Grant Agreement No.: 101102718 Call: DIGITAL-2022-DEPLOY-02

Type of action: DIGITAL-CSA

SEEBLOCKS.eu
Supporting Europe's effort in Blockchain/DLT Standardisation

D3.3 Landscape & Gap Analysis Report on Blockchain - Mid Term

Work package	WP3 "Pan-European and international synergies"
Task	T3.3
Due date	31/05/2024[1]
Submission date	28/06/2024
Deliverable lead	DCU
Version	V1.0 DRAFT NOT YET APPROVED BY THE EUROPEAN COMMISSION
Authors	Mohammad Fardad, Irina Tal, Fiona Delaney, Sharon Farrell
Reviewers	FhG (Simone Wurster & Knut Blind)
Keywords	Landscape Report, Open Standards, Terminology

[1] The "Due date" was postponed to 30/06/2024 after receiving permission from the Project Officer.

Document Revision History

Version	Date	Description of change	List of contributors
0.1	12/06/24	Table of Contents, Structure agreed	Sharon, Fiona, Mohammad, Irina
0.2	21/04/24	Section 1: Introduction	Mohammad, Fiona
0.3	21/04/24	Section 2, 3	Mohammad, Irina, Fiona
0.4	25/06/2024	Section 4, Conclusion, review and updates	Fiona, Irina
0.5	26/06/2024	Peer-review and formatting	Simone Wurster & Knut Blind
1.0	28/06/2024	Final quality check	Sharon

Disclaimer

SEEBLOCKS.eu has received funding from the European Union's Digital Europe Programme under Grant Agreement No. 101102718. The content of this document does not represent the opinion of the European Union, and the European Union is not responsible for any use that might be made of such content.

The European Commission is not liable for any use that may be made of the information contained herein.

Copyright notice

Dissemination Level		
PU	Public, fully open, e.g., web	✓
CO	Confidential, only for members of the consortium (including the Commission)	
EU-RES	Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)	
EU-CON	Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)	
EU-SEC	EU-SEC. Classified Information: SECRET UE (Commission Decision 2005/444/EC)	

* *R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

Executive Summary

Table of Contents

List of Tables

List of Figures

Abbreviations

Acronym	Description
AML	Anti Money Laundering
API	Application programming interface
AWI	Approved work item
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht
CD	Committee draft
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
DID	Decentralised Identifier
DLT	Distributed Ledger Technologies
DAO	Decentralized autonomous organization
EBP	European Blockchain Partnership
EBSI	European Blockchain Services Infrastructure
EC	European Commission
EIP	Ethereum Improvement Proposal
ERC	Ethereum Request for Comment
ETSI	European Telecommunications Standards Institute
EU	European Union
eWpG	Gesetz zur Einführung elektronischer Wertpapiere
FACR	Financial and Administrative Coordinator Representative
FATF	The Financial Action Task Force
FG	Focus group
HTTP	Hyper Text Transfer Protocol
INATBA	International Association for Trusted Blockchain Applications
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
ISMS	Information security management system
ISO	International Standards Organisation
ITU	International Telecommunication Union
JWG	Joint working group
KWG	Kreditwesengesetz
MiCA	Markets in Crypto Assets
MiFID	Markets in Financial Instruments Directive

Acronym	Description
NB	National (standards) body
NC	National committee
NFT	Non-fungible token
NSB	National Standard Bodies
OID	Object identifier
PWI	Proposed work item
RFC	Request for comment
SDO	Standard development organisation
TC	Technical committee
TR	Technical report
TS	Technical specification
URI	Universal resource identifier
VASP	Virtual asset service provider
WD	Working draft
WG	Working group
WSC	World Standards Cooperation

1. Introduction

Blockchain and Distributed Ledger Technologies (DLT) continue to play a transformative role in the modern digital economy and are regarded as a foundational technology in the European single digital marketplace. This report is the second in a series of three Landscape Reports to be published by SEEBLOCKS.eu that provide an extensive analysis of the existing international standards landscape, identifying gaps, and presenting some concrete responses to address these, aiming to foster a cohesive and resilient blockchain ecosystem.

The first report D3.1 Blockchain & DLT Standards & Landscape Report described the context of international standards-making, elaborating the formal consensus processes that underpin the voluntary standards-making activities at international standards development organisations (SDOs) such as ISO, IEC and CEN contrasting these with the informal consensus-building that takes place at IEFT, W3C and other open blockchain protocols such as Bitcoin, Ethereum and other public blockchains.

This new report focuses on the current state of the art in blockchain standards, reviews recent industry publications on emerging standards requirements and identifies common perspectives, gaps and priority areas for future standardisation, ensuring that our ongoing efforts are aligned with the needs of the market and society.

The SEEBLOCKS.eu initiative remains committed to accelerating the interoperability, preparedness, and resilience of the EU single digital marketplace through targeted research and development in blockchain and DLT open standards.

This report aligns with SEEBLOCKS.eu's mission to offer strategic analysis of the blockchain landscape and proposes actions to enhance standardisation efforts. This report focuses on several key areas, including the current adoption and use cases of blockchain technology, recent technological advancements, standardisation efforts, identified gaps, and future directions for research, development, and standardisation initiatives.

As a mid-term analysis, this report serves as a critical checkpoint for the SEEBLOCKS.eu project, ensuring that efforts are targeted and effective in supporting the growth and resilience of the European single digital marketplace.

2. Landscape Analysis

This report builds on the first SEEBLOCKS landscape and gap analysis report on Blockchain/DLT with a particular focus on the latest developments and publications in this area. D3.1 key areas were: 1) the focus on Blockchain in Europe and the importance of standardisation in this context, 2) the main standardisation bodies and industry representative bodies and the collaborative process behind creating open standards for blockchain and DLT and 3) some of the key Blockchain and DLT standards published.

This report expands on items 2) and 3) adding key analysis in the identification of gaps in blockchain and DLT standardisation and raises discussion on what might be prioritised in the near future.

D3.1. provided a classification of the standardisation organisations and their consensus-making characteristics. There are a number of types of SDOs including international, Regional, National and Industry organisations that are all recognised as standards-making bodies. Industry standards organisations and consortiums are important in driving progress in the Blockchain and DLT standardisation examples include: the International Token Standardization Association (ITSA), The Internet Engineering Task Force (IETF) and the Enterprise Ethereum Alliance (EEA).

An overview of standardisation organisations, working groups, their focus in the Blockchain and DLT standardisation and the output is presented in the table below, Table 1.

SDO	Organisation type	Committee/ Group	Focus Area	Published
ISO	International	ISO/TC 307	DLT Standardisation	12
ITU-T	International	TSAG	DLT, ICT	28
IEEE	International	CTS/BSC, C/BDL, BOG/CAG, CTS/DFESC, IES/IES, PE/SBLC, C/SAB, EMB/StdsCom	Blockchain, DLT, Consumer Technology, Digital Finance, Industrial Electronics, Smart Buildings, Standards Activities	15
CEN/CEN ELEC	European	JTC 19, WG 01	Decentralised Identity Management	
ETSI	European	ISG PDL, IPv6 groups	Permissioned Distributed Ledger, IPv6	17
ANSI	National	ASC X9, X9A	DLT Terminology, Blockchain Risk Assessment	3
NIST	National	CSD, ACD	Blockchain Security, Cybersecurity	5

SDO	Organisation type	Committee/ Group	Focus Area	Published
UNE	National	SC 307	Blockchain and Distributed Ledger Technologies	1
DIN	National	NA 043-0204 AA, NA 009-00-15-02 AK	DLT Specifications, Records Management	6
ITSA	Industry	PWG1, PWG2, PWG3	Token Standardisation, Token Identification, Token Classification, Token Analysis	1
IETF	Industry	Secure Asset Transfer Protocol WG	Secure Asset Transfer, Cross-Network Asset Transfer	many
EEA	Industry	6 Active Working Groups	Enterprise Ethereum, Blockchain Leaders, Adopters, Innovators, Developers, Businesses	many

Table 1: An overview of standardisation groups.

In the European context we understand there is an ongoing need for ongoing monitoring of ICT standards. This is highlighted by Action 1 of the EU Rolling Plan for ICT Standardisation[2] that calls for a continuous analysis of the possible standardisation gaps and identify solutions to fill them. in relation to blockchain and DLT, the published literature either focuses on particular areas (e.g. blockchain security standardisation [3], non-fungible tokens [2] or blockchain interoperability) or presents a very high-level, limited and outdated (at this moment) view on Blockchain standards as in [4] and [5]. ITU-T and ETSI conducted more comprehensive reviews on the DLT standardisation landscape in 2019 [6] and 2020 [7], respectively. However, ETSI's report is focusing on permissioned DLT only, and both of these reports are currently outdated. The most up-to-date efforts belong to SEEBLOCKS, D3.1 published in 2023, and INATBA. The latter published very recently (February, 2024) a systematisation of knowledge review on the DLT standardisation.

For this report, we will use as baseline, the most recent publications, our own D3.1 and INATBA's recently published review on Distributed Ledger Technologies standards [8]. In summary, [8] found 96 standard publications that can be found listed in a live Github repository [9] of INATBA's DLT Standards and Working Group. Noteworthy is the fact that BLOCKSTAND is mirroring this list in their Repository of Blockchain Standards[3]. SEEBLOCKS builds on this research and adds a new ISO publication, ISO/TR 6277:2024:

[2]https://joinup.ec.europa.eu/collection/rolling-plan-ict-standardisation/blockchain-and-distributed-digital-ledger-technologies-rp2024

[3]BLOCKSTAND Repositoty of Blockchain Standards, https://blockstand.eu/repository-of-blockchain-and-dlt-standards-online-catalogue/

Blockchain and distributed ledger technologies — Data flow models for blockchain and DLT use cases, led by SEEBLOCKS Strategic Lead, Fiona Delaney. This was published in February 2024. This new technical report consolidates a set of system-level models from ISO 23257:2022 and ISO/TR 3242:2022 to give a data-flow-centric description framework for blockchain and distributed ledger technology (DLT) use cases. This framework provides a clear understanding of data types and data flows in distributed ledger systems allowing for better-designed systems, better governance and risk management. It also represents a basis for interoperability modelling for the use cases that require data exchange in hybrid or orchestrated systems environments.

The latest overview of Blockchain and DLT standard publications is detailed in Annex 2. There are 97 standards listed, published by international, regional and national Standards development organisations. This listing is the most comprehensive to date and references will be added as content into the SEEBLOCKS Standards Visualisation Tool in due course.

In line with the analysis in the first Landscape Report and supporting the purpose of achieving SEEBLOCKS objectives, the same set of **Priority Areas (PA)** are itemised in the far right column in this section). In addition to foundational aspects (e.g., vocabulary, taxonomy, ontology), several blockchain and DLT-specific focus areas emerge including:

0. Foundations;
1. Identity management;
2. Data provenance;
3. Governance;
4. Token and asset creation and exchange;
5. Process optimisation;
6. Automation;
7. Cybersecurity;
8. Use cases.

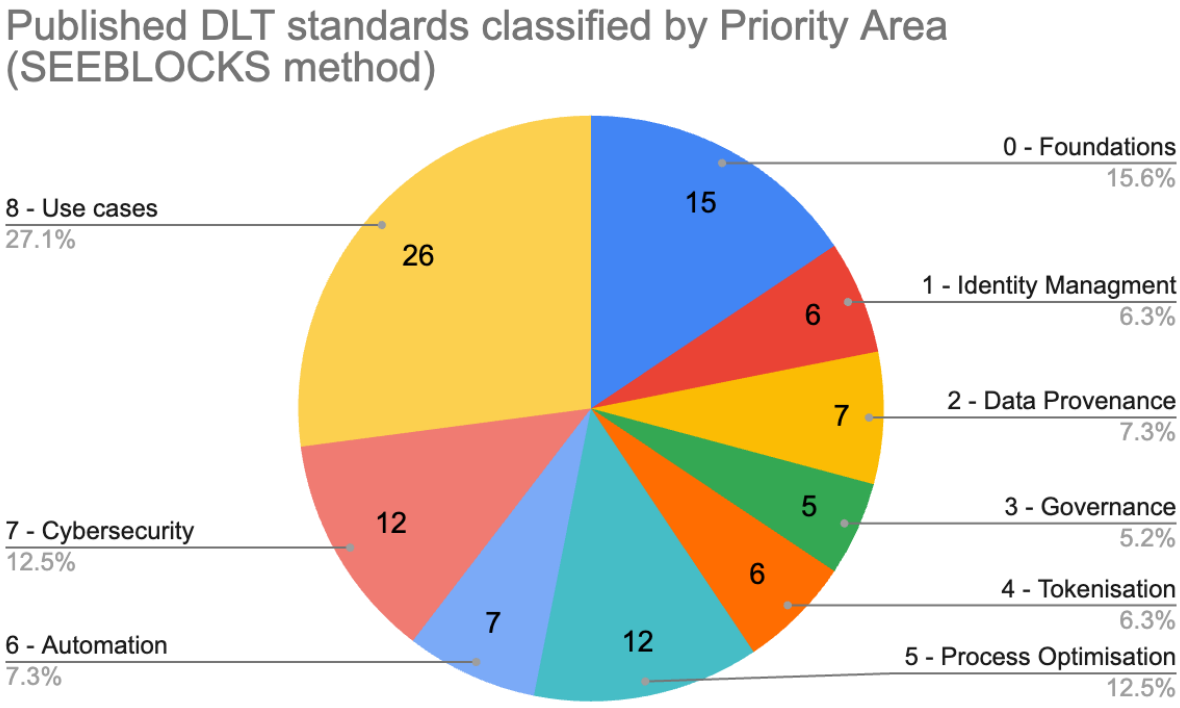

Figure 1. Standards distribution per Priority Area (SEEBLOCKS method)

Furthermore, the taxonomy proposed by INATBA [8], classifies these standards using Level 1 - 3 criteria/concepts as presented in ISO/TS 23258:2021, where Level 1 concepts are: Asset, Consensus, Smart Contract, Entity, Governance, Interoperability, Ledger, Permission, Record, Security, Service, System, Technology, and Trust.

Asset is further categorised in Digital Asset, Provenance (Level 2) and then further in Level 3 concepts: Digital Asset - Cryptographic Asset (Level 3), Povenanance - Origin of Asset, History of Asset, History of Custody and so on so forth for every Level 1 concept.

Our focus in this report is on Level 1 criteria. A distribution of the listed standards across Level 1 criteria is presented in the Figure below.

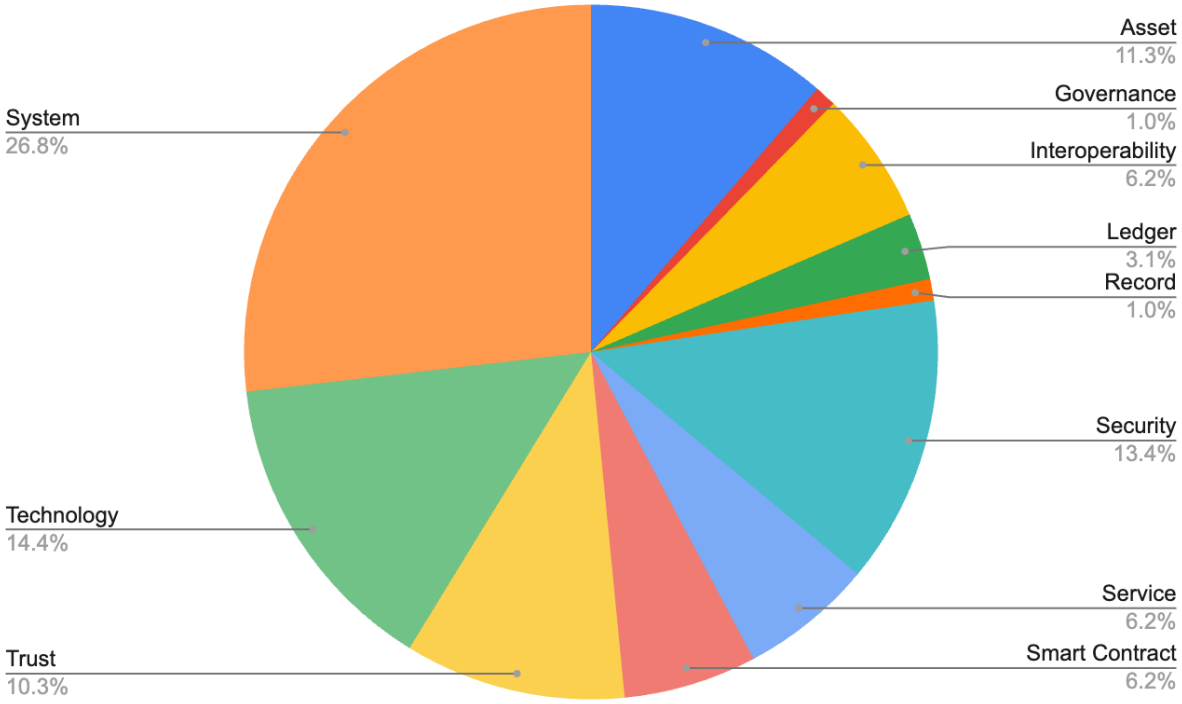

Figure 2: Standards distribution per Level 1 criteria (INATBA method)

Blockchain Industry Community Standards

While the INATBA report place protocol and smart contract standards (interface and application-specific, open blockchain protocols eg. Ethereum Enterprise Alliance) outside their scope. SEEBLOCKS research prefers to include consideration of these important open-source community efforts (usually occurring through informal RFC processes). D3.1 presented such standards, with a specific focus on the Ethereum Improvement Proposals (EIP) and Ethereum Request for Comments and the early SEEBLOCKS public consultation report evidences the importance of these community standards, and in the case of the respondents to the public consultation many had taken an active role in the development of such standards. Hence, a full landscape analysis on Blockchain and DLT standardisation would not be complete without reference to these industry community or protocol standards.

DLT standards development has been most actively done by industry and community organisations. Their work is different from that of formal standards-developing organisations as the specifications developed are usually published with an accompanying repository of open-source implementation code.

The Linux Foundation is an example of a community-driven organisation that provides support for a range of cross-industry blockchain applications. Hyperledger, hosted by the Linux Foundation, presently has a community of over 200 companies that are focused on the development and implementation of enterprise blockchain. Notably, their work has led one of their frameworks, Hyperledger Fabric, to be considered a de facto standard for enterprise blockchain platforms. An overview of the Hyperledger projects and their categorisation is presented in Table 3.

Hyperledger Project	**Category**
Solang	Tools
Iroha	General-Purpose Distributed Ledger
Indy	Decentralized Identity
Firefly	Connectivity/Integration Gateway
Fabric	General-Purpose Distributed Ledger
Cello	Deployment Automation
Caliper	Performance Benchmarking
Cacti	Cross-Chain Interoperability
Bevel	Deployment Automation
Besu	General-Purpose Distributed Ledger
Aries	Decentralized Identity
Anoncreds	Decentralized Identity
Web3j	Ethereum Integration Library
Identus	Decentralized Identity

Table 2: An overview of the hyperledger projects and their categorisation.

Additionally, the Eth.Global[4] movement uses community events and collaboration as a means to educate, test and raise awareness about novel applications and new use case domains, Recently, SEEBLOCKS.eu was pleased to sponsor the Eth.Dublin hackathon, hosting a challenge to complete a standard format project documentation based on ISO AWI 24878 new and emerging use cases. Below are summarised five of the winning projects described as DLT use cases. We showcase them here as a flavour of the innovative approach to social issues with decentralised socio-technical solutions.

[4] ETHGlobal website, https://ethglobal.com/

1. Arunraj Subburaj, Nandhini Kumar, Amir Thagadeshwaran, **TEAM: Block Trails.** *'Decentralized Clinical Trials: Enhancing Clinical Trial Management in Pharmaceuticals with Blockchain-Based NFT Systems'*. (Eth.Dublin hackathon, 2024)
2.

Decentralized Clinical Trials.	**Stakeholders**
Enhancing Clinical Trial Management in Pharmaceuticals with Blockchain-Based NFT Systems	1. Patients 2. Caregivers 3. Medical professionals 4. Clinical researchers 5. Pharma-cos 6. Regulatory bodies
Short description: Enhance clinical trial management in the pharmaceutical industry with a blockchain-based system that uses Non-Fungible Tokens (NFTs) to ensure transparency, access control, and stakeholder incentivization, addressing data access and tracking challenges.	
Why use DLT? Distributed Ledger Technology (DLT) is pivotal in this use case as it introduces a level of transparency, security, and efficiency previously unattainable with traditional data management systems. Blockchain ensures that all data related to clinical trials is immutable and traceable, which is crucial for maintaining integrity and trust. Smart contracts automate access and permissions, reducing the potential for human error and bias while ensuring compliance with regulations. Furthermore, DLT enables real-time tracking and automated incentivization, enhancing stakeholder engagement and ensuring that contributions are acknowledged and rewarded, thus fostering a cooperative and productive environment.	

3. Karleth, Faran, Harsha, Aws Al-Adhami, Luthiano Trarbach. **TEAM: ReguLend. *'Transforming Crypto into Instant Loans: Regulated lending intermediary'.*** (Eth.Dublin hackathon, 2024)

Transforming Crypto into Instant Loans.	**Stakeholders**
Regulated lending intermediary.	1. Central Bank 2. Crypto asset holders 3. Lenders 4. Other DeFi platfrom providers
Short description: We offer a regulated platform that empowers crypto asset holders to leverage their assets without needing to sell them. By using your crypto as collateral, you can access the funds you need quickly and securely. Our compliant and secure lending environment ensures your assets work for you, maintaining their value while providing financial flexibility.	
Why use DLT? The way people are choosing to pay for things is changing. According to a survey by the Federal Reserve of the United States in 2019 found that consumers used cash only for 26% of all payments. Users are relying more on the cashless transactions and prefer digital form of money. To facilitate the cashless transition in the society, central banks are planning to launch CBDCs to complement banknotes and coins. CBDC is a currency in digital form rather than having physical form like paper notes and coins. This could be considered as Euro being created and transferred in digital format instead of printing of physical notes. Unlike cryptocurrencies, CBDC is issued and backed by the central bank of that country and makes CBDCs less volatile than other digital currencies like Bitcoin and Ethereum. CBDC leverages a blockchain technology to create immutable and secure transactions. Blockchain is a peer-to-peer distributed ledger technology (DLT) in which immutable blocks are created to store data using a group of computer nodes. This technology is built using cryptographic hash functions, digital signatures, and consensus protocols to create a secure, transparent and trustless system.	

4. Conor D'Arcy, Evan McGrane. **TEAM: EVAN.** *'Ethereum vouched aggregator nexus: Improved swap UX - One-click confirmation for asset swap operations'*. (Eth.Dublin hackathon, 2024)

Improved swap UX	**Stakeholders**
Ethereum vouched aggregator nexus: Improved swap UX - One-click confirmation for asset swap operation	1. Blockchain end user
Short description: For EVM blockchains, each swap transaction requires an approval interaction and a signature interaction, sometimes with a supplementary permission interaction too. The best web2 systems have a simple "Confirm" or "Buy Now" single interaction. This use case matches that simplicity by securely bundling transactions and presenting a single signature interaction to the user.	
Why use DLT? The use case is an improvement for current EVM compatible swap transaction process limitations. So using a DLT, specifically an EVM compatible one, is a prerequisite for the user case.	

5. Taylor Ferran, Cat McGee, J. Murphy **TEAM: Private Peace Project.** *'Privacy-preserving emergency financing'.* (Eth.Dublin hackathon, 2024)

Privacy preserving emergency financing.	**Stakeholders**
Privacy preserving emergency financing.	1. Funders who wish to privately donate directly to people in need without a middle man. 2. People in need who wish to privately and directly
Short description: Enabling private financial aid for ZK verified humans in need.	
Why use DLT? Enables full privatisation of financial transactions. - Enables verification of a person's identity/geographical location without storing their data. - Cuts out the middle man of a centralised party/charity which would distribute these funds.	

6. Steven Neary, Eric McEvoy, Anthony Nixon, Robert Leahy TEAM: **SafeTi** *'Aiding the Irish Rental Crisis with Trustless Computing.'* (Eth.Dublin hackathon, 2024)

Aiding the Irish Rental Crisis with Trustless Computing.	**Stakeholders**
A trustless solution to balance incentives on both the renter and landlord sides of the rental equation.	1, Potential renters 2. Landlords
Short description: Aiding the Irish Rental Crisis with Trustless Computing. The Irish rental market is fraught with challenges. Viewings are rife with bias, Machiavellian competition, price disparities, and pure chance. No solutions exist to balance incentives on both the renter and landlord sides.	
Why use DLT? Safetí targets the most sensitive part of the rental process; rental viewings. The product empowers through: - Blind Bidding Auctions, configured with: Social Equity Boosted Points and Instantly Settled Immutable Matching Transactions. - The unique combination of TEE Hardware Execution Environments and Fully Encrypted Ethereum has not been applied to such a qualitative problem as this, within the rental market before.	

3. Gaps in Blockchain and DLT standardisation Landscape

This section identifies the current gaps that need to be addressed within Blockchain and DLT standardisation. We approach the topic from two strategic points of view, the first is industry informed the second, informed by the SEEBLOCKS Public Consultation findings, relies upon the EU Rolling plan for ICT standardisation (2024) to provide an analysis framework.

As aforementioned, the first analysis on the existing gaps employs an industry perspective informed by research outputs from INATBA and SEEBLOCKS.eu. INATBA has presented an analysis of how well different areas (as described by Level 1 criteria/concepts) are represented in terms of numbers of standards followed by an examination based on several factors. The determination of whether a concept should receive further standardisation can be made by considering the following criteria. INATBA defined criteria A, B, C, and SEEBLOCKS added criteria D and E.

Criteria Table of Concept and further Standardisation

ID	Description	Example
Note A-C are defined by INATBA [8], while D and E are SEEBLOCKS.eu additions.		
A	Concept is not DLT specific and can therefore be (or already is) covered by a standard that is not DLT specific.	eg. Reference Architecture (ISO 23257:2022, ITU-T F.751.2)
B	Concept is partially covered by a DLT standards publication which is categorised in a different (e.g. higher level) category, thus the need for a dedicated standard does not exist.	eg. Guidelines for governance (ISO 23635:2022)
C	Concept would benefit at least one main stakeholder group (users, regulators, infrastructure providers, node operators)	eg. Decentralised Media Rights Application Format (ISO/IEC 23000-23)
D	Concept is rapidly evolving, necessitating frequent updates to maintain relevance.	eg. Security requirements for digital integrity proofing service based on DLT (ITU_T X.1407)
E	Concept intersects with other emerging technologies, requiring a multidisciplinary standardisation approach.	eg. OID-based resolution framework for transaction of distributed ledger assigned to IoT resources (ITU_T Y.4476)

3.1 Gap analysis based on Industry perspectives (1)

If we look at Figure 1, we see that some areas have more dedicated standards than others, with best represented as foundational or system-level concepts. However, identifying a gap on the basis of the number of related standards is simplistic. Hence, we need the criteria A-E defined here for further analysis.

Following this analysis, we will further focus on 3 areas: Consensus, interoperability, and Permission.

Consensus

While it is a requirement for any distributed system, there are few publications specifically addressing consensus for DLTs. It is our view that ISO TS 23635:2022 Guidelines for Governance (per Criteria B) take a high-level view of consensus, but that deeper exploration can be useful. Apart from the Nakamoto Consensus, the sub-concepts of Consensus are still generic to distributed systems. Considering that consensus is integral to a DLT's integrity, functionality, and performance, dedicated standards for consensus in DLTs are key. Moreover, as consensus mechanisms are rapidly evolving (criteria D), with new approaches being proposed frequently, standardisation efforts in this area would require regular updates to stay relevant.

Interoperability,

Despite having five publications, their applicability is somewhat limited. Three publications are from the EEA and therefore (mostly) applicable to Ethereum, while another focuses on interoperability specifically between DLTs and the Internet of Things (IoT). This reveals a gap in a high-level, generic Interoperability standard applicable to different DLTs and use cases. Furthermore, as DLT interoperability often intersects with other emerging technologies such as IoT, 5G, and AI (criteria E), a multidisciplinary approach to standardisation would be beneficial. Much emphasis is placed on ISO/CD TS 23516 Blockchain and DLT Interoperability Framework which is at an early Committee Stage.

Permission

A key concept in maintaining IT system security is permissioned access. DLTs present unique challenges due to the large numbers of different actors trying to access the system and communicate to reach a consensus. Permission and its sub-concepts would greatly benefit from dedicated DLT standardisation, as opposed to just general standards. The absence of DLT publications in this category underscores that standardisation of the sub-concepts of Permission should be a priority. This is particularly important as we anticipate an increasing number of permissioned DLT systems to be deployed by enterprises, consortiums, and governmental bodies for various use cases in the future. The rapid evolution of these systems (criteria D) further emphasises the need for adaptable standardisation in this area.

These three areas are also pointed out by INATBA as in need for further standardisation efforts. Moreover, INATBA's is pointing out the following concepts in need of further standardisation efforts:

Governance (with 1 publication only), Smart Contracts, Asset (with focus on the Provenance), Record and Service.

3.2. Gap Analysis based on EU Rolling plan for ICT Standardisation Priorities (2)

The second analysis focuses on actions outlined by the EU Rolling Plan for ICT Standardisation. These actions were formulated on the basis of missing elements in the current Blockchain and DLT standardisation landscape. Moreover, we also took into account the results of SEEBLOCKS public consultation. The analysis concluded with the following recommendations and areas in need of attention from the standardisation community:

- "Standardisation of the operation and reference implementation of permissioned distributed ledgers and distributed applications, with the purpose of creating an open ecosystem of industrial interoperable solutions" (Action 5 of the Rolling Plan). The need for standards addressing the Permission concept was also highlighted in the previous analysis;
- Develop standards in line with the Data Act legislative proposal, in particular regarding essential requirements for smart-contracts. This is a recommendation made through Action 7 of the Rolling Plan. In addition, SEEBLOCKS public consultation confirms the importance of the Data Act within the Blockchain and DLT standardisation landscape, with 20% of the respondents considering Data Act being the EC legislation, regulation or policy with the greatest importance in this context. It was placed 3rd after Markets in Crypto Assets Regulation 2019 (25% of the respondents considered this regulation as having the greatest importance), and Framework for EU Digital Identity 2021 (with 22.5% of the respondents ranking this as having the greatest importance);
- Develop the standards needed for the introduction of Digital Euro (CBDC), and for digital assets (MiCA Regulation), in particular to ensure interoperability with smart-contracts, legacy systems, etc, linked with either CBDCs or private money - Action 8 of the Rolling Plan. The importance of Digital Euro is also highlighted through the SEEBLOCKS public consultation. This was ranked in fourth place overall in terms of its importance in the Blockchain and DLT standardisation landscape, with 17.5% of the respondents considering Digital Euro as the most important in this context;
- Develop standards towards assessing CO2 footprint of different blockchains/DLTs, MiCA, EU Sustainable Finance taxonomy. This gap is highlighted through Action 9 of the Rolling Plan. In addition, SEEBLOCKS public consultation also identifies the importance of addressing sustainability matters;
- Continuous investigation of new potential use cases for Blockchain and DLT and analysis on the need for their standardisation (Action 1 and Action 4 of the Rolling plan).

4. SEEBLOCKS research and response to existent gaps

Besides conducting a thorough analysis on Blockchain and DLT standardisation landscape and identifying existent gaps, SEEBLOCKS also aims to address some of these gaps. Specifically, we will focus on the work conducted by the SEEBLOCKS funded researchers through the SEP calls (please see more details on SEP in D2.1 and D2.2). Their work addresses several of the gaps identified as it is detailed below. Other relevant project activities aiming at closing this gap are considered as well.

Identified Gap/Recommendation - Develop the standards needed for the introduction of Digital Euro (CBDC), and for digital assets (MiCA Regulation), in particular to ensure interoperability with smart-contracts, legacy systems, etc, linked with either CBDCs or private money

SEEBLOCKS response to this gap:

- SEEBLOCKS Researcher Dymitar Kyosev's project, Digital Euro - Private Enforcement on Debt, is a specific response to this gap. The project aims to propose a standardisation approach for private payment service providers to adapt their internal procedures to the upcoming Digital Euro

Identified Gap/Recommendation - Develop standards towards assessing CO2 footprint of different blockchains/DLTs, MiCA, EU Sustainable Finance taxonomy/Sustainability topic

SEEBLOCKS response to this gap:

- SEEBLOCKS Researcher Belen Suarez' project is a specific response to this gap. Her funded project is conducting activities within the Working Group (WG) at CEN/Cenelec JTC19 WG2 Environmental Sustainability of Blockchain and Distributed Ledger Technologies. The WG aims to develop a set of European standards for the environmental (climate) sustainability of Blockchain and DLTs. Belen worked on the draft of the Technical Report on the environmental sustainability classification methodology of the Blockchain and DLTs consensus mechanisms (this was circulated for approval) and is currently continuing the preliminary research, administrative works and stakeholder engagement necessary to launch the ballot for approval of the Technical Specification that aims to provide a complementary classification of Environmental Sustainability Taxonomy of Blockchain and DLT which pursues to support as the basis for labelling these technologies and crypto assets according to energy efficiency categories.
- SEEBLOCKS Researcher Shakira Bedoya Sanchez's project is also tangential to this gap. Shakira is funded by SEEBLOCKS to actively engage in AHG3 FinTech in Carbon Markets under TC322 (Sustainable Finance) and is working concurrently on:
    - Standardisation in Carbon calculation (effectiveness and accountability): Revision of ISO 14016:2020 (Environmental Management Guidelines on the assurance of environmental reports)

- Standardisation in Carbon Market Methodologies: Partake in the standardisation work of ISO/WD TS 23516 (Blockchain and Distributed Ledger Technology Interoperability Framework) and ISO14068 (Greenhouse gas management and climate change management and related activities. Carbon neutrality)
- Standardisation in quality assurance of ETS (Development of Technical Reports)

- SEEBLOCKS researcher Paul Ferris, aims as part of his project to draft a new sustainability section for the ISO/TC307 Strategic Business Plan and hence develop new standards with a sustainability focus.

Identified Gap/Recommendation: Continuous investigation of new potential use cases for Blockchain and DLT and analysis on the need for their standardisation

One of SEEBLOCKS responses to this gap/recommendation was the organisation of a workshop (Blockchain Nexus: Bridging Innovations and Standards for Tomorrow's Digital Frontier)[5] in conjunction with IEEE COMPSAC that will be taking place in Japan, between 2nd and 4th of July. This international workshop invited researchers from both academia and industry to present their contributions to the Blockchain and DLT standardisation field, with a specific focus on the identification of new Blockchain use cases and the analysis on the need for their standardisation. The workshop received various contributions, including some from SEEBLOCKS funded researchers. Four papers were accepted for publications and their contributions are addressing the aforementioned gaps and some more. More information on these papers is presented next.

Dimitar Kyosev, **Distributed Ledger Technology as a Tool for Voluntary Standardization Compliance in Emerging Technologies: A Legal View**

This paper makes the case for empowering the users to police the voluntary standards. Utilising Distributed Ledger Technology (DLT), more precisely Directed Acyclic Graph – which reduces the costs of recording and storing individual measurements for each product allowing users to claim compensation every time the product does not perform according to specifications. The paper discusses the specific requirements the product should meet to utilise DLT as compliance tool. It is also discussing the specific legal issues that entail from empowering users to police standard compliance.

Ramin Ranjbarzadeh, Ayse Keles, Martin Crane, Shokofeh Anari and Malika Bendechache. **Secure and Decentralized Collaboration in Oncology: A Blockchain Approach to Tumor Segmentation**

This research presents a novel use case for Blockchain, an innovative framework that uses blockchain technology to improve tumor segmentation in medical imaging. The approach tackles issues related to data security, particularly when dealing with real private dataset, annotation

[5] https://ieeecompsac.computer.org/2024/blockchain-nexus/

Funded by the European Union

accuracy, and collaboration. With the growing reliance of the medical industry on accurate tumor segmentation from medical images for cancer diagnosis and treatment, current methods are inadequate in maintaining data accuracy and promoting collaboration among experts across different countries. Our suggested approach utilises blockchain technology to establish a decentralized, secure platform for the collaborative obtaining, annotation, and validation of medical images by data scientists, oncologists, and radiologists. Smart contracts streamline essential procedures such as verification of annotations, consensus among experts, and remuneration of contributors, guaranteeing the dependability and excellence of the data. Furthermore, the unchangeable record of transactions in the blockchain ensures a reliable basis for implementing artificial intelligence and machine learning algorithms. This improves the accuracy of segmenting data and allows for predictive modeling. This strategy not only improves the precision and effectiveness of tumor segmentation but also promotes a worldwide collaborative environment, which has the potential to revolutionize cancer diagnostics and treatment planning. Furthermore, it ensures the privacy and security of patient data.

Mohammad Fardad, Elham Mohammadzadeh Mianji, Gabriel-Miro Muntean and Irina Tal, **Hybrid Consensus Networks for Scalable and Secure Internet of Vehicles**

Permissioned distributed ledgers (PDLs) provide security and trust for Internet of Vehicles (IoV) applications, but face scalability issues due to resource-intensive consensus mechanisms. To address this, we propose a novel hybrid consensus network (HCN) architecture that leverages the computational capabilities of parked connected autonomous vehicles (CAVs) through a multi-layer vehicular edge computing (VEC) framework. The HCN is designed following guidelines outlined by ETSI regarding the structuring of PDLs. It aims to improve the performance, reliability and scalability of PDL-based IoV networks while maintaining their security and trust guarantees.

Ruochen Qi and Dong-Hyu Kim, **Geopolitical Manoeuvring in Blockchain Standardization: Comparative Analysis of the EU and U.S. Approaches**

This study examines the standardisation of blockchain technology and its applications across the EU, U.S., and ISO. It reveals the continued dominance of the U.S. in this field, driven by its focus on technological intricacies and institutional support, notably from NIST. Conversely, the EU's approach begins with reliance on ISO standards, potentially resulting in fragmented standardisation and limited proprietary blockchain development. The introduction of EUROC as a competitor to USD-pegged stablecoins illustrates the EU's strategy to challenge U.S. technological dominance, facilitated by initiatives like MiCA. This geopolitical manoeuvring underscores the EU's aspiration to solidify its position in the global blockchain landscape by leveraging standardisation as a tool for competitiveness and technological influence.

5. Conclusion

This mid-term landscape and gap analysis review updates the set of known international blockchain and DLT standards with the latest publications. It recognises the contributions to international standards development through both formal and informal avenues and includes consideration of Community Standards from Hyperledger Community and the Eth.Global hackathon movement, including a summary of winning work from the recent Eth.Dublin event (June 2024)

This document provides two strategic perspectives on gaps that exist and recommends further standards work be carried out under the headings of Consensus, Interoperability and Permission and furthermore, asserts that new standards be aligned with priority areas flagged in the EU Standardisation Rolling Plan in particular those that explore convergence and multi-technology domains.

The Report also offers a deeper consideration of the research areas that SEEBLOCKS.eu has funded and provides an analysis of how these topics fit across the recommended targets outlined in the EU Rolling Plan.

It is clear that a huge amount of activity is taking place across the industry, it is timely the standards be crafted that support business and technical interoperability in this current stage of maturing blockchain and DLT enabled business infrastructure.

6. References

[1] Fiona Delaney, D3.1 Blockchain & DLT standardisation landscape report (2023)https://zenodo.org/records/10797789

[2] Ko, Kyungchan, Taeyeol Jeong, Jongsoo Woo, and James Won-Ki Hong. "Survey on blockchain-based non-fungible tokens: History, technologies, standards, and open challenges." *International Journal of Network Management* 34, no. 1 (2024): e2245.

[3] Chen, Xiaofeng, Zunbo Wei, Xiangjuan Jia, Peiyu Zheng, Mengwei Han, and Xiaohu Yang. "Current status and prospects of blockchain security standardization." In *2022 IEEE 9th International Conference on Cyber Security and Cloud Computing (CSCloud)/2022 IEEE 8th International Conference on Edge Computing and Scalable Cloud (EdgeCom)*, pp. 24-29. IEEE, 2022.

[4] König, L., Korobeinikova, Y., Tjoa, S. and Kieseberg, P., 2020. Comparing blockchain standards and recommendations. *Future Internet*, *12*(12), p.222.

[5] Lima, C., 2018. Developing open and interoperable dlt\/blockchain standards [standards]. *Computer*, *51*(11), pp.106-111.

[6] ITU Telecommunication Standardization Sector. ITU-T FG DLT D1.3 DLT standardization landscape. Technical report, ITU Telecommunication Standardization Sector, Geneva, CH, 2019. https://www.itu.int/en/ITU-T/focusgroups/dlt/Documents/d13. pdf.

[7] European Telecommunications Standards Institute. ETSI GR PDL 001 V1.1.1 (2020-03) - Permissioned Distributed Ledger (PDL); Landscape of Standards and Technologies. Group report, European Telecommunications Standards Institute, Sophia Antipolis, FR, 2020.https://www.etsi.org/deliver/etsi_gr/PDL/001_099/001/01.01.01_60/gr_PDL001v010101p.pdf.

[8] Kjell-Erik Marstein, Luke Riley and Ismael Arribas (2024). Systematisation of Knowledge: Distributed Ledger Technology Standardisation. International Association for Trusted Blockchain Applications (INATBA), Brussels, Belgium. DLT Standardisation: A Comprehensive Report on Current Efforts and Future Directions - INATBA

[9] International Association for Trusted Blockchain Applications (INATBA). DLT Standards and Working Groups. GitHub repository. Retrieved 13 September 2023 from https://github.com/quantnetwork/sok-dlt-standardisation.

[10] X. Jia, J. Xu, M. Han, Q. Zhang, L. Zhang, and X. Chen, 'International Standardization of Blockchain and Distributed Ledger Technology: Overlaps, Gaps and Challenges', *Computer Modeling in Engineering \& Sciences*, vol. 137, no. 2, 2023, doi: 10.32604/cmes.2023.026357.

[11] Beck, R., Müller-Bloch, C., & King, J. L. (2018). Governance in the blockchain economy: A framework and research agenda. *Journal of the association for information systems*, *19*(10), 1.

[12] Lavayssière, Xavier, Tokenization of Financial Assets (2023). Available at SSRN: https://ssrn.com/abstract=4649162 or http://dx.doi.org/10.2139/ssrn.4649162

Annex 1 Summary of Blockchain & DLT Publications

SDO	Publication	PA
ANSI	ASC X9 Study Group Report Distributed Ledger and Blockchain Technology Study Group	0
ANSI	ANSI X9.138-2020 Distributed Ledger Technologies (DLT) Terminology	0
ANSI	ASC X9 TR 54-2021 Blockchain Risk Assessment Framework	3
DIN	DIN SPEC 16597:2018-02 Terminology for blockchains	0
DIN	DIN SPEC 3104:2019-04 Blockchain-based validation of data	2
DIN	DIN SPEC 3103:2019-06 Blockchain and distributed ledger technologies in application scenarios for Industrie 4.0	8
DIN	DIN SPEC 4997:2020-04 Privacy by Blockchain Design: A standardised model for processing personal data using blockchain technology	2
DIN	DIN SPEC 4996:2020-04 Blockchain-based approach to the transfer of software licenses	8
DIN	DIN/TS 31648:2021-04 Criteria for Trusted Transactions - Records Management and Evidence Retention in DLT and Blockchain	2
EEA	EEA EthTrust Security Levels Specification Version 1	7
EEA	EEA CIW - Crosschain Interoperability Use Case Version 1.0	6
EEA	EEA CIW - Crosschain Security Guidelines Version 1.0	7
EEA	EEA CIW - Crosschain Decentralization Guidelines Version 1.0	5
ETSI	ETSI GR PDL 001 V1.1.1 (2020-03) - Permissioned Distributed Ledger (PDL); Landscape of Standards and Technologies	0
ETSI	ETSI GR PDL 002 V1.1.1 (2020-11) - Permissioned Distributed Ledger (PDL); Applicability and compliance to data processing requirements	3
ETSI	ETSI GR IP6 031 V1.1.1 (2020-11) - IPv6 Security, Cybersecurity, Blockchain	7
ETSI	ETSI GR PDL 003 V1.1.1 (2020-12) - Permissioned Distributed Ledger (PDL); Application Scenarios	8
ETSI	ETSI GR PDL 004 V1.1.1 (2021-02) - Permissioned Distributed Ledgers (PDL); Smart Contracts; System Architecture and Functional Specification	6
ETSI	ETSI GR PDL 010 V1.1.1 (2021-08) - PDL Operations in Offline Mode	5
ETSI	ETSI GR PDL 008 V1.1.1 (2021-09) - Permissioned Distributed Ledger (PDL); Research and Innovation Landscape	6
ETSI	ETSI GR PDL 009 V1.1.1 (2021-09) - Permissioned Distributed Ledger (PDL); Federated Data Management	6
ETSI	ETSI GR PDL 006 V1.1.1 (2022-08) - Permissioned Distributed Ledger (PDL); Inter-Ledger interoperability	6
ETSI	ETSI GR IPE 012 V1.1.1 (2022-08) - IPv6 Enhanced innovation (IPE); IPv6-based Blockchain	7
ETSI	ETSI GS PDL 011 V2.1.1 (2022-09) - Permissioned Distributed Ledger (PDL); Specification of Requirements for Smart Contracts' architecture and security	7
ETSI	ETSI GS PDL 013 V1.1.1 (2022-10) - Permissioned Distributed Ledger (PDL); Supporting Distributed Data Management	6
ETSI	ETSI GR PDL 014 V1.1.1 (2022-10) - Permissioned Distributed Ledger (PDL); Study on non-repudiation techniques	7

SDO	Publication	PA
ETSI	ETSI GS PDL 015 V1.1.1 (2023-01) - Permissioned Distributed Ledger (PDL); Reputation management	1
ETSI	ETSI GR PDL 018 V1.1.1 (2023-04) - Permissioned Distributed Ledger (PDL); Redactable Distributed Ledgers	2
ETSI	ETSI GR PDL 019 V1.1.1 (2023-05) - PDL Services for Decentralized Identity and Trust Management	1
ETSI	ETSI GS PDL 012 V1.2.1 (2023-06) - Permissioned Distributed Ledger (PDL); Reference Architecture	0
ISO	ISO/TR 23455:2019 Blockchain and distributed ledger technologies — Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems	5
ISO	ISO 22739:2020 Blockchain and distributed ledger technologies — Vocabulary	0
ISO	ISO/TR 23244:2020 Blockchain and distributed ledger technologies — Privacy and personally identifiable information protection considerations	7
ISO	ISO/TR 23576:2020 Blockchain and distributed ledger technologies — Security management of digital asset custodians	7
ISO	ISO/TS 23258:2021 Blockchain and distributed ledger technologies — Taxonomy and Ontology	0
ISO	ISO 24165-1:2021 Digital token identifier (DTI) — Registration, assignment and structure — Part 1: Method for registration and assignment	4
ISO	ISO 24165-2:2021 Digital token identifier (DTI) — Registration, assignment and structure — Part 2: Data elements for registration	4
ISO	ISO/TR 3242:2022 Blockchain and distributed ledger technologies – Use cases	8
ISO	ISO/TR 23249:2022 Blockchain and distributed ledger technologies – Overview of existing DLT systems for identity management	1
ISO	ISO 23257:2022 Blockchain and distributed ledger technologies — Reference architecture	0
ISO	ISO/TS 23635:2022 Blockchain and distributed ledger technologies — Guidelines for governance	3
ISO	ISO/TR 6039:2023 Blockchain and distributed ledger technologies — Identifiers of subjects and objects for the design of blockchain systems	8
ISO	ISO 8000-117:2023 Data quality — Part 117: Application of ISO 8000-115 to identifiers in distributed ledgers including blockchains	2
ISO	ISO/TR 23644:2023 Blockchain and distributed ledger technologies (DLTs) — Overview of trust anchors for DLT-based identity management	1
ISO	ISO/TR 24374:2023 Financial services — Security information for PKI in blockchain and DLT implementations	7
ISO	ISO/TR 6277:2024: Blockchain and distributed ledger technologies — Data flow models for blockchain and DLT use cases	5
ISO	ISO/IEC TR 30176:2021 Internet of Things (IoT) —- Integration of IoT and DLT/blockchain: Use cases	8
ITU-T	ITU-T Technical Report D3.5 – Overview of blockchain for supporting IoT and SC&C in DPM aspects	5
ITU-T	ITU-T Technical Specification D3.6 – Blockchain-based data exchange and sharing for supporting IoT and SC&C	5
ITU-T	ITU-T Technical Specification D3.7 – Blockchain-based data management for supporting IoT and SC&C	5

SDO	Publication	PA
ITU-T	ITU-T Technical Specification D3.8 – Identity framework in blockchain to support DPM for IoT and SC&C	5
ITU-T	ITU-T FG DLT D1.1 DLT terms and definitions	0
ITU-T	ITU-T FG DLT D1.2 DLT overview, concepts, ecosystem	0
ITU-T	ITU-T FG DLT D1.3 DLT standardization landscape	0
ITU-T	ITU-T FG DLT D2.1 DLT use cases	8
ITU-T	ITU-T FG DLT D3.1 DLT reference architecture	0
ITU-T	ITU-T FG DLT D3.3 Assessment criteria for DLT platforms	7
ITU-T	ITU-T FG DLT D4.1 DLT regulatory framework	8
ITU-T	ITU-T FG DLT D5.1 Outlook on DLTs	8
ITU-T	ITU-T FG-AI4EE D.WG2-05 - Guidelines on energy efficient blockchain systems	5
ITU-T	ITU-T DSTR-IoT-DLT-Accounting - Accounting and billing aspects in Internet of Things (IoT) ecosystem and integrated approach using Distributed Ledger Technology (DLT)	8
ITU-T	ITU-T F.751.0 Requirements for distributed ledger systems	0
ITU-T	ITU-T F.751.1 Assessment criteria for distributed ledger technology platforms	7
ITU-T	ITU-T F.751.2 Reference framework for distributed ledger technologies	0
ITU-T	ITU-T F.751.3 Requirements for change management in distributed ledger technology (DLT)-based decentralized applications	3
ITU-T	ITU-T F.751.4 General framework for distributed ledger technology (DLT)-based invoices	8
ITU-T	ITU-T F.751.5 Requirements for distributed ledger technology-based power grid data management	8
ITU-T	ITU-T F.751.6 Performance assessment methods for distributed ledger technology platforms	5
ITU-T	ITU-T F.751.7 Functional assessment methods for distributed ledger technology platforms	5
ITU-T	ITU-T F.751.8 Technical framework for distributed ledger technology (DLT) to cope with regulation	8
ITU-T	ITU-T F.751.9 Trusted execution environment-based confidential computing on distributed ledger technology systems	2
ITU-T	ITU-T F.751.10 Framework and requirements for distributed ledger technology (DLT)-based digital collection services	8
ITU-T	ITU-T F.751.11 Performance test suite for distributed ledger technology systems	5
ITU-T	ITU-T F.751.12 Formal verification framework for smart contract on distributed ledger technology	6
ITU-T	ITU-T F.751.13 Framework and requirements for distributed ledger technology-based distributed power trading systems	8
IEEE	IEEE 2140.1-2020 IEEE Standard for General Requirements for Cryptocurrency Exchanges	4
IEEE	IEEE 2140.5-2020 IEEE Standard for a Custodian Framework of Cryptocurrency	4
IEEE	IEEE 2143.1-2020 IEEE Standard for General Process of Cryptocurrency Payment	4
IEEE	IEEE 2144.1-2020 IEEE Standard for Framework of Blockchain-based Internet of Things (IoT) Data Management	8
IEEE	IEEE 2418.2-2020 IEEE Standard for Data Format for Blockchain Systems	2
IEEE	IEEE 2140.2-2021 IEEE Standard for Security Management for Customer Cryptographic Assets on Cryptocurrency Exchanges	7
IEEE	IEEE 2142.1-2021 IEEE Recommended Practice for E-Invoice Business Using Blockchain Technology	8

SDO	Publication	PA
IEEE	IEEE 2418.7-2021 IEEE Standard for the Use of Blockchain in Supply Chain Finance	8
IEEE	IEEE 2146.1-2022 IEEE Standard for Entity-Based Risk Mutual Assistance Model through Blockchain Technology	3
IEEE	IEEE 2418.10-2022 IEEE Standard for Blockchain based Digital Asset Management	8
IEEE	IEEE 3207-2022 IEEE Standard for Blockchain-Based Digital Asset Identification	8
IEEE	IEEE 3218-2022 IEEE Standard for Using Blockchain for Carbon Trading Applications	8
IEEE	IEEE 3801-2022 IEEE Standard for Blockchain-based Electronic Contracts	8
IEEE	IEEE 3802-2022 IEEE Standard for Application Technical Specification of Blockchain-based E-Commerce Transaction Evidence Collecting	8
IEEE	IEEE 2140.4-2023 IEEE Standard for Distributed/Decentralized Exchange Framework using Distributed Ledger Technology (DLT)	8
NIST	NISTIR 8202 Blockchain Technology Overview	0
NIST	NIST CSWP 9 A Taxonomic Approach to Understanding Emerging Blockchain Identity Management Systems	1
NIST	NISTIR 8301 Blockchain Networks: Token Design and Management Overview	4
NIST	NISTIR 8419 Blockchain and Related Technologies to Support Manufacturing Supply Chain Traceability: Needs and Industry Perspectives	8
NIST	NISTIR 8403 Blockchain for Access Control Systems	8
UNE	UNE 71307-1:2020 Digital Enabling Technologies. Decentralised Identity Management Model based on Blockchain and other Distributed Ledgers Technologies. Part 1: Reference Framework	1