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Working Group on Blockchain and DLT

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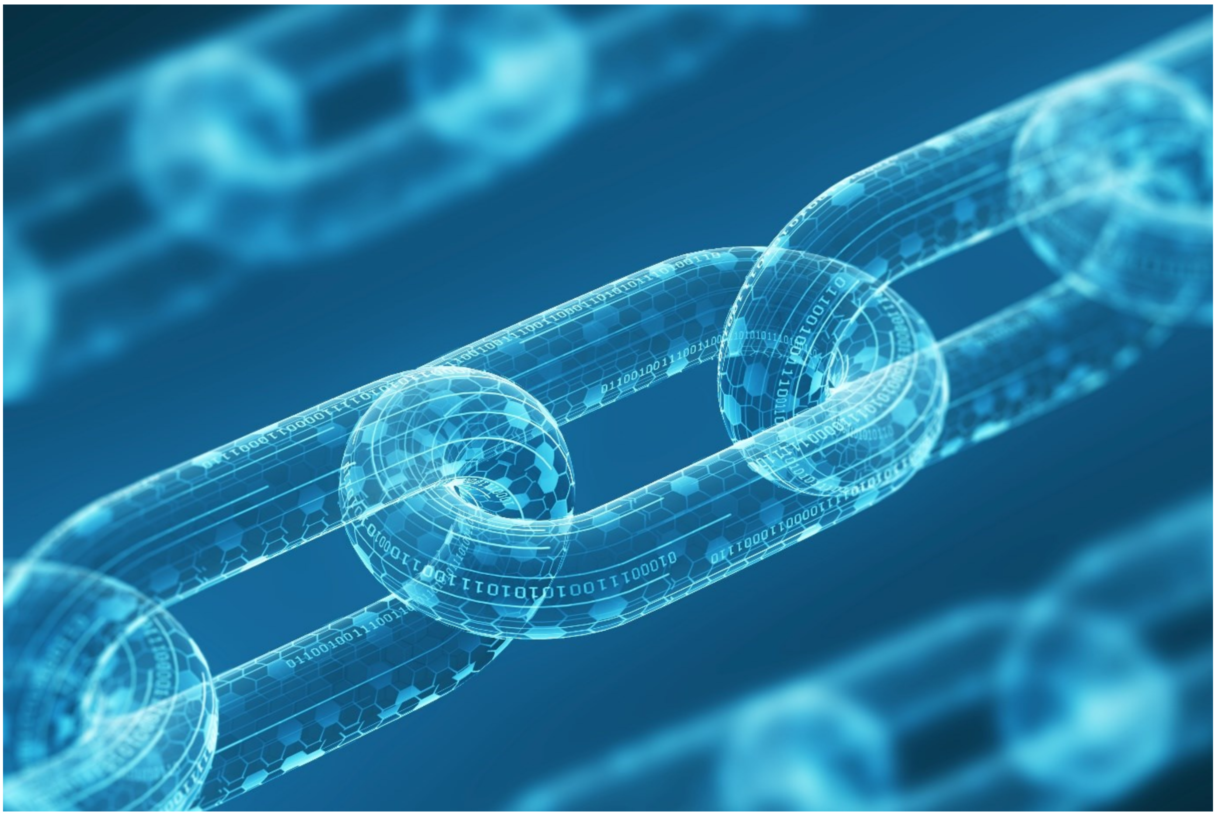

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Disclaimer

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Executive Summary

Europe's energy system is undergoing profound changes. The European Union is committed to becoming climate-neutral by 2050 to fulfil its commitment to the Paris Agreement. To reach this objective of a carbon-neutral energy system, the future energy system will have a strong decentralized component and the electricity sector will see an increase in variable renewable energy sources (RES) in the generation portfolio, with a massive raise of local and micro-production capacities, where new business models need to be developed to exploit these new trends in an efficient, robust, fair & transparent manner.

Secure information exchange between small, decentralized energy resources is a key component of these new business models. Distributed Ledger Technology (DLT) such as Blockchain has been identified as a potential key technology for achieving a more decentralized energy sector.

In 2019, CEN/CENELEC Sector Forum Energy Management-Energy Transition (SFEM) held a seminar on 'Blockchain in the energy sector: challenges and opportunities!'. The aim of the event was to contribute to the alignment of understanding and to motivate cross-sectorial cooperation on relevant blockchain-related actions, thus providing a key asset to the EU energy transition through efficient and relevant blockchain related actions. The event gathered a large audience for an interactive one-day seminar, during which participants shared common challenges and needs to identify how to foster the emergence of standardized references allowing the deployment of blockchain solutions in the energy sector. 'Recommendations' were collected from the participating stakeholders to deliver an effective framework for standardization, thus enabling the development of blockchain solutions in the energy sector; and an 'Action Plan' to develop practical actions based the recommendations, covering, among others, the issues of what, who and when. EC sees blockchain as an enabling tool to implement its strategy and attend EC targets.

A Working Group dedicated to Blockchain and DLT in the energy sector (SFEM recommendation 7/2020) has been crated following the CEN/CENELEC Sector Forum Energy Management-Energy Transition (SFEM) November 2020 plenary meeting, considering that it is now important to gather a community around the role of standardization to structure the use of blockchain across the entire energy chain; the aim being to map existing initiatives and identify gaps in the Energy Sector, then to make recommendations for further development. SNV has proposed to ensure the secretariat, and the **Swiss Federal Office of Energy** kindly agreed to support the leadership and drafting teams.

About 22 experts actively participated in this new WG.

The work has been organized in 3 phases:

- Phase 1: Preliminary mapping, in order to get an overview of existing initiatives on EU level and brief description of targets and topics to be considered.
- Phase 2: In dept mapping and analysis, in order to get a complete view of current challenges and standardization needs in the field of DLT4Energy.
- Phase 3: Final report with roadmap and recommendations towards EC and CEN/CENELC BTs based on a in dept mapping of the actual challenges and activities in the field of DLT4Energy.

The present report describes the different steps performed in each phase, towards mapping further needs about regulatory alignment and improvement, RD&I support for increasing maturity and capitalizing from use cases and best practices, and Pre-normative Research work in a way to feed standardization development.

Promises and challenges of the DLT/Blockchain technology have been identified. The key identified promises are:

Promise 1

Blockchain enables a more democratic, decentralized, and efficient energy system by fundamentally transforming how the energy sector does business across actors in the future.

Promise 2

Blockchain improves existing processes through improved features of DLT technology compared to centralized, legacy IT. Improvements associated with the use of DLT were cited as: increased data security, improved data protection in current market processes, and higher level of automation.

Regarding “Promise 1”, the general opinion was that Blockchain will only be successful if it comes along with a business transformation. A transformation of how organizations work together. A keyword is, for instance, the collaboration via a Decentralized Autonomous Organization (DAO), as an alternative to current collaboration approaches such as the building of consortium companies. Blockchain’s potential to reform the way collaboration is happening was acknowledged by most of the experts and interviewees. However, there are also those who say that DLT/Blockchain has the potential to improve current processes, e.g., to improve data security and data privacy in current market processes. Above, this train of thought is referred to as "Promise 2". Still, there are many critical voices that say that blockchain is almost never the best technology for improving today's processes. Also, the member of the working group could not identify current regulations that can best be met by DLT/Blockchain.

Hence, as the core conclusion, it can be said that there is still a debate about whether or not to use Blockchain in energy sector makes sense. Regarding promise 1, there is hardly any research, pilot, and innovation effort ongoing. In order to test promise 1 in the energy sector, very fundamental considerations are still needed to be developed and tested, to be able to say whether this promise can keep what it holds up to. In this sense, recommendations were derived. The recommendations are targeting to support the development of a more-digital European energy system of the future that re-thinks of how actors interact together. An architectural model of a digital energy system should be developed that is technology agnostic, so that Blockchain/DLT can but does not have to prevail. In addition, trust in a potential DLT solution and its governance would also need to be improved.

Final Recommendations from this CEN/CENELEC SFEM WG:

It is important to work on **new reference architectures and role definitions**, considering digital solutions including DLT. A major step in the past years was achieved by establishing the Smart Grid architecture model and the European harmonised Energy market role models. Both needs to be updated considering new digital technologies. This means an extensive top-down work on principles how existing and new organisations, actors and technical devices are working together in a future smart energy world including DLT solutions.

We propose to set up a group of experts like the proposal of EU-Commission for the “Data for Energy” (D4E) working group as described in the commission staff working paper for the EU action plan for digitalising the energy system[1]. The new “Smart Energy Expert Group (SEEG)” could be the host-group for this **new working group focussing on a digital ecosystem allowing for DLT integration with a focus on architecture-model and governance principles including identity principles in integrated but decentralised markets.**

We propose that this arrangement for the working group is also considering that the SEEG is the follow-up organisation of the “Smart Grid Task Force (SGTF) who was the main driver for the Smart Grid architecture model.

The group should also **support the commission and all European states in flagship initiatives** to support the digitalisation of the energy system. Further support should be given by this group to **RD&I projects**, i.e., Horizon Europe and national calls, in a way to gain maturity about real numbers, benefits and real case impacts of DLT in the energy systems. The present SFEM WG concentrated on the electricity sector, while the future reference architecture and role model could be extended to related sectors, i.e., heating & Cooling, gas and mobility and include green finance issues.

About standardization, **it is too early for proposing development of new technical standards**. Indeed, there is a need for additional maturity and reference best practices and use cases first. However, technical development in digitalisation is a global and cross-sectoral issue. Thus, **a group of experts should think about a possible global standardisation exchange with focus on DLT** (CEN-CENELEC, ISO, IEC, IEEE, Cigré, ITU-T, EBSI etc). A collaborative framework to integrate/align technical standards with accounting and financial standard to comply with legislative provisions and regulations (such as taxonomy, CSRD, SFDR, Sustainable Finance Platform, proposal for Corporate Sustainability Due Diligence Directive) to drive investment decision and report/disclose results over time. This could be organised through a **CEN Workshop Agreement (CWA)** as an initial step towards future coordinated standardization work. Such a CWA would contribute to alignment of understanding, setting principles of governance, harmonizing future approaches and, of course, paving the way to standards.

[1] https://energy.ec.europa.eu/topics/energy-systems-integration/digitalisation-energy-system_en

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1. Introduction

1.1 Background

The future energy system will have a strong decentralized component. This is due to the increased spread of decentralized new renewable energy sources, decentralized electro-chemical energy storage systems (stationary or in grid-connected electric cars), and electrification of loads. There are several drivers for this trend, including strongly decreasing prices of solar panels and batteries, political pressure to reduce greenhouse gas emissions, or a lack of public acceptance for centralized large-scale energy projects such as large wind turbines, overhead power lines, or nuclear power. One of the core challenges of decentralization will be to ensure a transparent and secure information exchange between many small, decentralized energy resources.

Distributed Ledger Technology (DLT) such as, e.g., Blockchain has the potential to play an important role in a more decentralized energy sector. DLT is a technology that enables the secure sharing of information. Data is stored in a distributed database and transactions are recorded in an account book called a ledger. Blockchain allows for the permanent, immutable, and transparent recording of data and transactions. DLT/Blockchain has three central attributes:

a) the database must be cryptographically secure;
b) a digital log or database of transactions, meaning it happens fully online;
c) the database that is shared across a public or private network.

DLT/Blockchain enables organization to establish:

- immutability of records;
- auditability of transactions;
- traceability of transactions throughout the supply and value chain ;
- embedded security;
- interoperability of energy devices;

In the context of the energy sector, for instance, the distribution, consumption, and trading of electric power can benefit from DLT characteristics such as distributed, secure, immutable, and tamper-proof data management as well as the anonymity of participants. The Blockchain transaction scheme allows transactions to be made directly between providers and customers, where all data are stored on a distributed Blockchain and accessible by all stakeholders along the value chain. Smart contracts are precising all related rules about quality, price, amount of energy, etc. One of the advantages of such a Blockchain model lies in decentralized transactions without intermediaries third-party. Other than being used to execute energy supply transactions, it could also provide the basis for metering, billing, and clearing processes. Other possible areas of application are in the documentation of ownership, the state of assets (asset management), guarantees of origin, emission allowances, renewable and energy efficiency certificates (White Certificates). Blockchain technology has the potential to radically change energy as we know it, by starting with individual sectors first but ultimately transforming the entire energy market. However, moving from such promising contributions of new and digital models to decarbonized energy systems and reduced EU energy dependency, needs alignment of regulation, policies, and standards, with mature technologies and trust from stakeholders along the full value chain. Blockchain models could represent a relevant contribution to meeting our EU Energy Strategy (i.e., Green Deal) and roadmaps (i.e., fit for 55), including through offering innovative management of decentralized energy systems, especially with large share of renewables, as well as in support of local smart grid management. However, moving from promises to effectiveness, requires new economic model, new partnership model, with consumer becoming prosumer, where flows of activities and their values would be open and transparent. In this context, Digital Energy must be perceived as essential enabler/driver.

The recent evolution of the electricity and gas market that calls for a decoupling of the electricity price from the gas price (Electricity Market Design Directive) and blockchain can be a key enabler toolbox for its implementation.

Many projects, start-ups and initiatives have been launched to make such a decentralized electricity system possible, i.e., to interconnect the increasing number of small production, storage, and demand units of local energy systems. However, until today, no DLT/Blockchain solution has been widely adopted by energy system stakeholders. The question that needs to be answered is why is this the case? Is there a lack of standards, are there unsolved technical challenges, or is Blockchain not suitable in this environment at all?

With the above in mind, CEN-CENELEC Sector Forum Energy Management (SFEM) established a working group on Blockchain and Distributed Ledger Technology that aims to achieve a complete view of the current challenges (technical and non-technical), use cases, and standardization needs in the field of “DLT in energy”. Within the energy sector, a particular focus will be put on the electricity sector, however, sector coupling and other energy sectors (e.g., Heating & Cooling, and gas) will be considered as well. Furthermore, even though the focus of the working group is on DLT in the energy sector, learning from other sectors could bring auxiliary input. In addition, it is expected that DLT will significantly contribute to Taxonomy implementation as well as enabling materiality and transparency in Non-Financial Reporting (NFR Directive) and Corporate Sustainability Reporting (CSR Directive). The work should, ultimately, support the implementation of the European Green Deal, a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral in 2050. More details about the CEN-CENELECT SFEM Working group will be given next.

We would like to explicitly state here that this report addresses the general investigation of the standardization possibilities of DLT/Blockchain applications in the energy sector. We are aware that the topic area of DLT has resulted in many controversial discussions in recent years. For example, the energy consumption of some Blockchain protocols, such as Bitcoin, or the recent bankruptcy of the centralized exchange platform FTX. We will explicitly not discuss these individual incidents, but will address the risks of the technology. At this point, we would like to point out that it is important to look at these individual cases in a differentiated manner and to research the reasons carefully.

1.2 Establishment and aims of the CEN-CENELEC SFEM Working group on Blockchain and Distributed Ledger Technology

Following the SFEM 2019 annual seminar on “Blockchain in the Energy Sector”, and the expression of interest from the audience to have a dedicated Working Group to map existing initiatives, gaps, and standardization related issues, SFEM took a decision at its November

24th, 2020, plenary meeting - recommendation 7/2000 – to establish a new working group on Blockchain and DLT in the Energy Sector, with a secretariat held by SNV (Swiss Association for Standardization).

This working group has started its activity in April 2021, with Dr. Bernard Gindroz, the vice-chair of CEN/CENELEC SFEM, as convenor. In the following, the most important assumptions and aspects of the working group are summarized.

1.2.1 Challenges and Opportunities:

Opportunities of Blockchain solutions in the energy sector have been mentioned by several organizations, academia and in white papers, and are included in the standardization strategy and the contribution program of CEN/CENELEC to the Green Deal. Some identified opportunities include:

- Supporting achievements of major European energy objectives, e.g., in the Clean Energy for all Europeans Package.
- Blockchain has the potential to promote energy efficiency and the integration of renewables into energy systems, by mitigating the risk of investments and ensuring transparency, integrity and traceability of technical and commercial transactions and reporting. DLT has the potential to decrease business risks (technological, financial, accounting, reporting) throughout the supply and value chain.
- For smart- and micro-grids, Blockchain links consumers and prosumers and enables exchanges decoupled of any man-in-the-middle control. This feature provided by Blockchain technology is crucial for efficient usage of volatile renewables.
- It is a key technology that allows managing the complexity of future energy markets, i.e., to achieve quasi-real-time coordination of electricity supply and demand data, proper management of energy storage capacities on the energy grids, support e-mobility, etc.
- It has the potential to reduce compliance costs with energy, environment, and accounting/financial regulations. DLT can couple/integrate the attributes of the energy sector (energy efficiency, use of renewables, multiple or co-benefits) with the requirements of due diligence and reporting of financial and corporate organizations.
- It is an enabling tool for reporting compliance with Sustainable Finance, ESG criteria, NFRD and CSRD.
- DLT/Blockchain can drive automated and secure contract fulfillment (for example smart energy contracts, energy flexibility [demand response, modulation] contracts, energy performance contracts, energy community, taxonomy compliance, sustainable finance, monitoring-reporting- disclosure). This has the potential to create more cost-efficient transactions for energy trading (B2B, B2C and private prosumers/consumers).

As part of the standardization activities of CEN/CENELEC, this WG reflects activities and lacks in standards for DLT based energy projects that are discussed in this report. Many pilots, demo projects and initiatives effect promising impacts on changes towards future energy production and distribution systems in the EU for raising maturity in integrating renewables. The WG's final report (i.e., the document at hand) provides the collected knowledge from these initiatives and identifies how to make market(s) ready for implementation of such new schemes, how to support remaining RD&I gaps, as well as how to boost innovation to market(s) through standardization development (especially bringing interoperability, harmonization throughout Europe and trust).

1.2.2 Aim of this Working Group (as defined before launching the WG activities):

• Providing CEN/BT and CENELEC/BT with concrete proposals on the way forward to address standardization needs in this emerging field to satisfy stakeholders needs.

• Providing CEN/CENELEC JTC19 and JTC 14 (Joint Technical Committee) with concrete proposals in coherence with JTC19 and JTC 14 related scope.

• Providing European Commission & concerned stakeholders with RD&I needs in this field.

• Providing European Commission with regulation related needs in this field.

1.2.3 Expected Outcomes (as anticipated before forming the WG):

Mapping (Phase I)[2]

- Mapping existing Blockchain and DLT related projects and initiatives in Europe towards use cases.
- Mapping existing standardization initiatives (national, EU, global).
- Identifying standardization needs for DLT applications in energy sector and in connection with sustainable finance (Taxonomy, ESG, NFRD, CSRD).
- Mapping RDI needs: Recommendation for RDI priorities.

Liaison (Phase II)

- Liaise through SFEM with CEN/CENELEC SABE, JTC19.
- Liaise with Joint Research Center (JRC) and its team working on Blockchain related/integrated activities. Liaise through SFEM with EU Energy Efficiency Financial Institution Group (EEFIG).
- Strengthen cooperation between regulatory work, standardization work and RD&I programs.
- Interviews with experts in the field

Recommendations (Phase III)

- Recommendations for new work items and/or extension of work within existing Technical Committees (TC), Joint Working Groups (JWG).
- Preparing a strategy roadmap with list of standardization priorities, including pre-normative research (PNR) ones.

Generally, the above points could be fulfilled, however, the role of standardization has been critically questioned by many actors in the sector. Hence, standardization needs in connection with DLT in the energy sector are only discussed in principle without going into detail in this report. Why this is the case is outlined in this report.

[2] The results were divided into three phases, which are presented in the following Section 1.3.

1.3 Organisation of the CEN-CENELEC SFEM Working group on Blockchain and distributed ledger technology

The WG is chaired by the SFEM of CEN-CENELEC, co-chaired by Sipenco (Schlegel Power Consulting) and the secretariat is provided by SNV, the Swiss Association for Standardization. In addition, a drafting team from Lucerne University of Applied Sciences and Arts funded by the Swiss Federal Office of Energy is assisting the WG in drafting the report. To cover the entire value chain as described in the above scope of this new WG, a call for experts from energy production, grid management, regulatory, financial and IT sectors, in addition to those from the Blockchain related technologies (industry, SMEs and Start-ups, Research Institutes, …) has been circulated. Moreover, the call aims at gathering experts with experience from local operational applications and decision making, such as local authorities, cooperatives, and associations, as well as representing the civil society/citizens. In total more than 40 European companies, organisations, institutes, and authorities have replied to the call and have been participating in the WG.

The work of the working group is split in three phases:

- **Phase I:** Prepare a map of existing related initiatives in energy sector (pilots, startups, standardization initiatives, etc.). The goals and expected outcomes of standardization and research projects like INATBA, DLT4POWER, etc., are identified. Phase I ended with this preliminary report.
- **Phase II:** The objective of Phase II is to have a more complete view of the current challenges and standardization needs in the field of "DLT in energy". The analysis will base on interviews with experts that are involved in DLT initiatives in the energy sector, as well as the liaison to various organizations and working groups in this environment.
- **Phase III:** Development of recommendation and strategy roadmap. Complete final report and provide it to SFEM for approval and dissemination.

A kick-off meeting has been held on April 28th, 2021. Plenary meetings have been organised approximately every other month to work towards the objectives and expectations of the WG.

2. Overview and mapping of applications and initiatives

The global transformation to an environmentally friendly power system is tackled by many different stakeholders and organizations. The overarching objective is to develop technical and economical solutions to better integrate renewable sources. DLT is often seen as a key technology that could play an important role in the acceleration of the energy transition. However, despite high efforts with many DLT/Blockchain initiatives around the world, a broad adaption of this technology is still awaited. Reasons for that may be in regulatory frameworks that are not in favour of DLT solutions, low technology readiness level (TRL), a lack of standards, or a lack of established base infrastructure. Or, maybe, DLT/Blockchain does not solve any pressing problem at all.

To answer this question, in a first step, DLT/Blockchain applications/use cases in energy sector have been identified. These applications are outlined in the following section. Subsequently, a mapping of the applications will allow to identify most promising use cases, gaps (i.e., fields where DLT applications were not found, despite its potential attractiveness), and unattractive applications for DLT. In a second step, political and standardization initiatives are identified and mapped.

2.1. DLT applications in Energy sector

A clear interest has been recorded among digital energy businesses to exploit the blockchain potential. In general, blockchain can enable energy trading in various (local, retail or whole-sale) markets, support the financial settlement of energy transactions, contribute to energy management and flexibility services provision, and aid certification and billing procedures. Pilots and experiments, addressing a range of use cases, are deployed, and tested around Europe and in the world.

Figure 1 gives an overview of identified DLT applications/use cases in the energy sector. The applications are ranked according to their maturity level from low (”Pilot & Demonstration”) to high (“Commercial Products”), as well as to “use classes” (i.e., classes of use cases). It includes activities all around the world but with a focus on European efforts.

It is worth to mention that sometimes an exact separation between use classes is difficult. For instance, an application in the class “Energy trading” also requires “Metering and billing”. However, “Metering and billing” can also be a Blockchain application without “Energy trading”, hence, a use case is always assigned to its most generic use case class.

Another segmentation of the initiatives is done through the colouring of the use case boxes. The different shading indicates the lead initiator’s institution. So, it classifies initiative whether it is an academia project, a start-up project or product, an industry driven activity or an activity that is initiated by a public organisation i.e., government or municipality. Furthermore, activities concentrated on DLT platforms are highlighted with a red border.

The following interesting observations can be drawn from the Figure:

- There is a remarkable spot of start-up companies that already passed the pilot and demonstration states and that are shortly before or after market release. Specifically, many platforms with TRL 8/9, although it is unclear how successful they are, and whether they are being used by electricity actors at all.
- Start-ups mainly concentrate on market data registering, certification, and energy trading. Market data registering is a medium for organizing market data. One example is the startup VIA, which is building a data collaboration platform to bring data users and data owners together.
- Three interesting industry initiatives have been identified: (i) Equigy is a joint venture of the transmission system operator TenneT (DE and NL), Swissgrid (CH), Terna (IT), APG (AT), and TransnetBW (DE) and “uses Blockchain technology to access, via aggregators, new sources of electricity from the owners of consumer-based devices.”; (ii) Share & Charge is a consortia of different actors in the field of electric vehicle charging that wants to improve the charging experience / enable EV roaming across Europe by means of Blockchain technology; (iii) Enerchain was a consortia of more than 40 energy trading firms that brings Blockchain to “Whole Sale Trading”. Enerchain, however, has been discontinued.
- DLT platforms are close to market release or have already launched their products. A reason for that could be a DLT hype that led to substantial technical advancements in

DLT for the energy sector, however, without commercial sustainability. The Gartner's hype cycle analysis of Blockchain technology in 2020 underlines this assumption [1].

- Only few applications have been identified that address Sector Coupling aspects, and hardly anything driven by government in lead.

Figure 1 – Mapping of DLT applications in energy sector (see Appendix for a brief introduction to each initiative)

2.2. Blockchain Framework Initiatives

So far, DLT applications and platforms that cover one or more use cases have been identified. These Blockchain activities are in a large part business oriented. That means, many activities are pilot and demonstration projects with the goal of establishing a new business. However, there are also many initiatives trying to organize technology's development and providing frameworks for collaborative development on a common base. These initiatives can have different originators, such as sector associations, regulators, etc. This allows for a more focused and goal-oriented development, leading to solutions that are compatible with the various stakeholders or legacy systems.

Figure 2 shows a map of framework initiatives. The initiatives are ordered according to their focus (y-axis) and their originators (i.e., initiative’s key stakeholder) (x-axis). Please note that the standardization bodies themselves are not actually stakeholders, but their experts in the committees are. Nevertheless, to simplify the wording, "standardization bodies" is used as a term on the x-axis. The framework map covers initiatives of various industry sectors, as is indicated by the shade color. The color code separates initiatives into initiatives from the energy sector, other sectors, or to initiatives that are sector-agnostic.

The identified standardization bodies identified are listed below, with their goals or DLT aspects indicated in parentheses:

- ISO/TC 307 Security, privacy, governance, scalability, and interoperability
- ISO/TC 307/JWG4 Several overviews
- ITU-T group Use cases and recommendations (requirements, assessment criteria, ref. Framework)
- CEN CENELEC JTC19 EU legislative and policy requirements (ID management)
- ETSI ISG PDL Trust and security of IoT data conduits and flows
- IEEE Blockchain Std. General standards for Energy, Healthcare and FinTech

Apart from an IEEE working group on energy, the other activities are non-sector specific.

The map of framework initiatives shows following first findings:

- There are many DLT framework initiatives outside the energy sector, with focus on DLT standardization and regulatory needs within their sectors. Nevertheless, there are quite a few similar initiatives in the energy sector (e.g., INATBA GO P2P, IEEE WG “Blockchain in Energy”, DLT4POWER), or initiatives that are sector agnostic. But actual standardization initiatives in the Energy Sector are rare, or have been discontinued (e.g., DLT4POWER has been stopped). It would be interesting to understand why other sectors are more active in working on standardization.
- Not many initiatives have been found that focus on "Supporting collaboration for projects/funding" and Sustainable Finance (Taxonomy, ESG, NFRD, CSRD, etc) and this requires further investigation. By "Supporting collaboration for projects/funding" we mean initiatives that aim to fund interesting and new ideas in the blockchain field (e.g., research calls, seed money, or similar).
- No initiatives that are focusing specifically on Sector Coupling could be identified.

The various standardization activities of the individual organizations can lead to overlaps in standards and recommendations (i.e., there are multiple standards/recommendations for some aspects in DLT applications). This fact was also noted by the a research conducted by the World Economic Forum, where gaps and overlaps in standardization have been identified [2]. WEF outlined standard overlaps in security, IoT, identity, DLT requirements as well as taxonomy and terminology.

In general, each SDO (mainly ISO, IEC and ITU) manages its own development; however, there are several areas where two or three of them coordinate their development; in addition, ISO and IEC have a joint technical committee. At the EU level CEN and CENELEC are managed by the same structure, which is closely linked to ETSI and has a permanent agreement and coordination with ISO, IEC and ITU. There is also a joint ISO and IEC technical committee for DLT.

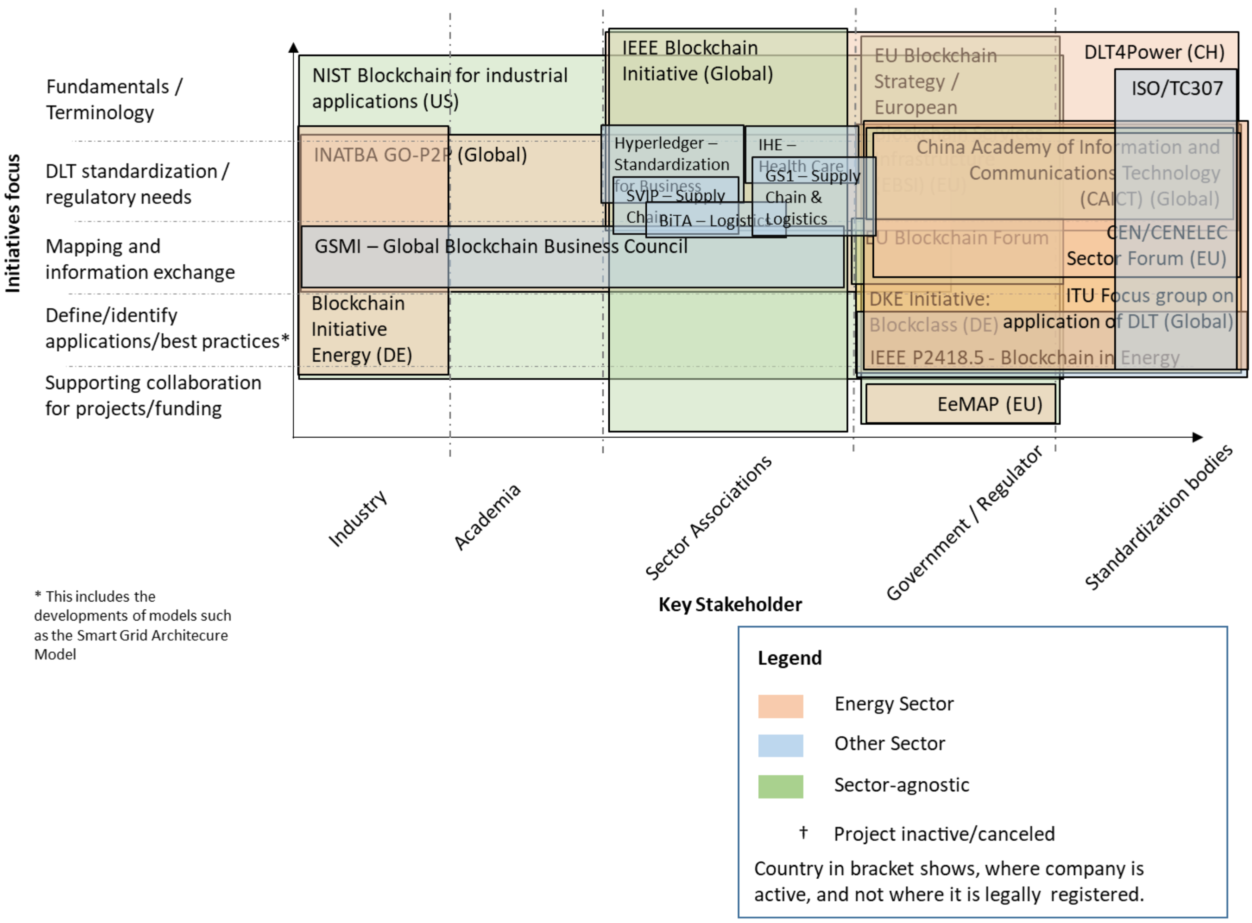


Figure 2 – Mapping of Blockchain framework initiatives (see Appendix for a brief introduction to each initiative).

2.3 Results - Findings from mapping of initiatives

The mappings resulted from desk research of various Blockchain use cases and initiatives. From the mapping of existing DLT/Blockchain initiatives, the following key takeaways have been drawn:

1. **Startup data availability/confidence**
   Since the application of DLT/Blockchain in the energy sector is a very trending topic, many startups are active in this space. Many startups seemingly provide solutions with high technological readiness and maturity. Within our data collection, the main source of information is from websites of startups and press releases. However, there is some concern about the confidence level of these data sources. It is often not clear how commercially successful the proposed solutions are, and which solutions were indeed

deployed in the field and are fully operational. Several undertakings have also come to an end, which underlines our hypothesis.

2. **Operational level of industry-based initiatives**
   While many start-ups seemingly provide applications with high maturity, many industry-based initiatives are not (yet) at an operational level. From the data collection and mapping it is observed that many of the industry-based initiatives are currently in the pilot and demonstration phase.

3. **No platform covers the whole value-chain**
   While many start-up companies provide DLT platforms for specific use cases (e.g., VIA, Brooklyn MG, Equigy), none of the considered platforms cover the whole value-chain end-to-end. Yet, several DLT platforms such as Power Ledger, Lo3-Energy, and Prosume address multiple use cases.

4. **Many platforms, not much information of real-life use cases**
   There is a significant amount of DLT platforms, and much information can be found about their purpose/use case. However, there is a limited amount of information on real-life use cases when these DLT platforms are applied in the field. It can be questioned whether these platforms actually add value to real world.

5. **Lack of Ancillary Services Use Cases**
   The mapping activities have revealed that there is a limited amount of DLT projects in the area of ancillary services, and the existing ones (Equigy, Prosume) are aimed at the transmission level to provide grid flexibility reserves by aggregating local resources.
6. **Lack of Sector Coupling Use Cases**
   A limited number of use cases in the area of sector coupling have been identified. The ones that have been found are focusing on the coupling between the electricity and the transportation sector (Share&Charge), and the provision of green hydrogen from renewable resources (GreenH2chain). It will be analyzed in Phase II whether this is because of a lack of use cases, or because of a narrow, electricity-oriented expert pool. If so, we would invite additional experts to the working group.

7. **Boundaries of standardization in electricity sector, with other sectors/existing standards**
   Many Standardization initiatives in the map that are of importance for the energy sector are sector-agnostic, hence they do not have a clear boundary of the applied scope and cover IT-related aspects, such as e.g., Internet-of-Things. It is important that these initiatives will be taken into consideration. In other words, it is crucial to understand whether an initiative is considering DLT-only aspects or is integrated in a sector context.

8. **Overlap with financial sector**
   Several DLT applications in energy sector aim to provide a fully automated energy trading system/platform for prosumers and consumers. This implies an automated settlement and payment. The payment touches the already published “IEEE Standard for

General Process of Cryptocurrency Payment" (2143.1-2020). And therewith it overlaps with financial sector.

9. **Largest penetration of DLT/Blockchain applications in Australia and Asia**
   There are a lot of DLT activities in Australian and Asian markets. The reason for this could be the political and regulatory framework that favors DLT/blockchain. This thesis, however, requires further verification.

3. Challenges and Standardization Needs

DLT/Blockchain is a technology that is predicted to have a promising future. However, as addressed in the mapping above, we have not observed a widespread adoption of DLT/Blockchain in the energy sector. Only a few operational applications use DLT/Blockchain today. Some individual use cases/applications could be identified that embed Blockchain/DLT in their core but are isolated from other applications. In addition, there are some platforms, but they are not yet widely operational.

This raises the question of what the reasons for the lack of DLT/Blockchain implementation are. Why is DLT/blockchain not yet widely used in the energy sector? A deeper understanding of the current challenges (technical and non-technical) and standardization needs in the field of "DLT in energy" is needed.

To achieve this goal, in a first step, a literature search was conducted: how does science and other sources currently answer this question? In a second step, a survey among experts was conducted. From the literature research and the survey, questions for interviews were then developed. These interview questions led to a good overview of potential current challenges. The survey and the interview questions revealed the need to address certain sub-topics in detail: the question of whether or how blockchain could play an important role for identity management and for the interface between the financial sector and the energy sector. In addition, in order to hear voices outside the Blockchain/DLT environment, the E-World in Essen, Germany (6/21 - 6/23, 2022) has been visited. The topic of Blockchain/DLT was discussed with various people, in an unstructured way. Nevertheless, this allowed to sense the current state of Blockchain. In the following text, conclusions that refer to discussions at E-World are always stated.

3.1. Literature

A literature review will analyze whether the reasons for the lack of adoption of DLT/Blockchain lie in the energy sector itself, e.g., no viable business model, too strict regulations? Or whether the reasons lie in the DLT technology, e.g., lack of standards, interoperability issues, data issues (GDPR)?

First, a high-level understanding of the promises and challenges of the Blockchain technology are given. Later, a review of the academic literature to identify reasons for the lack of DLT/blockchain usage is being conducted, followed by literature published by the European Commission.

3.1.1. General Promises and Challenges

Over the past decade, blockchain-based energy start-ups multiplied and raised a few hundred million EUR. More recently, EU funding devoted EUR 347 million to support blockchain research and innovation, out of which EUR 48 million went to sustainability (energy and transport) projects [3], [4]. Blockchain applications are very promising in the climate and energy sectors, also for the following reasons [3]:

- **Disintermediation:** blockchain removes the need for traditional financial, economic, and technical intermediaries (such as banks and market operators), since the blockchain infrastructure can directly oversee transactions without the intervention of trusted third parties.
- **Transparency and verifiability:** transactions recorded on the blockchain can be checked by nearly every actor independently. Illicit transactions are detected and excluded from the blockchain, making it hard to perform malicious operations.
- **Immutability and security:** it is almost impossible to modify or tamper with information recorded on the blockchain (even when many nodes are cyber or physically attacked at the same time).

The literature has long explored the role of blockchain in the energy sector (and beyond). A further look at the popular science literature leads to a list of promises and challenges according to Figure 3 [2], [5], [6]. That these points are partly disputed or outdated is shown by the interviews conducted later. To dig one level deeper, the academic literature was consulted to identify challenges.

Promises

- **No intermediaries needed**
  (reduced transaction costs, no single point of failure)
- **Increased data credibility**
  (tamper-proof, Immutable, trust without third party)
- **Increased transparency**
  (e.g., close to real-time information about energy transactions)
- **Increased automation via smart contracts**
- **Increased participation by new/more actors via decentralization**

Challenges

- **No identified business model(s)**
- **Performance of Blockchain**
  (high cost, slow transaction speeds)
- **General high trust in centralized electricity operators**
  (DSO/TSO, exchanges, …)
- **Regulatory and legal challenges**
  (Electricity regulation (e.g., P2P not foreseen), data regulation (e.g., GDPR))
- **Lack of standards**

Figure 3 - Promises / Challenges of DLT

Another important source on general promises and challenges was found in [7]. The article from the Gottlieb Duttweiler Institute describes the two core benefits of blockchain technology as follows: "*More robust and efficient digital infrastructures*" and "*Reduction of dependencies*." These two benefits are revisited later in the report, as interviews led to a similar conclusion.

3.1.2. Academic Review

DLT technology constitutes a promising technology, which is being reviewed in academic literature for many applications. Nevertheless, the long-term value has not been clearly seen yet since there are several challenges, which have been identified in the literature. The challenges of DLT technology in the energy sector can be summarized as follows:

- Infrastructural constraints
- Consensus algorithm
- Regulatory framework
- Scalability
- Security

DLT technology comes with infrastructural challenges, such as vulnerability to errors and malfunctions, given the early phase of the technology as well as the development cost compared to existing solutions, given that verification and validation of blockchain transactions require significant hardware and energy cost. A representative example of the infrastructural challenges is the current deployment of smart meters. The computational capabilities of the existing or widely deployed smart meters are limited, therefore the integration of DLT technology requires additional cost, in order to make smart meters ready for P2P transactions [8]. In addition, the conventional databases can offer faster and less costly solutions with lower latency. Another aspect regarding infrastructural challenges is the required bandwidth. For example, bandwidth requirement for a system based on blockchain can be 10 times larger than the maximum requirement for a real-time advance metering infrastructure [9]. Moreover, emergency cases for the grid operation such as outages, require an efficient communication platform and blockchain might not perform as required under these critical circumstances [10]. These issues should be addressed and the benefits of DLT technology should outweigh the additional required cost.

Furthermore, an efficient mechanism which can reach a consensus with secure and fair methodology, which can also ensure significant energy savings is a key element for DLT adoption. According to the literature, Proof of Work (PoW) is the most frequently used algorithm [10], but it comes with high energy cost, and it is vulnerable to attacks. An alternative algorithm is the Proof of Stake (PoS), but its mechanism gives higher voting power to nodes with more tokens, formulates a market monopoly [11], [12]. Different other consensus algorithms have been proposed and used, but only few of them can efficiently handle all the relative concerns, which can be summarized as:

- High computational need
- Monopoly formation
- User information disclosure

These three aspects of consensus algorithms are significant burdens for DLT adoption. The high computational demand could significantly affect the grid operation. The monopoly formation would influence the energy market, by endorsing users who can manipulate the system and finally the disclosure of user information could not be perceived as acceptable compromise due to the high requirements for privacy and data protection [10]. An example of a consensus algorithm that could overcome these concerns is the Proof of Authority [13]. Or other non-Blockchain DLT solutions, such as IOTA, which are specifically designed for IoT applications, have lower computational cost due to their different consensus algorithm.

Furthermore, an important challenge for the DLT adoption is the regulatory and legal framework in the energy sector [8]. For example, consumer to consumer energy trading is not allowed within the current regulatory framework. Moreover, the energy sector has well established roles in the whole energy value chain and there are challenges regarding imbalances, coordination with central operators and limitations regarding the physical operation of the grid. These issues make the access control in DLT applications an important requirement [13]. In addition, this concern is also linked to the anonymity of the users, which increase the vulnerability towards undesired activities. Therefore, permissionless platforms might be problematic for the energy sector. A solution to that might be consortium blockchains, which are permissioned platforms and give the power and the control to consortium [10].

The scalability issue is one of the most important factors for DLT technology. Currently the number of transactions per minute are limited to low numbers for blockchain applications. The increased workload, in case of DLT adoption in power grids, will drastically affect the latency and the storage capacity. Several solutions have been proposed, which come with compromises on security due to longer propagation time. However, solutions which can fit well to the needs of energy industry have been proposed, e.g., Sharding approach [10]. Directed Acyclic Graphs (DAG) platforms perform better regarding the scalability and the computational overhead due to mining as well [13].

An additional concern is the data protection and the framework around this topic, which is mainly managed by the central authorities. DLT system users should be identified and in parallel sensitivity information, such as prices within a smart contract, should be protected and stay confidential. These actions should also be aligned with the legal framework, however in the distributed ledger technology there is not a unique central authority, which might be legally responsible towards any malfunction since the trust is on the technology and not on the authority [10]. Moreover, the security aspect which is supposed to be an inherent characteristic of DLT is still challenge for the current technology. Blockchain technology is vulnerable to attacks or other security issues. Some of them reported to the bibliography are Sybil attack, selfish mining, denial of service attack, Eclipse attack, etc. [14], [15].

In addition, another aspect which slows down the further adoption of DLT technology is the lack of standardization based on a solid reference architecture for the energy industry. This is a barrier for interoperability between different technology solutions and stakeholders [8], [14]. In addition, any new change in the ruling protocol of DLT technology should be approved by all users, in case the system is deployed, which might lead to disagreements and finally prevent the adoption and acceptance of DLT technology [8].

Finally, the energy consumption of DLT is a critical topic for the further adoption of the technology. As stated in the explanatory study commissioned by Swiss Federal Office of Energy [11], the energy consumption can be divided into the following three categories:

- Data storage
- Communication
- Computational effort

More analytical, the communication required for message exchange and coordination counts less than 1kW per bitcoin and a few MWh per year. In addition, the storage of more than 10,000 Bitcoin replicas can lead to an average power of 4-400kW and energy consumption of tens MWh per year. Finally, the PoW mechanism counts for an average of 10GW and energy consumption of around 100TWh. According to the report from the Swiss Federal Office of Energy and the policy brief from Electronic Devices and Networks Annex (EDNA) [11] (EDNA, 2022) the use of another consensus mechanism is required, in order to reduce energy consumption. The proof of Stake is a good alternative, which can significantly lower the energy consumption.

	DLT-related	**Energy Sector-related**
DLT Governance	*Decentralized governance does not have a single point of authority, which makes more difficult the decision process (unaccountable power of entities and participants in the ecosystem)* [10].	*A centralized governance with a grid operator as a trusted third party is better aligned with the energy sector structure.*
DLT Consensus	*Challenges related to high computational effort, high energy consumption and user information disclosure* [10].	*Thread of monopoly formation (for some consensus algorithms), which might affect the energy markets* [11].
Interoperability	*DLT platforms cannot easily communicate to external platform and services* [8], [14]. *Challenges to be resolved are related to lack of secure data transfer, low interaction speed etc* [14], [15].	*The number and complexity of stakeholders in the energy sector require interoperable solutions & platforms* [8], [14]. *The lack of standardization prevents the acceleration of interoperable solutions* [8], [14].
Technological limits	*Transactions throughput of common DLT platforms are too low* [8]. *Bandwidth requirements can be 10 times larger than real-time advanced metering system* [9]. *The wide adoption will have impact on the latency* [8].	*Permissionless DLT does not match energy sector structure*[10], [13]. Blockchain might not perform as fast as required under emergency cases [10].

Figure 4 - DLT/Blockchain Challenges

3.1.2. Literature by the European Commission / JRC

According to publications of the Joint Research Centre (JRC), the European Commission's science and knowledge service, several aspects and interfaces must still be analysed, tested, and regulated for a successful introduction of blockchain-based energy services. In particular [3], [16] :

- **Security, privacy & identity.** Adequate cybersecurity and supply security levels should be defined and guaranteed when using blockchain applications. Mechanisms for safeguarding data security and integrity shall be further developed. Data should be protected ‘by design’ and shared only as needed to activate consented blockchain-enabled services. Effective integration strategies between data protection and cyber-security initiatives are needed. The impact of telecommunication networks and the Internet on digital energy resilience and security should be assessed from a cybersecurity perspective. Adequate cybersecurity certification schemes are needed to cover both the blockchain core infrastructure and the end user applications and devices (e.g., IoT). The authentication schemes embedded in the blockchain applications shall be strengthened to avoid identity theft issues.

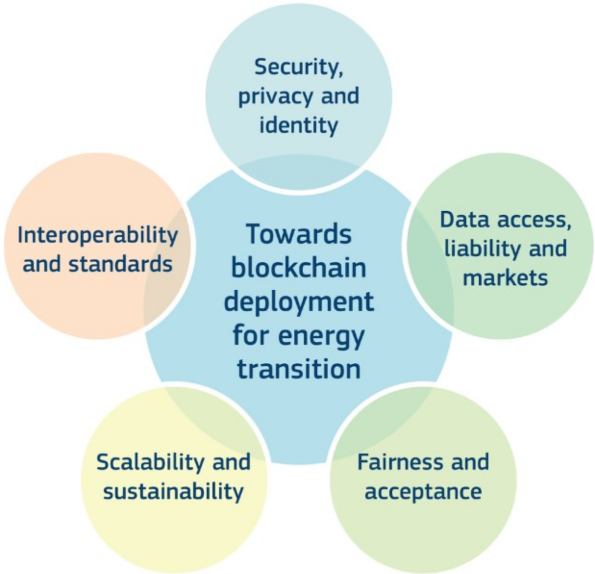


Figure 5 - Blockchain deployment issues [3]

- **Interoperability and standards.** Blockchain applications and digital energy devices (including meters, sensors, and appliances) shall be fully interoperable. Several pilots have confirmed the need for ensuring the interoperability of different blockchain solutions, of on-chain and off-chain systems, of IoT devices and cloud-based solutions with blockchain networks. The blockchain solutions integration and interoperability with existing legacy systems, particularly to gather readings and system data, still constitutes a big challenge. To this aim adequate and flexible standards are needed.

- **Fairness principles** are needed to design more decentralized energy markets not discriminating players, be they people or businesses. Consumers should be further involved to understand the potential benefits of blockchain projects. A trade-off between consumer empowerment and protection shall be identified. Most of the blockchain-enabled energy projects rely on permissionless design, which generally entails that every user contributes to manage the blockchain in a trust-less environment. However, this comes at a cost of a more expensive validation process. Permissioned applications need instead a small group of nodes to validate transactions. This allows for reducing the validation costs but also requires full trust on the validators.

- **Data access, Data Quality, liability, and markets.** Robust energy data hubs/platforms, with concerted rules for data access and use, should be designed. Market rules should be adjusted to account for the emergence of ‘automated agents’ aside the human players. Identifying roles and liabilities is particularly important in case of security breaches which could lead to financial losses, market anomalies or electricity disruptions. Those breaches could be linked to human/technical errors - such as loss of keys, issues in blockchain updates, smart contract malfunctions, payment defaults, technical failures - or malicious events and intentional tampering. Clear criteria to allocate accountability and responsibilities to decentralized actors involved in the electricity supply and delivery should be defined.

- **Scalability and sustainability.** Regulatory experimentation should be promoted to understand how projects could be scaled up. The sustainability and intensity of the energy requirement for blockchain is a heavily debated, but not always fairly analyzed, issue (as an example, some blockchain technologies, including a leading one such as Ethereum, moved to less energy intensive verification protocols). Studies on the energy footprint of the blockchain solutions under testing/deployment should always accompany the analysis on scalability and performances.

Time will tell whether blockchain can really support - or even subvert - business models in the transitioning digital electricity systems and markets. Indeed, blockchain is just one of the enabling digital technologies for a smart energy system. Other digital solutions, such as AI, digital twin, big data and IoT, can also be and are effectively being deployed and combined to achieve the climate-neutrality and sustainability targets.

3.2. Expert Survey

An expert survey was conducted in order to validate the results from the mapping activity (see Figure 1 and Figure 2), and to identify initial indications of possible reasons for the lack of DLT/Blockchain adoption. The survey was targeted at individuals who are currently working on a specific DLT/Blockchain initiative. Accordingly, the response rate was rather modest with only 12 respondents. Nevertheless, some interesting findings were obtained. The detailed questions and answers are given in 'Appendix 3 – Survey Questions'. The following is a summary of the key findings:

- The results from the mapping were mostly confirmed. For example, only one industry initiative was mentioned (industry initiatives are initiatives that are launched by incumbents), and most initiatives are still with a TRL below seven. It seems that the industry is currently not very interested in Blockchain as a topic. This was also confirmed in a visit to E-World 2022 in Essen, Germany. Furthermore, the mentioned use cases and political/legal or standardization initiatives correspond well with the use cases from the mapping.
- Approximately 50% of the respondents are working on integrating new players and roles in the energy sector using DLT/Blockchain. How exactly, and how "disruptive" this will be, could not be determined via the survey. The interviews will shed more light on this.
- The current regulation of the electricity sector seems to be a more fundamental problem: e.g., P2P trading is not possible and prevents scale-up, or there is a lack of regulation between sectors (e.g., Finance and Energy). In contrast to regulation, standardization was less mentioned (the term "interoperability" was mentioned three times, more about standardization has not been mentioned).
- The expected energy consumption of the proposed solutions when scaled up is not seen as a problem.

The survey further unveiled that the complexity and versatility of Blockchain is too great to determine its true problems in a survey. The idea was therefore to develop hypotheses by means of interviews (in an "inductive research setting"), which will then be critically questioned in the expert group. Furthermore, as a sector coupling between energy and finance seems important (most DLT/Blockchain use cases were mentioned in the field of sustainable finance.), we proposed to launch a sub-working group about "Finance". As mentioned later, there is also a second sub-group ("Identity"). In a next step, the conducted interviews are being discussed.

3.3 Interviews

3.3.1. Interview structure

Interviews with experts were conducted to better understand where the current challenges (technical and non-technical) and standardization needs in the field of "DLT in energy" lie. The questions tended to be open-ended to allow interviewees to express new ideas and to reduce interviewer bias. The open questions allow to get answers to the above question in a more qualitative way. Nevertheless, a few hypotheses derived from the literature review were asked to all interviewees.

The questions are listed below (not all questions fit all interviewees, accordingly the questions are to be understood as a basis for a semi-structured interview):

1. How do you see the use of blockchain in your company? Is it already being used? Are you planning to use it? Please elaborate.
2. Do you see Blockchain more as a tool to improve current processes or to transform the business structure? Please explain.
3. In your opinion, what are the most important promises of the Blockchain technology for the energy sector?
4. What issues do you see hindering the adoption of Blockchain in the energy sector?
5. We identified promises as well as challenges of the Blockchain technology. Does this list trigger new thoughts? *(Figure 3 slide was then shown to the interviewees).*
6. Where would you identify issues that are preventing the spread of DLT in the energy sector? *(This question was discussed along the following table)*

Table 1 - Structure to discuss Blockchain/DLT challenges

	DLT Standardization (e.g., Gaps/Overlaps)	Energy Sector-related	Others
Governance		***Example to better understand the table:*** *a centralized governance with a grid operator as a trusted third party is better aligned with the energy sector structure.*	
Consensus alg.			
Interoperability			
Oracle	***Example to better understand the table:*** *No default way of how to trust measurement data*		
Technology		***Example to better understand the table:*** *Transaction throughputs of common DLT platforms too low.*	
Others			

Specifically, the need for standardization along the above topics was asked. As backup, further slides and publications were shown if purposeful. The complete interview slide deck is given in 'Appendix 2 – Interview Questions'. A thematic analysis has been conducted to identify the most important findings. A thematic analysis is well suited as it allows to identify the main themes in a large amount of unstructured data (gained through interviews).

3.3.2. Interview Partner

An attempt was made to find a set of interview partner who are as representative as possible. Table 2 shows the interview partners. Interviewees were selected who use Blockchain at incumbents (e.g., Equigy as a subsidiary of European TSOs, or a project manager of Con Edison), from startups (e.g., VIA), technology providers (e.g., at IBM, Ponton), from the academic environment (HSLU or Uni Reutlingen), or employed in umbrella organizations like ENTSO-E. Furthermore, interviewees come from different countries and world regions. Interview responses are kept confidential so that individual responses could not be traced back to the interviewees. This was done to allow the interviewees to speak more openly. After the tenth interviews, often similar statements have been recorded from the interviewees, i.e., a certain information saturation set in. This gives a feeling that the data has a high significance.

Table 2 - List of Interviewees

Name	Affiliation
Tim Weingärtner	Professor, HSLU, CH
Colin Gounden	Founder, VIA, USA
Martin van't Verlaat	CTO, Equigy, EU
Norela Constantinescu	ENTSO-E, EU
Ariana De Almeida	DLT Expert, NL
Debora Coll-Mayor	Professor, Uni Reutlingen; DE
Delvin Stephens	Project Manager, Con Edison, USA
Ettore Piantoni	Energy Management Consultant; CEN CENELEC JTC 14 Chair
Michael Merz	Ponton GmbH; DE
Jos Röling	DLT Expert @ IBM; Global
Kai Siefert	Managing Director, RIDDLE&CODE Energy Solutions GmbH, AT
Winfried Braumann	AEE INTEC, coordinator of EU TrustEE project
Simone Accornero	FlexiDAO, Co-Founder and CEO
Andres Schöndube	Energy Web Foundation
Romain Losseau	RTE – French TSO
Steven Fawkes	EEFIG – Energy Efficiency Financial Institutions Group
Peter Sweatman	EEFIG – Energy Efficiency Financial Institutions Group
Isidoro Tapia	EIB – European Investment Bank
Valeria Portale	Blockchain Observatory from Politecnico di Milano
Jacopo Fracassi	Blockchain Observatory from Politecnico di Milano

As discussed above, we have visited the E-World 2022 in Essen, Germany. It was striking that DLT/Blockchain was hardly a topic at the show (neither vendors nor visitors had this topic on their radar, as far as we could tell). Generally, most people were neutral towards the Blockchain technology ("*Blockchain is not for us, maybe in the future*"). Some firms and organizations referred to activities, however, these activities were not represented at E-World (e.g., Engie, Shell, EFET). Quotes from the E-World are integrated in the text below.

3.3.3. Results of literature review and expert interviews

3.3.3.1. Role and Promises of Blockchain in the Energy Sector

The first two interview questions are aimed at the promise of blockchain, as well as what role blockchain might play in the energy sector of the future.

One aspect that was mentioned by almost all interviewees is that DLT/Blockchain is a tool that has the potential to take collaboration between different stakeholders to a new level. DLT/blockchain enables the formation of new ecosystems where data and value can be shared in ways that incentivize desired behavior (e.g., through tokenization of energy or energy provenance). A DLT-based data and transaction layer (e.g., a new layer in the Smart Grid Architecture Model) that enables all participants in an energy market (which will number in the millions in the future) to control their data, and to transact with each other. One interviewee said that "*Blockchain is an infrastructure that enables that*". A new form of collaboration between stakeholders can emerge. This new kind of collaboration allows a better and more democratic integration of small assets in different markets. Especially the integration of decentralized assets in different markets as well as their coordination could be mapped in the Blockchain respectively in Smart Contracts (i.e., the system is being turned on its head: distributed control requires new ways of interaction between devices, blockchain could play an important role here). It could allow actors to collaborate without a trusted third party facilitating the collaboration, hence, simplifying collaboration. Various interviewees then also see the core promise of DLT in this new type of collaboration. One quote that summarizes this finding was:

"*DLT will only be successful if it comes along with a business transformation. A transformation of how organizations work together*".

A Keyword is, e.g., the collaboration via a Decentralized Autonomous Organization (DAO), as an alternative to current collaboration approaches such as the building of consortium companies. It was then also noted that there are hardly any initiatives in the energy sector to investigate such a transformation (e.g., through Pilot + Demonstration projects).

Blockchain's potential to reform the way collaboration is happening was acknowledged by most of the interviewees. However, there are also those who say that DLT/Blockchain has the potential to improve current processes, e.g., to improve data security and data privacy in current market processes. For instance,

"*The process of a homeowner granting permission to a solar installer to access utility data. This process exists, but can be automated through blockchain technology*",

or the validation of the activation of decentralized assets, such as performed by Equigy. Nevertheless, there are critical voices that say that blockchain is almost never the best technology for improving today's processes. The argument made is that blockchain is a more computationally intensive technology compared to a centralized data architecture, and that there are hardly any real-live use cases and that various pilot projects have failed (e.g., Enerchain).

In summary, for Blockchain to be truly successful, collaboration in the energy sector needs to be rethought, but this is hardly being addressed by market actors. The improvement of existing processes through Blockchain could also play a role, but this is not happening. It is also interesting to mention that a visit to E-World 2022 in Essen showed that Blockchain was hardly a topic, in contrast to 3-4 years ago. This is an indication that the initial promises could not (or at least not yet) be fulfilled.

3.3.3.2. Challenges of Blockchain

Various challenges have been cited that keep blockchain from widespread adoption. According to the discussion above, there are basically two promises of blockchain technology:

(1) Blockchain enables a more democratic, decentralized, and efficient energy system by fundamentally transforming how the energy sector does business across actors (Promise 1).

(2) Blockchain improves existing processes through improved features of DLT technology compared to centralized, legacy IT (Promise 2).

These two promises are different in nature; accordingly, the related challenges must be discussed independently. In the following, the Promise 1 is discussed first, then followed by a discussion about Promise 2.

Of the interviewees who mentioned Promise 1, all agree that little is happening in this direction. The main assumptions were:

- Culture in the energy sector is centralized. It would take a fundamental cultural shift for actors to start thinking in this direction. The governance of collaboration would have to be rethought. Current regulation is not favoring this way of thinking.
- There is a great deal of distrust towards the blockchain technology. Few wrong prejudices are that Blockchain consumes a lot of energy, blockchain is a new technology that is not tested or not scalable.
- Incumbents fear disruption, or benefit from their current role as intermediaries (e.g., aggregators, utilities, etc.).
- Little innovative sector in which the regulator says what to do. The "pain" to innovate is not great enough: the central system functions stably.
- Unclear value proposition, i.e., it is not obvious how new business areas can be developed through new collaboration. Or more generally, the idea of a DAO or similar concepts is very new and difficult to grasp. There is a lack of knowledge about these new concepts. It is worth noting that the financial sector is more advanced in this area, but still in its infancy.
- Regulation is often still in favor of a centralized system (e.g., P2P trading is not yet possible in many countries).

The last point in particular shows that unless clear incentives are given in this direction, it is not attractive for players (incumbents and startups) to think in this direction. However, it should also be mentioned that there have been critical voices as to whether this vision of new collaboration mechanisms is worthwhile. This question is not trivial to answer, as little activity in the energy sector in this direction could be identified. The point will be taken up again later.

Regarding promise 2, i.e., the use of DLT/blockchain to improve existing processes, there were various reasons for a lack of adoption identified. A quote from a startup founder at the E-World that probably sums it up was the following: "*Nobody is paying me for an overengineered solution like Blockchain*". In other words, assuming that Blockchain really adds value (which has been controversial, we'll get to that again), regulatory requirements or customer preferences accept cost-effective, but potential second-best solutions without Blockchain. A non-blockchain solution is generally less expensive to implement and operate (*note:* Blockchain means that the same data set is stored on many nodes, which requires a complex algorithm to reach consensus in case of data changes as well as a higher storage requirement). One interviewee stated based on his experience that "*to build truly decentralized system is extremely difficult*". That is, if a solution can be implemented without Blockchain and is accepted by the market, it will prevail. Conversely, this means that stricter regulatory requirements will have to come in order for blockchain technology to be successfully deployed (e.g., in terms of cybersecurity, as one interview partner detailed). It can be assumed that for use cases such as peer-to-peer (P2P) energy trading or green certificates, two adjustments in regulation will have to happen in order to favor a Blockchain usage: (1) the use case must be "legalized" in principle in the first place (e.g., P2P trading is not yet possible in many countries), and (2) requirements for e.g. data security, transparency, etc. must be so strict that a blockchain solution will be implemented. As mentioned above, it was disputed whether blockchain can provide this added value at all, e.g., whether blockchain can provide higher data security, however, this question will not be further elaborated here (it goes beyond the scope of this report). Nevertheless, it is worth noting that the concept of "tokenization" or a "chain of immutable ledgers" is not only provided by blockchain technology, but can also be implemented in centralized systems, such as Amazon Web Services, as one interviewee explicitly mentioned.

Technological reasons or GDPR reasons were not considered as problematic. The technology is developing rapidly, and solutions for scalability problems, power requirements and other often mentioned problems already exist. GDPR or the requirement that personal data must be able to be deleted is acknowledged. But there are approaches to solve this challenge, e.g., that not effectively personal are stored on the blockchain (e.g., "zero knowledge proof") or the use of “pseudo anonymity” in private Blockchain. This point will be discussed in more details later in this report. These findings in the context of GDPR or the performance requirements are at odds with the findings from the scientific literature. Furthermore, some of the findings are also not supported by other initiatives such as INATBA. Why this might be the case is discussed later.

Another general point that was mentioned is that there is a lack of skills in this area. Particularly, a lack of people that understand the energy sector as well as Blockchain. That makes, on the one hand, the implementation of blockchain/DLT projects difficult, and on the other hand, the opportunities of DLT/blockchain technology are not seen. There is also a wrong perception of the blockchain technology (too much energy required, not secure enough, etc.) that comes with a lack of understanding of the technology. This is a typical chicken-and-egg problem.

The challenges of the Blockchain, and why there is no widespread of DLT/Blockchain is summarized in Figure 6.

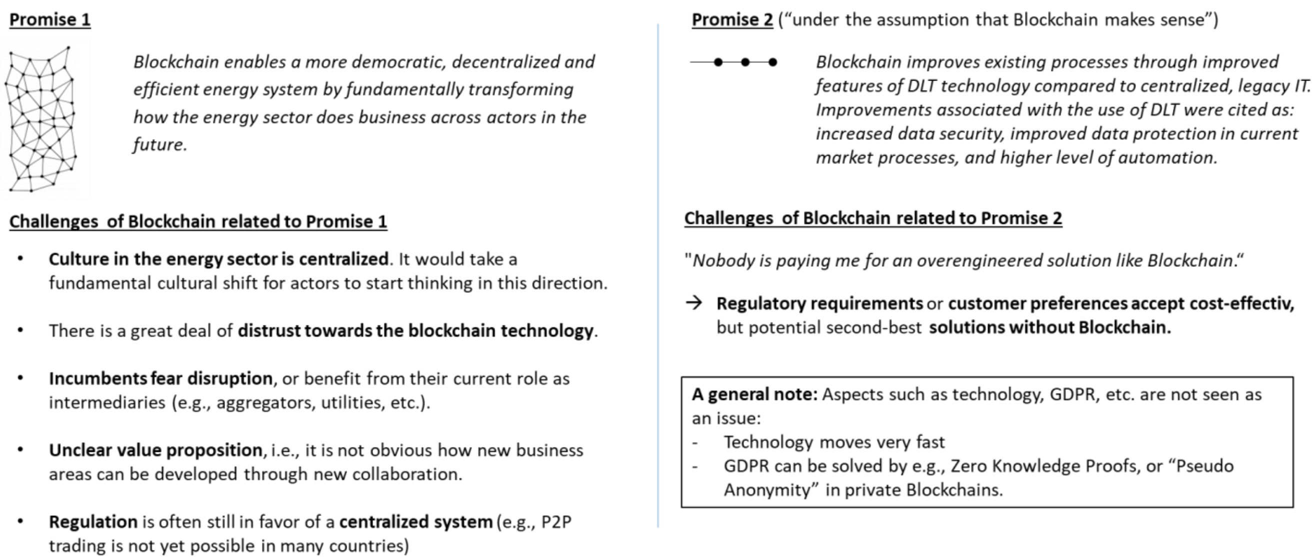


Figure 6 – Promises and Challenges of Blockchain – why no widespread?

3.3.3.3. Regulation and standardization

The majority of interviewees pointed out that they would like to see improvement of the regulatory context towards coherence with decentralized energy systems (in some cases this was also referred to as “de-regulation”) so that decentralized use cases become possible. Regulation is needed that is not *"in favor of large, central assets"*. For example, many interviewees would like to see use cases such as peer-to-peer trading legalized, so that the basic promises of blockchain can become possible. Other regulations and tariffs are also criticized, which hinder the integration of decentralized resources (e.g., *"cost-based regime for redispatch in Germany"*). Since the regulation is strongly country-dependent, this discussion is not being conducted in detail here. In general, however, regulation seems to play an important role as a topic.

Concerning promise 2, and under the assumption that Blockchain adds value for promise 2, interviewees mentioned that stricter regulatory requirements will have to come in order to justify the usage of blockchain technology (e.g., in terms of cybersecurity, as one interview partner detailed).

Regarding standardization, many interviewees think that it is too early to think about standardization. One interviewee summarized this as follows: *"I am a bit hesitant about standards because we do not yet know what we actually want. De facto standards are needed, and not de jure standards"*. One interviewee added that integration of the Blockchain itself is a strong push towards standardization, as a token, for example, is nothing more than a standard of a unit of energy. One company explicitly mentioned that it is written in their mission statement to develop a “de-facto standard”. Hence, many interviewees do not want externally defined formal standardizations (i.e., a standard endorsed by a formal standards organization) at this point as the technology is in its infancy and the development is moving too fast. Standard aspects that have been mentioned though are "blockchain-blockchain interoperability" and "blockchain-real world interoperability" (e.g., standard to overcome oracle problem). However, most of the interviewees were unclear how such standards should look like. One interviewee said that *"first we need an architectural model, i.e., a model that shows which processes are on- and which are off chain"*. However, it can be argued that it is probably also too early for an architectural model, since there is still debate about whether or not to use blockchain at all (this makes it hard to decide which processes should run on chain or off chain). A discussion of governance standards led to similar conclusions: It is too early to establish governance principles, as future potential interactions among stakeholders are still unclear. Nevertheless, one interviewee pointed out that the mere fact to have a standardization body working towards DLT standards (e.g., standard for tokens) legitimates and, thus, supports innovations in the field of DLT. However, these standards must be very flexible, i.e., they must adapt quickly to new findings and technological advances.

It was undisputed that there is a need for standards on how smart meter data can be validly read into the blockchain, i.e., something like an "oracle standards". However, these are not blockchain standards per se, it defines how data can be accessed by centralized or decentralized IT architectures. In this sense, this is outside the scope of this report. It was then also explicitly stated that this "blockchain-real world interoperability" can presumably be solved by conventional IT approaches.

3.3.3.4. Excursus: Standardization activities in the context of the results from the interviews

There are standardization activities in the area of DLT/Blockchain, as the initial mapping unveiled. Most of them are outside the Energy sector (e.g., by WEF or ISO), but there are also standardization activities in the energy sector (INATBA, IEEE). The WEF report [2] identified overlaps and gaps in current standards, as is shown in Figure 7. Other organizations identified standardization need with regard of “interoperability”, such as the working group ISO/TC 307/SG 7 that focus on “Interoperability of blockchain and distributed ledger technology systems”. Findings are expected to be reported in unpublished ISO/NP TR 23578.

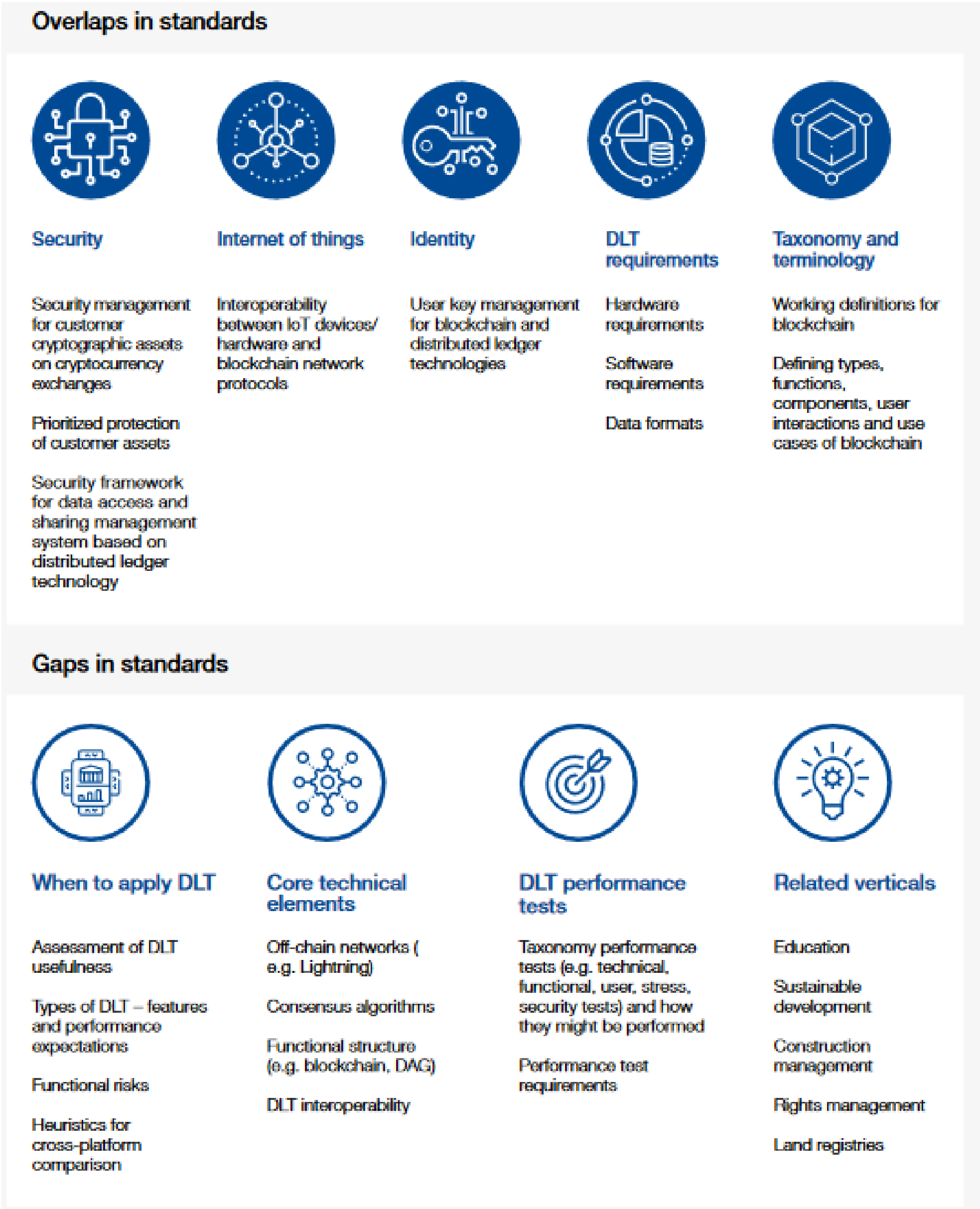


Figure 7 - Overlaps and gaps in DLT standards, according to a WEF report [2] (Figure taken from report)

We have asked the interviewees about standardization needs, as well as gaps and overlaps in today's standardization environment. However, as the discussion above showed, the discussion was more about fundamental aspects, such as the level and type of standardization rather than the identification of concrete points for standardization. Gaps and overlaps in today's standardizations do not seem to be a problem when implementing blockchain use cases in the energy sector. Presumably, the identified gaps and overlaps are important for use cases outside the energy sector, but more fundamental questions need to be answered beforehand in the energy sector. Nonetheless, we will draw on insights from other activities in the final discussion and recommendations.

GO-P2P INATBA (https://inatba.org/p2p-energy-task-force/), IEEE Blockchain in Energy (https://sagroups.ieee.org/2418-5/), and ISO/TC 307 (https://www.iso.org/committee/6266604.html) have been identified as two very interesting initiatives that are related to our work. We reached out to these initiatives to discuss our findings. Next follow the most important conclusions from the discussions.

GO-P2P INATBA:

The GO-P2P Energy Task Force will "*tackle standardization gaps around energy trading using distributed ledger technologies*". It is an initiative between the International Association for Trusted Blockchain Applications (INATBA) and the Global Observatory on Peer-to-Peer, Community Self-Consumption and Transactive Energy Models (GO-P2P). The final report is being published soon. At the writing of our report (4.10.2022), the report has not been published. However, a very interesting discussion with Alexandra Schneiders and Anna Gorbatcheva, both working on the INATBA GO-P2P initiative, led to the following interesting inputs:

- One argument for a formal standardization process could be that it makes DLT solutions more democratic by involving more stakeholders in the standardization process. This is advantageous compared to a "de facto" standardization process driven by powerful institutions.
- However, the speed at which the technology is advancing presents a challenge for standardization. Similar to our observations, involvement and interest in standardization are "*generally lower than expected*".
- Regulatory issues have also been identified.
- GDPR is seen as a key issue for DLT/blockchain implementation. It seems that DLT is not supported by the law.
- The role of DLT in P2P use cases is also discussed, similar to our discussion of the role of blockchain in general.

The report will add more details to the above list. However, a first discussion indicated similar results to ours.

IEEE Blockchain in Energy:

A discussion with Ümit Cali, the Chair of the IEEE TEMS Special Interest Group: Blockchain and DLT in Energy (Jointly with Blockchain in Energy – IEEE SA P2418.5 Working Group), led to interesting insights of how IEEE is tackling DLT/Blockchain standardization activities. The key messages from the conversations with Ümit Cali are as follows:

- Ümit Cali sees a misconception about the role and promise of Blockchain in the energy sector. This often leads to hype around Blockchain in a field that is not justified. One reason for this is the lack of education in this area.
- According to Ümit Cali, there is a need for standardization and the development of architectural models. For example, current smart grid models/definitions are old and outdated. An update is needed, and DLT/blockchain could play an important role in this. A key issue will be the development of a common language and terminology around DLT/Blockchain.

- Generally, a collaboration between organizations in this field is important (e.g., CEN/CENELEC, Cigré, and IEEE)
- The work of the special interest group of IEEE will lead to interesting publications that are soon to be published.

The conclusions from the discussions with INATBA GOP2P and IEEE Blockchain in Energy are mostly similar to our findings. The need for an architectural model, as well as the role of GDPR, are assessed slightly differently.

ISO/TC 307:

A first ISO work in the form of a study period highlighted the need to explore the links between consensus algorithms and governance, on the one hand, and consensus algorithms and use cases, on the other hand, based on feedback from industry.

This could be the subject of pilot projects in the field of energy, as a specific use case and specific governance issues. The experience acquired will in turn help promote standardization initiatives, concerning ISO or any other standardization body.

This point was the subject of a presentation made by Stéphane Caporali during the work of the SFEM working group. It will be considered in the recommendations.

3.3.3.5. Excursus: Literature reviews in the context of the results from the interviews

The literature research led to similar conclusions regarding regulatory and legal aspects, but there to different interpretations regarding technological aspects such as scalability. Probably both views on technical challenges are correct: scalability is a challenge, but one that is solvable (e.g., by 2nd layer approaches). Furthermore, the currently running pilots (at least the ones discussed by the interviewees) do not have preliminary technical issues that prevent mass adoption, but others as described above.

The literature review reveals two other issues:

- Lack of standards. As we know, standards have been criticized, but this could also be a chicken-egg problem: no standards, no activities, no need for standards. This point will be revisited later.
- An interesting point that the literature raises is the question of responsibility. Who is responsible for a system without a central authority? This point definitely needs to be considered in the development of governance standards or principles.

A publication that came out only at the end of the work of this working group, was a report of the Gottlieb Duttweiler Institute [7]. The report was published in 2023, i.e., after the results of the interview were available. As outlined in the literature chapter (see chapter 3.1), the report identifies two core benefits of blockchain technology: "*More robust and efficient digital infrastructures*" and "*Reduction of dependencies*". The first point roughly describes our Promise 2, although there is also a focus on "cross-organization collaboration" through tokenization (i.e., the point can be characterized as the intersection of our Promises 1 and 2). The second point "Reduction of dependencies" describes in principle our Promise 1 ("*all members make decisions together and control each other without a central authority: Internet without Google,* *ridesharing without Uber, and payments without banks*"). This is well aligned with our results that are summarized in Figure 6.

4. Deep Dives

In the previous chapters, important topics were identified that are of particular interest for DLT/Blockchain. For example, the topics of identity management (of people and things), smart contracts, and finance were mentioned as important areas in which DLT could play a major role. In addition, the importance of regulations and policy was also elaborated. Accordingly, there are three deep dives below to learn more about these topics. This Chapter 4 is intended to be part of Phase II of the working group activities, i.e., in support of the "Liaison activties" as introduced in the Section 1.2.3. It follows the four core topics:

1. EU Policy Initiatives and Prospects on Digital Energy
2. Financial sector liaised with energy
3. Identity issues in in the digital transformation
4. Smart Contracts

This Chapter is not directly linked to the Chapter 3 before, it has been written independently. However, it is used to derive better recommendations in a synthesis with Chapter 3 in the following chapter. By the way, the ISO publication "Trend Report 2022" also identifies, among other, the same topics [17].

4.1. EU Policy Initiatives and Prospects on Digital Energy

In Europe, the green transition heavily depends on the implementation and the follow-up of policies, also in the new policy cycles and in highly uncertain geopolitical and security scenarios, pursuing climate neutrality and reducing the environmental footprint by 2050.

Against this backdrop, the EU and national decision makers are making efforts to combine energy and climate change policy actions with other proposals linked to, among others, digital markets, circular economy, innovation agendas, and capital market/investment plans [18].

Several EU policy initiatives over the past two decades are relevant for the digital energy uptake. Among the more important ones, one can include, in chronological order:

- Several data/information-related legislative provisions issued in the second decade of 2000: the NIS Directive on Network and Information Security (currently under review), the eIDAS Regulation on electronic IDentification, Authentication and trust Services in the internal market, and the General Data Protection Regulation (GDPR).

- The Energy Union Strategy, put forward in 2015, and the herein included Clean Energy Package, finally adopted in 2019. The former embraced five dimensions: security, solidarity, and trust; internal energy market; energy efficiency; economy decarbonization; research, innovation, and competitiveness [19]. The Clean Energy Package consisted of several different legislative acts addressing, among others, the energy performances of buildings, the renewable energy penetration promotion, several energy efficiency measures, the electricity systems and markets organization and their risk-preparedness [19].

- The Green Deal - the EU's plan aiming at net emissions of greenhouse gases by 2050, with an economic growth decoupled from resource use and social inclusion - was presented in 2019 and then reinstated at the center of the EU policies as a means to overcome both the pandemic crisis started in 2020 and the geopolitical/energy market crisis begun in 2022 [20].

- A Europe fit for the digital age - The EU's digital strategy aims to make this transformation work for people and businesses, while helping to achieve its target of a climate-neutral Europe by 2050 [21].

- The Fit for 55 package, issued in 2021, includes proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels) [22].

- The Digital Compass, proposed in 2021, promotes an EU's digital decade revolving around four cardinal points [23]: skills, digital transformation of business, secure and sustainable digital infrastructures, and Digitalisation of public services.

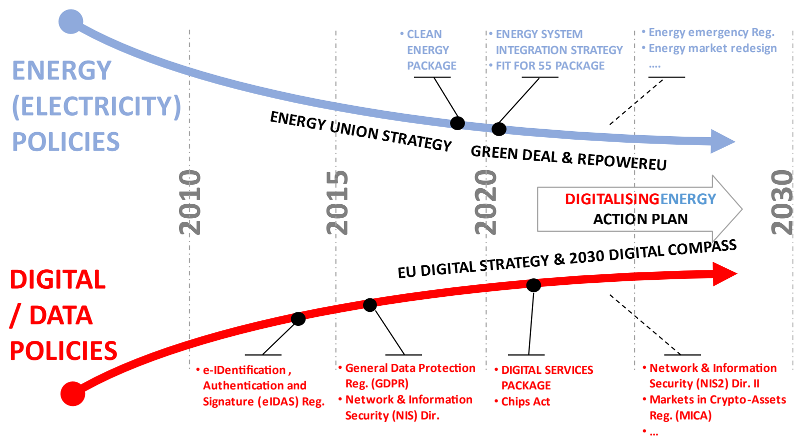


Figure 8 - Energy and Digital Policies in EU

- REPowerEU is the EU's plan, issued in 2022, to reduce dependence on Russian fossil fuels by accelerating the green transition and attaining a resilient energy system. Building on the Fit for 55 package (see below), its main actions include: securing and diversifying energy supply (also via storage), saving energy by promoting energy efficiency and enhancing preparedness; quickly substituting fossil fuels by accelerating the energy transition and smartly combining investments and reforms [24].

- The Digital Services Act package, proposed in 2020, comprises of the Digital Services Act (DSA), which introduces rules on intermediaries' obligations and accountability across the single market, in order to open up new opportunities to digital service providers, while protecting consumers; and the Digital Markets Act (DMA), which makes sure that the large online platforms, which act as "gatekeepers" in digital markets, behave in a fair way online [25].

- The EC Digitalization of Energy Action Plan, initially proposed in 2021, represents a toolbox to implement actions for a wider deployment of digital technologies in the energy sector [26].

Europe's future will be influenced by the achievement of the digital energy transition. A deeper electrification of the energy consumption is a concrete option to achieve the energy and climate change targets.

Policies should aim at integrating the economics of digital energy as a whole, fairly distributing costs and benefits through all the involved sectors (rather than specifically per sector). This is where Blockchain could be especially relevant.

Several questions are still open:

- How to reconcile the top-down market/system developments - often promoted by regulation - with the bottom-up somewhat surprising changes in the market arrangement/participation?
- To what extent can emerging socio-political and technological trends subvert the wholesale transmission and retail distribution boundaries and equilibria (e.g., moving from a few, centralised to manifold, decentralised marketplaces)?
- How are the local energy communities and the active consumers going to affect the distribution grid and the energy market, also having in mind the rising sustainability and climate change drivers and concerns? [18]

The success of digital and energy twinning towards long-term sustainability and security goals will depend on the capability to roll out existing and new technologies at scale, as well as on various geopolitical, social, economic, and regulatory factors [27].

Standards can establish a common ground for the development of technologies, promoting a high level of interoperability and ensuring fair and just market operations (avoiding or removing entry barriers built by dominant actors). Adopting adequate and flexible standards would impede technology obsolescence and lack of interoperability (also with new generation of technologies). Additionally, setting up standards early in the process would provide a competitive advantage and create a fertile ground for attracting perspective innovative companies leading the growing economic sectors of the future.

The EU and national legislators are developing a pro-innovation legal framework for digital energy applications. Among the different digital solutions, blockchain technologies promise to streamline evidence-based decision-making in the fields of climate and sustainable energy.

Recommendations of this chapter are to be discussed on a European level based on the open questions mentioned above. These recommendations will be taken up in the final Chapter 5.

4.2. DLT in Energy Finance

In this section we discuss two applications which are important processes in the energy sector: the financial transaction, or settlement of a contract execution and the ownership, resp. the financing of projects using renewable sources and the guarantees of origin (GoO) which goes along with the production to guarantee green investments. The general interest of green investments and the implementation of the European taxonomy will be discussed only in short in a following section.

4.2.1. P2P Financial transactions as a key element of a DLT based value chain

DLT/Blockchain technology changes the way we transact, with the underlying transaction model shifting away from a centralized structure (banks, exchanges, trading platforms, energy companies) towards a decentralized system (end customers, energy consumers). Third party intermediaries, whose services are needed today in most industries, are no longer required in such systems – at least according to the Blockchain theory – given that transactions can be initiated and carried out directly “from peer to peer”. This can cut costs and speed up processes. As a result, the entire system becomes more flexible, as many previously manual work tasks are now carried out automatically through smart contracts.

Almost every use case in the energy sector knows the process of settlement or financial transactions based on the contract conditions agreed on. Bechtel et al. [28] gives a good overview of the European discussion regarding financial transactions, or payment systems, by using DLT. This section is built on results and analysis set out in this whitepaper.

There are three payment systems analyzed, an account-based transfer and two token based transfers using DLT;

A) bank accounts used for transfer (BAC)
B) synthetic digital currencies, backed by central bank money (sCBDC)
C) central bank digital currency (CBDC)

While the European regulation is preparing a digital economy, digital payment solutions form a basic process of such a plan. Whether it will be based on DLT or centralized business logics its not to be discussed here. But programmable payments through smart contracts using DLT show great potential and flexibility for complex business process such as settlement in energy markets. Furthermore, devices operating in the energy networks such as sensors and actors able to manage the flexibility necessary to guarantee system stability, building machine to machine interactions entering into binding contract-based agreements including financial settlements. The use of DLT-based smart contract also allows tokenisation of assets or rights and push DLT to the favourite technology for the future energy system.

The future payments system in the energy sector will therefore most probably be token based (sCBDC and CBDC). Token based solutions based on a DLT based value chain have the advantage of allowing real-time-settlement (P2P trade) and trust shifted from intermediaries to technology.

In order to justify our recommendations, we have to take a look at the value chain of digital payments. Based on Bechtel et al. is the value chain based on three pillars.

1. Contract execution
2. Digital payment infrastructure
3. Monetary unit

The first pillar, the contract execution (CE) comprises the control business logic as an automated process triggering payments. Both are decentralized and predefined based on contracts and/or regulated processes in a DLT network using smart contracts. In this network devices, will become market participants executing, controlling, and documenting transactions.

The second pillar, the digital payment infrastructure (DPI) contains the definition of payment channels used to execute the settlement. Within this pillar there are several ways of payment channels possible and developments are ongoing. A detailed overview and the development path is discussed in the white paper (Bechtel et al).

The third pillar, the monetary unit (MU) is the holder of the account resp. the commercial or central bank guaranteeing and backing the currency. For a full CBDC solution with token-based money from the central bank, the MU becomes the DPI and therefore a fully integrated infrastructure for all digital applications (DLT and Non-DLT). This solution might be available in future but needs fare more regulatory adaption work, including the finical sector.

For the Energy sector, where a smooth development from the legacy system towards a digital infrastructure is recommendable, we expect a step wise approach. This includes bridge solutions where the CE is bridged to conventional account based money transfers. This solutions are today available but have the disadvantages of not being interoperable as solitary company solutions. More interoperability would possible by using sCBDC or e-money tokens (EMT). While sCBDCs can be issued by private sectors and are not regulated, the EMTs backed by European Central Bank in Euro, are regulated in the directive 2019/1937 Markets in Crypto Assets (MICA) and 2009/110 E-Money directive (EMD).

For further discussion in our paper we consider the EMT[3] as a regulated sCBDC.

P2P trade and related roles

The use-case of the P2P trade is a promising application for DLT. To enroll its full potential, the DPI must be included. This adds two main role-streams to the energy and network operation part (ENP) of the P2P use case. These are the system operator of the DPI and DLT-technology related roles. If both application-portions, the ENP and the DPI, later can be issued on any appropriate DLT. The discussion on the detailed roles, both for the ENP as well as for the DPI are ongoing. But looking at the advantage of combining ENP and DPI on different DLT technology platforms, these discussions might be conducted in parallel and individual. As a precondition to this approach, we assume that interfaces within the business process must be described and standardized. Any standardized DPI would also allow other uses-cases, especially in Smart City and E-Mobility applications.

4.2.2 Sustainable finance in general and long-term Power Purchase Agreements (PPA)

Financial institutions

Role and direct opportunities are not obvious for financial institutions, as, indeed, blockchain principle is characterized by no financial institutions as element of its operational value chain.

[3] like stable coin

However, financial institutions are essential investors, and thus will have to be considered as key partners in funding appropriate infrastructures and equipment towards full operationality. In this context, financial institutions need material KPIs in support of their due diligence, underwriting procedures to de-risk investment.

The implementation of the framework for sustainable finance (NFRD 2013/347EU, SFRD Regulation 2019/2088, Taxonomy regulation 2020/852, CSRD regulation proposal COM(2021 189 Final) which requires the reporting and disclosure of the eligibility and alignment over time may require blockchain /DLT solutions to reduce costs and provide greater market transparency.

The Interreg Central Europe Feedschools report [29] about “Collection of existing financing mechanisms” illustrates financial partnership in energy related projects, such as energy renovation costs that depend on the depth of the refurbishment, including RES equipment, It is essential to carefully evaluate the costs prior any decision on energy renovation of a building, to identify the level of investment and ensure financing, for a clear evaluation of the benefits of the retrofitting.

Same for our energy related blockchain approaches where the boundaries of each project need to be defined, with the determination of capacities of energy production, distribution and consumption, stakeholders of the value chain and contracting issues towards a sustainable model, prior to estimating the financial investment for the infrastructures and related equipment, then the benefits of the project implementation (technical, financial, societal).

Another example is the large and ambitious support from the Irish gov towards retrofitting existing buildings (500’000+ buildings) by 2030 with a combination of public and private funds.

The blockchain model requires partnerships’ schemes, that includes especially assets owners, ESCOs, banking communities, citizens, municipalities, etc., with a standardized approach towards decision making, monitoring, and reporting. Keeping in mind that standards bring trust and confidence, through fair and transparent “rules” and “protocols”.

However, the projects are usually not “big enough” for motivation financial institutions to engage and support. There is a need for Horizon Europe projects in support of the deployment of blockchain projects in the energy sector with participation of financial institutions to raise maturity and align understanding and cooperative development. Such projects are essential for creating and collecting best practices towards feeding standardization development as key boosters from innovation to market.

Opportunities for financial institutions could also integrate the investment side of the ESCO model towards a new business model.

Long term PPAs - Green PPAs and Certificates of Origin (CoO)

Early in the year 2022 the EU commission (EC) launched a consultation on how to improve permit-granting procedures for renewables projects and facilitating PPAs. The EC plans to issue a guidance document during the year to foster the market-based renewables deployment in the EU.

PPAs are direct contracts between corporate companies and electricity suppliers providing competitive prices to production facilities using renewable sources based on long term contracts linked to market prices. The main driver for companies engaging in PPAs is based on the EU-climate policy for decarbonization and high-level of renewable energy in the electricity system. Many leading companies would like to go further and using 100% renewable energy[4]. But there is today only bottleneck in this wish, a true 24/7 supply from renewables cannot be traced based on the existing Energy Attribute Certificate (EAC) or CoO scheme. Today's schemes consider a monthly or even yearly validity of the certificates, and a 24/7 allocation is not possible. The use of DLT has the potential of creating shorter term CoOs and pilots are already ongoing which uses at least partially DLT, such as:

- FlexiDao, https://www.flexidao.com/resources/case-studies
- Axpo https://www.axpo.com/ch/en/business.html

Further to the pilot projects there is an independent industry-led initiative named „EnergyTag" with the aim of enabling a 24/7 clean energy supply and to develop and promote generation certificates (GC) standards which are technology agnostic. 1st standard published 31.03.2022 https://www.energytag.org/wp-content/uploads/2022/03/20220331-EnergyTag-GC-Scheme-Standard-v1-FINAL.pdf

Discussion on roles in the use-case of 24/7 GC

Possible processes using DLT for a GC system are described in literature [30] and consists of DLT network with associated roles (according to IEC 23257; 2022) and the business processes enabling trade execution. The final goal of a full digitized solution is an integration of the CoO to every kWh traded or self-consumed.

Several questions remain open from this Chapter 4.2:

- How to define financial related roles in the different reference architectures
- How to integrate accounting and financial standard as a driver for investment
- Finance and Energy focussed cross sectorial research and pilot projects would be useful towards raising maturity and strengthening partnerships' models.
- How to ensure enhanced interoperability of conventional account-based money transfers
- How to describe and standardize interfaces in the framework of DPI
- How to support required partnerships' schemes through standardization
- What role for financial institutions; opportunities for financial institutions to integrate the investment side of the ESCO model towards a new business model

Recommendations of this chapter are to be discussed on a European level with stakeholders from the whole value chain, and based on the open questions mentioned above. These recommendations will be taken up in the final Chapter 5.

[4] See www.there100.org

4.3. Identity

This chapters provides a general overview of identity principles in a digital ecosystem. Every business process in a digital ecosystem starts with an identity cycle. Figure 8 shows a simplified process which can be applied to almost every business use case.

Figure 9 – Basic business process

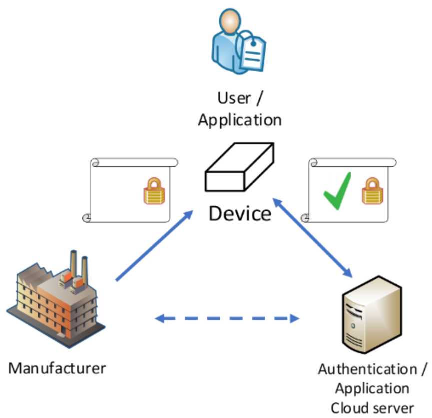
The following section is giving an overview of some existing identity (ID) principles to be used in digital ecosystems in order to establish trust between partners.

4.3.1 ID of persons and things – general discussion

4.3.1.1 ID for devices

The Internet of Things (IoT) is present almost in every sector today. But it’s not new and the rise started with the worldwide spread of the Internet. IoT means in general a device with a sensor, logic and communication.

IoT is today a common technology in industrial applications and other sectors such as building, mobility, logistic, Smart Cities, etc. But each sector has its leading manufactures providing devices, connectivity protocols, cloud platforms creating its own device network. Most of the IoT networks use restricted access networks, where devices are connected and operate on dedicated cloud-based applications. This has led to siloed ecosystems with tricky interexchange between systems and limiting scale up. Although date exchange between cloud platforms is a new business model, it’s not really unlocking the potential of an IoT ecosystem.



Basic configuration of a centralized cloud-based identity management system (IDMS). It is based on single-factor authentication (SFA) where the certificate is issued by the manufacturer and authenticated by an IDMS. In consequence, most IoT networks have their own standard how to manage device registration. Centralized identities are created and administrated by an external entity and their basic configuration using SFA is shown in left side figure 9, where the central entity is the manufacturer.

Figure 10, centralised IDMS

These IoT applications have an authentication based on so called “Centralized Identity’s” (CI) or “federated identities”. A kind of a standard of CIs avoiding the look-in to a manufacturer and today widely applied in digital ecosystems, is the Public Key Infrastructure (PKI) framework. In today’s internet driven data exchange, a secure and trusted network environment for applications and device communication is essential. PKI uses digital certificates[5] and key pairs (public key and private key), generates digital certificates as digital identities for subjects on the network and authenticate them. Popular use and best known is TLS/SSL protocols for HTTPS web security standard.

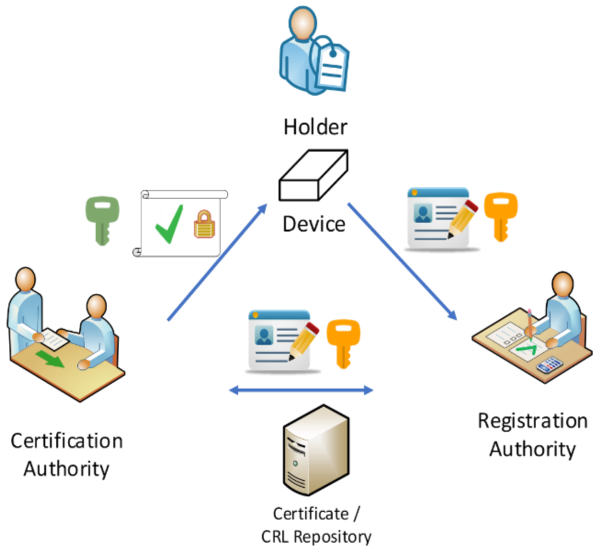


Figure 11, PKI framework setup phase

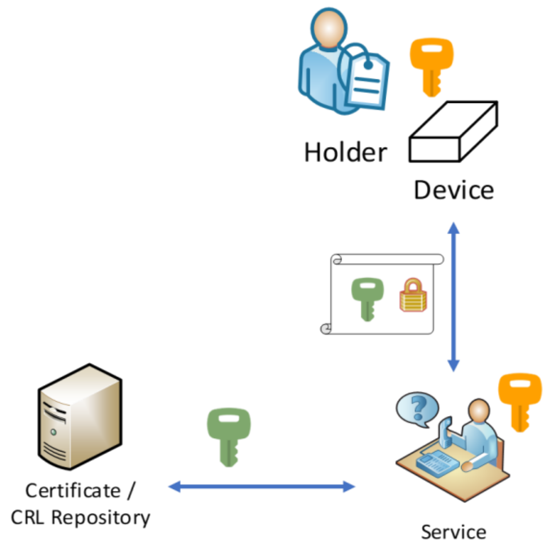


Figure 12, PKI framework operation phase

To transfer sensitive information between user applications and devices a two-factor authentication (TFA) or multi-factor authentication (MFA) is established. To establish a communication, they have to authenticate themselves. For this purpose, the application (host) and the device use a key-pair, a public and a private key. To establish an encrypted transfer, they share their public keys in the communication. The PKI infrastructure is an arrangement for a specific purpose ensuring that public keys are assigned to the right entities (hosts or devices).

PKI solutions for IoT applications exists and external sources are available as business services. For each device, one or several identities and their lifecycles need to be managed. These identity lifecycles start during manufacturing and software development, continues during deployment and operation and finally ends when the identities are revoked, and the device is discontinued or reset. The corresponding lifecycle management applies for users, software as well as for the devices themselves.

As shown so far, most authentication frameworks are centralized. The World Wide Web Consortium (W3C) has introduced a new type of verifiable identifiers, which does not require a

[5] X.509 standard

centralized registry. These Decentralized Identifiers (DIDs) enable identity holders having control outside of centralized authorities. According to the W3C[6] organization Decentralized identities are defined as follows:

"Decentralized identifiers (DIDs) are a new type of identifier that enables verifiable, decentralized digital identity. A DID refers to any subject (e.g., a person, organization, thing, data model, abstract entity, etc.) as determined by the controller of the DID. In contrast to typical, federated identifiers, DIDs have been designed so that they may be decoupled from centralized registries, identity providers, and certificate authorities. Specifically, while other parties might be used to help enable the discovery of information related to a DID, the design enables the controller of a DID to prove control over it without requiring permission from any other party. DIDs are URIs[7] that associate a DID subject with a DID document allowing trustable interactions associated with that subject."

Yki Kortesniemi et al mentioned in [31] criteria's for IoT devices in order to use DID. These are sufficient performance, a nonvolatile storage capacity and sufficient entropy source to generate random cryptographic keys. Considering Moore's law, it is therefore more likely that future devices will be able to handle DID framework criteria's and it's recommended to include these framework principles in future work on standards.

No case is known to the authors on time of creating this report, where an open DID framework is applied for devices, except in Sweden, where the SSI concept is also being considered for IoT applications. There are smart energy applications for energy communities like the one in Vienna[8] using devices (trusted gateway). But the whole ecosystem behind this use-case is closed, includes cloud services and is linked through APIs to the legacy world. Developing of such ecosystems is challenging and expensive and understandable if the solutions are protected by patents. But leads to other siloed systems without effect to the Energy Transition.

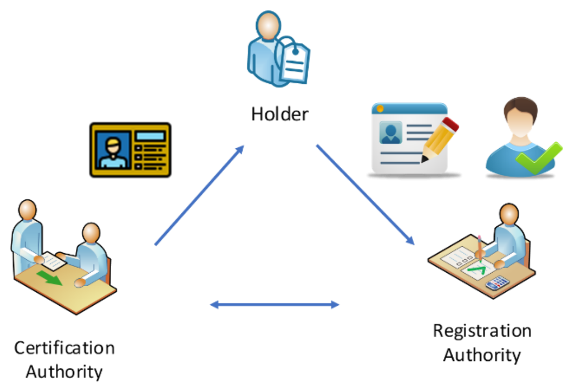
The main discussion as per today on DID, is based on the application for electronics identification systems for persons (eID), see next section.

[6] https://www.w3.org/TR/did-core/

[7] Uniform Resource Identifier (URI) is a unique sequence of characters that identifies a logical or physical resource used by web technologies.

[8] Vienna Energy and Riddle&Code introduced a platform called MyPower; https://www.riddleandcode.com/energy

4.3.1.2 ID's for persons – electronic Identification (eID)



Person IDs

Also, in this case of setup an Identity we see a triangle relationship between the holder, a registration authority and an authority issuing the certificate, in this case a passport or Id-card (see figure 12). The use of this certificate is mainly based on MFA meaning the certificate itself and a second proof mainly the visual check with the photo.

Figure 13, principle of ID authentication for person

Electronic Identification of persons and related management systems are under development in many countries. To support these developments and ensure interoperability between countries in the EU, the eIDAS Regulation has been put in force in 2014[9]. The Regulation does not interfere with electronic identity management systems and related infrastructures established in the Member States. The past two years have proven to be a globally challenging period caused by COVID-19 pandemic, in which eIDAS has been under revision and has urged the development of new models.

In parallel, the new technology of DID's has emerged for identification to the so called "self-sovereign identities" (SSI). This technology gives identity holders greater control over its identity by adding features which provides a degree of distribution of identity related information.

This includes the ability of identity holder to issue individual "verifiable credentials" (VC) issued for different activities. In contrary to certificates used in a PKI framework which shows all attributes associated with the holder. This gives the holder greater control over how its identity is represented to parties relying on the identity information and, in particular greater control over the personal information that it reveals to other parties.

In the SSI environment, there are three responsibilities (roles) that are usually agreed upon:

- Issuer: the person or organization that issues a verifiable credential (VC) about a persons' or things' identification traits.
- Holder: the person or subject to whom the identification attribute belongs and to whom the issuer is providing evidence in form of a VC.
- Verifier: a person or institution that gets presented the VC from the holder and therefore confirms a holder's identification.

[9] Regulation (EU) No 910/2014 of the European Parliament and of the Council of 23 July 2014 on electronic identification and trust services (eIDAS) for electronic transactions in the internal market and repealing Directive 1999/93/EC

For a so-called Trust Triangle, all three are required:

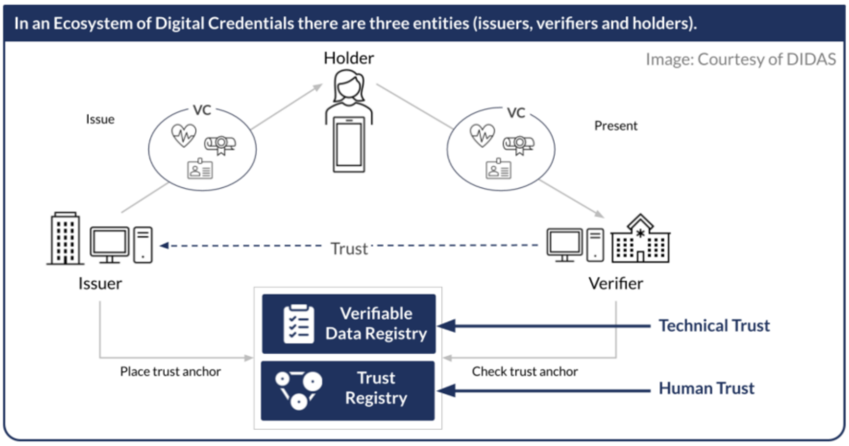


Figure 14, Trust Triangle [32]

In order to handle digital identities, the holder need a tool that allows him or her to store VCs and communicate with the issuer and verifier. Wallet is the name of this instrument.

Activities in the EU regarding eID:

This Section shows projects that are addressing digital identity in the Horizon 2020 program.

The report from the European Union Agency for Cybersecurity (enisa) has issued a report on digital identity in Januar 2022 [33] and listed 9 projects working on digital identities using DLT in the fields of digital economy, Next-Generation Internet (NGI), secure society, eHealth, eGovernment, mobility, and big data.

In addition there are initiatives in several countries with different maturity on an eID ecosystem.

- Estonia
- Germany,
- Netherlands
- Poland
- Spain

some countries have decided to introduce an eID like Switzerland or are working on principles like Austria, Denmark, Sweden, Portugal Luxembourg, Czech republic (list not exhaustive).

4.3.1.3 General difference between eID and IoT:

Devices can act in two different main roles in a digital ecosystem. The following two questions helps to identify the roles and related main issues like security and data protection in order to structure the discussion in following sections:

- Are devices coupled with persons or services that persons perform but the device is representing the person in the use case and acts independently or;

- Is the device independent from a person? Does it act in a digital ecosystem and specific use case as a sole device with dedicated functionality not interacting with roles possessed by a person (e.g., control devices in a manufacturing process or smart grid application).

As previously explained, the latter point is more exposed to security issues while the first role is related to GDPR.

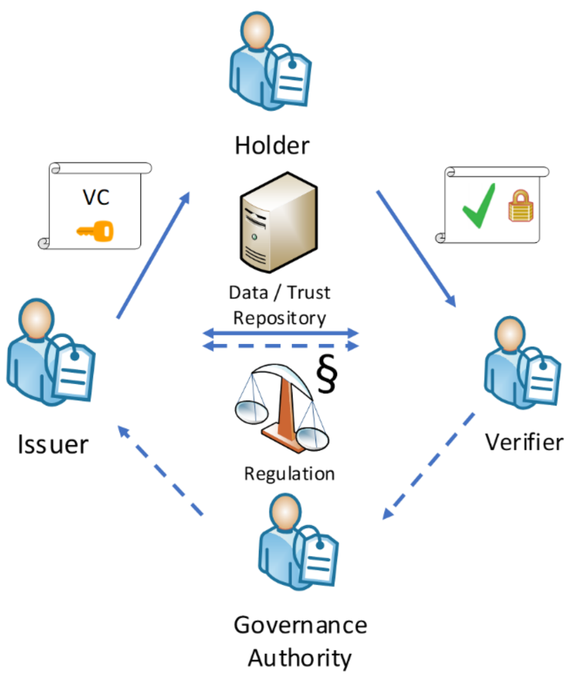
It is common for eID and IoT, that personal data may not be shared with all involved parties for market and/or operation tasks. Since eID always comes with personal data, this leads to other architectures and applications, considering the General Data Protection Regulation in the EU (GDPR). IoT is not necessarily tight to personal data but more to locations and applications and therefore the security of network and information systems across the EU must be considered.

An IoT architecture in industrial applications using SFA includes most likely a dedicated communication and cloud service layer, where eID based on MFA does not rely on such specific layers. Future IoT systems based on DID and or PKI might be similar organized. E.g., also private PKI are closed systems with communication to the private web services only. Public PKI on the other hand have also open communication paths similar to an eID ecosystem.

It is therefore not easy to determine the difference between eID and IoT IDs. Both are technology driven and it is finally the role of the device or person with related ID who describes the process and business integration.

4.3.2 New roles in an Identities ecosystem (persons and things)

The roles within an eID and an IoT-ecosystem might be different even though they have analogue responsibilities. But since basic architecture-models, applicable for several use cases, are not defined yet, we can only start the discussion on roles in a digital-ID-ecosystem here. With respect to the energy market we would like to refer also to the report from the “bridge H2020” working group on the harmonized electricity market role model and the differential analysis with respect to ENTSO-E – ebix -EFET Model [34]. Considering this as a basis for the legacy system and the following discussion in this section, you will find recommendations for further steps in Section 4.3.6 and 5.



The roles in ID-ecosystem are basically along the triangle system as discussed in the ID and authentication systems above (Section 4.3.1).

In general, as shown in figure 14, there is the triangle of governance-trust applied in the setup phase, indicated with

and the user-trust triangle, applied in the operation phase, indicated with

Figure 15, Digital Governance Trust Diamond

The roles in the triangles of the systems used, are described briefly in the previous chapters. The new role of the governance authority is completing the ecosystem and leads to the “Digital Governance Trust Diamond” introduced by the Trust Over IP Foundation[10].

Examples of roles are administrators, developers, and maintenance personnel. They are all a part of the trust chain. Finally, trust cannot be established by technology alone, although this is promised by DLT. It requires policies and procedures and that the roles and responsibilities of the different stakeholders in the IoT eco system solution is set by regulation.

Several questions regarding basic architecture-models and roles remain open, such as:

- How can the architecture-models used in the smart grid world and the SW-standards be merged. In particular the Smart grid architecture model (SGAM) and the DLT architecture based on ISO 23257. A working group of the German standardisation organisation DKE[11] (DKE/AK 901.0.5 Energy Blockchain) is working on a guideline looking at this topic.
- Merging of new roles based on the DLT architecture-model and the roles in the legacy system.
- Roles of devices in a new DLT-ecosystem need most probably new definitions of device classes based on their functions in the SGAM.

[10] https://trustoverip.org/toip-model/ [30]

[11] https://www.dke.de/de/ueber-uns/dke-organisation-auftrag/dke-fachbereiche/dke-gremium?id=3006733&type=dke%7Cgremium

- Role of authority to define credentials and definition of VCs similar to X.509 Certificates
- Etc.

IoT ID service companies and communication infrastructure providers are already today acting as a kind of ancillary service providers in the digital market. In a digital organised market, this could be seen as core platform services for specific sectors and in the role of gateways or gatekeepers[12] between business users and end users. Leading manufacturers in a sector could create own platform ecosystems with key structuring elements of today's digital economy, intermediating the majority of transactions. Many of these services enabling also comprehensive tracking and profiling of end users and the Digital Market Act protects against misuse. But if the ID service is based on DLT, the role of the gatekeeper is replaced and must be new defined and integrated in new regulations.

4.3.3 Blockchain in the ID handling

SSI is employing numerous technologies and cryptographical techniques. Per se there is no obligation to use blockchain in the identification or approval process. Nevertheless, confidence between verifier and issuer must be built through a verified data registry and trust registry. The verifiable data registry holds proofs regarding VCs so the verifier may check if they are elicitable issued and legitimate. The trust registry demonstrates that the issuer is approved by a higher organization and makes the public keys of the issuer available to each verifier without establishing a direct connection between verifier and issuer. Both registries may be achieved utilizing blockchain technology which permits the decentralized, fail-safe and immutable trust layer.

The general advantage of DLT solutions is creating trust in the ecosystem. Since the energy system is highly regulated, especially in the EU, it is not obvious why the energy system should be trust-less organized. This might also explain why pilot projects using DLT in the energy system failed on their way to commercialization (see Section 2 and 3).

The disadvantage of using DLT based applications might be, that lifecycle of IoT devices must be guaranteed. Considering the existing and future number of IoT devices it's questionable if ID information shall be written in a chain forever. The existing PKI framework has the advantage that certificates can be revoked at the end of the lifetime of the devices

4.3.3.1 Who is active in the field of blockchain based identity?

Different countries in Europe are working on digital identity systems at the time of this publication. Some of these solutions are based on blockchain or distributed ledger technology (DLT)[13]. In those systems, DLT is frequently utilized as a trust anchor for storing identification

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[12] As defined in the EU Digital Market Act, Regulation (EU) 2022/1925

[13] Some examples: IDUnion (DE) (https://idunion.org/) FINDY (FI) (https://findy.fi/en/), ID Alastria (ES) (https://alastria.io/en/home/), or from NL https://dutchblockchaincoalition.org/en/bouwstenen-2/self-sovereign-identity-ssi. Further information can be found here: [33], [35].

proofs in an immutable manner. It is worth noting that personally identifiable information should never be written on a blockchain. The ISO standard TR23249_2022 provides a review of current DLT systems for identity management as well as conceptual designs. It should be noted that this ecosystem is constantly changing, therefore this overview can only be considered a snapshot.

Trust over IP (https://trustoverip.org/) is working on a worldwide framework for electronic identification based on the Self-Sovereign Identity (SSI) principles at the international level. Alastria ID (Spain) and the European Self Sovereign Identification Framework (ESSIF) are two examples of existent DLT identity systems in Europe. Decentralized Identity Foundation (DIF), Hyperledger Indy, Sovrin, and the World Wide Web Consortium (W3C) are all working on reference implementations on a global scale. In addition to these examples, there are further projects and efforts underway in a number of European nations.

Other sectors are also working on DLT based applications with focus on authentication frameworks like:

- Swiss project “cardossier” in the transport sector with the goal of managing the life cycle of a car with DLT [36].
- The international BITA Standards Council, a non-profit organization for transport industries, is focusing on data formats for use on blockchain platforms to assure consistency and interoperability across platforms.
- In the health sector there are proposals for regulations concerning than European Health Data Space under discussion [18]. it includes regulations for a digital identity based on the amendment of the eIDAS regulation[14].
- A worldwide alliance “ID2020” is supporting principles for digital identities and has projects for health ID in Indonesia and Thailand and starting in Bangladesh
- Etc.

The list shows only a few examples and is not exhaustive. Additional and recent information can also be found on the website of the World Economic Forum (weforum.org).

4.3.4 ID in the energy ecosystem and the interface/difference to other sector ecosystems especially IoT for network-operation and IoT in industry (things)

The energy ecosystem knows several individual ID systems depending on the application (use case). They are mainly based on a SFA or MFA process between two entities (e.g., supplier and customer). For the authentication in a market context, and especially the international market, a prequalification process is introduced defining the ID for entities based on the Energy Identification Code (EIC). The central issuing office in Europe for this ID is ENTSO-E for

[14] COM/2021/281

electricity and ENTSO-G for gas. In the distribution markets (or retail market) the ID is mainly[15] linked with the metering point ID managed by the network operator. In addition, the Object Identification System (OBIS) will be used in the energy market and is based on IEC 62056 standard.

Once registered, the data exchange is standardised. The EU regulation 2015/703 of April 30th, 2015 established AS4[16] as the standard protocol, based on webservices, for all natural gas transmission network users. By October 1st, 2023, AS4 will be mandatory as the communication standard also for the German electricity and gas market. Austria changed already to AS4 standard in spring 2022.

IoT-networks have their roots in the industrial applications and are widely applied during the Industry 3.0 phase. The change to Industry 4.0 will bring more interconnectivity between systems involved in production and product life cycle, meaning an increase and total integration of IoT and digital services.

IoT-networks used for network operation are standardised in the IEC 61850 series. There are several subsections dealing with all kind of use-cases and related communication requirements including authentication and security issues. In recent years efforts have been made to integrate also applications related to other sectors in order to secure fully smart grid functionality for the energy system transition.

A direct interface between industrial used IoT systems and the energy system is up to now not existing. But the ongoing transition of the energy system shows an increasing cooperation between sectors. The sector-coupling is recognized and necessary to achieve the green transition in the energy system. The European Commission has stated that only “Interoperable and open digital solutions, as well as data sovereignty, are key to the digital transformation of the energy system”[17]. The integration of IoT is part of this strategy.

How the two paths of developments, Industry 4.0 and the Energy system Transition can use common technology and standards, remains to be seen (see also recommendations, section 3). Further to this, it has to be considered that the energy ecosystem is somehow “quasi-static” compared to the industrial sector. This means that devices used in networks of the energy system have lifetimes between 10 and 30 years (some even longer).

With the introduction of the smart meter technology the authentication became a new and system critical position. Germany for example defined a PKI framework to ensure IoT security and privacy including device enrolment, communication between devices and related services. Other countries use less challenging frameworks but also closed systems of authentication and communication between devices and services, leading to fragmented solutions allowing easy data exchange only within defined network boundaries and service areas.

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[15] In Germany is the Meter ID replaced by the “Marktlokations- ID-Nr.)

[16] AS4 is a standard profile of the Organisation for Advancement of Structured Information Standards (OASIS)

[17] See: https://digital-strategy.ec.europa.eu/en/policies/digitalisation-energy

4.3.5 Applications – Use Cases

Below are some examples of use cases for digital identity in the energy ecosystem using DLT

Use cases with DLT applications have been discussed widely in different papers and pilots have been conducted. However, most pilots have not been evolved to successful business application. Various reasons led to this and are described in section 2 of this report.

Various standardization projects have also been started in recent years and provide an overview of possible applications of DLT in the energy industry such as the Swiss DLT-for-Power – Guide on transforming Electricity Market processes using DLT [30].

For use cases having DLT elements using smart contracts it's essential that devices, executing such contracts, have their own identity with clear assigned roles and duties. It's not clear up to now how these devices act in digital ecosystem, but it means that IoT technology will be a part of the future energy ecosystem Referring to ID-frameworks, there is today only the PKI framework used for smart meter infrastructure as a first widely used IoT application in the energy system[18].

4.3.6 Summary of identified barriers and recommendations for further work in the ID-ecosystem

Each nation starts building its own eID ecosystem which can create problems in international exchange of ID-information either for governmental, health or market related issues. The national and international eID development is actually ongoing (see Section 1) and there are efforts taken by governmental organizations such as the European Union and sector organizations such as World Health Organization (WHO)[19]. Especially for handling pandemic situations exchange of data is crucial and they also look into DLT solutions in order to secure trust over different organizations and countries.

The international coordination of eID for Persons is in our opinion not critical for the energy ecosystem (see also section 4.3.4). Nevertheless, it is recommended to establish some kind of basic principles based on the existing regulation and considering the transition into a CO^2 free energy system. Especially for new international regulations, a harmonized link of eID with the energy ecosystem is recommended. Dealing with this issue, an intersectoral working groups could be established, especially linking national and international developments.

IoT identification service providers for devices create and enjoy an entrenched and durable position, often as a result of the creation of enterprise ecosystems around their platform services, which reinforces existing entry barriers for new frameworks.

Another major barrier for a common approach of an ID-ecosystem for active IoT devices in the energy system is the lifecycle of the devices (see also section 4.3.4). Devices in the network infrastructure have an extremely long lifetime compared to the devices in a digital eco-

[18] We do not consider the network control functions based on IEC 61850-xy as IoT system discussed in this document

[19] https://www.who.int/multi-media/details/emerging-technologies-in-response-to-covid-19-blockchain-ict-and-data-for-pandemic-management#

system known today (e.g. smart phones). The same is valid for Metering devices. Once installed, systems with a national standard cannot be replaced easily within a few years. Despite the cost such a replacement would entail.

We recommend establishing a common architecture-model for digital markets, configuration to be used in Energy businesses applications and a common definition of the roles associated to such an architecture. Further work should concentrate on the roles and responsibilities in order to guarantee some kind of interoperability between new market models in the EU, allowing the development of PKI based solutions as well as DID based solutions (see also section 4.3.2).

A common definition of the roles might also be the difficult part. Stakeholder organizations have already started describing the roles of their ecosystem fitted to their technical solutions. Other international organization like ISO have defined roles for DLT application from a SW-viewpoint which do not correspond one to one to roles in the energy use cases. The task on role and architectural model definitions is challenging and, in our opinion, cannot be performed by an organization with a technological focus alone.

Initiatives on applications and regulatory work on eID based on DID (SSI) are already ongoing and needs coordination. DID or other ID-schemes for IoT is still left to the industry. The authors therefore recommend enforcing standardization work and structures for coordination of regulatory work in the energy and industrial sector. This coordination should focus on semantic and functional interoperability rather than technical interoperability

4.4. Smart Contracts

The ability to perform distributed computation on the ledger state within the context of the blockchain can provide vastly more functionality than a distributed ledger that is only used for the passive recording of data. This is especially useful in situations in which two or more parties have contractual obligations that are based on an alteration in the ledger state. The addition of smart contracts to blockchains enables this kind of executable extension to be provided. A computer protocol is referred to as a smart contract when it is designed to digitally facilitate, verify, or enforce the execution of a contract during its negotiation or performance. Smart contracts mimic paper-based contracts in the digital realm by using DLT infrastructure. Smart contracts are a solution to a flaw in the original design of the Internet, which was the absence of any protocol or method to account for the generation and transfer of value on a decentralized basis. Smart contracts mimic paper-based contracts in the digital realm by using DLT infrastructure [37].

The advantages of DLT such as immutability, scalability, and security, are automatically inherited by smart contracts because of the way they are designed. They may, however, present new attack routes, which may lead to cybersecurity explorations. These explorations have the potential to put the end application’s capacity to function as it was designed in jeopardy or result in data breaches and privacy violations. Within the scope of a study presented recently [38], an investigation of previously identified issues and potential attack scenarios will be given. This is followed by a list of suggested best practices and mitigation measures that are meant to help developers, researchers, and other relevant parties make SC implementations that are safe.

Cali et al. [39] presented a first attempt toward the standardization of smart contracts within the field of power and energy as a work-in-progress activity under the IEEE Standards Association (IEEE SA) P2418.5 Working Group. Smart contracts are defined as computer-executed agreements that have predetermined terms and conditions that govern their performance. This work also proposes a holistic, language-agnostic reference model with the goal of accelerating the adoption of DLT by industry stakeholders by providing standardized processes. This reference model is intended to help accelerate the adoption of DLT by providing standardized processes. In the last part of the document, the main takeaways are discussed, and all of them need to be improved so that smart contracts are used more in the energy business.

The current generation of electricity grids is making great strides toward becoming more digitalized and decarbonized. It is envisioned that smart contract requirements would be an inherent element of the architecture of transactive energy systems. Adopting digitalization technologies like DLT and, in particular, smart contracts could change many business subsectors, including the energy sector, by creating new opportunities that were not available before. The degree of technical maturity of smart contracts is constantly improving over time. The currently available smart contract tools are opening up new windows of opportunity for establishing new business territories in the energy industry. It is unavoidable that a growing number of companies and authorities will use smart contracts as an essential component of their day-to-day operations. In general, legislative frameworks for DLT, smart contracts, and cryptocurrencies are being suggested at the national and international level. After legal loopholes are closed and highly interoperable versions of smart contracts are developed, the full potential of smart contracts will be integrated into for use in the energy sector [40].

5. Way forward & Recommendations

In this Section, recommendations on how to reduce barriers to blockchain adoption according to the analyzes in this report are given. These recommendations are divided into three key points: “Standardization in context of regulation”, “Standardization in general”, and “Research & Innovation”.

5.1. Standardization in context of regulation

To meet the Green Deal objectives of the EU member states in the most cost-efficient way requires an energy system that is much smarter and more interactive than it is today. This means a decentralized, decarbonized, and flexible energy system that requires innovative digital solutions.

DLT is considered to be such an innovative solution, but as observed during our work on this report, initiatives on these technologies failed mainly due economical and regulatory hurdles.

The EU-Commission pays special attention to aligning the **Digital and Energy** Strategies, while bringing together stakeholders from different domains (electricity grids, charging electric vehicles, energy efficient buildings) and ensures that EU policies create a momentum on the market rather than become a burden and delay the digital transformation of industry. Nevertheless, a regulatory roadmap for digitalization of the energy system that requires DLT as a technology does not exist. The member of the working group could not identify regulations that can best be met by DLT/Blockchain. This might of course be justified; regulation is not there to push a specific technology and should be tech-agnostic. Still, DLT may well enable something that is not currently on the radar of regulators. In other words, DLT/Blockchain might add some feature to the energy system that is not considered at the moment.

As far as standardization is concerned, the time is not ripe for standards at the moment, as the use of blockchain as such is still being debated (as the discussion on regulation has shown).

5.2. Standardization in general

The discussion so far showed that it is too early for standardization with regard to DLT/blockchain in energy. Even if we look at the usual suspected standardization needs for Blockchain (e.g., the ISO publication "Trend Report 2022" [17] mentions the standardization topics "Interoperability", "Governance", "Identity", "Security", and "Smart Contract"), we see that, in relation to the energy sector, DLT is not mature enough to discuss these standardization topics, as the following example illustrate:

- Interoperability between Blockchains makes little sense if the use of Blockchain as such is still debated. Interoperability of DLT solutions to legacy systems does make sense (e.g., the integration of smart meters via IoT into a blockchain) but should be addressed in non-DLT standards (as new non-DLT systems will connect to legacy systems as well).
- For governance standards it is too early, as, to the authors' knowledge, there is no DLT use case in the energy sector implemented (or tested) that uses adequate governance principles (i.e., "on-chain decision", see in the next section).
- DLT standardization regarding identity will follow if decentralized identities prove useful in the energy sector (or wanted by regulators), something that has not been tested to date. See "Section 4.3. Identity" for more details about identity.

Hence, the member of the working group believe that RD&I efforts are needed to increase the maturity level of DLT/Blockchain in the energy sector promoting a holistic approach that goes beyond the financial transaction of energy trading.

5.3. Research & Innovation

ISO/IEC 38500 defines Governance as "*a system by which the current and future use of IT is directed and controlled*". Furthermore, ISO/TS 23635 states that "*DLT systems should enable decentralized, on-ledger decision-making processes*". This is rather obvious, because if a single entity could change the DLT system on its own, that entity would have to be trusted not to do anything bad. But then the DLT loses its purpose.

If DLT/Blockchain is used in the context of the energy sector, governance principles and standards are therefore required. However, since we know of no pilot project or other activities addressing the issue of governance in the field of "DLT in energy", first research and pilot projects are needed in this area before one can address standardization. Research and pilot projects that are focusing on collaboration and governance are needed, ideally across sectors (e.g., finance and energy). So-called regulatory sandboxes in innovation projects can help to test the approaches.

The discussion so far has shown that the use of blockchain itself is being critically questioned and that research and development work or pilot projects for new approaches to collaboration are still needed. Since it is still unclear how this new form of collaboration will look like, very fundamental analysis is needed. A possible research focus could be which options DLT offers in terms of collaboration, as well as their advantages and disadvantages. For example, the use of a DAO ("Decentralized Autonomous Organization") in the energy sector would be very interesting. It should be noted that Promise 1, i.e., changing the way we collaborate, could be triggered not only by regulatory changes, but also by more efficient, democratic, and faster decision-making processes that blockchain could enable.

The members of the working group believe that the idea around Promise 1 (i.e., a collaborative energy future) should be further elaborated, and that the drafting of potential architecture models (e.g., roles, how they interacted, and how they are governed) would be a promising step forward. These architecture models or reference architectures could be then further detailed and tested in the course of Horizon Europe projects, or similar. RD&I and pilots and demos could establish best practices and, subsequently, support scaling-up, including feeding knowledge into standardization initiatives.

In the context of developing a reference architecture, various use cases and aspects could be analyzed, however, always through the lens of how DLT can support the case. For instance, one could work on the basics to establish Green Certificates with low granularity (i.e., close to real-time, and with a small basic energy unit (e.g., KWh instead of MWh) to enable small prosumers to participate in the market. This would help to facilitate a market-based approach towards a 100% renewable energy supply. Important here, however, is to focus on how such a system could look like without a central governance, and with on-ledger decision-making processes. As mentioned before in this report, another important aspect is the link between consensus algorithms and governance, on the one hand, and consensus algorithms and use cases, on the other hand.

5.4. Final recommendation

As the final recommendation of this CEN/CENELEC SFEM working group, it is necessary to work on a future business transformation of the energy sector allowing decentralised solutions. This may imply DLT as well as other digital solutions. The solutions might even be a combination of DLT with other digital technologies. Even though DLT is associated with trust without third party, the trust in a DLT solution must be established as well. We concluded, that besides of trust in technology, the trust in governance is key to establish digital solutions in an ecosystem. It is therefore most important to work on new reference architectures and role definitions, considering digital solutions including DLT.

A major step in the past years was achieved by establishing the Smart Grid architecture model and the European harmonised Energy market role models. Both needs to be updated considering new digital technologies. This means an extensive top-down work on principles how existing and new organisations, actors and technical devices are working together in a future smart energy world including DLT solutions.

We propose to set up a group of experts like the proposal of EU-Commission for the “Data for Energy” (D4E) working group as described in the commission staff working paper for the EU action plan for digitalising the energy system[20]. The new “Smart Energy Expert Group (SEEG)” could be the host-group for this new working group focussing on a digital ecosystem allowing

[20] https://energy.ec.europa.eu/topics/energy-systems-integration/digitalisation-energy-system_en

for DLT integration with a focus on architecture-model and governance principles including identity principles in integrated but decentralised markets.

We propose this arrangement for the working group also considering that the SEEG is the follow-up organisation of the “Smart Grid Task Force (SGTF) who was the main driver for the Smart Grid architecture model.

The group should also support the commission and all European states in flagship initiatives with open results to support the digitalisation of the energy system. Further support should be given by this group to RD&I projects, i.e., Horizon Europe and national calls, in a way to gain maturity about real numbers, benefits and real case impacts of DLT in the energy systems. The present SFEM WG concentrated on the electricity sector, while the future reference architecture and role model could be extended to related sectors, i.e., heating & Cooling, gas and mobility and include green finance issues.

About standardization, it is too early for proposing development of new technical standards. Indeed, there is a need for additional maturity and reference best practices and use cases first. However, technical development in digitalisation is a global and cross-sectoral issue. Thus, a group of experts should think about a possible global standardisation exchange with focus on DLT (CEN-CENELEC, ISO, IEC, IEEE, Cigré, ITU-T, EBSI etc). A collaborative framework to integrate/align technical standards with accounting and financial standard to comply with legislative provisions and regulations (such as taxonomy, CSRD, SFDR, Sustainable Finance Platform, proposal for Corporate Sustainability Due Diligence Directive) to drive investment decision and report/disclose results over time. This could be organised through a CEN Workshop Agreement (CWA) as an initial step towards future coordinated standardization work. Such a CWA would contribute to alignment of understanding, setting principles of governance, harmonizing future approaches and, of course, paving the way to standards.

Bibliography

[1] L. Chainstack Pte, “Gartner - hype cycle for blockchain.” https://pages.chainstack.com/hype-cycle-for-blockchain-technologies-2020 (accessed Aug. 04, 2021).

[2] WEF, “WEF_GSMI_Technical_Standards_2020.pdf”, Accessed: Aug. 03, 2022. [Online]. Available: https://www3.weforum.org/docs/WEF_GSMI_Technical_Standards_2020.pdf

[3] G. Fulli *et al.*, “Blockchain solutions for the energy transition, Experimental evidence and policy recommendations,” *JRC Publications Repository*, Mar. 15, 2022. https://publications.jrc.ec.europa.eu/repository/handle/JRC128651 (accessed Nov. 09, 2022).

[4] “Overview of EU-funded blockchain-related projects | Shaping Europe’s digital future.” https://digital-strategy.ec.europa.eu/en/news/overview-eu-funded-blockchain-related-projects (accessed Nov. 09, 2022).

[5] M. Iansiti and K. R. Lakhani, “The Truth About Blockchain,” *Harvard Business Review*, Jan. 01, 2017. Accessed: Aug. 31, 2022. [Online]. Available: https://hbr.org/2017/01/the-truth-about-blockchain

[6] International Renewable Energy Agency, “Blockchain – Innovation Landscape Brief,” p. 28.

[7] J. Bieser and D. Fasnacht, *HYPE OR HELP? The real benefits of blockchain*. GDI Gottlieb Duttweiler Institute, 2023. [Online]. Available: www.gdi.ch

[8] M. Andoni *et al.*, “Blockchain technology in the energy sector: A systematic review of challenges and opportunities,” *Renewable and Sustainable Energy Reviews*, vol. 100, pp. 143–174, Feb. 2019, doi: 10.1016/j.rser.2018.10.014.

[9] A. Meeuw, S. Schopfer, and F. Wortmann, “Experimental bandwidth benchmarking for P2P markets in blockchain managed microgrids,” *Energy Procedia*, vol. 159, pp. 370–375, Feb. 2019, doi: 10.1016/j.egypro.2018.12.074.

[10] M. Choobineh, A. Arab, A. Khodaei, and A. Paaso, “Energy innovations through blockchain: Challenges, opportunities, and the road ahead,” *The Electricity Journal*, vol. 35, no. 1, p. 107059, Jan. 2022, doi: 10.1016/j.tej.2021.107059.

[11] International Energy Agency, “Blockchain Energy Consumption”, Accessed: Aug. 31, 2022. [Online]. Available: https://www.iea-4e.org/wp-content/uploads/2021/12/4E-Policy-Brief-EDNA_14-010322.pdf

[12] S. Aggarwal, R. Chaudhary, G. S. Aujla, N. Kumar, K.-K. R. Choo, and A. Y. Zomaya, “Blockchain for smart communities: Applications, challenges and opportunities,” *Journal of Network and Computer Applications*, vol. 144, pp. 13–48, Oct. 2019, doi: 10.1016/j.jnca.2019.06.018.

[13] A. Hrga, T. Capuder, and I. P. Žarko, “Demystifying Distributed Ledger Technologies: Limits, Challenges, and Potentials in the Energy Sector,” *IEEE Access*, vol. 8, pp. 126149–126163, 2020, doi: 10.1109/ACCESS.2020.3007935.

[14] S. N. G. Gourisetti *et al.*, “Standardization of the Distributed Ledger Technology cybersecurity stack for power and energy applications,” *Sustainable Energy, Grids and Networks*, vol. 28, p. 100553, Dec. 2021, doi: 10.1016/j.segan.2021.100553.

[15] B. Putz and G. Pernul, “Detecting Blockchain Security Threats,” in *2020 IEEE International Conference on Blockchain (Blockchain)*, Nov. 2020, pp. 313–320. doi: 10.1109/Blockchain50366.2020.00046.

[16] “Electricity digitalisation and blockchains,” *JRC Smart Electricity Systems and Interoperability*. https://ses.jrc.ec.europa.eu/node/31966

[17] International Organization for Standardization, “ISO Standardization Foresight Framework Trend Report 2022,” p. 146, 2022.

[18] G. Fulli, M. Masera, A. Spisto, and S. Vitiello, “A Change is Coming: How Regulation and Innovation Are Reshaping the European Union’s Electricity Markets,” *IEEE Power and Energy Magazine*, vol. 17, no. 1, pp. 53–66, Jan. 2019, doi: 10.1109/MPE.2018.2872303.

[19] “Energy strategy.” https://energy.ec.europa.eu/topics/energy-strategy_en (accessed Nov. 09, 2022).
[20] “A European Green Deal,” *European Commission - European Commission*. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed Nov. 09, 2022).
[21] “A Europe fit for the digital age,” *European Commission - European Commission*. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en (accessed Nov. 09, 2022).
[22] “EU economy and society to meet climate ambitions,” *European Commission - European Commission*. https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541 (accessed Nov. 09, 2022).
[23] “Europe’s Digital Decade: digital targets for 2030,” *European Commission - European Commission*. https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en (accessed Nov. 09, 2022).
[24] “REPowerEU: affordable, secure and sustainable energy for Europe,” *European Commission - European Commission*. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en (accessed Nov. 09, 2022).
[25] “The Digital Services Act package | Shaping Europe’s digital future.” https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package (accessed Nov. 09, 2022).
[26] “Digitalisation of the energy system.” https://energy.ec.europa.eu/topics/energy-systems-integration/digitalisation-energy-system_en (accessed Nov. 09, 2022).
[27] S. Muench, E. Stoermer, K. Jensen, T. Asikainen, M. Salvi, and F. Scapolo, “Towards a green & digital future,” *JRC Publications Repository*, Jun. 27, 2022. https://publications.jrc.ec.europa.eu/repository/handle/JRC129319 (accessed Nov. 09, 2022).
[28] A. Bechtel, A. Ferreira, J. Gross, and P. Sandner, “THE FUTURE OF PAYMENTS IN A DLT-BASED EUROPEAN ECONOMY: A ROADMAP,” p. 28.
[29] Interreg Central Europe Feedschools, “Collection of existing financing mechanisms – case: Italy,” Feb. 2019, Accessed: Nov. 09, 2022. [Online]. Available: https://www.interreg-central.eu/Content.Node/Deliverable-D.T2.2.1-IT.pdf
[30] “DLT-for-Power – Guide on transforming Electricity Market processes using DLT, supporting Energy Efficiency and RES integration.” SNV, Jul. 01, 2021.
[31] Y. Kortesniemi, D. Lagutin, T. Elo, and N. Fotiou, “Improving the Privacy of IoT with Decentralised Identifiers (DIDs),” *Journal of Computer Networks and Communications*, vol. 2019, pp. 1–10, Mar. 2019, doi: 10.1155/2019/8706760.
[32] V. Ammann *et al.*, “Building a Swiss Digital Trust Ecosystem – Perspectives around an e-ID ecosystem in Switzerland,” *digitalswitzerland*, Apr. 2022, Accessed: Nov. 09, 2022. [Online]. Available: https://digitalswitzerland.com/building-a-swiss-digital-trust-ecosystem/
[33] European Union Agency for Cybersecurity., *Digital identity: leveraging the SSI concept to build trust.* LU: Publications Office, 2022. Accessed: Nov. 21, 2022. [Online]. Available: https://data.europa.eu/doi/10.2824/8646
[34] E. De Luca, A. Vito Mantineo, G. Fedele, E. D’Alessandro, A. Colafrancheschi, and K. Kukk, “Harmonized Electricity Market Role Model.” Apr. 2021. [Online]. Available: https://energy.ec.europa.eu/document/download/54f49c2e-bb65-40d3-b237-c01805bd9333_en
[35] “eIDAS-Verordnung über elektronische Identifizierung und Vertrauensdienste,” *Bundesamt für Sicherheit in der Informationstechnik*. https://www.bsi.bund.de/DE/Themen/Oeffentliche-Verwaltung/eIDAS-Verordnung/eidas-verordnung.html?nn=129796 (accessed Nov. 21, 2022).
[36] “cardossier - Managing the life cycle of a car with blockchain technology.,” *Cardossier*. https://cardossier.ch/ (accessed Nov. 09, 2022).
[37] U. Cali, M. Kuzlu, M. Pipattanasomporn, J. Kempf, and L. Bai, *Digitalization of Power Markets and Systems Using Energy Informatics*. Cham: Springer International Publishing, 2021. doi: 10.1007/978-3-030-83301-5.

[38] D. Sebastian Cardenas *et al.*, “Cybersecurity and Privacy Aspects of Smart Contracts in the Energy Domain,” preprint, Sep. 2022. doi: 10.36227/techrxiv.21191197.v1.

[39] U. Cali *et al.*, “Standardization of Smart Contracts for Energy Markets and Operation,” preprint, Feb. 2022. doi: 10.36227/techrxiv.19142081.

[40] U. Cali, M. Kuzlu, J. Kempf, S. S. Saha, S. N. G. Gourisetti, and T. Hughes, “Unlocking New Opportunities Towards Smart Contracts for Transactive Energy Systems: Technical and Legislative Perspectives,” in *2022 IEEE PES Transactive Energy Systems Conference (TESC)*, Portland, OR, USA, May 2022, pp. 1–5. doi: 10.1109/TESC53336.2022.9917266.

Appendix

Appendix 1 – Mapping

The description of initiatives has been taken from public available resources, e.g., their websites.

DLT Application in energy sector

Application	Description	Link
TRUST EE	TRUST EE is a Horizon 2020 project, with the aim to create and implement new and innovative options, to develop, finance and implement energy efficiency and renewable energy projects in Europe‘s industry.	https://www.trust-ee.eu/files/other-files/0000/0032/TrustEE_Introduction_FINAL_Website.pdf
Share&Charge	Share&Charge is a Switzerland foundation that is building a decentralized blockchain protocol for electric vehicle charging. The goal is to create more seamless and intelligent networks of charging stations to facilitate the adoption of electric vehicles and the use of more sustainable energy. The solution is based on the already established open charge point interface (OCPI) protocol, and the objective is to enable e-roaming across Europe.	https://shareandcharge.com
Electrify	Synergy is a peer-to-peer (P2P) energy trading platform that allows for trading energy among individual producers of energy, reaping stable revenues to consumers across city-wide energy grids, providing greater energy options at fairer prices.	https://electrify.asia/about/
Riddle&Code / Wien Energie	Riddle&Code offers products and services to build the trusted connection between the physical and digital world and create the basis for the industrial token economy. Riddle&Code combines the highest security standards with the potential of blockchain technology and integrate robust hardware & software stacks into the infrastructure of Riddle&Code's global, tier-one clients.	https://www.riddleandcode.com/
Enerchain	The Enerchain software was developed by 40+ trading companies. It relies on the WRMHL freamework developed by PONTON that performed the first EU energy trade at EMART conference. The software provides a Tendermint powered market for different products of power and gas.	https://enerchain.ponton.de/
Swytch	Swytch provides the security layer that runs independently of the Swytch network, routing out rogue actors and sources of bad data.”	https://notbrady.medium.com/how-swytch-operates-at-the-intersection-of-the-iot-and-the-blockchain-30c47cc6e0f9

Alpiq Initiative	An Alpiq internal project (2018) for testing the feasibility automatically electricity delivery and settlement using Ethereum. The goal was to demonstrate suitability of a smart-contract instantiated on Ethereum to manage the pay-outs between two entities depending on the differences of electricity consumption with respect to the base.	
Grid+	Grid+ is a startup of the NY company ConsensSys. It provides a direct access to wholesale energy market. Their Smart Energy Agent automatically buys energy for the best price and allows user to meet most cost-effective future energy demand when crypted sharing private schedule. The system is fully automated as long as there are enough tokens available.	https://gridplus.io/
Parity	The vision of PARITY focuses on implementing local energy sharing that helps with pricing and easing the stress on the grid as well as giving value to its flexibility sources such as EVs, heat pumps and batteries. It is also a new business model that puts prosumers on a pedestal, allowing the opportunity for energy exchange such as P2P energy trading and dynamic pricing.	https://parity-h2020.eu/
Hive Power	The Hive Platform is a Smart Grid Analytics solution, offered as a SaaS to Energy Suppliers and Grid Operators. It allows industry participants for improving their operations, using data-driven and AI-powered solutions. One part of the provided platform builds the 'community manager' that allows for P2P energy trading based on blockchain.	https://hivepower.tech
Quartierstrom	In 2018 several universities and industry partners started the pilot "Quartierstrom" to demonstrate a DLT based p2p energy trading market in Walenstadt. The project focuses on technical feasibility, market design price, user motivation and behaviour, privacy, scalability, regulations and potential business models. The project finished and published a final report in 2020.	https://quartier-strom.ch/
GreenH2chain	It is a platform based on blockchain technology that guarantees the renewable origin of green hydrogen. It has been developped by ACCIONA together with the startup FlexiDAO. It will be implemented in the Green Hysland project, which is developing a green hydrogen infrastructure on the Balearic island of Mallorca.	https://www.flexi-dao.com/post/green-hydrogen-how-to-guarantee-its-renewable-origin
ioCAT	The project promoted by the Government of Catalonia targets tokenized rewards for sustainable actions such as recycling. Citizens will be able to exchange either in shops and businesses providing sustainable products and services or as tax discounts and benefits at city council level.	
EFFORCE	A blockchain based energy savings platform. Starting from a standard ESCO business model, energy savings	https://efforce.io/

	are recorded in a blockchain and smart contracts redistribute savings. Investors can participate in energy efficiency projects by acquiring tokenized future savings.	
ESI project	The Energy Savings Insurance (ESI) project provides a model for reducing the risk for firms to invest in energy efficiency and create trust and credibility among key actors. The model relies on: 1) Standardised contracts, 2) Energy Savings Insurance 3) Validation 4) Financing	https://www.esi-europe.org/
Lition & SAP	Lition seeks to be a blockchain standard for business and to that end the team is building the first of a kind, advanced scalable private-public blockchain with deletable data feature suitable for entities. Lition developed a P2P energy trading platform that connects clean energy producers and suppliers directly with end users on the blockchain.	
Brooklyn Microgrid	Brooklyn Microgrid (BMG) is an implementation of a p2p energy trading community in Brooklyn NY. Prosumer can offer excess energy from solar power plants while consumer can bid for local produced energy. The microgrid is connected to the national grid. In case of emergencies, it can be decoupled and operate standalone in a island mode. In BMG, all participants in the community are connected to Lo3's exergy platform through the Lo3 proprietary smart meter.	https://www.brooklyn.energy
Prosume	PROSUME is a DLT-based platform providing a novel decentralized and autonomous digital marketplace for p2p energy trading. PROSUME promotes new energy community models, which ultimately can support the transition to a sustainable economic model for energy production, distribution and storage based on renewables.	https://prosume.io
VAKT	The London-based consortium VAKT provides a blockchain-powered commodities post-trade processing platform.	https://www.vakt.com
EWF	In 2017 Rocky Mountain Institute (RMI) cofounded with Grid Singularity the Energy Web Foundation (EWF). Main goals are a) building a blockchain platform specifically tailored to the performance and regulatory requirements of the energy sector, and b) to foster a global ecosystem of utilities, grid operators, startups, regulators and other energy companies.	https://www.energyweb.org/
WePower	WePower platform connects corporate energy buyers and energy retailers directly with green energy generators so that all businesses, no matter the size, can easily purchase locally produced green energy at competitive rates and full transparency. It is the only platform that allows to have a portfolio of energy supply from multiple projects, fix prices and trade existing contracts from a single location.	https://wepower.com/
Elblox	It is a retailing platform for green energy. Elbox supports producer with information about consumption,	https://elblox.com/

	forecasts to help avoiding power from grid. It guarantees the origin of energy and allows retailer to facilitate customer sharing energy inside a building or over short distances.	
Lo3-Energy /Exergy	Exergy™ is a distributed ledger system combining software and hardware layers, a token system for permitting data, and an architecture that advances market design and technology in tandem. The Exergy blockchain software creates secure data pathways for decentralized markets, p2p transactions, predictive analytics, micro-hedging and other applications that are only beginning to be explored.	https://exergy.energy/
Equigy	With the European crowd balancing platform, Equigy creates a trusted data exchange to enable aggregators to participate with smaller flexibility devices, such as home batteries and electric vehicles, in electricity balancing markets, turning consumers into prosumers. Owned by leading European transmission system operators, Equigy aims to set cross-industry standards throughout Europe.	https://equigy.com/
Fidectus AG	Fidectus offers a Plug´n´Play SaaS solution that connects market participants in real-time. Backed by cloud and blockchain technology, the platform allows energy traders to manage the high pressures of operational costs, cash limits and risks by automating and accelerating the settlement process in cross-company workflows.	https://fidectus.com/
Power Ledger	PowerLedger is a company providing a platform for tracking, trading and tracing energy. It gives consumer the choice of electrical energy and allows for trading excess. Also, it allows for trading commodoties.	https://www.powerledger.io/
Restart Energy	Restart Energy, one of the biggest suppliers on the liberalized energy market in Romania is moving towards realizing the first tokenized energy trading platforms restart energy democracy (RED). The RED Platform is a blockchain-based decentralized worldwide energy trading platform.	https://restartenergy.ro/en/restart-energy-democracy-mwat-token/
Decentriq	The confidential data platform Decentriq enables enterprises to access sensitive data. This may enable artificial intelligence/ machine learning on distributed data sets belonging different data owners.	https://decentriq.com/
Via Science	VIA's solution TAC securely connects confidential data, distributed across many locations/companies to potential AI solutions while providing privacy protection, virtual data pooling and regulatory compliance. Instead of sending the data to the algorithm, the algorithm is sent to the data on premise of the data owner, and access is very selective with permissions managed by blockchain technology.	https://www.solvewith-via.com/

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1 Blockchain Framework Initiatives

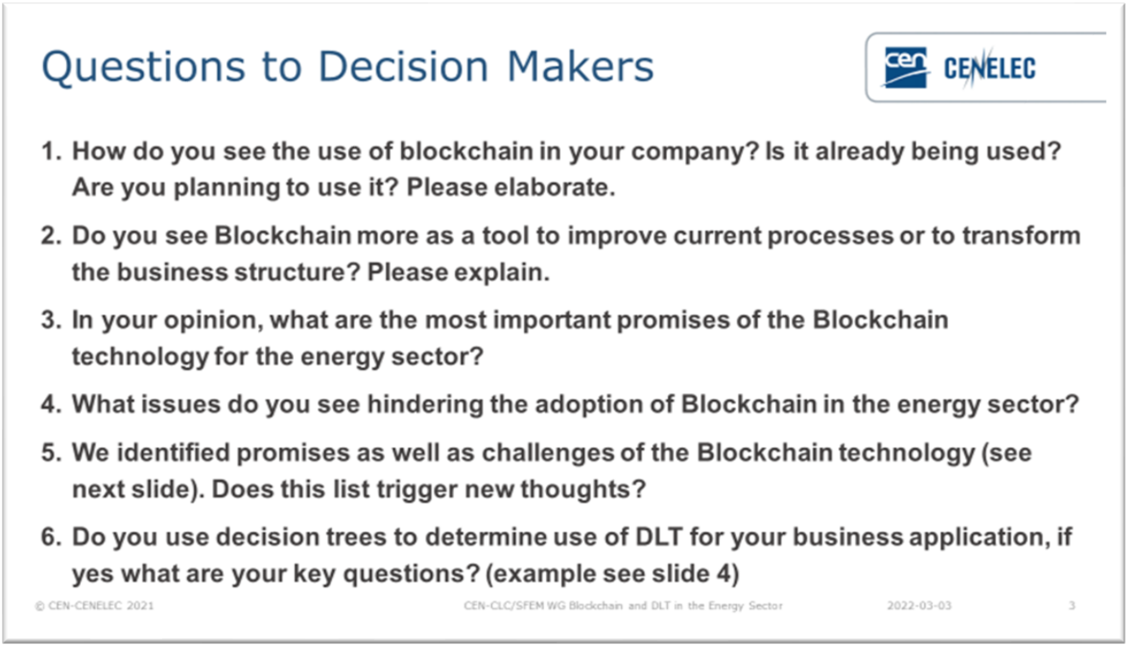
Initiative	Description	Link
NIST	The BIA COI (Blockchain for Industrial Applications Community Of Interest) is providing guidelines to create a (better) synergy between end users, research community, and solution providers to reduce complexity, cost, and delay of adoption of blockchain technologies.	https://www.nist.gov/el/systems-integration-division-73400/blockchain-industrial-applications-community-interest
INATBA Go-P2P	The GO-P2P Energy Task Force will tackle standardisation gaps around energy trading using distributed ledger technologies. The Task Force is a joint initiative between the International Association for Trusted Blockchain Applications (INATBA) and the Global Observatory on Peer-to-Peer, Community Self-Consumption and Transactive Energy Models (GO-P2P), an Annex of the User-Centred Energy Systems Technology Collaboration Programme by the International Energy Agency.	https://inatba.org/p2p-energy-task-force/
GSMI	The Global Blockchain Business Council (GBBC), World Economic Forum, and industry leaders released the Global Standards Mapping Initiative (GSMI), the first comprehensive effort to survey blockchain standards. 185 JURISDICTIONS, 379 INDUSTRY GROUPS , 30+ TECHNICAL STANDARD-SETTING ENTITIES	https://gbbcouncil.org/gsmi/
Blockchain Initiative Energie (DE)	The initiative's focus (since November 2017) is on energy-specific business models and functionality based on blockchain. BCI-E+ wants to investigate possible applications and suitable frameworks based on concrete business models.	https://blockchain-initiative.de/
IEEE Blockchain initiative	The IEEE Blockchain Initiative (BLK), effective since January 1, 2018, encompasses a comprehensive set of projects and activities supported by the following core subcommittees: Pre/Standards, Education, Conferences and Events, Community Development and Outreach, Publications, and Special Projects.	https://blockchain.ieee.org/
Hyperledger	Launched by the Linux Foundation in 2015, Hyperledger also aims to develop blockchain technology standards for businesses. The goal is to create a permission-based blockchain infrastructure that can be deployed as modules by enterprises.	https://www.itransition.com/blog/blockchain-standards
SVIP	The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) is partnering with blockchain development companies to set standards for supply chain processes. S&T's Silicon Valley Innovation Program (SVIP) launched a project that focuses on blockchain interoperability and uniform standards.	https://www.itransition.com/blog/blockchain-standards
BiTA	Blockchain in Transport Alliance (BiTA), a consortium of shipping and logistics companies, is developing a uniform framework for companies to build blockchain-based applications. The standards framework will cover smart con-	https://www.itransition.com/blog/blockchain-standards

	tracts and freight payments, asset maintenance and ownership history, as well as the chain of freight custody. BiTA creates standards relevant only to transportation, rather than making them suit a broad range of industries.	
IHE	IHE is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information. IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care.	https://www.ihe.net/
GS1	GS1, a global business communications standards organization, has created standards for their enterprise blockchain applications for the supply chain and logistics niche in partnership with IBM and Microsoft. GS1 encourages the usage of EPCIS as the standardized data exchange format.	https://www.itransition.com/blog/blockchain-standards
EU Blockchain strategy	The European Commission strongly supports blockchain on the policy, legal and regulatory, and funding fronts. It focuses on building a pan-European public services blockchain (European Blockchain Services Infrastructure (EBSI)), promoting legal certainty and blockchain for sustainability, supporting interoperability and standards among others	https://digital-strategy.ec.europa.eu/en/policies/blockchain-strategy
DLT4Power	Initiative of the national normative association (SNV) and the electricity industry, sponsored by the Swiss Federal Office of Energy. It focuses on developing 2 SNV Guides as fundamentals for further national standardization, providing overview of power market processes with potential for DLT application, recommendations how DLT can be uses as supporting technology, identification of standardization needs.	https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=5590
CAICT	China Academy of Information and Communications Technology (CAICT) provided three proposals for the development of international standards being approved during the plenary meeting of ITU-T SG16 in April 2021. The approved proposals are: - ITU-T F.DLT-FAM - Function assessment methods for distributed ledger technology (DLT) platforms - ITU-T H.DLT-PAM - Performance assessment methods for distributed ledger technology (DLT) - ITU-T H.DLT-TFI - Technical Framework for DLT Interoperability	SESEC Newsletter April-May 2021
EU Blockchain Forum	The forum monitors blockchain initiatives in Europe, produces a comprehensive source of blockchain knowledge, creates an attractive and transparent forum for sharing information and opinion and makes recommendations on the role the EU could play in blockchain.	https://www.eublockchainforum.eu/initiative-map
DKE BlockClass	Project leaded by the Reutlingen University and the German electrotechnic commission with focus on identification and classification of blockchain use cases, derivation of main parent use cases and their architecture solutions, mapping to reference architecture & interoperability	https://dltlab.reutlingen-university.de/projekte/blockclass/

	analysis, electromobility use cases, VDE-Anwendungsregel for the use case tested and VDE-SPEC for the analysis of use cases.	
ISO/TC307	Technical ISO committee focussing on standardisation of blockchian and distributed ledger technologies. The committee was founded in 2016 and last till end 2023.	https://www.iso.org/committee/6266604.html
ITU FG DLT	The ITU-T Focus Group on Application of Distributed Ledger Technology (FG DLT) was established in May 2017 to identify and analyse DLT-based applications and services, to draw up best practices and guidance which support the implementation of those applications and services on a global scale and to propose a way forward for related standardization work in ITU-T Study Groups.	https://www.itu.int/en/ITU-T/focusgroups/dlt/Pages/default.aspx
IEEE P2418.5 WG Blockchain in Energy	This standard provides an open, common, and interoperable reference framework model for distributed ledger technology (DLT), such as blockchain in the energy sector. It also covers three aspects: 1) Serve as a guideline for Blockchain DLT use cases in Electrical Power industry; Oil and; energy Gas value industry chain, covering the Renewable energy industry and their renewable related sources services of generation. 2) Create standards on reference architecture framework, including interoperability, terminology, functionality, and system interfaces for blockchain DLT applications in the energy sector by building an open protocol and technology agnostic layered framework. 3) Evaluate and provide guidelines on scalability, performance, security, and interoperability through evaluation of consensus algorithm, smart contracts, and type of blockchain DLT implementation, etc. for the Energy sector.	https://sa-groups.ieee.org/2418-5/ https://blockchain.ieee.org/standards

Appendix 2 – Interview Questions

Below is the set of slides we took to the interviews. These were semi-structured interviews. Depending on the interviewee, we asked different questions, and discussed different slides.


Questions to Decision Makers
CENELEC
1. How do you see the use of blockchain in your company? Is it already being used? Are you planning to use it? Please elaborate.
2. Do you see Blockchain more as a tool to improve current processes or to transform the business structure? Please explain.
3. In your opinion, what are the most important promises of the Blockchain technology for the energy sector?
4. What issues do you see hindering the adoption of Blockchain in the energy sector?
5. We identified promises as well as challenges of the Blockchain technology (see next slide). Does this list trigger new thoughts?
6. Do you use decision trees to determine use of DLT for your business application, if yes what are your key questions? (example see slide 4)
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2022-03-03
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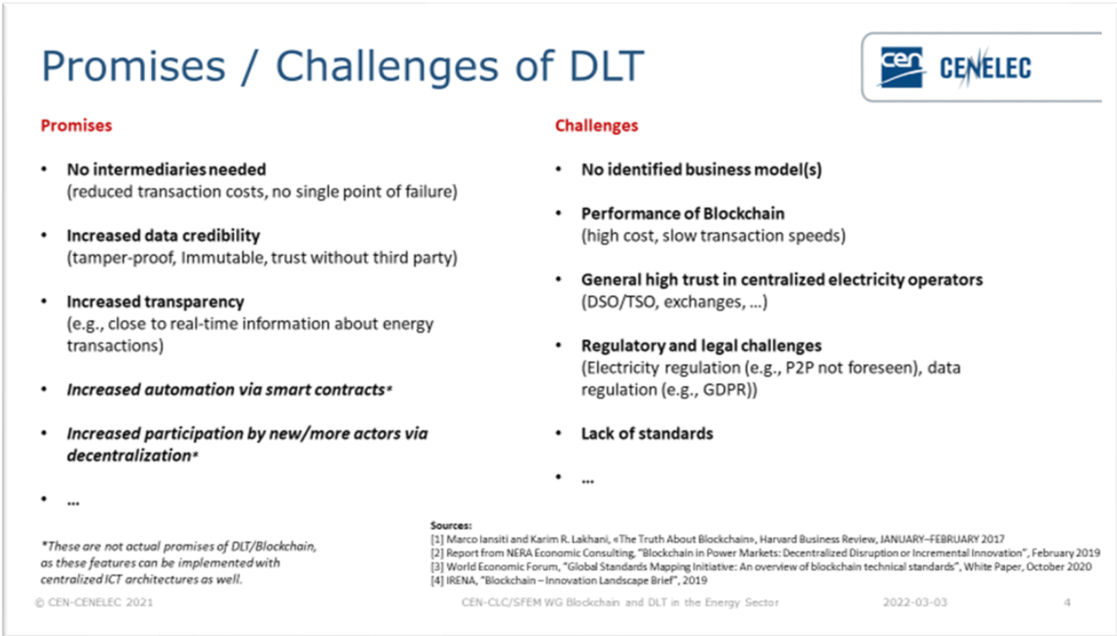
Promises / Challenges of DLT
CENELEC
Promises
No intermediaries needed
(reduced transaction costs, no single point of failure)
Increased data credibility
(tamper-proof, Immutable, trust without third party)
Increased transparency
(e.g., close to real-time information about energy transactions)
Increased automation via smart contracts*
Increased participation by new/more actors via decentralization*
...
Challenges
No identified business model(s)
Performance of Blockchain
(high cost, slow transaction speeds)
General high trust in centralized electricity operators
(DSO/TSO, exchanges, ...)
Regulatory and legal challenges
(Electricity regulation (e.g., P2P not foreseen), data regulation (e.g., GDPR))
Lack of standards
...
*These are not actual promises of DLT/Blockchain, as these features can be implemented with centralized ICT architectures as well.
Sources:
[1] Marco Iansiti and Karim R. Lakhani, «The Truth About Blockchain», Harvard Business Review, JANUARY–FEBRUARY 2017
[2] Report from NERA Economic Consulting, "Blockchain in Power Markets: Decentralized Disruption or Incremental Innovation", February 2019
[3] World Economic Forum, "Global Standards Mapping Initiative: An overview of blockchain technical standards", White Paper, October 2020
[4] IRENA, "Blockchain – Innovation Landscape Brief", 2019
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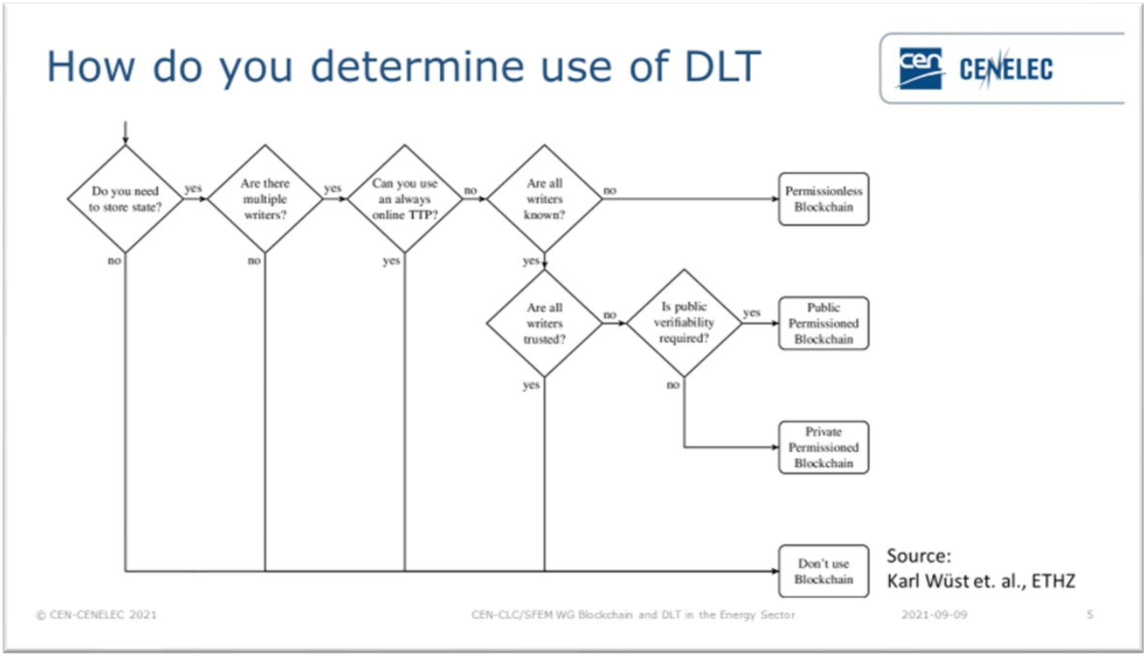
How do you determine use of DLT
CENELEC
Do you need to store state?
yes
no
Are there multiple writers?
yes
no
Can you use an always online TTP?
no
yes
Are all writers known?
no
yes
Permissionless Blockchain
Are all writers trusted?
no
yes
Is public verifiability required?
yes
no
Public Permissioned Blockchain
Private Permissioned Blockchain
Don't use Blockchain
Source:
Karl Wüst et. al., ETHZ
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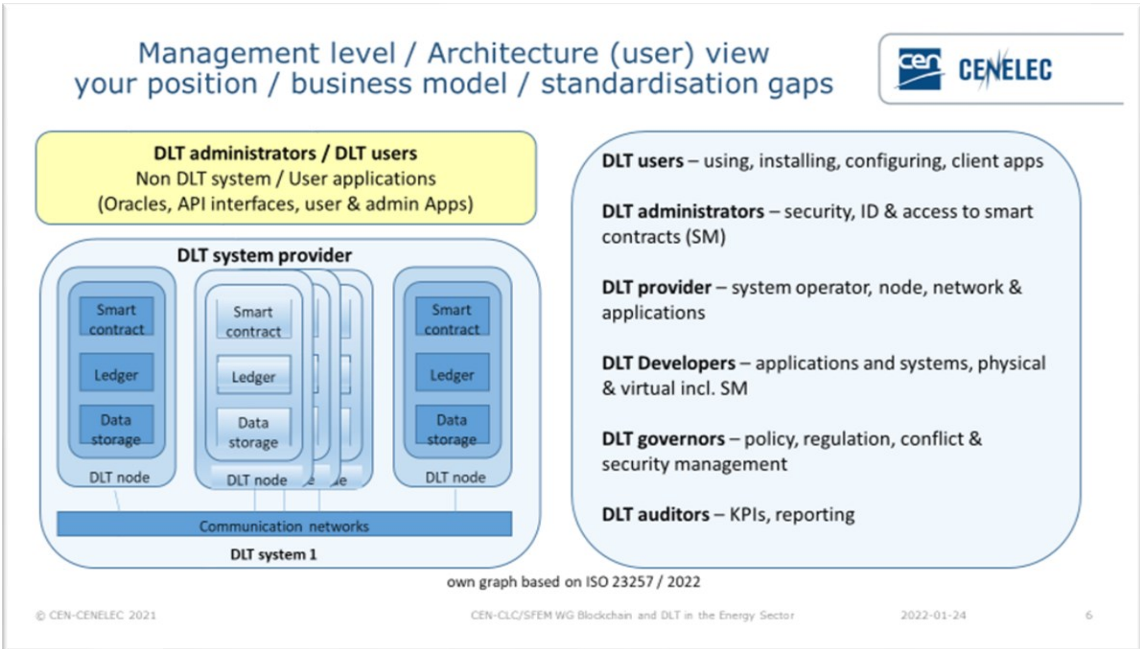
2021-09-09
5


Management level / Architecture (user) view
your position / business model / standardisation gaps
CENELEC
DLT administrators / DLT users
Non DLT system / User applications
(Oracles, API interfaces, user & admin Apps)
DLT system provider
Smart contract
Ledger
Data storage
DLT node
Communication networks
DLT system 1
DLT users – using, installing, configuring, client apps
DLT administrators – security, ID & access to smart contracts (SM)
DLT provider – system operator, node, network & applications
DLT Developers – applications and systems, physical & virtual incl. SM
DLT governors – policy, regulation, conflict & security management
DLT auditors – KPIs, reporting
own graph based on ISO 23257 / 2022
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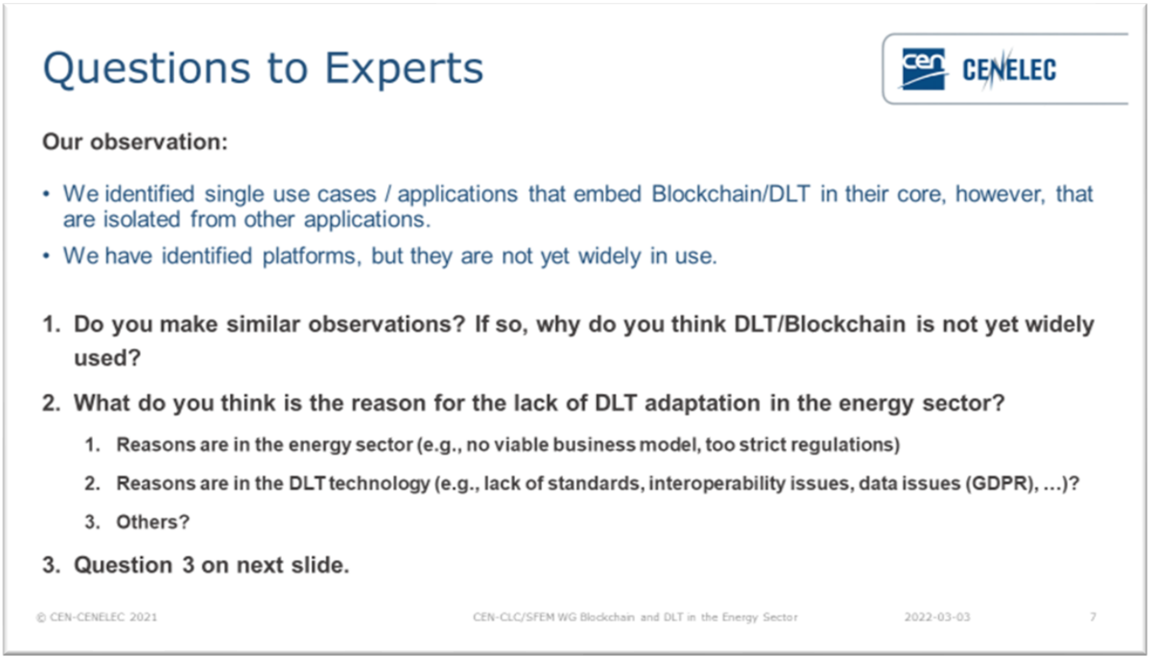
2022-01-24
6



Questions to Experts

Our observation:

- We identified single use cases / applications that embed Blockchain/DLT in their core, however, that are isolated from other applications.
- We have identified platforms, but they are not yet widely in use.

1. **Do you make similar observations? If so, why do you think DLT/Blockchain is not yet widely used?**
2. **What do you think is the reason for the lack of DLT adaptation in the energy sector?**
    1. Reasons are in the energy sector (e.g., no viable business model, too strict regulations)
    2. Reasons are in the DLT technology (e.g., lack of standards, interoperability issues, data issues (GDPR), …)?
    3. Others?
3. **Question 3 on next slide.**

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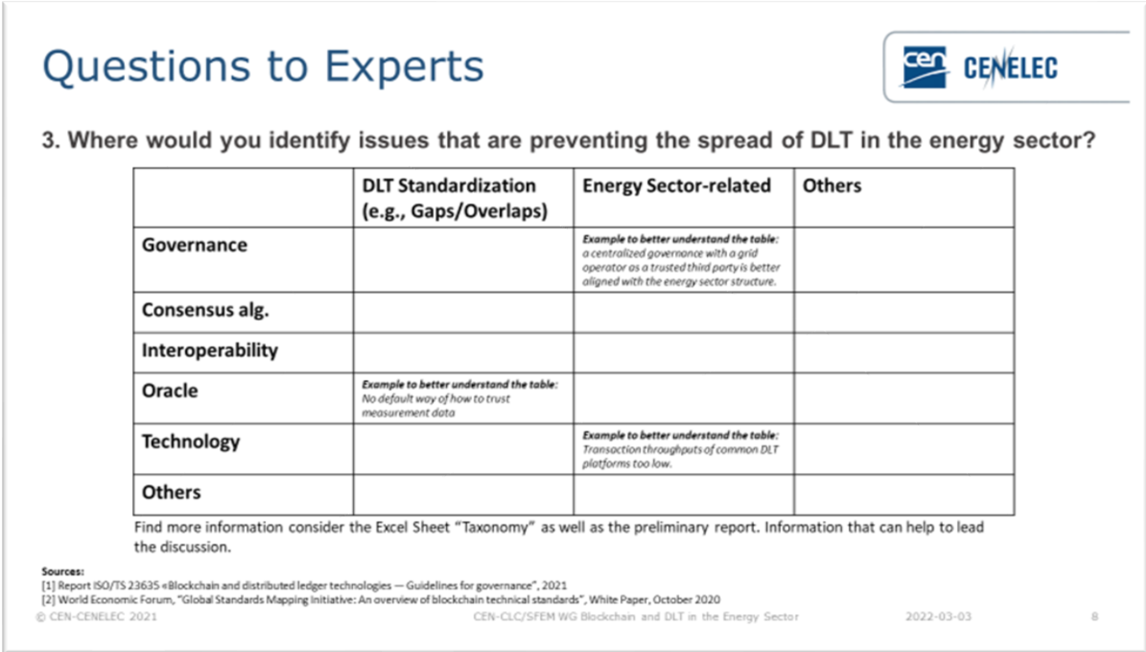

Questions to Experts

3. Where would you identify issues that are preventing the spread of DLT in the energy sector?

	DLT Standardization (e.g., Gaps/Overlaps)	Energy Sector-related	Others
Governance		***Example to better understand the table:*** *a centralized governance with a grid operator as a trusted third party is better aligned with the energy sector structure.*	
Consensus alg.			
Interoperability			
Oracle	***Example to better understand the table:*** *No default way of how to trust measurement data*		
Technology		***Example to better understand the table:*** *Transaction throughputs of common DLT platforms too low.*	
Others			

Find more information consider the Excel Sheet "Taxonomy" as well as the preliminary report. Information that can help to lead the discussion.

Sources:
[1] Report ISO/TS 23635 «Blockchain and distributed ledger technologies — Guidelines for governance", 2021
[2] World Economic Forum, "Global Standards Mapping Initiative: An overview of blockchain technical standards", White Paper, October 2020

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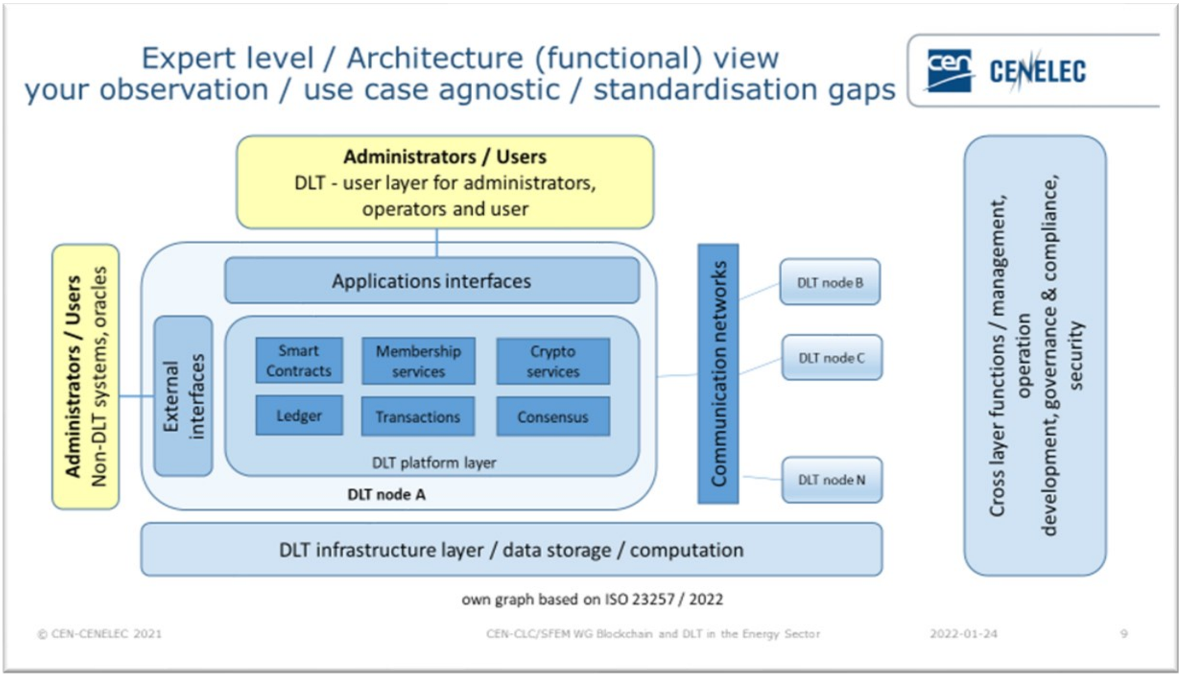
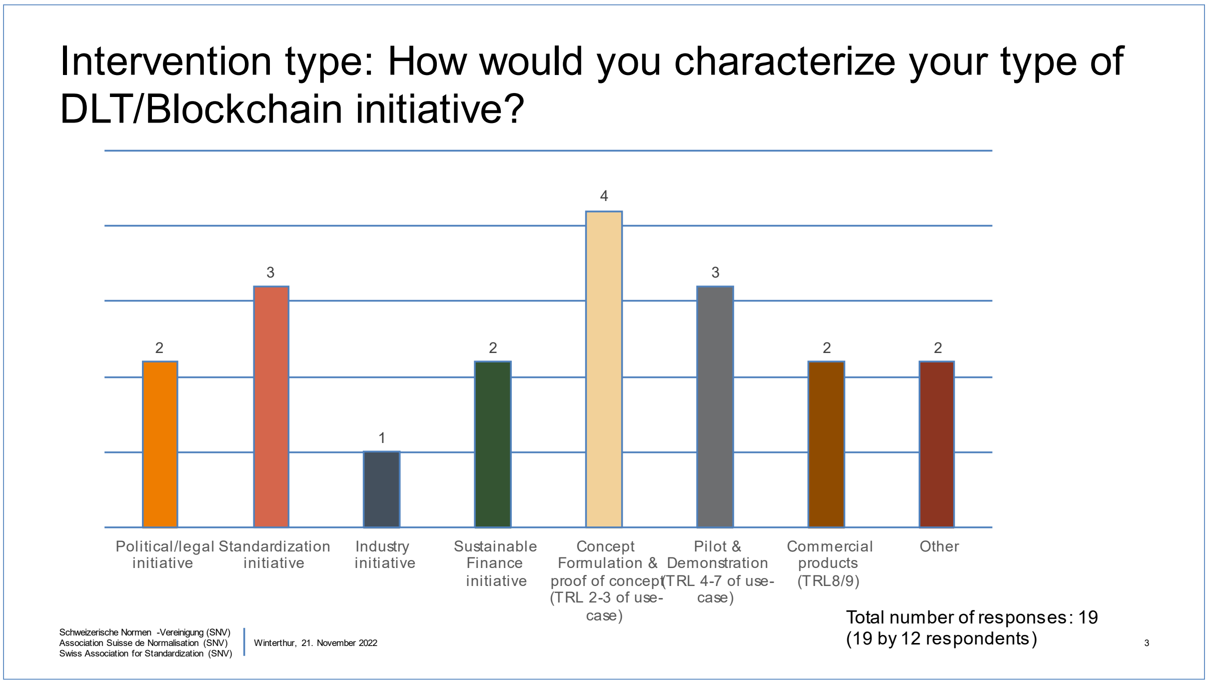


Appendix 3 – Survey Questions

The survey questions and responses are presented below in raw format.



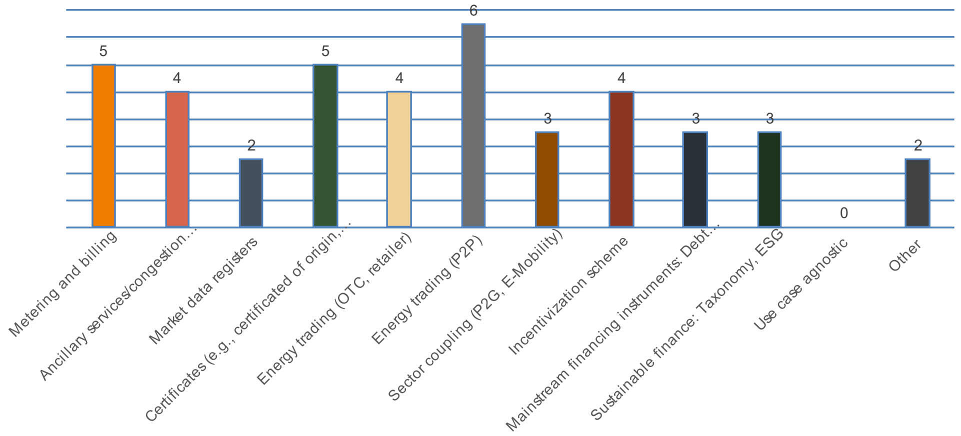
What is the commercial orientation of your DLT/Blockchain initiative?

Total number of responses: 12

Does your DLT/Blockchain initiative, or use -case foresee new roles and/or a full replacement of traditional roles resp. actors (e.g., market operators) or a combination/supplement of incumbents with emerging actors? Please elaborate.

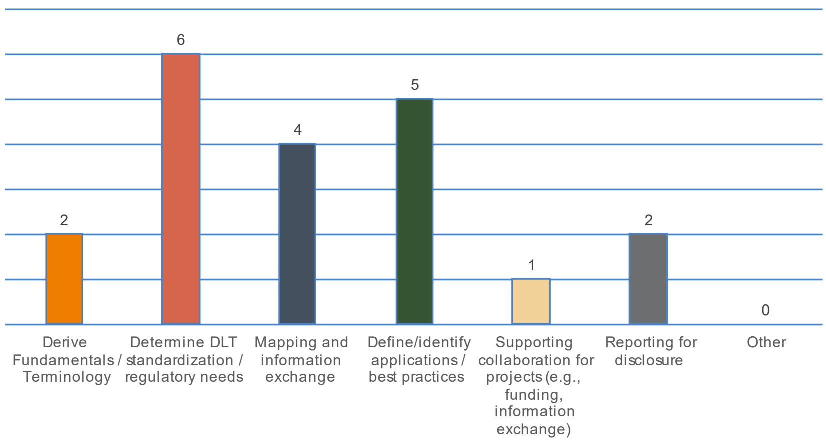
Response
The use of blockchain in the management information system of the ESI Europe project is for introducing a new process, put into motion an innovative business model, which is the ESI model. The form of (SME) clients contracting energy efficiency upgrades with savings guaranteed by the technology provider and backed by a surety insurance and validated by an independent technical validation entity is new. The online platform is the place where the exchange of documentation and follow-up of the project in each stage can be done: from contract signature, to contract activation, project installation, annual monitoring. Currently, the platform is designed for actively engagement of client, technology provider(EE project developer) in the process with actions such as creation of profile, input of project information, attachment of documentation, and approval/rejection. Future applications can be incorporated to the platform, including the access of additional stakeholders in the ESI model, such as the insurance company and financial institution.
Yes, allows individuals to act as energy suppliers and traders
We do see new emerging actors (the prosumers) taking part at the energy market, specifically in "Energy Communities" but more widely in the overall energy market. Thus, DSOs/TSOs will have to interact so to accept prosumers (in the form of Aggregator/Community) as new players in local BSP.
We held a design thinking workshop with stakeholders for a project initiated by HES-SO called SCODES. After the workshop the group identified two possible use cases for blockchain in the energy sector and developed initial business models.
No. Replaces existing.
Not replacement of roles, but change in some tasks, for example related to data management
Re-centring of players on their core job.
I am involved in multiple initiatives, particularly at the intersection of "finance" and "non-finance" players in the growing field of "sustainable finance". Unlike traditional finance, sustainable finance requires extensive knowledge of the specific economic sector and the close interaction between financial and non-financial data (depending on the boundaries of materiality definition). In some of the cases disintermediation will replace or consolidate some jobs while in others it will just speed processes and lower costs.
Combination/supplement of incumbents with emerging actor
The use-case foresee new roles and business models for traditional actors

Type of use case: What use cases are you covering with your DLT/Blockchain initiative?



Total number of responses: 41
(by 12 respondents)

In case of a Political/legal or Standardization initiative (see question 1): What is the focus of your initiative and the objectives, e.g., unmet need, you want to solve?



Total number of responses: 20

DLT-only system or integrated system Does your use case or initiative provide a DLT -only solution in an unregulated space, or does it provide a fully integrated solution within a regulated framework (i.e., is your use case affected by sector regulations and how)? Is a lack of regulation, or too much regulation hindering a scale -up of your solution? Please elaborate.

Response
There is no specific regulation required for our ESI Europe management information system application. The regulation regarding the sharing of sensitive data and information (commercial contract signed, contact information) of EE project needs to be assessed once additional stakeholders are integrated into the platform, such as financial institutions and insurance companies. We are working on setting up the GDPR requirements regarding by not having the user ID directly stored in the blockchain.
Yes, it is affected by regulation relating to P2P trading which is very limited at present, preventing scaling.
At the moment the regulation is not aligning the sectors, which would need to be unified in a simpler regulation providing more freedom of interoperation. Thus the scale-up is hindering the value proposition
The idea was to brainstorm about the regulatory framework that supports the innovation, as well.
No
Both. Too much regulation is hindering the implementation
Regulators have yet to acknowledge the outcome of the first phase of the Swiss initiative.
Many good cases of DLT for real-life application (non-financial) require some regulatory involvement. For example, Energy is a regulated market in most countries, even in countries where private market players exists. Similar for housing/land registry, etc. I work on the field of "Sustainable FinTech" with applications that require not 1 but multiple regulators. For example, decarbonising the real estate sector is a huge priority, but efforts during years had produced little progress. In the UK, there is ongoing work to develop ideas such as "building renovation passports". These concepts will bring finance (to help finance the projects), land registry (to help ensure that such funding remains with the property and it is not associated to a specific person who could sell the house) and energy regulator (which helps improve return on investment of projects thanks to smart grid energy trading). Solutions to many of the existing problems requires holistic and not isolated solutions.
Adequate regulation is crucial for market uptake
- Fully Intergrated Solution - Sector is regulated - Regulation is not hindering scale-up

Association Suisse de Normalisation (SNV)
Swiss Association for Standardization (SNV) | Winterthur, 21. November 2022 | 8

How has the particular initiative contributed to the objectives of the EU Energy transition (rank from 1 to 9, where "1" is the objective that is supported most)

1. Sustainable finance related topics
2. Improved customer experience (e.g., by a customer centric focus)
3. Grid management integration
4. CO2 reduction (climate change mitigation?)
5. Market efficiency
6. Climate change adaptation
7. Market integration
8. Security of supply
9. Renewable Energy Sources (RES) production

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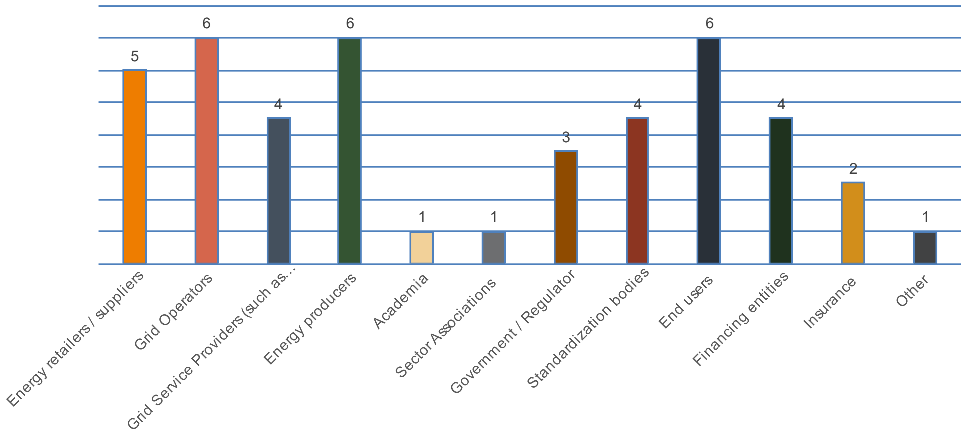
Who are the main stakeholders in your DLT initiative / use case?



Total number of responses: 43

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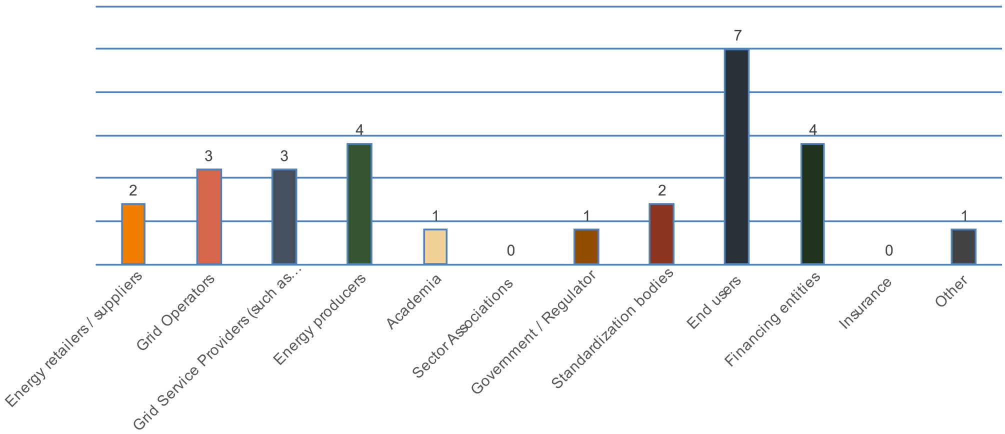
10

Who are the main beneficiaries of your DLT/Blockchain initiative / use case?



Total number of responses: 28

Schweizerische Normen -Vereinigung (SNV)
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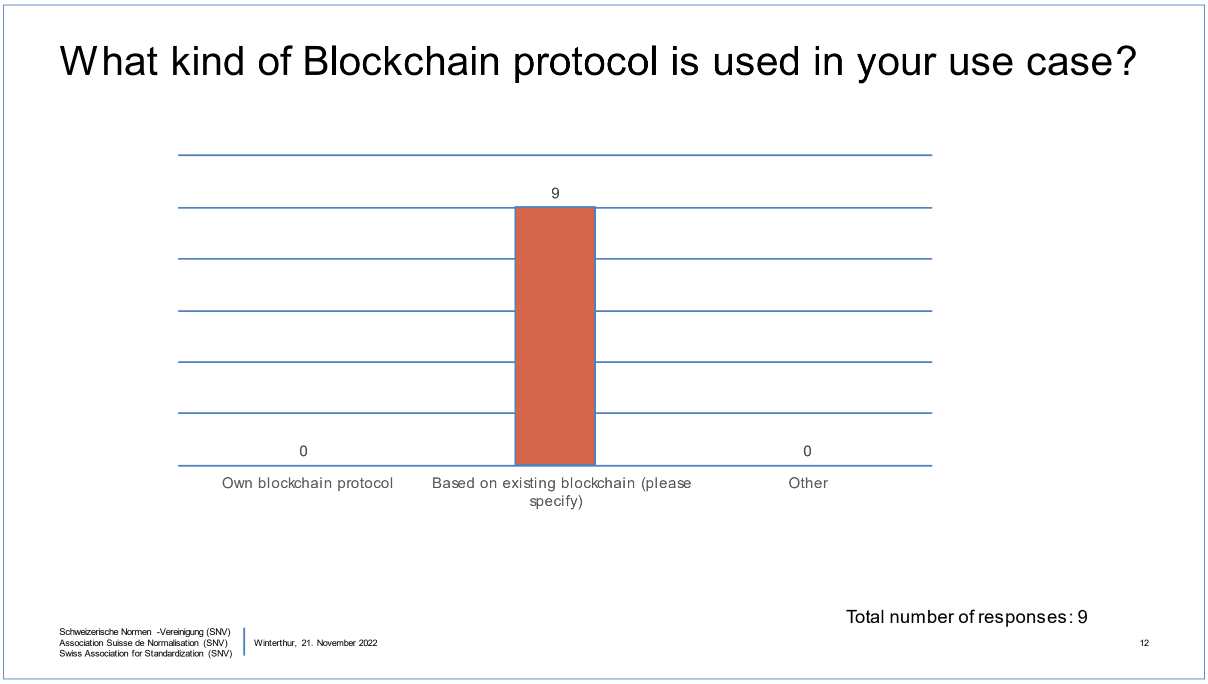
What kind of Blockchain protocol is used in your use case?
9
0
0
Own blockchain protocol
Based on existing blockchain (please specify)
Other
Total number of responses: 9
Schweizerische Normen -Vereinigung (SNV)
Association Suisse de Normalisation (SNV)
Swiss Association for Standardization (SNV)
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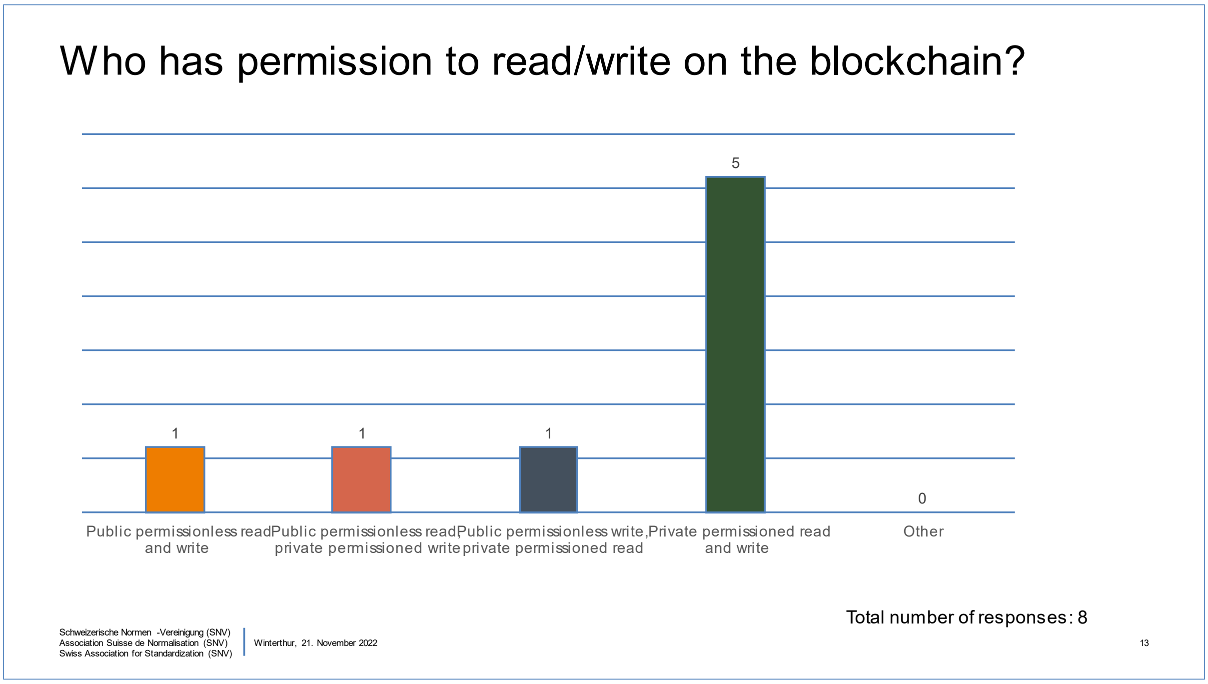
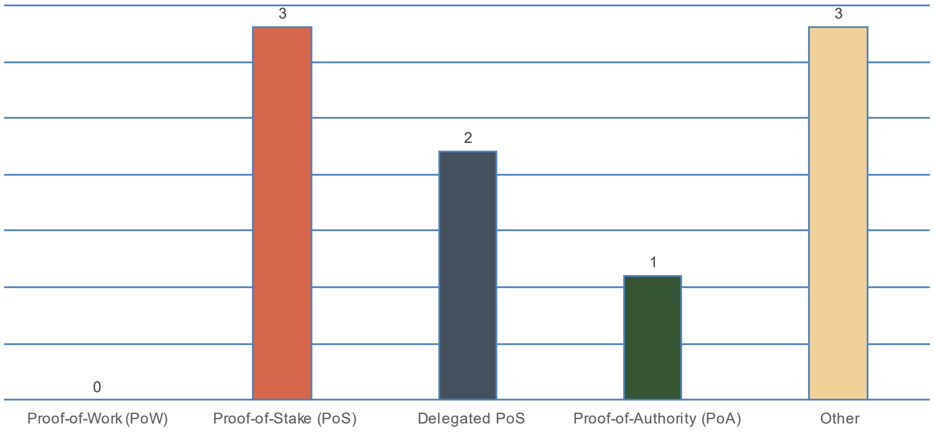
12

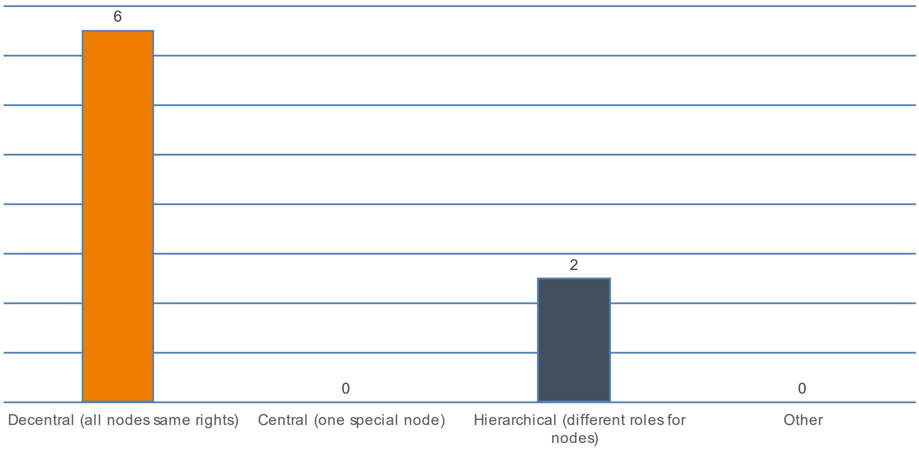

Who has permission to read/write on the blockchain?
5
1
1
1
0
Public permissionless read and write
Public permissionless read, private permissioned write
Public permissionless write, private permissioned read
Private permissioned read and write
Other
Total number of responses: 8
Schweizerische Normen -Vereinigung (SNV)
Association Suisse de Normalisation (SNV)
Swiss Association for Standardization (SNV)
Winterthur, 21. November 2022
13

What consensus algorithm is used?



Total number of responses: 9

What is the network structure of nodes?



Total number of responses: 8

Do you know the expected energy consumption of your proposed solution when scaled up? If you know, how much electricity will be needed? If not, are you somehow taking energy efficiency into consideration? Have you performed for example a cost -benefit analysis to value the social benefit or to understand if the energy consumption is compensated in terms of energy savings? Please elaborate on this issue.

Response
The current design does not imply in significant energy use. Nevertheless, we are considering running the blockchain nodes system that makes use of the thermal energy of the hardware for building heating. It is an innovative solution being offered by the local energy utility company (see: https://submer.com/). The heat is used and no cooling is required, therefore we consider that the overall energy consumption of the system is reduced. For the energy consumption is not an issue, but we looking into to already piloting the thermal energy recovery of the operation of the nodes with the solution mentioned above.
Very limited electricity use
The energy consumption is related only to metering devices which need to be installed there where still are present old meters devices (not digital and/or not IoT). the consensus method is not impacting and this is not a DLT only type of solution
No, we did not get this far yet. Project still requires some financial support to emerge to the second level of our brainstorming process, or at least requires some industry interest to move forward. We will try to find funding from Innosuisse, or other sources, in the next year in order to move forward with one of the concep developed following the SCODES project end.
We do know it yet
Please tell once and for all to the BFE that this is not a topic... This should be understood by all now
I work with multiple DLTs, but some of them are very energy efficient, https://www.algorand.com/resources/algorand announcements/carbon_negative_announcement
Cost-benefit analysis shall properly quantify all the benefits outweighing the costs (including energy consumption): as an example, if a blockchain-based financial system were to become mainstream, its cost/energy consumption should be compared with that of the whole banking system/financial services
Energy for operation of nodes should come from renewable energy sources or compensated by GoO certificates.

Large scale adoption Issues: In case of a Political/legal or Standardization initiative (see question 1): Do you see challenges that prevents DLT solutions from large scale adoption? What are key challenges for the DLT deployment? (e.g., technology, regulation, standardization, business model, interoperability, ICT/GDPR, others?) Otherwise: Do you see challenges that prevents your solution from scaling? What are key challenges for the deployment of your particular DLT solution? (e.g., regulation, standardization, business model, ICT/GDPR, others?)

Response
The challenge of scaling the model is not a technological aspect, but the market uptake of the business model we are proposing: Energy Savings Insurance model (GoSafe with ESI solution in Europe). It is a proposition of a new way of technology providers to offer their energy efficiency projects/upgrades, with the addition of a guarantee on the savings that is covered by an insurance and validated by an external validation entity. The involvement of several stakeholders and changes to the way they make business is the most challenging part.
Regulation heading in the right direction but at slow pace.
GDPR, Liability, Interoperability and how regulation adapts specifically to the market but aligned with privacy rights and digital identity, there we have to consider precisely the implications in new type or market and business models.
Yes, no existing legislation for white certificates in Switzerland (to support one of the ideas we came up with). The debate about microgrids is not particularly blocked by legislation because of the new rules in Switzerland but the lack of clarity regarding how these rules should be applied leads to a barrier for most investors.
Main Challenge is regulatory framework
Challenge is now the structuring of a sector governance. In lack thereof, then the disruption will come from external players.
DLTs as their concept implies require a "network", hence that should be the top priority of use cases. Thats requires few key components such as regulation, standardization and interoperability.
The key challenge is, in my opinion, to have a good project methodology, and also to be attentive to the needs raised by the professionals who work on the use cases, particularly that of energy.
Interoperability and consumer acceptance (blockchain is complicated to understand/accept)
Business Model, Interoperability, Technology