinite knowledge has inspired me to delve into the depths of understanding. As I present this work, I offer it as an expression of gratitude for the countless blessings and opportunities you have bestowed upon me. May it stand as a testament to your greatness and serve as a humble offering to honor and glorify your name.

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NÁZEV

Sektorová analýza inovace blockchainu a smart kontraktů v Evropské unii

ABSTRAKT

Tato práce představuje sektorovou analýzu inovace blockchainu a smart kontraktů v Evropské unii. Cílem je poskytnout náhled na jejich přijetí a dopad v konkrétních odvětvích průmyslu. Blockchain a smart kontrakty mohou revolučně změnit sektory díky zlepšené transparentnosti a efektivitě. Výzkum využívá kombinaci různých metod, včetně studia literatury, pro analýzu aplikací a výzev v jednotlivých sektorech. Identifikuje odvětví příznivá pro inovace, což usměrňuje alokaci zdrojů a formulaci politik. Jsou zde poskytnuty praktické doporučení pro odvětví financí, dodavatelského řetězce, zdravotnictví, energetiky a správy, podporující informovaná rozhodnutí a rozvoj inovací v EU.

KLÍČOVÁ SLOVA

Smart kontrakty, Technologie blockchainu, Sektorová analýza, Aplikace, Transformační potenciál

TITLE

Sectoral Analysis of Block chain and Smart Contract Innovation in the European Union

ABSTRACT

This thesis presents a sectoral analysis framework for block chain and smart contract innovation in the European Union. It aims to provide insights on adoption and impact within specific industry sectors. Block chain and smart contracts can revolutionize sectors through enhanced transparency and efficiency. The study uses mixed-methods, including a literature review, to analyze sector-specific applications and challenges. It identifies innovation-friendly sectors, guiding resource allocation and policy formulation. Practical recommendations are given for finance, supply chain, healthcare, energy, and governance sectors, supporting informed decision-making and fostering EU innovation and growth.

KEYWORDS

Smart Contracts, Block chain Technology, Sectoral Analysis, Applications, Transformative Potential

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LIST OF ABBREVIATIONS AND ACRONYMS

IoT - Internet of Things

GDPR - General Data Protection Regulation

DLT - Distributed Ledger Technology

KYC - Know Your Customer

EHR - Electronic Health Records

R&D - Research and Development

P2P - Peer-to-Peer

API - Application Programming Interface

ICO - Initial Coin Offering

PoW - Proof of Work

PoS - Proof of Stake

ROI - Return on Investment

B2B - Business-to-Business

B2C - Business-to-Consumer

SaaS - Software as a Service

Crypto – Cryptography

EVM - Ethereum Virtual Machine

Introduction

In recent years, the European Union (EU) has shown a growing interest in block chain technology and its potential to revolutionize various industries. As emerging technologies like block chain continue to disrupt traditional business models, the EU has recognized the need to adapt and embrace these advancements to enhance competitiveness and productivity.

The EU's approach to block chain has evolved, driven by sectoral analysis and a deep understanding of the technology's capabilities. Initially associated mainly with the financial sector due to its connection with cryptocurrencies, the EU has expanded its vision to explore blockchain's benefits beyond finance. Sectoral analysis have highlighted the potential of block chain in diverse areas such as government, energy, healthcare, and supply chain management.

To leverage the transformative power of block chain effectively, the EU has undertaken initiatives to encourage research and innovation. As part of its reformation efforts, the EU has facilitated collaboration between academia, industry, and government bodies to develop tools and frameworks for block chain adoption.

In response to the challenges faced in implementing novel technologies like block chain, the EU has focused on creating comprehensive guidelines for organizations. These guidelines are designed to aid decision-making and mitigate the high failure rates observed in block chain projects. By consolidating and synthesizing existing block chain literature and research, the EU aims to provide a holistic and generic block chain assessment approach that benefits a wide range of organizations.

This paper examines the EU's changing attitudes and reformation efforts concerning block chain technology. It discusses the sectoral analysis conducted by the EU to identify use cases and potential benefits of block chain across various industries. Additionally, the paper explores the tools and frameworks developed by the EU to support informed decision-making in block chain implementation.

Problem Statement

The lack of a comprehensive sectoral analysis on blockchain and smart contract innovation in the European Union (EU) poses a significant challenge in understanding the true impact and potential of these technologies across various industries. Despite the EU's efforts to establish a regulatory framework, policymakers and stakeholders lack vital insights into the adoption rate, regulatory compliance, and specific challenges faced by different sectors in implementing these technologies effectively. A sectoral analysis is crucial to identify best practices, address barriers, and harness the full potential of blockchain and smart contracts to enhance efficiency, transparency, and competitiveness in sectors such as finance, healthcare, supply chain, energy, and more, ultimately fostering further innovation and growth within the EU.

Main Objective

The thesis aims at exploring the use instances of Blockchain and smart contract innovation and adoption in the EU region delving into various economic sectors including finance, healthcare, supply chain and energy to gain an understanding on the status of blockchain and smart contract implementation in the EU region.

Research Questions

To get the desired results for this hypothesis, the following research questions have been formulated as a guide to determine the parameters of the research.

1. Definition of block chain and smart contracts
2. Regulatory framework influencing the block chain adoption in the EU
3. Sectoral analysis of block chain adoption in the EU
4. Critical evaluation of block chain adoption in the EU

Significance of Study

The importance of smart contracts in this fast-changing digital world cannot be underemphasized and this study when carried out successfully would to a large extent layout the processes, importance, definition, strengths, and weaknesses involved in smart contracts and block chain implementation as well as the legal implications, regulations, application of smart contracts and block chain technologies in the European Region.

Limitations of Study

Even though smart contracts are global concepts, it is difficult to find hard coated books and print media resources, so the research must be based extensively on forums, conferences, and tech articles as well as other online sources and repositories.

2 Literature Review

2.1 Technical Foundations of Block chain and Smart Contracts

This section provides an overview of the technical foundations of smart contracts and block chain. The literature review explores the underlying principles, architecture, and functionalities of smart contracts and block chain technology. It delves into key concepts such as decentralized databases, cryptographic techniques, consensus mechanisms, and the execution of programmable contracts (Buterin, 2013; Szabo, 1997; Nakamoto, 2008).

Smart contracts are self-executing contracts with terms written in code and stored on a decentralized database, known as a block chain. They automatically execute when predetermined conditions are met. Smart contracts enable the exchange of digital assets and the execution of complex business logic in a transparent and immutable manner (Szabo, 1997).

Block chain is a distributed ledger technology that maintains a continuously growing list of records, called blocks, linked together using cryptographic hashes. Transactions are validated and confirmed by a network of participants through consensus mechanisms. The Bitcoin block chain, proposed by Nakamoto (2008), is the most well-known example and serves as the foundation for cryptocurrencies.

Decentralized databases ensure transparency, security, and resistance to tampering. Cryptographic techniques, such as digital signatures and cryptographic hash functions, verify transaction authenticity and ensure block chain immutability.

Consensus mechanisms, such as Proof of Work (PoW), Proof of Stake (PoS), and Practical Byzantine Fault Tolerance (PBFT), achieve agreement among network participants on the state of the block chain.

To implement smart contracts and build block chain networks, various technical frameworks, platforms, and languages are available. Ethereum (2021) is widely used, providing the Solidity programming language for writing complex smart contract logic. Hyperledger (2021) offers a modular and customizable platform for enterprise-grade block chain applications.

2.2 Block chain Technology

The studies has been ranting about block chain technologies up to now, so it is about appropriate to delve into block chain and why it is essential to the study of smart contracts.

2.2.1 What is Block chain?

IBM (2022) defines block chain as a shared and immutable ledger that facilitates the documentation of transactions and tracking of assets within a corporate network. Assets encompass both tangible items such as houses, cars, cash, and land, as well as intangible ones like intellectual property, patents, copyrights, and branding.

The structure of block chain technology is based on the concept of a chain of blocks, where each block contains a set of transactions (Nakamoto, 2008). These blocks are linked together using cryptographic techniques, ensuring that each new block is connected to the previous one. This forms an immutable and auditable ledger of transactions.

The Merkle tree structure allows for efficient and secure verification of transactions. When a new block is added to the block chain, the Merkle root of that block is included in the header of the subsequent block. This linkage ensures that any change or tampering of a transaction within a block would result in a completely different Merkle root, and thus, the integrity of the block and the entire chain can be verified providing a high level of trust and transparency in decentralized systems.

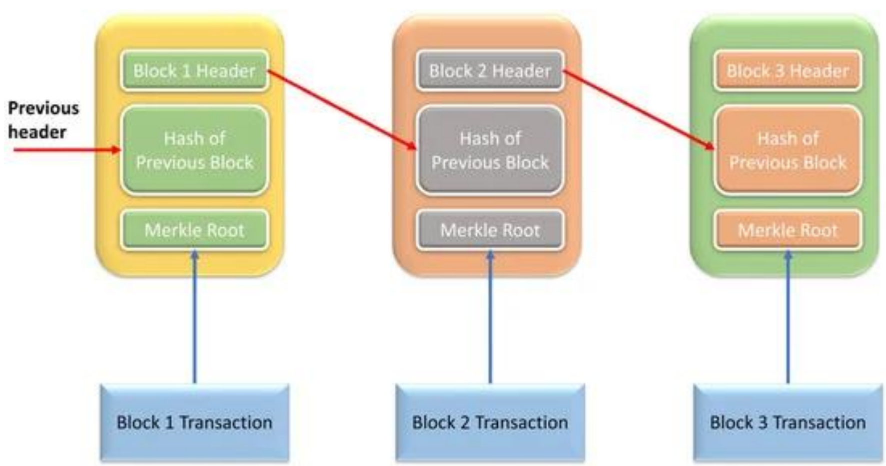


Figure 1 blockchain structure

(Source: https://www.researchgate.net/figure/Representation-of-blockchains-structure-each-block-of-the-chain-contains-a-header-and-a_fig1_338712777**)**

2.2.2 Why is block chain important?

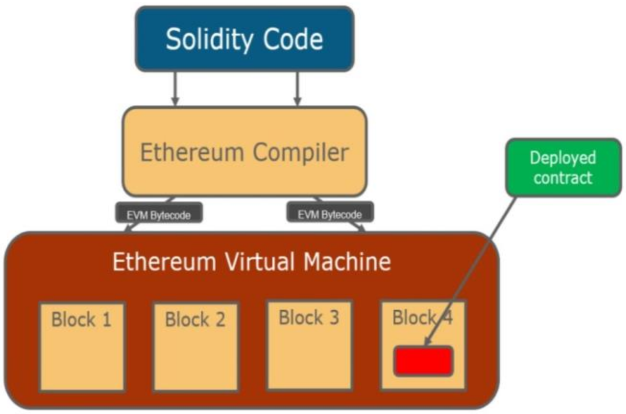
Block chain technology holds significant importance for various reasons. The following points highlight some key reasons why block chain is considered important:

i. Decentralization and Trust: Block chain eliminates the need for intermediaries by decentralizing data storage and transactions. It enables peer-to-peer interactions, fostering trust and transparency among participants (Swan, 2015).
ii. Immutable and Tamper-Resistant: Once data is recorded on a block chain, it becomes virtually impossible to alter or tamper with, thanks to cryptographic techniques and consensus mechanisms. This feature enhances the security and integrity of the information (Nakamoto, 2008).
iii. Transparency and Auditability: Block chain provides a transparent and auditable record of transactions. Every participant has access to the same information, ensuring accountability and reducing fraud (Tapscott & Tapscott, 2016).
iv. Efficiency and Cost Savings: By eliminating the need for intermediaries, block chain streamlines processes, reduces transactional friction, and minimizes costs associated with third-party involvement (Mougayar, 2016).
v. Smart Contracts and Automation: Block chain enables the execution of self-executing smart contracts, which automate and enforce predefined rules and agreements. This automation eliminates manual intervention, reduces errors, and enhances efficiency (Szabo, 1997).
vi. Data Security and Privacy: Block chain offers enhanced data security through cryptographic techniques, ensuring the privacy and confidentiality of sensitive information (Drescher, 2017).
vii. Potential for Innovation: Blockchain's decentralized nature and programmable capabilities provide a fertile ground for innovation, enabling the development of new business models, applications, and decentralized solutions (Buterin, 2013).

2.2.3 What is EVM in Block chain?

The Ethereum Virtual Machine (EVM) is an off-chain network of computers that runs parallel to the Ethereum block chain. It interacts with data through consensus protocols and connects to the main chain via smart contracts. Each Ethereum node runs an instance of the EVM, which defines the rules for calculating the blockchain's state. The EVM is programmed in various languages and ensures the immutability of the Ethereum network (Cryptory, n.d.).

Figure 2 how block chain is stored in an evm
(**Source:** Ethereum Tutorial for Beginners - Ethereum Architecture | Edureka)



2.2.4 Block chain Programming Languages for Smart contracts.

There is not an official ranking of block chain programming languages for smart contracts so for the sake of this research the ranking is generated by comparing the TVL (Total Value Locked).The metric known as Total Value Locked (TVL) is utilized to quantify the overall value of digital assets that have been locked or staked within a specific decentralized finance (DeFi) platform or distributed application (DApp).

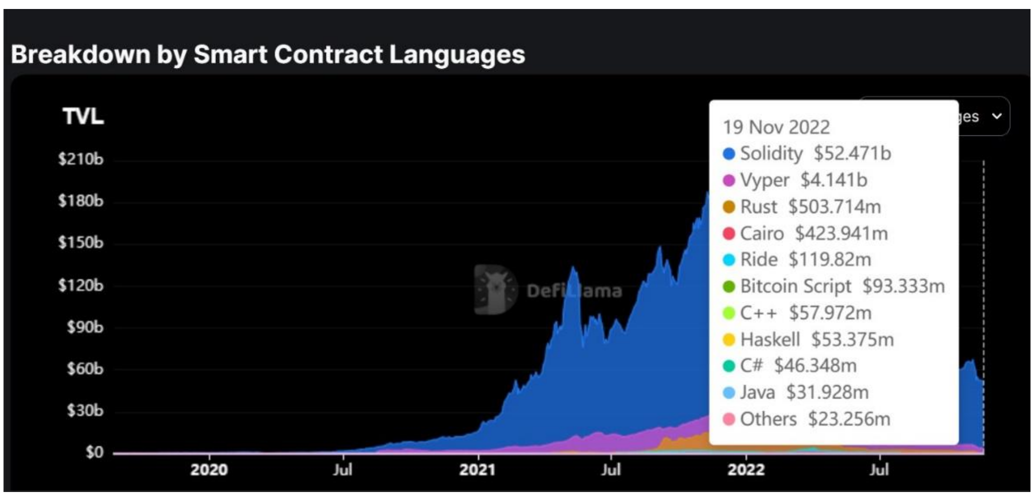


Figure 3 most in-demand programming languages
(Source: https://defillama.com/chain/Tron)

Comparing the data from DeFi, it can be seen that the top two languages for smart contracts is mainly Solidity comparing the TVL followed by Vyper with the second highest TVL. However when close attention is given to figure 2.3 it denotes clearly the gap between Solidity and the rest of programs.

2.3 Block chain operation

Block chain technology utilizes blocks as the foundational units within the system, storing a collection of transactions over a specific time frame or until a block size limit is reached. These blocks are linked together chronologically, forming an immutable digital ledger (Fernández-Caramès and Fraga-Lamas, 2020). A block consists of two main components: the block body, which contains recorded transactions, and the block header, which holds crucial information such as block version, timestamp, block hash, parent block hash, and other essential data for block chain operations.

To prevent unauthorized alterations and ensure consistency of block data, block chain systems employ consensus mechanisms (Zheng Z. et al., 2018). Consensus mechanisms involve network validators reaching agreement on the ledger's state through predefined rules and procedures (Swanson, 2015). Various consensus mechanisms exist, employing different approaches to achieve consensus.

The shared and distributed nature of block chain enhances its strength by fostering transparency among participants (Yaga et al., 2018). All network nodes, including users and maintainers, share the complete transaction history. The type of block chain (permissioned, permissionless, private, or public) determines access to this information (Pilkington, 2016). Additionally, the decentralized nature of block chain eliminates a single point of failure as nodes can join the network from various locations.

2.4 Characteristics and Types of Block chain

Block chain solutions can be classified into different types based on two main characteristics: data access and consensus participation.

2.4.1 Data Access

Data access refers to the ability to transact on the block chain and view its transaction history, and it can be categorized as either public or private. In a public block chain, unrestricted participation is allowed, and the transaction history is openly accessible. Conversely, a private block chain limits access to a select group of authorized participants who can transact and view the transaction history (Bitfury Group, 2022).

2.4.2 Consensus Participation

Consensus mechanisms play a vital role in block chain technology by ensuring agreement among distributed nodes regarding the ledger's state. These mechanisms implement protocols to determine how transactions are validated and added to the block chain (Allessie, 2017; Zheng Z. et al., 2018). Consensus mechanisms aim to achieve frequent and secure updates of the distributed ledger, establishing a shared state across all nodes (Lashkari and Musilek, 2021). When a node proposes a block that is accepted by all other nodes, it is added to their copies of the block chain (Singhal et al., 2018).

In the block chain ecosystem, several consensus mechanisms are available. However, this study focuses on the most relevant and widely used mechanisms, considering practical experience and existing knowledge. Here are brief explanations of these commonly used consensus mechanisms:

1) **Proof-of-Work (PoW):** In PoW, nodes earn the right to validate and append the latest block by solving computationally intensive problems. This solution serves as proof of work and rewards the node for its efforts (Yaga et al., 2018).

2) **Proof-of-Stake (PoS):** PoS allows nodes to validate and add the latest block based on their stake in the network. The probability of being chosen is proportional to the number of digital tokens held by the node (Yaga et al., 2018).

3) **Delegated-Proof-of-Stake (dPoS):** In dPoS, a limited number of verifying nodes are chosen through a voting process within the network. Nodes' voting power is determined by their stake in digital tokens, and they receive rewards proportional to their stake if the node they voted for successfully verifies a block (Yaga et al., 2018; Veinović, 2021).

4) **Proof-of-Elapsed-Time (PoET):** PoET assigns random wait-times to nodes using specialized hardware and software. A node earns the right to validate and append the latest block once its

assigned wait-time has elapsed without any other node claiming the opportunity (Nguyen and Kim, 2018; Yaga et al., 2018).

5) **Practical Byzantine Fault Tolerance (pBFT):** In pBFT, a leader node is selected by a group of validating nodes, which can change in each round. The leader node validates and groups transactions into the latest block once a time or size limit is reached. The consensus process involves three stages: pre-prepare, prepare, and commit, ensuring the validity and consensus of each new block before broadcasting it to non-validating nodes (Castro and Liskov, 1999; Sukhwani et al., 2017; Nguyen and Kim, 2018).

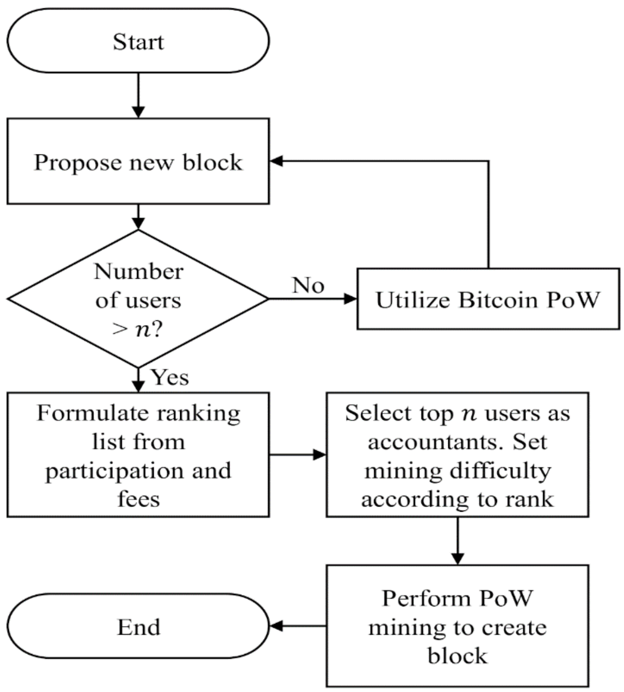


Figure 4: flow chart for consensus participation (proof of participation)
(Source: Symmetry | Free Full-Text | Block chain Consensus: An Overview of Alternative Protocols (mdpi.com))

2.4.3 Types of Block chain

Based on these characteristics, four main types of blockchains can be identified: public permissionless, private permissionless, private permissioned, and private permissionless. However, it is important to note that private permissionless blockchains currently have limited practical applications due to their conflicting properties (Allessie, 2017; Bauer et al., 2019).

2.5 Block chain Usage Instances

Realizing the potential value of block chain has proven to be more challenging than anticipated, as evidenced by the significant failure rates of block chain projects. To identify block chain use cases that have demonstrated verifiable value, several approaches have been employed to classify them. Crosby et al. (2016) categorized use cases into financial and non-financial applications, while Swan (2015), Zhao et al. (2016), and Angelis and da Silva (2019) classified them based on different iterations of block chain (1.0, 2.0, and 3.0). Additionally, Zheng Z. et al. (2018) and Casino et al. (2019) classified use cases according to major application areas, such as finance, education, IoT, governance, and data management.

Similarly, Carson et al. (2018) identified six categories of block chain use cases, divided into "Record Keeping" and "Transactions." These categories align well with Mougayar's ATOMIC concept and provide a concise and relevant classification of use cases. The categories and their definitions are as follows:

2.5.1 Record Keeping

i. **Static Registry:** A distributed database used to store reference data.
ii. **Identity:** A distributed database that contains identity-related information (a specific case of a static registry).
iii. **Smart Contracts:** Conditions recorded on a block chain that trigger automated, self-executing actions when predefined conditions are met.

2.5.2 Transactions

i. **Dynamic Registry**: A dynamic distributed database that updates as assets are exchanged within the block chain network.
ii. **Payments Infrastructure**: A dynamic distributed database that updates as payments are made among network participants.
iii. **Other:** A standalone use case that does not fit into any specific category and often combines elements from the previous categories.

2.6 What Are Smart Contracts?

In 2018, Cannarsa described a smart contract as computer code that executes all or part of a contract and is stored on a block chain-based platform. The code can be the sole manifestation of the agreement or complement traditional text-based agreements. It benefits from the security, durability, and immutability provided by block chain, and it is executed whenever a new block is added to the block chain (Cannarsa, 2018).

According to IBM, smart contracts are programs stored on the block chain and executed when predetermined conditions are met. They automate execution, eliminate the need for intermediaries, and provide instant confidence in the outcome. They can be automated to match a workflow and trigger the next action when conditions are met (IBM, 2022).

Smart contracts possess three essential characteristics originally defined by Szabo: observability, verifiability, and privity. Observability allows parties to observe and prove each other's performance, verifiability enables the provision of evidence for fulfillment or violation, and privity involves direct involvement of parties associated with the contract (Szabo, 1997).

1) **Observability**: This characteristic allows the involved parties in a contract to observe and prove each other’s performance regarding the stipulations of the contract.

2) **Verifiability:** Parties in a contract should be able to provide evidence that demonstrates the fulfillment or violation of the contract stipulations, either through direct means or by accessing relevant information.

3) **Privity**: Contract enforcement should primarily involve the parties directly associated with the contract, excluding external entities or intermediaries. Only those parties who require knowledge and control over the contract’s performance and contents should be involved in the enforcement process.

Blockchains use smart contracts to enforce contractual agreements. These contracts are encoded in computer code, stored, and executed on the block chain. They facilitate verification of obligations and enable faster and automated settlement processes. Smart contracts are secure, self-executing, and reduce the need for human intervention, thus minimizing risks and increasing cost-effectiveness. They exhibit determinism, represented as logical flowcharts such as "if A, then B, else C" (Hon et al., 2016; Mattila, 2016; Morabito, 2017).

2.6.1 How Smart Contracts are Initiated Using the Vending Machine Analogy

According to Ting (2021), the logic behind smart contracts is simple, operating on an "if-then" basis. For example:

i. If you send me object A, then the sum of money (in cryptocurrency) will be transferred to you.
ii. If you transfer a certain amount of digital assets (cryptocurrency), then object A will be transferred to you.
iii. If I finish the work, then the digital assets mentioned in the contract will be transferred to me.

To further explain looking at a practical example with the analogy of a vending machine, to purchase an item from a vending machine you will need to insert the amount that corresponds to the id number of the commodity you want. If your money is equal or above the price range then the machine is triggered to dispense the commodity you want and also reimburse you if you are due for a change. However if the funds are less than the price for the commodity then no transaction is initiated and your funds gets returned to you.

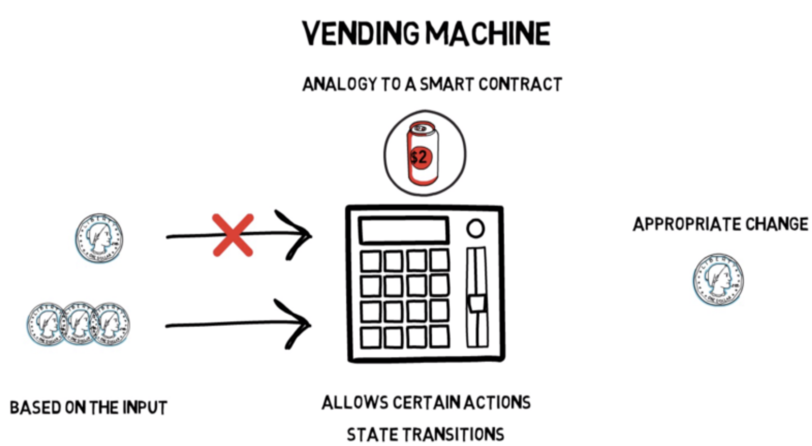


Figure 5: vending machine analogy of smart contracts
(Source: https://finematics.com/smart-contracts-explained/)

Within a smart contract, there could be numerous conditions to be satisfied by the involved parties. To establish these terms, involved parties must determine how every transaction and their related data are represented on the block chain, agree on the "if/when...then what…" stipulations governing those transactions, understand all possible exceptions, and concisely define an agreeable framework for dispute resolution.

2.6.2 Enforcement of Smart Contracts

While smart contracts operate within a decentralized and automated system, they still operate within the bounds of existing laws and regulations. It is crucial for smart contracts to align with legal requirements and obligations. This alignment ensures that the terms and conditions defined in the smart contract reflect the intentions and obligations of the parties involved.

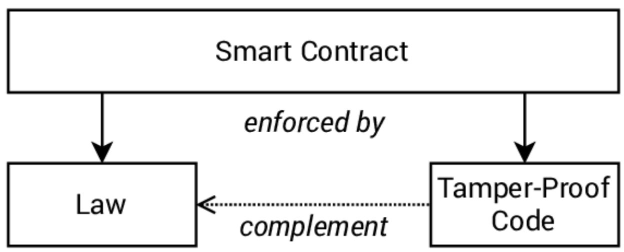


Figure 6: enforcement of smart contracts
(Source: https://www.researchgate.net/figure/Enforcement-of-a-smart-contract_fig1_356949298)

Enforcing smart contracts in compliance with the law requires careful considerations. Developers must design smart contracts with legal compliance in mind, ensuring that the code accurately reflects the contractual terms and adheres to applicable legal frameworks. Additionally, off-chain legal agreements may be necessary to supplement smart contracts, addressing legal nuances or providing additional details that cannot be entirely captured within the code.

2.7 Status of Smart Contracts and Block chain in Europe

The European Commission (2018) has recognized the potential of block chain technology and has outlined a European strategy for block chain, emphasizing the need for a common approach to enable interoperability, foster innovation, and ensure legal certainty and consumer protection. The European Block chain Partnership (2019), consisting of several European countries, has been established to foster collaboration in the development of block chain solutions and services.

Specific countries in Europe, such as Estonia, Switzerland, Malta, and the United Kingdom, have been at the forefront of adopting and implementing smart contracts and block chain technology. These countries have implemented policies and initiatives to support the development and use of smart contracts, such as creating regulatory sandboxes, establishing block chain-friendly legislation, and promoting block chain innovation hubs.

2.8 Regulatory Framework for Block chain Adoption in the EU

The European Union (EU) has been actively working on establishing a regulatory framework for block chain technology and smart contracts to ensure legal certainty, consumer protection, and foster innovation (European Commission, n.d.). This section provides a detailed explanation of the regulatory initiatives and key principles that shape the regulatory framework in the EU.

2.8.1 General Data Protection Regulation (GDPR)

The General Data Protection Regulation (GDPR) is a comprehensive data protection and privacy regulation implemented by the European Union (EU). It came into effect on May 25, 2018, and applies to all EU member states, as well as organizations outside the EU that handle the personal data of EU residents.

The GDPR aims to protect the fundamental rights and freedoms of individuals by regulating the processing of their personal data. It provides individuals with greater control over their personal data and imposes obligations on organizations to ensure the proper handling and protection of this data.

Under the GDPR, individuals have the right to access, rectify, and erase their personal data, as well as the right to restrict or object to its processing. Organizations are required to obtain explicit consent from individuals before collecting and processing their personal data, and they must implement appropriate security measures to safeguard this data.

The GDPR also introduces stricter requirements for data breach notification, data protection impact assessments, and the appointment of data protection officers in certain cases. Non-compliance with the GDPR can result in significant fines and penalties.

2.8.2 EU Representative

According to Article 27 of the General Data Protection Regulation (GDPR), non-EU establishments that are subject to the GDPR are required to appoint an "EU Representative" located within the European Union. This representative acts as a point of contact for the establishment's obligations under the GDPR. They serve as the contact person for European privacy supervisors and individuals whose data is being processed, ensuring compliance with the GDPR.

The EU Representative can be an individual or a company and must be designated through a signed document (letter of accreditation) issued by the non-EU establishment. The designation must be in writing.

Failure to designate an EU Representative is considered a violation of the GDPR, indicating ignorance of the regulation and related obligations. This violation can result in fines of up to €10 million or up to 2% of the establishment's annual worldwide turnover from the preceding financial year, whichever amount is greater. The intentional or negligent nature of the infringement may be considered aggravating factors.

However, an establishment is not required to appoint an EU Representative if they only engage in occasional processing that does not involve large-scale processing of special categories of data or data relating to criminal convictions and offenses. Additionally**,** non-EU public authorities and bodies are exempt from this requirement.

2.8.3 Reception

A study conducted by Deloitte in 2018 found that 92% of companies believed they could comply with GDPR in the long run. Companies operating outside of the EU made significant investments to align their practices with GDPR requirements. Consent under GDPR has implications for businesses that record calls, as a typical disclaimer is not considered sufficient. If a caller withdraws consent during a recording, the agent must be able to stop the recording and ensure it is not stored.

IT professionals anticipated that GDPR compliance would require additional investments, with over 80% of surveyed professionals expecting to spend at least US$100,000. Concerns were raised about the need for additional budget and effort to comply with consent, data mapping, and cross-border data transfer requirements.

The estimated cost of GDPR compliance is around €200 billion for EU companies and $41.7 billion for US companies. Some argue that smaller businesses and startups may lack the financial resources to comply effectively, unlike larger technology firms targeted by the regulation. Lack of knowledge and understanding of the regulations was also a concern, although companies had two years to prepare.

The GDPR has faced criticism for potential administrative burden and unclear compliance requirements. The lack of guidance on effective data de-identification schemes and the impact on block chain systems have raised concerns. The introduction of a "right to explanation" for algorithmic decisions has been widely discussed but remains unclear and limited.

The GDPR has received support from businesses as an opportunity to improve data management. Mark Zuckerberg has viewed it as a positive step and called for similar laws in the US. Consumer rights groups and whistleblower Edward Snowden have also supported the legislation. Richard Stallman, a free software advocate, praised certain aspects of the GDPR but advocated for additional safeguards against manipulation by technology companies.

2.8.4 Impact

The GDPR is hailed as a groundbreaking regulatory development in information policy, providing a comprehensive framework for protecting personal data. However, its implementation faced challenges, with companies making last-minute privacy policy changes and sending numerous notifications, leading to criticism and concerns about misinformation. Phishing scams and violations of anti-spam laws related to GDPR notices also emerged. Memes and a blog called GDPR Hall of Shame humorously highlighted unusual notice delivery methods and non-compliance instances. Research shows that GDPR has implications for software vulnerabilities, prompting experts to recommend investing in vulnerability identification processes and disclosure mechanisms. Some websites blocked EU visitors, and certain companies ceased operations due to perceived GDPR burdens. The volume of online behavioral advertising declined in Europe. Nevertheless, two years after implementation, the GDPR increased public awareness of data protection rights and made privacy a competitive factor for companies.

2.8.5 Enforcement and Inconsistency

Max Schrems's non-profit organization NOYB filed lawsuits against Facebook, WhatsApp, Instagram, and Google for their use of "forced consent" just hours after the GDPR came into effect. Google was later fined €50 million by the French DPA for insufficient control and transparency over personal data use. British Airways faced a record fine by the British Information Commissioner's Office for security vulnerabilities that led to a web skimming attack. However, the final penalty was reduced due to the impact of COVID-19 on their business.

There have been concerns about backlogs and varying interpretations of the GDPR among EU member states, particularly in Ireland and Luxembourg. Politico reported on the complexities and challenges faced by these countries in investigating major foreign companies under the GDPR. The Irish Council for Civil Liberties lodged a complaint against the Commission for breaching its obligation to monitor how Ireland applies the GDPR.

Despite legal obligations, there are inconsistencies in the practical implementation of the GDPR. Companies have faced criticism for not providing data subjects with accurate information, raising concerns about compliance. The enforceability of obtaining lawful consent has been challenging, with evidence of dark patterns used by big tech companies.

The number of GDPR fines has been increasing, with over one billion Euros in fines imposed in 2021 alone.

2.8.6 Timeline

Date	**Event**
25 January 2012	Proposal for the GDPR is released.
21 October 2013	European Parliament Committee on Civil Liberties, Justice and Home Affairs (LIBE) orientation vote.
15 December 2015	Negotiations between the European Parliament, Council, and Commission result in a joint proposal.
17 December 2015	European Parliament's LIBE Committee votes for the negotiations.
8 April 2016	Adoption by the Council of the European Union, with Austria as the only member state voting against.
14 April 2016	Adoption by the European Parliament.
24 May 2016	Regulation enters into force, 20 days after its publication in the Official Journal of the European Union.
25 May 2018	Provisions of the GDPR become directly applicable in all member states, two years after the regulations enter into force.
20 July 2018	GDPR becomes valid in EEA countries (Iceland, Liechtenstein, and Norway) following agreement with the EEA Joint Committee.

Table 1: timeline for gdpr
(Source: europa.eu)

2.9 Digital Single Market Strategy

The Digital Single Market Strategy is an initiative by the European Commission to establish a single digital market within the EU. It aims to remove barriers and create a favorable environment for the development and deployment of digital technologies, including block chain and smart contracts. The strategy recognizes the potential of block chain technology to enhance transparency, security, and efficiency across various sectors.

The EU Block chain Observatory and Forum, established as part of the Digital Single Market Strategy, actively monitors block chain developments and provides expertise to policymakers. It produces reports, conducts studies, and organizes workshops to promote understanding and dialogue on block chain-related topics (European Commission, n.d.).

2.9.1 The Three (3) Pillars

The Digital Single Market Strategy (DSMS) implemented by the European Commission from 2014 to 2019 aimed to improve access to the digital world for citizens and businesses. The strategy was structured around three pillars: access, environment, and maximizing the growth potential of the European digital economy. Each pillar had specific objectives and actions to achieve, such as regulating cross-border markets, addressing consumer discrimination, strengthening data protection, and fostering the digital switchover of industries.

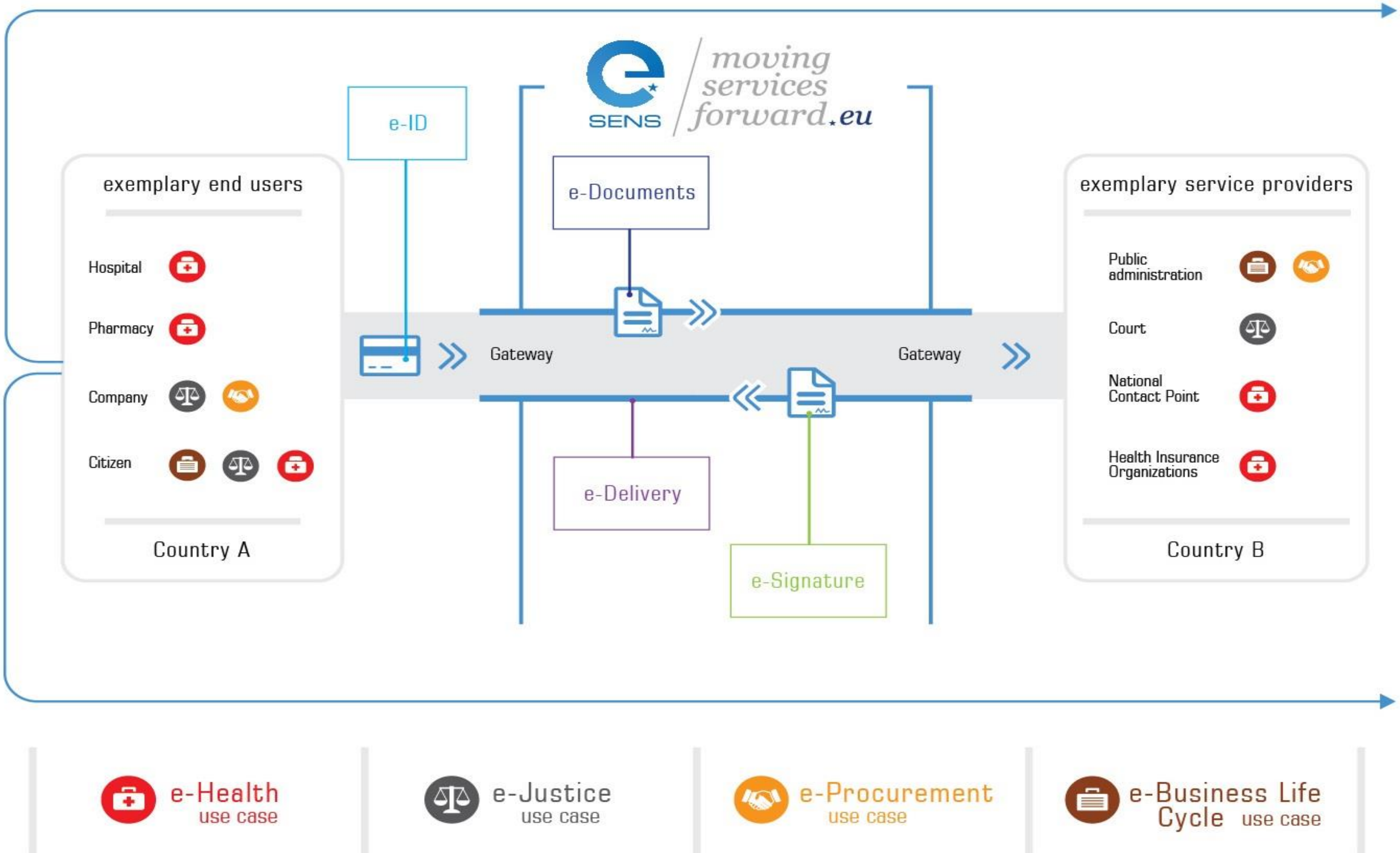


Figure 7: diagram of the eu digital single market and the facilitation of public services across border (Source: https://upload.wikimedia.org/wikipedia/commons/thumb/b/ba/E-SENS_architecture.jpg/220px-E-SENS_architecture.jpg)

Pillar	Objectives
Access	- Implement better access for consumers to the digital world across Europe.
	- Regulate cross-border markets to reduce differences between Member States.
	- Address problems of consumer discrimination and geographical blocking.
Environment	- Provide a favorable environment for fair competition and strengthen data protection.
	- Make access to networks and services more reliable and affordable.
	- Enable the market to adapt to changes in its environment, particularly in cybersecurity.
Growth	- Foster the digital switchover of industry and services in all economic sectors in Europe.
	- Stimulate investment through strategic partnerships and networks.
	- Ensure data protection, free movement of data, and the creation of a European cloud.

Table 2: the 3 pillars
(Source: europa.eu)

The successful implementation of the DSMS required the establishment of favorable environments for fair competition, reliable and affordable access to networks, and the protection of data and free movement of data.

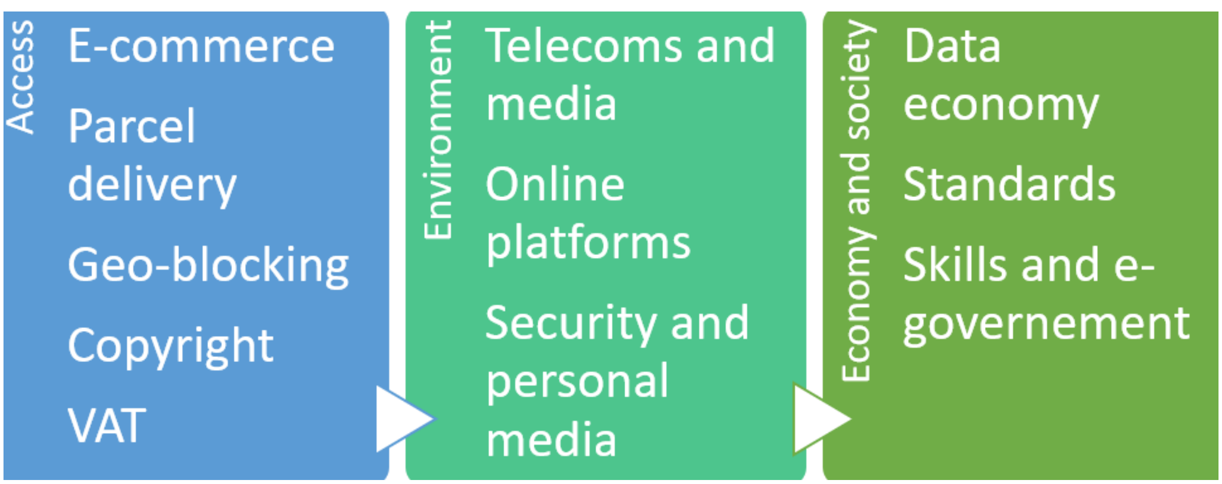


Figure 8 summary of the 3 pillars
(Source: https://upload.wikimedia.org/wikipedia/commons/thumb/3/32/Three_pillars_.png/395px-Three_pillars_.png)

2.9.2 Objectives

The Digital Single Market aims to achieve several key objectives in order to modernize regulations and promote a harmonized digital environment in the European Union. These objectives, as specified by the European Commission, are as follows:

1. Boost e-commerce: Efforts are focused on addressing barriers to cross-border online trade, such as geo-blocking, and improving the affordability and efficiency of cross-border parcel delivery services. The goal is to encourage increased e-commerce activities within the EU.
2. Modernize copyright rules: The objective is to update and adapt European copyright regulations to align with the digital age. This involves finding a balance between the rights of content creators and the needs of users, ensuring fair usage and fostering innovation in the digital sector.
3. Update audiovisual regulations: The aim is to revamp EU audiovisual regulations to create a more equitable environment. This includes working with online platforms to promote European films, protect children from inappropriate content, combat hate speech, and ensure compliance with regulatory standards.
4. Strengthen cybersecurity response: Efforts are being made to enhance Europe's ability to respond to cyber-attacks. This involves strengthening ENISA, the EU agency responsible for cybersecurity, and establishing effective European cyber deterrence strategies. The goal is to protect businesses, public institutions, and European citizens from cyber threats.
5. Promote digital skills and research: The objective is to support businesses, researchers, citizens, and public authorities in maximizing the benefits of new technologies. This includes ensuring that everyone has the necessary digital skills to thrive in the digital era and providing funding for European research activities, particularly in areas such as health and high-performance computing.

2.9.3 Main Achievements

The Digital Single Market strategy encompasses several key achievements and regulations aimed at promoting a unified digital marketplace in the European Union. These include:

1. Prohibition of unjustified geographical blockade: The Geo-blocking regulation prevents discrimination against consumers based on their nationality or country of residence, ensuring equal access to goods and services in e-commerce without additional fees.

2. End of roaming charges: Retail roaming charges were eliminated in June 2017, allowing mobile users to use their domestic tariff for calling, texting, and internet access while traveling within the EU.

3. Innovate cross-border parcel delivery: The regulation on cross-border parcel delivery improves price transparency and facilitates fair assessment of high cross-border tariffs, enhancing the efficiency and affordability of cross-border parcel services.

4. Portability of online content services: Consumers can access digital services, such as online distribution platforms for films and TV series that they have already paid for when traveling to another EU Member State without restrictions or additional costs.

5. Simplification of VAT declaration: The introduction of a one-stop shop for VAT registration simplifies VAT rules, encourages cross-border trade, combats VAT fraud, ensures fair competition for EU businesses, and provides equal treatment for online publications.

6. Revision of consumer protection cooperation regulation: The regulation strengthens the enforcement of consumer protection by enabling authorities to request information from domain registrars and banks to identify rogue traders and take down websites hosting scams.

7. Platform-to-business (P2B) Regulation: This regulation addresses unfair contracts and trading practices in platform-to-business relations, aiming to create a fair and transparent business environment for smaller businesses and traders on online platforms. It seeks to balance the market power between platforms and traders and foster a trusted online ecosystem.

2.10 European Block chain Partnership

The European Block chain Partnership was formed in 2018 with the objective of establishing a European Block chain Services Infrastructure (EBSI). The partnership consists of EU member states and aims to create a trusted and secure block chain infrastructure for public services across Europe.

The signatory countries of the Block chain Partnership Declaration include:

1. Austria
2. Belgium
3. Bulgaria
4. Czech Republic
5. Estonia
6. Finland
7. France
8. Germany
9. Ireland
10. Latvia
11. Lithuania
12. Luxembourg
13. Malta
14. Netherlands
15. Poland
16. Portugal
17. Slovakia
18. Slovenia
19. Spain
20. Sweden
21. Norway

Additional countries that joined the initiative after the launch include:

1. Greece (signed on 23 May 2018)
2. Romania (signed on 29 May 2018)
3. Denmark (signed on 1 June 2018)
4. Cyprus (signed on 4 June 2018)
5. Italy (signed on 27 September 2018)
6. Liechtenstein (signed on 1 February 2019)
7. Hungary (signed on 18 February 2019)
8. Croatia (signed on 16 October 2019)

United Kingdom (UK) was a signatory initially but is no longer a member of the European Block chain Partnership (EBP) since the entry into force of the Withdrawal Agreement on 1 February 2020.

The EBSI focuses on use cases such as notarization, education, healthcare, and regulatory reporting. It promotes interoperability and standardization in the implementation of block chain solutions, ensuring compatibility and seamless integration between different national systems. The European Block chain Services Infrastructure is expected to enhance the efficiency, transparency, and security of public services within the EU (European Block chain Partnership, n.d.).

2.11 Markets in Crypto-assets MiCA Regulation

The Markets in Crypto-assets Regulation (MiCA) is a proposed regulatory framework specific to cryptocurrencies and stablecoins. It aims to establish a comprehensive regulatory regime for issuers of crypto-assets and providers of related services within the EU. MiCA seeks to ensure investor protection, market integrity, and financial stability in the crypto-asset market.

Timeline and Activities of the MiCA

1. Digital Finance Package: The MiCA proposal is part of the digital finance package presented by the European Commission on 24 September 2020. The package aims to foster technological development, ensure financial stability, and enhance consumer protection in the context of digital finance.

2. Digital Finance Strategy: The package includes a digital finance strategy that outlines the European Commission's vision and objectives for promoting digital finance in the EU. It sets out the overarching goals and principles guiding the development of the regulatory framework.

3. Digital Operational Resilience Act (DORA): The package also includes the Digital Operational Resilience Act, which covers not only traditional financial institutions but also crypto-asset service providers. DORA aims to ensure operational resilience and cybersecurity of digital financial services.

4. Distributed Ledger Technology (DLT) Pilot Regime: The package features a proposal for a DLT pilot regime for wholesale uses. This proposal aims to facilitate the experimentation and adoption of DLT-based solutions in the financial sector while managing associated risks.

5. Negotiating and Agreement Process: The Council adopted its negotiating mandate on MiCA on 24 November 2021, indicating the start of discussions between the co-legislators. Trilogues, which are negotiations between the European Commission, the European Parliament, and the Council of the EU, began on 31 March 2022 and concluded with a provisional agreement reached on 30 June 2022.

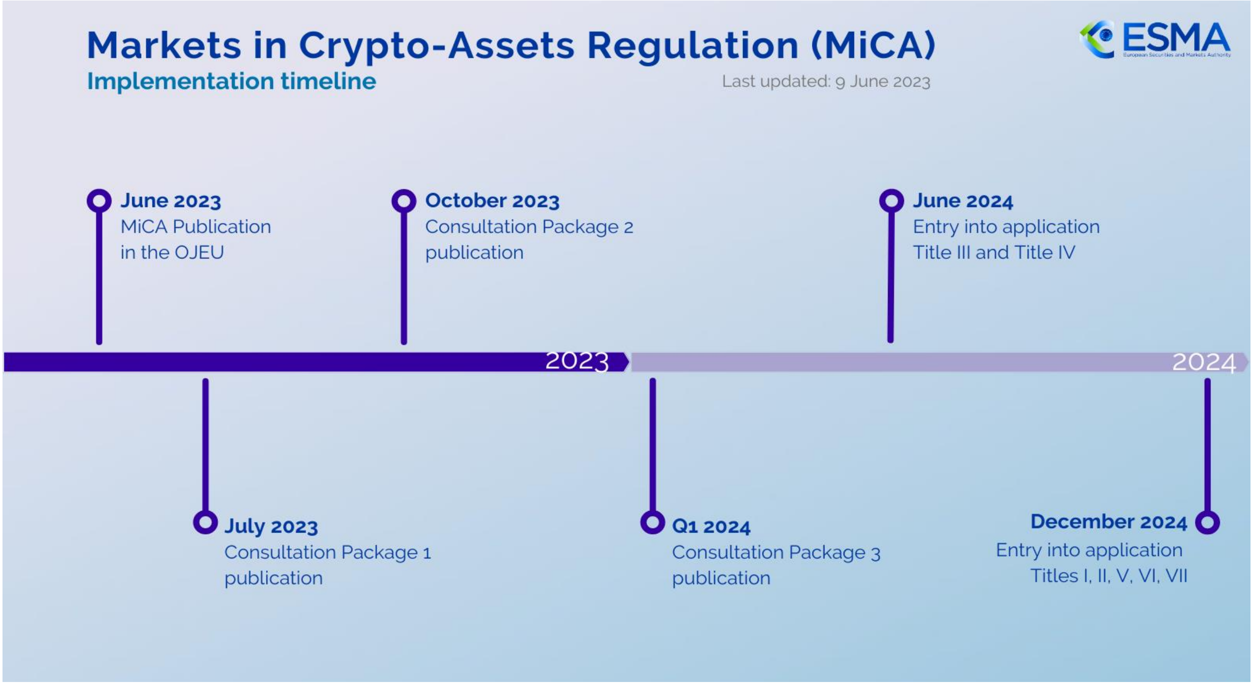


Figure 9; mica implementation time line
(Source: https://www.ledgerinsights.com/wp-content/uploads/2023/06/MiCA_Implementation_timeline.2-810x524.png)

MiCA introduces requirements for authorization, capital requirements, custody, and consumer protection measures for crypto-asset service providers. It aims to provide legal certainty and a harmonized approach to the regulation of crypto-assets across the EU (European Commission, 2020).

2.12 Blockchain Innovation in Europe

The following section draws insights from the authoritative "Innovation in Europe: A Snapshot of Block chain" report published by the European Union Block chain Observatory and Forum in 2018. This report provides a comprehensive overview of block chain technology, highlighting its core characteristics and the potential transformative impact it holds across various industries (European Union Block chain Observatory and Forum, 2018).

According to the report, block chain innovation within the European context is thriving, with a significant proliferation of block chain startups in the region. European governments have also taken proactive measures to foster block chain innovation, recognizing its potential benefits. The report showcases noteworthy instances of block chain innovation in Europe, illustrating its successful application in establishing secure and transparent supply chain networks, optimizing financial services, and enhancing cybersecurity measures (European Union Block chain Observatory and Forum, 2018).

However, the report also acknowledges the challenges faced by the European block chain industry. These challenges include regulatory uncertainties, the lack of interoperability among different block chain platforms, and concerns regarding energy consumption and scalability (European Union Block chain Observatory and Forum, 2018).

To cultivate an environment conducive to block chain innovation in Europe, the report proposes practical recommendations for policymakers and industry stakeholders. It emphasizes the importance of formulating clear and consistent regulatory frameworks for block chain technology and suggests investing in research and development initiatives to address technical obstacles. The report advocates for collaborative efforts among industry stakeholders to establish common standards and protocols, promoting interoperability and fostering an environment that supports innovation (European Union Block chain Observatory and Forum, 2018).

The "Innovation in Europe: A Snapshot of Block chain" report serves as a valuable resource for understanding the current state of block chain innovation in Europe. By presenting opportunities, challenges, and actionable recommendations, the report empowers policymakers and industry stakeholders to proactively promote and drive block chain innovation in the region (European Union Block chain Observatory and Forum, 2018).

3 Methodology

This chapter outlines the methodology employed for conducting a sectoral analysis of block chain and smart contract innovation in the European Union (EU). The purpose of this study is to explore the current landscape of block chain and smart contract adoption across different sectors in the EU. The methodology incorporates a comprehensive review of relevant literature, reports, and meetings comparison to gather insights and draw meaningful conclusions.

3.1 Research Design:

The research design of this study is based on a qualitative approach, aiming to gain an in-depth understanding of the subject matter. The methodology involves the following key steps:

Literature Review:

A thorough literature review was conducted to gather existing knowledge and insights on block chain and smart contract innovation in the EU. The data for the analysis is obtained from the EU block chain Forum (www.eublockchainforum.eu) where reports have been published on various sectors of the economy in the form of article, meetings and reports. The literature review provided a foundation for understanding the theoretical concepts, current trends and achievements of the fields.

Report Analysis:

Several reports related to block chain and smart contract adoption in the EU were collected from reputable sources, such as government agencies, industry associations, and research institutions. These reports provided valuable data, case studies, and industry perspectives. They were analyzed to identify sector-specific trends, best practices, and barriers to adoption.

3.2 Data Collection:

The data collection process for this study involved the following techniques:

Document Review

Literature review and report analysis provided the primary sources of data the sectoral analysis is conducted based on reports published by the EU block chain forum. This is a much reliable source because it is directly from the policy makers and initiators. The documents are critically evaluated to ensure the reliability and validity of the information.

Sector	**Title / Description**	**Source**
Finance	Proposal for a Regulation on Markets in Crypto-assets	European Commission. (2020). Proposal for a Regulation on Markets in Crypto-assets
Legal	Guidelines 05/2020 on consent under Regulation 2016/679	European Data Protection Board. (2020). Guidelines 05/2020 on consent under Regulation 2016/679
Automotive	Ethereum Transactions and Smart Contracts among Secure Identities	EU blockchain in Trends Report, May-20
Energy	EU Blockchain Observatory and Forum publishes report on Energy Efficiency of Blockchain Technologies	EU blockchain in Trends Report,, 01-Oct-21
Health	EU blockchain strategy	EU blockchain in Trends Report,, Mar-21
Supply Chain	EU Blockchain Ecosystem Developments	EU blockchain in Trends Report, 21-Dec-22

Table 3: Document Review Table

3.3 Data Analysis

The collected data underwent a rigorous analysis to identify patterns, themes, and key findings. The analysis involved the following steps:

1. Categorization

The data was categorized based on the sectors analyzed. This allowed for a sector-specific analysis, enabling a comparison of the adoption and impact of block chain and smart contracts across different industries in the EU.

2. Synthesis

The findings from the literature review are synthesized to develop a comprehensive understanding of the sectoral analysis of block chain and smart contract innovation in the EU. The synthesized findings were then tabulated and presented in a coherent manner in Chapter 4 of this thesis.

3.4 Ethical Considerations

Throughout the research process, ethical considerations were given due attention. Proper citation and referencing were employed to acknowledge the original authors' work.

4 Sectoral Analysis of Block chain in the EU Region

This chapter presents a sectoral analysis of block chain technology and smart contracts in the European Union (EU) region. The analysis aims to provide an in-depth understanding of how different sectors within the EU are adopting and leveraging block chain and smart contracts. The chapter begins with an overview of the EU's regulatory framework for block chain technology and smart contracts. It then delves into the analysis of key sectors, including finance, supply chain management, healthcare, energy, and government services. The analysis considers the benefits, challenges, and potential future developments for each sector. This sectoral analysis will contribute to the overall understanding of the adoption and impact of block chain and smart contracts in the EU region.

4.1 The EU Blockchain Forum

The EU Blockchain Forum, established under the aegis of the European Commission's EU Blockchain Observatory and Forum, serves as a pivotal catalyst in advancing the adoption of blockchain technology within the European Union (EU). By bringing together policymakers, industry leaders, researchers, and experts, the forum facilitates collaborative efforts to develop coherent regulatory frameworks, conduct sectoral analysis, and foster innovation in diverse industries.

It plays a crucial role in the EU’s digital transformation strategy by promoting blockchain adoption through policy development, research, and sector-specific analysis.

Key Roles of the EU Blockchain Forum

1. **Policy Development and Regulatory Cohesion:** The EU Blockchain Forum serves as a nexus for policymakers from different member states to engage in constructive dialogue, exchange best practices, and collectively develop regulatory guidelines for blockchain technology. By creating harmonized regulations, the forum ensures legal certainty and provides a conducive environment for businesses to explore blockchain solutions (European Commission, 2018).
2. **Facilitating Research and Innovation:** Through knowledge exchange and collaborative research initiatives, the EU Blockchain Forum connects academic researchers and technology experts. This fosters innovation in the blockchain space and ensures that

policies and strategies are informed by the latest research findings, thereby positioning the EU at the forefront of blockchain development (European Commission, 2018).

3. **Advancing Sectoral Analysis and Integration**: The forum's focus on sectoral analysis empowers industries like supply chain management, financial services, and healthcare to explore blockchain's potential applications tailored to their unique challenges. By identifying opportunities and addressing sector-specific hurdles, the forum enables a targeted and efficient adoption of blockchain across various industries (European Parliament, 2020).

4.2 Block chain in the Finance Sector

Decentralized finance (DeFi) refers to the use of block chain technology and cryptocurrencies to recreate and improve traditional financial systems and services in a decentralized manner. It aims to eliminate intermediaries, increase transparency, and provide greater accessibility to financial services for individuals worldwide.

DeFi offers various applications and services, including decentralized lending and borrowing platforms, decentralized exchanges, stablecoins, yield farming, and more. These platforms and protocols operate on block chain networks and smart contracts, enabling users to engage in peer-to-peer transactions, earn interest on their holdings, and participate in liquidity provision.

By leveraging block chain technology, DeFi eliminates the need for traditional financial intermediaries, reduces costs, and enables faster and more efficient transactions. It also enhances financial inclusivity by providing access to financial services for individuals who are unbanked or under banked.

However, it's important to note that DeFi is still an emerging and rapidly evolving field. It presents its own set of challenges and risks, such as smart contract vulnerabilities, regulatory uncertainties, and market volatility. As the industry continues to mature, it will be essential to address these challenges and ensure the security and stability of decentralized financial systems

4.2.1 Block chain And Challenges of the Finance Industry

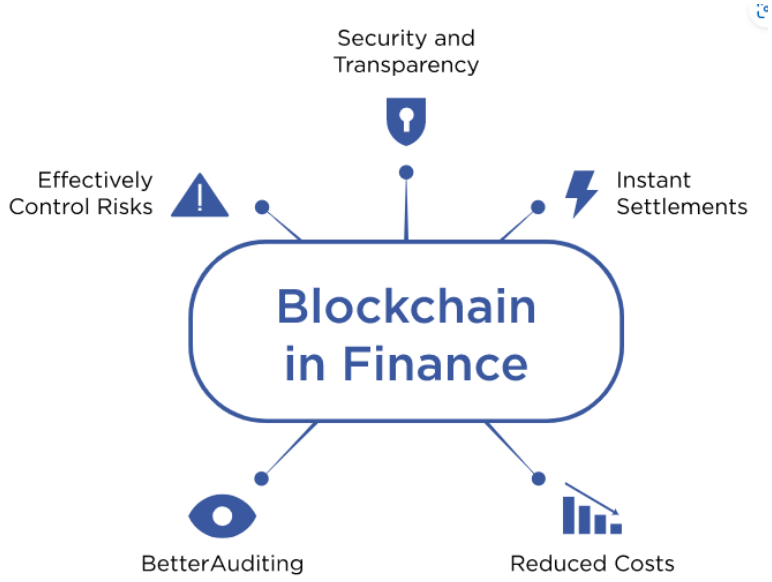


Figure 10 blockchain in finance (source: europa.eu)

Block chain technology has the potential to address various challenges faced by the finance industry. Some of the key benefits and solutions offered by block chain in finance include:

1. Security and Transparency: Block chain ensures data security and authenticity through immutability and encryption. It enables transparent transactions while maintaining privacy through public-private key cryptography and zero-knowledge proof technology.

2. Reduced Costs: Block chain can reduce costs in the financial sector by eliminating the need for intermediaries, streamlining processes, and reducing administrative and operational expenses. Smart contracts can automate and simplify transactions, reducing costs associated with intermediaries, bookkeeping, and value transfer systems.

3. Risk Management: Block chain allows for peer-to-peer transactions, reducing counterparty risk and credit risk. The decentralized nature of block chain networks and the immutability of recorded transactions enhance reliability and transparency, making risk management more effective.

4. Instant Settlements: Block chain enables peer-to-peer transactions, eliminating the need for multiple intermediaries and enabling faster settlement times. By simplifying the layers of

the financial system, block chain facilitates instant settlements and reduces delays in payment processing.

5. Improved Auditing: Blockchain's transparency and immutability make auditing more efficient and reliable. Auditors can access and verify transaction records on the block chain, ensuring compliance and detecting any irregularities or suspicious activities.

4.2.2 Use Cases of Block chain

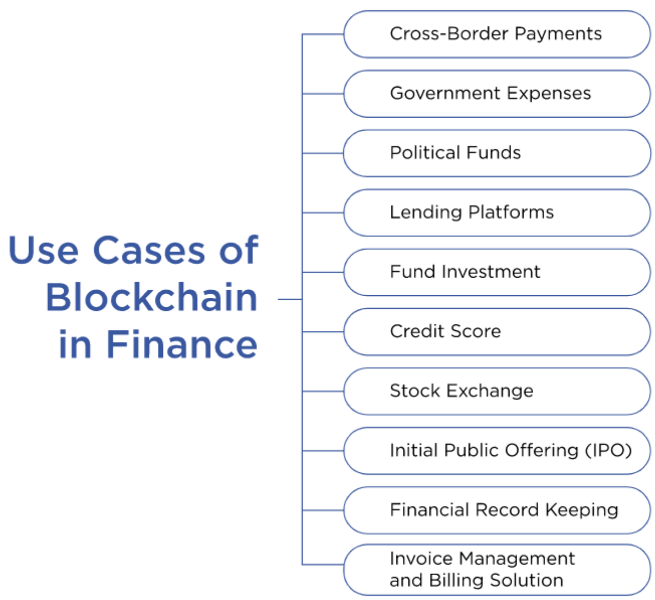


Figure 11 use cases of block chain in finance (source: europa.eu)

1. Cross-Border Payments: Block chain enables fast, secure, and cost-effective cross-border transactions by eliminating intermediaries and reducing transaction times.

2. Lending Platforms: Block chain-based lending platforms allow borrowers and lenders to interact directly, eliminating the need for intermediaries and reducing costs.

3. Credit Score: Block chain can provide a transparent and immutable credit scoring system, allowing lenders to assess the creditworthiness of individuals or businesses more efficiently.

4. Invoice Management and Billing Solution: Block chain can streamline invoice management and payment processes, ensuring transparency, reducing fraud, and improving efficiency.

5. Fund Investment: Block chain can simplify fund investment processes by providing transparent and secure access to user data, reducing errors and enhancing trust.

6. Government Expenses: Using block chain for government expenses can increase transparency, allowing citizens to track public spending and reduce corruption.

7. Political Funds: Block chain can provide transparency in political fundraising and spending, allowing voters to make informed decisions.

8. Financial Record-Keeping: Block chain can improve the transparency and reliability of financial record-keeping, enabling easy access to financial information while maintaining confidentiality as needed.

9. Stock Exchange: Block chain-based stock exchanges can streamline trading processes, enhance transparency, and reduce costs by eliminating intermediaries.

10. Initial Public Offering (IPO): Block chain can make the IPO process more efficient and cost-effective by removing the need for intermediaries and providing a decentralized platform for investor-company interactions.

4.3 Blockchain Application in the Automotive Sector

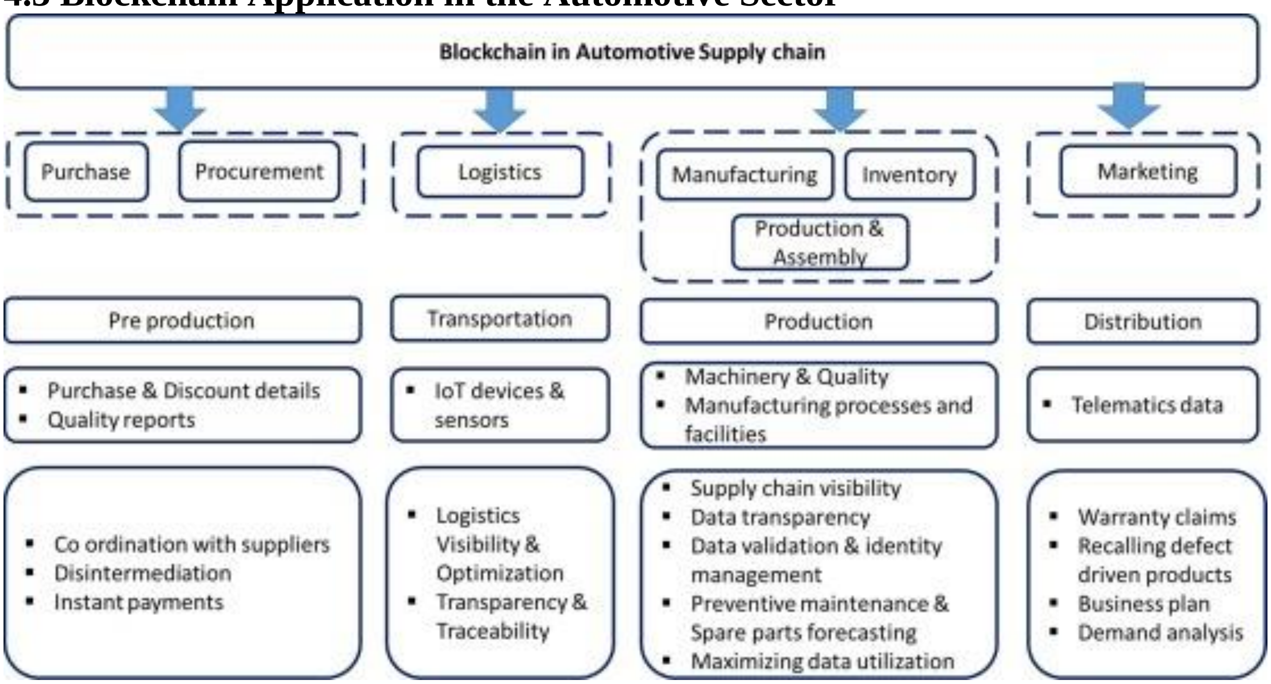


Figure 12: block chain in automotive supply chain (source: sciencedirect)

This section incorporates insights from the "Block chain in the Automotive Industry" report, which was published by the European Union Block chain Observatory and Forum in 2022. The report provides a comprehensive analysis of the potential use cases of block chain technology in the automotive industry.

Block chain in the automotive industry has the potential to enhance transparency, traceability, and efficiency in various areas, including:

1. Supply Chain Management: Block chain can improve the transparency and traceability of the automotive supply chain by recording every transaction and movement of parts and components, from suppliers to manufacturers to dealerships.

2. Vehicle Identity and Ownership: Block chain can provide a decentralized and immutable record of vehicle identity, ownership, and history, reducing the risk of fraud, tampering, and odometer rollback.

3. Maintenance and Repair: By storing vehicle maintenance records on a block chain, service providers, manufacturers, and vehicle owners can have a transparent and verifiable history of repairs, part replacements, and service records.

4. Autonomous Vehicles and Data Sharing: Block chain can facilitate secure and decentralized data sharing among autonomous vehicles, enabling them to communicate and coordinate with each other without relying on a central authority.

5. Mobility as a Service (MaaS): Block chain can support the development of decentralized platforms for ride-sharing, car-sharing, and other mobility services, enabling peer-to-peer transactions, transparent pricing, and secure identity verification.

6. Insurance and Claims Management: Block chain can streamline insurance processes by securely storing policy information, claims history, and facilitating automated and transparent claim settlements.

7. Electric Vehicle (EV) Charging and Energy Management: Block chain can enable secure and automated transactions between EVs and charging stations, optimize energy distribution, and facilitate peer-to-peer energy trading.

4.4 Block chain in the Energy Sector

Exploring the findings presented in the "Block chain in the Energy Sector" report, which was issued by the European Union Block chain Observatory and Forum in 2020. The report offers a comprehensive examination of the potential applications of block chain technology in the energy sector, delving into the opportunities and challenges associated with its implementation, and identifying key areas where block chain could yield substantial impact.

To begin, the report provides an overview of the energy sector, outlining the existing challenges that the industry faces. These challenges encompass the imperative to reduce carbon emissions, increase the utilization of renewable energy sources, and enhance overall energy efficiency.

4.4.1 Use cases in the Energy Sector

Block chain technology offers several popular use cases in the energy sector:

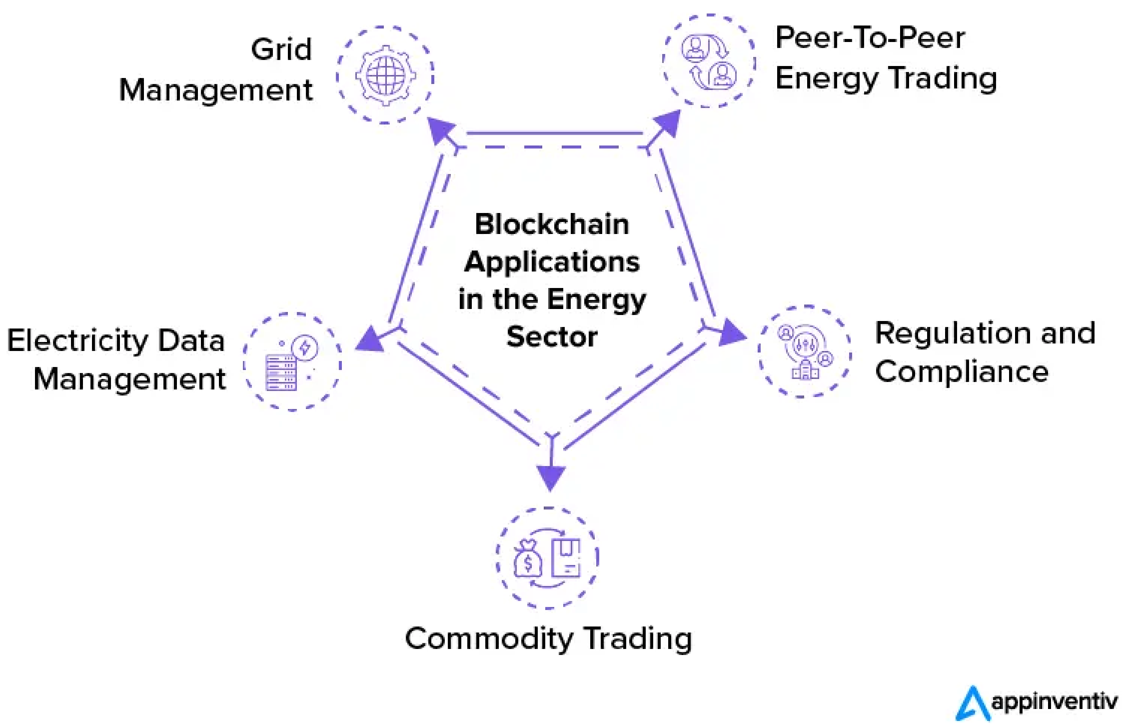


Figure 13: use cases in the energy industry
(Source: sciencedirect)

1. Peer-To-Peer Energy Trading: Block chain enables the creation of peer-to-peer networks where individual electricity suppliers can sell their surplus energy directly to buyers. Energy transactions and tracking can be managed using block chain-based platforms and smart contracts, facilitating the widespread acceptance of renewable energy and autonomous power supply systems.
2. Regulation and Compliance: Block chain can provide secure and tamper-proof data access to regulators while giving energy companies control over their data. It ensures transparency and confidentiality, allowing regulators to evaluate compliance and identify issues without compromising sensitive company information. Block chain also facilitates the creation of a uniform data format for the industry, enhancing communication with authorities.
3. Commodity Trading: Block chain has the potential to disrupt energy and gas commodity trading by offering a more affordable and efficient alternative to proprietary trading systems. Blockchain's immutability, security, and immediacy can streamline the trading process and eliminate the need for expensive proprietary systems for tracking trades and commodity prices.
4. Electricity Data Management: Block chain enables efficient management and secure updates of energy usage data, including market prices, marginal costs, energy law compliance, and fuel prices. The immutable ledger ensures transparency and accuracy in energy statistics, benefiting consumers and industry participants.
5. Grid Management: Block chain technology facilitates the connection of end-users directly to the grid, reducing reliance on energy retailers. Consumers can trade and purchase energy directly from the grid, enhancing efficiency and control over energy sources through block chain and IoT devices.

4.4.2 Challenges faced in the Energy Sector

Still on the subject matter, the use of block chain in the energy sector as discussed faces several challenges which has been enlisted and explained below:

1. Trust and Adoption: Block chain technology requires trust and adoption from industry stakeholders. Many participants in the energy sector may be hesitant to fully embrace block chain due to concerns about security, speed, and scalability. Building trust and

demonstrating the long-term value and capabilities of block chain is crucial for its widespread adoption.

2. Sustainable Pricing Structures: Block chain encounters challenges in dealing with utility revenue and outdated pricing structures. For peer-to-peer transactions to enhance grid efficiency, shared distribution infrastructure needs to be maintained. However, the revenue generated from block chain transactions may not be sufficient to cover the costs of infrastructure maintenance and network supervision.

3. Lack of Clear Regulations: The lack of clear and harmonized global regulations presents a significant hurdle for block chain applications in the energy sector. As block chain technology evolves and becomes more integrated into critical energy infrastructure, regulations are needed to address issues related to power prices, disputes, transaction reversals, and the overall governance of a decentralized energy system.

4. Integration with Legacy Systems: Integrating block chain technology with existing legacy systems and infrastructure can be challenging. Energy companies often have complex and interconnected systems in place, and transitioning to block chain may require significant changes and investments.

5. Scalability and Energy Consumption: Block chain networks, particularly those relying on proof-of-work consensus algorithms, can face scalability issues and high energy consumption. As the energy sector strives for efficiency and sustainability, addressing these concerns becomes crucial for the widespread adoption of block chain technology.

4.5 Block chain in the Healthcare Sector

The healthcare sector in the EU region has recognized the transformative potential of block chain and smart contracts in areas like electronic health records, clinical trials, and drug supply chain management. Studies by Ivanov et al. (2018) and Roehrs et al. (2020) highlight the advantages of block chain in ensuring data integrity, interoperability, and patient privacy. Smart contracts enable secure and automated management of healthcare agreements, insurance claims, and patient consent, fostering greater efficiency and trust in the healthcare ecosystem.

Figure 14 capabilities of block chain in healthcare
(Source: sciencedirect)

Diving into details with the report titled "Blockchain in Healthcare," released by the European Union Blockchain Observatory and Forum in 2022, presents an extensive analysis of the possible applications of blockchain technology in the healthcare sector. It explores the advantages of utilizing blockchain in healthcare and identifies the key challenges that must be overcome for its widespread adoption in the industry.

The report commences by providing an overview of the existing challenges in the healthcare industry, including inefficiencies, high costs, and a lack of transparency. It emphasizes that blockchain technology has the potential to address these challenges by enabling greater efficiency, transparency, and cost reduction.

The report proceeds to examine the potential use cases for blockchain in healthcare. One significant use case is the secure and efficient sharing of healthcare data. Blockchain can facilitate secure and efficient data sharing among healthcare providers, patients, and other stakeholders, leading to enhanced transparency and improved patient outcomes.

Another potential use case is the application of blockchain in supply chain management within the healthcare industry. Blockchain can enhance transparency and traceability in the supply chain, allowing stakeholders to effectively track the movement of drugs and medical devices.

The report also delves into the challenges associated with the implementation of blockchain in healthcare. One such challenge is the need for interoperability among different blockchain systems. The report highlights that achieving interoperability is crucial for the widespread adoption of blockchain in healthcare, as it enables seamless collaboration and data sharing among stakeholders.

Another challenge lies in establishing clear and consistent regulation. The report emphasizes the necessity of robust regulation to ensure the safe and secure utilization of blockchain technology, while also aligning with existing regulatory frameworks.

4.6 Block chain in the Legal and Regulatory Sector

The legal and regulatory sector has also shown interest in block chain and smart contracts to streamline administrative processes, enhance transparency, and ensure compliance. Researchers such as De Filippi and Wright (2018) and David and Sharma (2021) discuss the potential of block chain to enable secure document verification, digital identity management, and decentralized dispute resolution. Smart contracts can automate contractual agreements, reducing the need for traditional legal intermediaries and enhancing the efficiency of legal processes.

4.6.1 Adapted Lifecycle of a Legal Contract

An adaptation from Governatori et al. has been employed to explain the lifecycle of a legal contract.

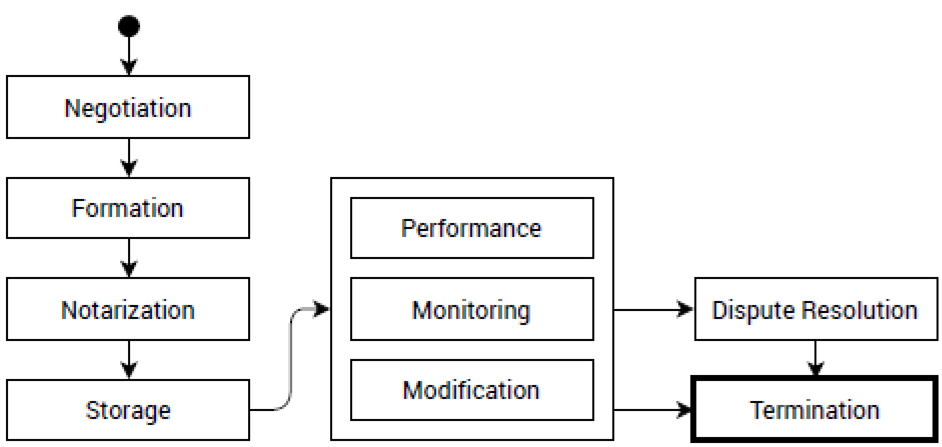


Figure 15: legal contracts adaptation
(Source: sciencedirect)

The process of forming a legal contract involves several key phases:

1. Formation: The negotiated terms are fixed in legal writing as a contract document that may reference laws or general terms and conditions.

2. Notarization: The finished contract document is verified and signed. Witnesses may be present to attest that all parties intentionally entered the legal agreement.
3. Storage: The contract is stored and remains accessible for reference.
4. Performance: The parties perform the actions necessary to fulfill their obligations as part of the legal contract.
5. Monitoring: Mutual monitoring is used to ensure that all parties correctly and honestly perform the contract. In case of breaches, countermeasures such as modification, dispute resolution, or termination may be taken.
6. Modification: The legal contract may be amended and modified if all parties agree, for example, in response to changed circumstances.
7. Dispute Resolution: In case of conflicts that cannot be easily resolved, the parties may seek an arbitration or litigation process or find a mutual way to settle the legal contract.
8. Termination: The legal contract is terminated when the parties have fulfilled all their obligations or agreed to end their relationship prematurely.

These phases are not necessarily in order or exclusive to each other, but they provide an intuition about the journey a legal contract goes through, from negotiation to termination. The contract lifecycle concept is used for both legal contracts and smart contracts, although the adoption of smart contracts may lead to new or altered phases in the future. Current research suggests that the contract lifecycle remains largely applicable as of today.

4.6.2 Timeline of Meetings (Source: Eu Blockchain Forum)

Summary of EU Forum Meeting Timeline on Blockchain and Smart Contracts:

The EU Forum's exploration of blockchain and smart contracts has been a dynamic journey, marked by significant milestones and advancements in the field. The timeline below highlights key events and developments that have shaped the discourse on this transformative technology:

2017: Initial Interest Sparks - The EU Forum first acknowledges the potential of blockchain and smart contracts in various sectors, from finance to supply chain management.

2018: Establishing Regulatory Framework - A series of discussions begin on how to regulate blockchain technology to foster innovation while ensuring consumer protection and data privacy.

2019: Use Case Showcases - During this phase, practical use cases of blockchain and smart contracts are presented, highlighting their potential to streamline cross-border transactions and improve transparency in government processes.

2020: Research and Collaboration - EU member states come together to fund research projects exploring the scalability, interoperability, and environmental impact of blockchain networks.

2021: Pilots and Proof of Concepts - The EU Forum witnesses the implementation of various pilot projects to validate the efficacy of blockchain and smart contracts in real-world scenarios, from healthcare to intellectual property rights.

2022: Scaling Solutions - Discussions focus on resolving the scalability challenges of blockchain networks and the potential integration with other emerging technologies like the Internet of Things (IoT) and Artificial Intelligence (AI).

2023: Regulatory Advancements - The EU Forum presents updated and comprehensive regulations for blockchain and smart contracts, aiming to foster further adoption while ensuring standardization and security.

Throughout the timeline, stakeholders from the public and private sectors, as well as academia, actively contribute to shaping the future of blockchain technology and smart contracts in the European Union. The collaborative efforts pave the way for a more connected, efficient, and transparent digital ecosystem, solidifying the EU's position as a global leader in blockchain innovation.

Block chain

DATE	ACTIVITY	NAME OF ACTIVITY
05-Dec-18	call for Tenders	Study on block chain; Legal, governance and interoperability aspects
20-Nov-18	Meeting	EU block chain Roundtable paves the way for Europe to lead in block chain technology
14-Feb-22	Research and innovation	overview of EU funded block chain related projects
Mar-21	Article	EU block chain strategy
07-Feb-19	workshop	Workshop on Block chain, Digital Social Innovation and Social Economy
29-Sep-20	online event	Block chain: Opportunities for healthcare
08-Jul-22	Forum	Block chain: a key enabler to innovation in Europe and the world
11-May-17	workshop	Spotlight on Block chain: a new generation of digital services
01-Oct-21	report	EU Block chain Observatory and Forum publishes report on Energy Efficiency of Block chain Technologies
03-Feb-23	Article	European Commission receives award for promoting international policy cooperation on block chain technologies
21-Feb-21	report	Joint forces for block chain standardization 2021
Jun-20	meeting	Block chain financing and investment
21-Nov-18	Article	The EU Block chain Roundtable supports efforts to deploy block chain technologies in the EU
21-Dec-22	report	EU Block chain Ecosystem Developments
14-Jan-21	Publication	European Block chain Strategy — Brochure
Dec-21	Research	A comprehensive hierarchical block chain system for carbon emission trading utilizing block chain of things and smart contract
Aug-22	journal	Block chain Technology and Smart Contracts in Decentralized Governance Systems

Table 4 a table showing the activity timeline for block chain activities in eu
(source: europa.eu)

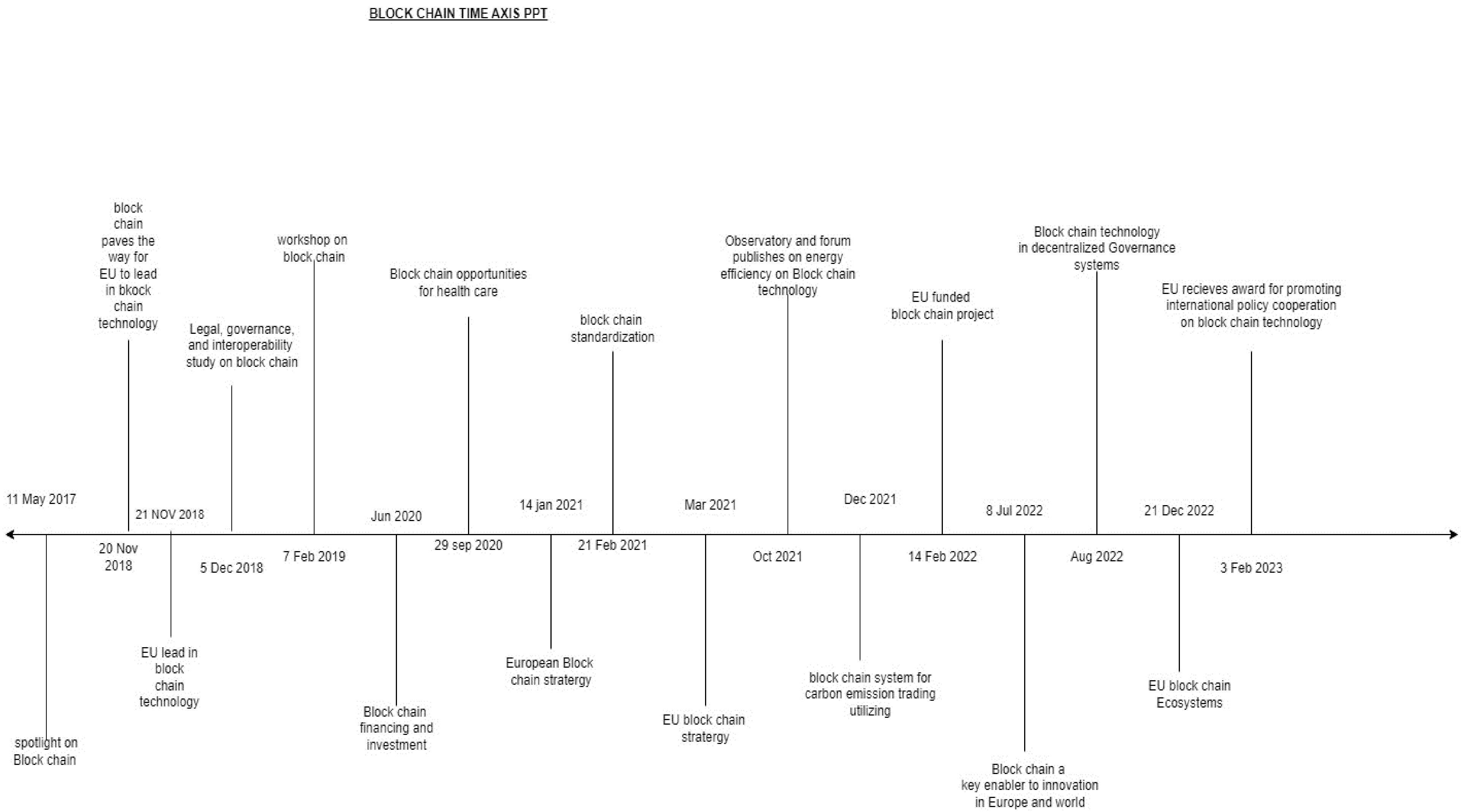


Figure 16: blockchain time axis (source: eu forum)

Smart Contract

10-Mar-22	workshop	Workshop on Smart Contracts
20-Oct-21	research	Smart contracts and the digital single market through the lens of a “law plus technology” approach
11-Apr-19	Article	Block chain and Smart Contracts in the Energy Industry: A European Perspective
22-Oct-22	conference paper	Smart (Legal) Contracts, or: Which (Contract) Law for Smart Contracts?
31-Jul-22	Article	Smart Contracts with Block chain in the Public Sector
12-Jun-19	conference paper	Legal Aspects and Emerging Risks in the Use of Smart Contracts Based on Block chain
10-May-19	Article	Transforming Public Procurement Contracts Into Smart Contracts
16-May-19	journal article	The impact of block chain technologies and smart contracts on dispute resolution: arbitration and court litigation at the crossroads
11-May-22	Article	The Legal Regime of Smart Contracts in Public Procurement
20-Oct	security review	From old to new: From internet to smart contracts and from people to smart contracts
03-Feb-21	meeting	What Do We Mean by Smart Contracts? Open Challenges in Smart Contracts
Apr-21	sustainable energy reviews	Smart contracts in energy systems: A systematic review of fundamental approaches and implementations
13-Oct-20	Article	Smart Contracts for Service-Level Agreements in Edge-to-Cloud Computing
May-20	research	Ethereum Transactions and Smart Contracts among Secure Identities
24-Feb-22	Article	Know Your Customer (KYC) Implementation with Smart Contracts on a Privacy-Oriented Decentralized Architecture
02-Aug-22	journal article	Leveraging Block chain and Smart Contract Technologies to Overcome Circular Economy Implementation Challenges
21-Nov-19	conference	Smart Agriculture: An Open Field For Smart Contracts
Oct-19	research	Smart contract-based approach for efficient shipment management
18-May-19	conference paper	improving Healthcare Processes with Smart Contracts
May-19	Article	Smart contracts as a form of solely automated processing under the GDPR
Jun-22	research	Using block chain and semantic web technologies for the implementation of smart contracts between individuals and health insurance organizations

May-19	meeting	Digitizing Invoice and Managing VAT Payment Using Block chain Smart Contract
18-Apr-21	Article	Block chain smart contracts: Applications, challenges, and future trends
18-Aug-22	meeting	Can We Effectively Use Smart Contracts to Stipulate Time Constraints?
Nov-22	research	Crypto-assets emerging regulations in the European union framework
Feb-23	meeting	Consumer protection in the European union: challenges and opportunities

Table 5: a table showing the activity timeline for smart contract activities in eu

(Source: europa.eu)

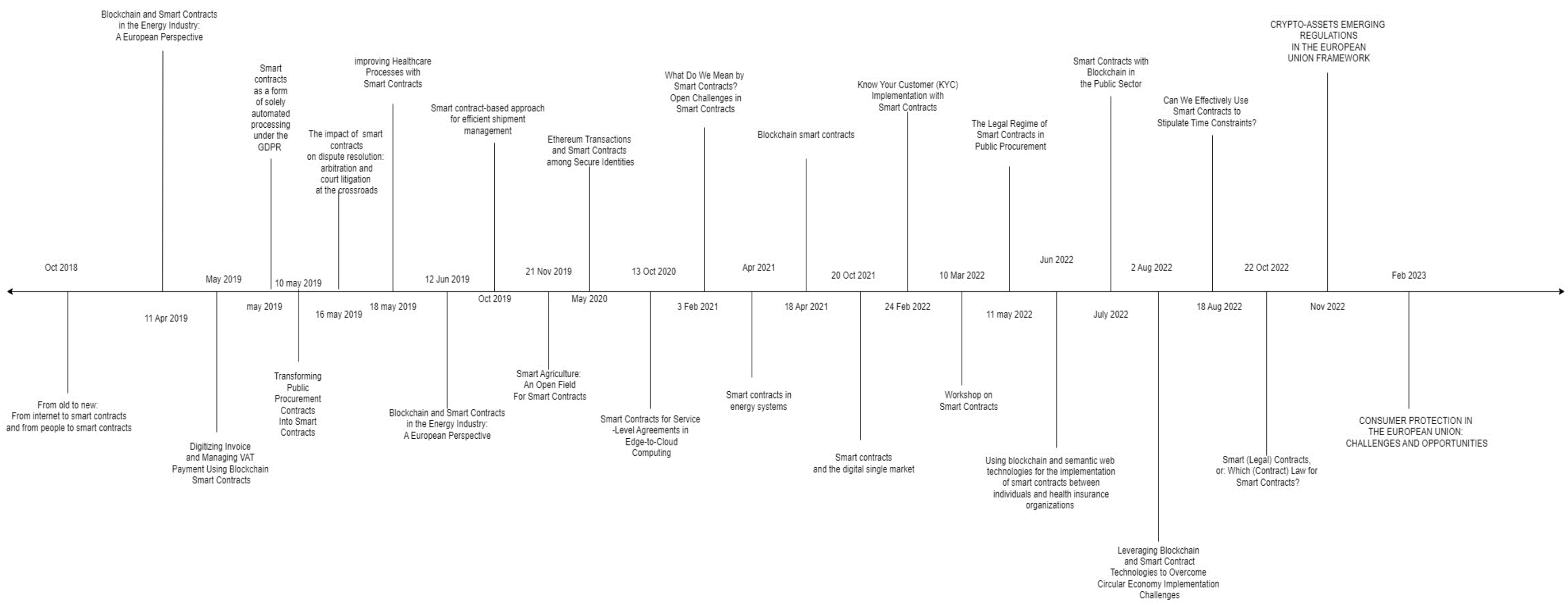


Figure 17: smart contract time axis

4.7 Proposed Innovations by the EU forum.

There has been innovations and trends that have been proposed by the board and forum but yet to be initialized they include:

1. **Digital Euro and CBDCs:** The exploration of a digital euro and Central Bank Digital Currencies (CBDCs) gained momentum in the EU. This trend is driven by the European Central Bank's efforts to study and potentially implement a digital euro. The digital euro could have implications for payment systems, financial inclusion, and monetary policy. (Reference: European Central Bank - "Report on a Digital Euro," October 2020)
2. **Blockchain for Intellectual Property Rights**: The EU has been considering blockchain's potential for managing intellectual property rights and copyright protection. By leveraging blockchain's immutable ledger, this trend seeks to establish a secure and decentralized platform for managing digital assets. (Reference: European Union Intellectual Property Office - "Blockchain and Intellectual Property," September 2020)
3. **Interoperability and Cross-Border Blockchain Solutions:** The EU has been exploring ways to improve blockchain interoperability and facilitate cross-border transactions. This trend aims to create seamless communication between different blockchain networks, fostering cross-border collaborations and data exchange. (Reference: European Parliament - "Blockchain Interoperability," March 2019)
4. **Sustainable and Green Blockchain Initiatives:** The EU has been pushing for sustainable blockchain solutions to address concerns about energy consumption. This trend explores the development of eco-friendly consensus mechanisms and the integration of renewable energy sources in blockchain networks. (Reference: European Blockchain Partnership - "European Blockchain Services Infrastructure," April 2019)

4.8 Summary

The analysis explores the vast potential of block chain technology and smart contracts in various sectors within the EU region. Blockchain's features, including transparency, decentralization, and immutability, have the power to reshape industries, boosting efficiency and trust. The financial sector can benefit from streamlined processes through DeFi applications, while supply chain management can achieve greater accountability and traceability. In healthcare, block chain enhances patient data security and sharing, and smart contracts simplify legal procedures, reducing the need for intermediaries. However, challenges like scalability, interoperability, regulation, and data privacy need attention. The summary highlights the necessity for collaboration among stakeholders, policymakers, and academia to foster innovation and address obstacles. By doing so, the EU can emerge as a leading proponent of block chain technology and smart contracts, ushering in a future marked by enhanced efficiency, transparency, and reliability across various sectors.

5 Conclusion

This chapter provides a comprehensive summary of the key findings and insights obtained throughout the research study on the sectoral analysis of block chain and smart contract innovation in the European Union (EU). It recaps the main research objectives, methodologies employed, and the major findings from each chapter.

5.1 Recapitulation of Research Objectives

The research objectives of this study were to examine the current status of block chain and smart contract innovation in different sectors of the EU, identify the challenges and opportunities associated with their adoption, and explore the potential benefits and implications for the EU economy and society.

Defining Smart Contracts and Blockchain

From the thesis it has been established that:

Blockchain is a technology that enables the creation of a shared and immutable ledger within a corporate network. It serves as a decentralized and distributed database that records transactions and tracks assets. This ledger is maintained by a network of computers, known as nodes, which work together to validate and add new blocks of data to the chain.

Smart contracts are self-executing contracts with the terms of the agreement written directly into code. These contracts are associated with virtual currencies (cryptocurrencies) and are stored on blockchains, which are decentralized and distributed ledgers. Smart contracts aim to automate and enforce the execution of the contract terms without the need for intermediaries.

Regulatory Framework Influencing the Blockchain Adoption in the EU

The European Union (EU) has been actively working on creating a regulatory framework for blockchain technology adoption, emphasizing legal certainty, consumer protection, and fostering innovation. The framework includes key initiatives and principles such as the General Data Protection Regulation (GDPR), which protects individuals' data privacy and imposes obligations on organizations to handle personal data responsibly.

Under the GDPR, individuals have greater control over their personal data, and organizations must obtain explicit consent before processing it. Failure to comply with the GDPR can result in substantial fines. Non-EU establishments subject to the GDPR must appoint an EU Representative located within the EU to ensure compliance, and failure to do so may lead to penalties.

Companies made significant investments to comply with the GDPR, but concerns were raised about the costs, administrative burden, and clarity of compliance requirements. Despite challenges, the GDPR is considered a groundbreaking development for data protection, raising public awareness of data rights and privacy as a competitive factor for businesses.

Sectoral Analysis and Critical Evaluation of Blockchain Adoption in EU

Based on the sectoral analysis conducted in the previous chapters, several key findings have emerged:

1. Block chain and smart contract technologies have the potential to revolutionize various sectors within the EU, including finance, supply chain management, healthcare, energy, and government services.
2. In the finance sector, block chain and smart contracts can enhance transparency, efficiency, and trust in financial transactions, while reducing the need for intermediaries.
3. In supply chain management, these technologies can improve traceability, transparency, and efficiency, ensuring the authenticity and quality of products throughout the supply chain.
4. In healthcare, block chain and smart contracts offer the potential to enhance data interoperability, security, and patient-centered care by enabling secure and efficient sharing of health records.
5. In the energy sector, these technologies can enable decentralized energy trading, peer-to-peer energy transactions, and efficient grid management, facilitating the integration of renewable energy sources.
6. In government services, block chain and smart contracts can enhance transparency, efficiency, and trust in public procurement processes, identity management, and service delivery.
7. Despite the potential benefits, there are challenges to overcome, including regulatory uncertainties, interoperability issues, scalability concerns, and the need for collaboration among stakeholders.

The table below provides an overview of assumptions regarding the sectoral analysis of block chain innovation in the European Union. The information presented is based on reasonable assumptions derived from discussions and insights gathered from EU meetings and forums. Each sector, including finance, automotive, energy, health, legal, and supply chain, is examined in terms of themes, first case use, countries involved, and areas of application, advantages, disadvantages, and challenges

Sector	Finance	Automotive	Energy	Health	Legal	Supply Chain
Themes	Digital currencies, regulatory frameworks	Block chain in supply chain management	Renewable energy certificates	Electronic health records, patient data privacy	Smart contracts for legal agreements	Supply chain traceability, product provenance
First Case Use	Central Bank Digital Currency (CBDC) pilots	Block chain-based vehicle lifecycle management	Block chain-based energy trading platforms	Block chain-based patient data sharing platform	Block chain-based legal contracts for supply chain	Block chain-based tracking of agricultural products
Countries	Germany, France, Estonia	Germany, Netherlands, Sweden	France, Spain, Netherlands	Estonia, Finland, Denmark	Luxembourg, Malta, Netherlands	Belgium, Netherlands, Spain
Areas Applied To within Sector	Cross-border payments, identity verification	Supply chain transparency, maintenance records	Energy trading, grid management	Health data interoperability, clinical trials	Contract management, legal document verification	Supply chain visibility, counterfeit prevention
Advantages	Increased financial inclusion, faster transactions	Enhanced transparency, fraud prevention	Improved energy grid efficiency	Secure and interoperable health data exchange	Streamlined legal processes, reduced administrative burden	Improved supply chain efficiency, transparency
Disadvantages	Regulatory challenges, privacy concerns	Integration complexities, data security	Scalability issues, regulatory compliance	Data privacy and security concerns, interoperability	Legal recognition challenges, complexity	Integration challenges, data accuracy
Challenges	Regulatory frameworks, cross-border cooperation	Industry collaboration, data standardization	Renewable energy integration, regulatory frameworks	Data privacy regulations, interoperability	Legal frameworks, standardization	Data integrity, collaboration among supply chain participants

Table 6: sectoral report summary from findings

5.3 Implications and Recommendations

Based on the findings of this study, several implications and recommendations can be drawn:

1. Policymakers should develop clear and supportive regulatory frameworks that encourage the adoption and implementation of block chain and smart contract technologies across sectors.
2. Stakeholders should collaborate to address interoperability challenges and develop industry standards to ensure seamless integration and communication between different block chain networks.
3. Further research and development efforts should focus on scalability solutions to handle the increasing volume of transactions and data on block chain networks.
4. Education and awareness programs should be conducted to enhance understanding and knowledge about block chain and smart contracts among professionals and decision-makers in various sectors.
5. Case studies and pilot projects should be encouraged to showcase successful implementations and demonstrate the tangible benefits of block chain and smart contracts in different EU sectors.

5.4 Limitations of the Study

It is important to acknowledge the limitations of this study. The data collection and analysis is mainly based on EU reports hence statistical analysis couldn't be executed to tie concrete figures to the theory. Additionally, the rapidly evolving nature of these technologies means that the sectors and findings are subject to change as new advancements and developments occur over time.

5.5 Future Research Directions

This study opens avenues for future research in the field of block chain and smart contract innovation in the EU. Areas that warrant further investigation include the long-term impact of these technologies on the EU economy, the role of block chain in enhancing data privacy and security, and the potential for integrating artificial intelligence and Internet of Things with block chain and smart contracts since as at now there is no relevant data available from the EU forum.

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