EU Blockchain
Observatory and Forum

Blockchain Applications in the Energy Sector

A thematic report prepared by
the European Union Blockchain Observatory & Forum

An initiative of the European Commission

About this report

This is the first thematic report prepared by the new team leading the EU Blockchain Observatory and Forum, aiming to present the latest updates and developments within the EU blockchain ecosystem.

This is the first of a series of reports that will be published addressing selected topics in accordance with the European Commission priorities. The aim is to reflect on the latest trends and developments and discuss the future of blockchain in Europe and globally.

Credits

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Note

While we have done our best to incorporate the comments and suggestions of our contributors where appropriate and feasible, all mistakes and omissions are the sole responsibility of the authors of this paper.

Disclaimer

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Section 1: Overview of blockchain technology in the energy sector

STANDARDISATION ACTIVITIES

IEEE SA P2418.5 Standards for distributed ledger technology

Introduction

The global energy arena is rapidly changing; meanwhile, “Industry 4.0” technologies such as artificial intelligence (AI) and distributed ledger technology (DLT) are emerging as new drivers of the new industrial landscape. The energy transition, named Digital Green Shift, is driven by the five “D”s: deregulation, decarbonisation, decentralisation, digitisation and democratisation. The rapid adoption of such emerging technologies is gaining momentum; DLT, especially, is considered a key enabler technology which has very high potential to influence or even disrupt various industries including the energy sector. Digitalisation and decentralisation of the energy industry are two game-changing components of the Digital Green Shift, which offers various new opportunities for future transactive energy systems and markets. Nevertheless, such newly opened territory of opportunities and technological advancement options requires development of a new generation of standardisation efforts that considers the use of emerging technologies such as DLT in the field of energy.

The IEEE Standards Association (SA) P2418.5 Blockchain in Energy Standards Working Group (WG) was established in 2018 to address these needs.

IEEE SA P2418.5 Working Group (WG) description and framework

The IEEE SA P2418.5 Blockchain in Energy Standards WG aims to propose, develop and communicate a set of open, common and interoperable standardisation procedures as well as a reference framework model to create holistic and vendor agnostic blockchain-/DLT-related guidelines applicable to the energy industry by also covering the following objectives:

- Serve as a guideline for blockchain/DLT use cases in the electrical power industry and the oil and gas value chain; also cover the renewable energy industry and their related renewable sources/services of generation.
- Propose, design and develop an open, interoperable, safe and implementable reference standardisation framework that is based on a wide consensus between seasoned industrial and academic members (WG members), comprehensive desktop surveys and the solid reference architecture framework for the energy sector (mainly the power industry, and partially the oil and gas industry).
- Create a technological map of the conceptualised initial reference architecture framework with the selected energy use cases where blockchain/DLT can be applied, providing additional value. Valuable inputs from the international WG members, industrial surveys and continuous literature reviews are the main inputs for the energy use case identification process.
- Further improve the initially developed reference architecture framework by interacting with other IEEE standardisation WGs and other related organisations such as the IEEE Blockchain Transactive Energy (BCTE) initiative in a coordinated way which aims to effectively enable synchronisation and create synergies. Some of the essential tasks, for example publishing position papers, developing initial architecture, and developing demonstration projects and further communication activities via

dedicated webpages, are among the most correlated activities performed jointly with the IEEE BCTE initiative.

- Evaluate and provide guidelines on scalability, performance, security and interoperability through the evaluation of consensus algorithms, smart contracts and type of blockchain/DLT implementation for the energy sector.
- Disseminate and communicate the WG findings and outcomes via position papers, reports, articles, joint events with other institutions, newsletters, panels, webinars and standard documents.

CEN-CENELEC: Sector Forum Energy Management – Working Group on Blockchain and DLT

Introduction

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

Distributed ledger technology (DLT) such as for example blockchain has the potential to play an important role in a more decentralised 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.

Many projects, start-ups and initiatives have been launched to make such a decentralised electricity system possible, i.e., to interconnect the increasing number of small production, storage and demand units of local energy systems. However, to this day, no blockchain/DLT solution has been widely adopted by energy system stakeholders. The question that needs to be answered is why this is 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 overview of the current challenges (technical and non-technical), use cases and standardisation needs in the field of “DLT in energy.” Within the energy sector, particular emphasis will be placed on the electricity sector; however, sector coupling and other energy sectors (e.g., heating & cooling, 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, and it will also enable 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 by 2050. More details about the CEN-CENELEC SFEM working group will be given next.

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 standardisation-related issues, SFEM made a decision at its November 24 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 Standardisation).

This working group began its activity in April 2021, with Dr Bernard Gindroz, the vice-chair of CEN/CENELEC SFEM, as convenor. The most important assumptions and aspects of the working group are summarised below.

Challenges and opportunities

Blockchain solutions present major opportunities in the energy sector such as:

- 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, renewables and their integration into energy systems, by mitigating the risk of investments and ensuring transparency, integrity and traceability of technical and commercial transactions and reporting.
- 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 us to manage 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, e-mobility support, etc.
- It is an enabling tool for reporting compliance with sustainable finance, ESG criteria, NFRD and CSRD.

These opportunities have been mentioned by several organisations, academia and in white papers, and are included in the standardisation strategy and the contribution programme of CEN/CENELEC to the Green Deal. As part of the standardisation 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 changes towards future energy production and distribution systems in the EU, raising maturity in integrating renewables. The WG's final report will provide the collected knowledge from these initiatives and identify how to make the 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 standardisation development (especially bringing interoperability, harmonisation throughout Europe and trust).

Aim of this WG

- Providing CEN/BT and CENELEC/BT with concrete proposals on the way forward to address standardisation needs in this emerging field to satisfy stakeholder needs.
- Providing CEN/CENELEC JTC 19 and JTC 14 (Joint Technical Committees) with concrete proposals in coherence with JTC 19- and JTC 14-related scope.
- Addressing the European Commission's & concerned stakeholders' RD&I needs in this field.
- Addressing the European Commission's regulation-related needs in this field.

Expected outcomes

- Mapping existing blockchain/DLT-related projects and initiatives in Europe towards use cases.
- Mapping existing standardisation initiatives (national, EU, global).

- Identifying standardisation needs for DLT applications in the energy sector and in connection with sustainable finance (taxonomy, ESG, NFRD, CSRD).
- Providing recommendations for new work items and/or extension of work within existing Technical Committees (TC) and Joint Working Groups (JWG).
- Preparing a strategy roadmap with a list of standardisation priorities, including pre-normative (PNR) ones.
- Liaising through SFEM with CEN/CENELEC SABE, JTC19.
- Liaising with Joint Research Centre (JRC) and its team working on blockchain-related/integrated activities.
- Liaising through SFEM with EU Energy Efficiency Financial Institution Group (EEFIG).
- Strengthening cooperation between regulatory work, standardisation work and RD&I programmes.
- Mapping RD&I needs: recommendation for RD&I priorities.

Organisation of the CEN-CENELEC SFEM Working Group on Blockchain and Distributed Ledger Technology

The WG is chaired by the SFEM of CEN-CENELEC and its vice-chairs Dr Bernard Gindroz and Mr Walter Schlegel, from Schlegel Power Consulting, and the secretariat is provided by SNV, the Swiss Association for Standardisation. 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 the energy production, grid management, regulatory, financial and IT sectors, in addition to blockchain-related technology ones (industry, SMEs and start-ups, research institutes, etc.) has been circulated. Moreover, the call aims at gathering experts with experience on local operational applications and decision-making, such as local authorities, cooperatives and associations, as well as representatives of 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 WG is split in three phases:

- **Phase I (May 2021 – August 2021):** Prepare a map of existing related initiatives in the energy & sustainable finance sector (pilots, start-ups, standardisation initiatives, etc.). The goals and expected outcomes of standardisation and research projects such as INATBA, DLT-4-POWER, etc., are identified. Phase I ends with a preliminary report.
- **Phase II (September 2021 – May 2022):** The objective of Phase II is to have a more complete view of the current challenges and standardisation needs in the field of “DLT in energy.” The analysis will be based on interviews with experts involved in DLT initiatives in the energy sector.
- **Phase III (June 2022 – September 2022):** Complete final report and provide it to SFEM for approval and dissemination.

Section 2: Blockchain use cases for energy

FLEXIBILITY SERVICES

Problem statement

Whereas utility spending on generation, transmission and distribution is expected to be relatively flat through 2030, spending *by the customers* on physical assets – solar PV, electric vehicles, storage, flexible loads and other "smart" devices – is expected to grow from USD 140 billion to more than USD 2 trillion. Customers will not want to pay twice, meaning that grid operators need a way to optimise the use of these assets to run the power system efficiently.

Any system that solves this problem must answer four questions:

1. How can it onboard so many behind-the-meter assets?
2. How can these assets participate in flexibility markets?
3. How can grid operators activate these assets when needed?
4. How can settlement be fast and efficient?

Application of blockchain technology

The entire life cycle required to integrate distributed energy resources (DERs) into flexibility markets is shown in this figure:

1. Registration of the transmission system operator (TSO), distribution system operators (DSOs), balancing responsible parties (BRP), hardware manufacturers and hardware installers in the system, each with their own secure digital identity.
2. Qualification of the manufacturers' products (e.g., specific models of batteries and inverters) for use in the system.
3. Registration of customers (owners of DERs) and their specific DERs, again each with their own secure digital identity.
4. Participation by these DERs in flexibility markets, including the entire life cycle of offers, security-constrained least cost optimisation and acceptance.
5. Activation of DERs when indicated by the grid operator.
6. Settlement for flexibility delivered by the DERs.

The technical components of the blockchain-based technology approach include the following:

- A *decentralised registry* of secure identities – the assets, people and organisations that interact in the system.

- A *decentralised (multi-nodal) flexibility hub* that manages the assets, people and organisations, life cycle, activation and settlement.
- A *decentralised storage* system that is customisable to privacy and other requirements.
- A *blockchain* to store certain data (where, e.g., time-ordering is critical) and allow automated execution where advantageous.

The key to this approach is the following: the decentralised nature of these components allows the various actors to transact with each other without any one party "owning" the system and without needing to manually establish trust in each other.

Returning to the four questions posed above, the blockchain-based approach provides the following answers:

- Onboarding DERs: grid operators are able to prequalify *types* of DERs (e.g., a specific model produced by a specific manufacturer), and then a qualified installer verifies that the customer's asset is of that type and located behind that customer's meter.
- Participating in flexibility markets: TSOs and DSOs submit their requests and constraints into the system, DERs submit their offers (themselves or via third-party providers of intelligence), and the system determines the lowest-cost way to meet the requests.
- Activation: TSOs and DSOs can activate the reserved DERs when needed and within required response time limits.
- Settlement: when DERs deliver flexibility in response to activation, clear records are produced, and settlement can be conducted at appropriate frequencies and at very low cost.

The approach is unique in its usage of decentralised technology and allows a modus operandi which is impossible in a centralised solution:

- The DSOs and TSOs do not need to share any customer data with one another or the platform. The decentralised identity system facilitates the creation of trust without disclosing information about the users.
- The settlement and the transaction volume are available only to the parties in the transaction. This allows all the participants to stay in control of their data and avoids the centralisation of information and the possibility to monetise customer or grid data.
- By design, a decentralised system has no single point of failure and is therefore more resilient. It is quasi-impossible to shut down a blockchain-based application by attacking it. Just as it is impossible to shut down email or DNS.
- The security and confidentiality of the data is guaranteed by end-to-end encryption and the encryption of the data at rest. Furthermore, in order to gain access to a user's data, the private key of that specific user is required. This makes an attack on the full system much harder as each user must be hacked individually before an attacker can gain access to the entire system.
- An open protocol allows third parties to provide services to end users, DSOs and TSOs. The openness of the system is by design and does not require the permission of a central authority. Every user in the system can give and withdraw permission to a third party to act on their behalf. This openness allows for more innovation because no participant can protect themselves against competition.

Grid balancing

The blockchain-based architecture described in the previous chapter can be further refined to provide solutions for specific products such as balancing power and connecting devices such as electric vehicles that are otherwise out of reach for the energy industry. Balancing power is requested and purchased by transmission system operators to ensure stable and reliable grid operation. However, traditionally TSOs don't have device-level visibility and access. Further, neither electric vehicle owners nor manufacturers inherently trust the TSOs since a generic and trustworthy consent management is missing.

Something that all types of control power have in common is that they require a large minimum plant size. Although it is possible to bundle plants, the minimum bids are 1 MW of primary control reserve and 5 MW of secondary and minute reserve. A decentralised solution based on blockchain technology ensures that vehicles with appropriate charging infrastructure can also provide grid services and even participate in the balancing power market. Something similar can be investigated for loads such as combined heat and power plants and heat pumps.

For this purpose, two questions need to be answered:

1. What should a regulatory framework look like to enable smaller, non-stationary plants, such as electric vehicles, to provide grid services and even participate in the balancing power market so that stable and reliable grid operation is also ensured?
2. How can the verification of the suitability of a plant (prequalification) be supported technically in such a way that the effort of the transmission system operators remains proportionate and a secure and verifiable connection of the plants is ensured?

Status quo device connection & current alternatives

Currently, transmission system operators have no visibility on individual, small plants (<1 MW). These can therefore only participate in the balancing power market in bundled form since the prerequisite for prequalification includes a minimum bid of 1 MW. However, bundling obscures the identity and characteristics of the individual plants so that prequalification of small plants is not possible later, either, via this route.

In various projects, the proprietary connection of smaller plants and also vehicles is being investigated. However, this does not allow for switching between providers as all trust comes from the service providers rather than the equipment and its owner.

Complicating matters further is the fact that only the unit of vehicle and charging pole together describe the characteristics of the entire system. In the case of public charging columns, this dynamically results in new system properties based on the properties of the individual devices. Without a verifiable device identity, it is therefore not yet generally possible to allow vehicles and charging columns to participate in the flexibility and balancing power market.

In its vision paper on e-mobility, Elia Group therefore formulates blockchain-based digital identities for integrating vehicles into the power grid as one of the important cornerstones of its corporate strategy.

Key to any functioning energy market is the ability to:

- Register assets, participants and potentially third parties (e.g. metering providers or "agents" who can control DERs such as solar PV or EVs).
- Enable efficient communication between market participants and the market operator, between market participants, and between market participants, the market operator and third parties.
- Manage relationships between participants and devices in order to, for example, manage churn in the portfolios or fleets of devices aggregators may use to deliver grid services.

- Exchange data between and across all organisations, people and devices within the market.

Existing legacy solutions – point-to-point integrations (with or without standards) or "centralised hubs" – either suffer from an inherent inability to scale to the volumes required for a DER-rich landscape (P2P solutions) or face increasingly expensive retrofits (and finally large switching costs) in order to manage new use cases or innovations within a sector for which they were not originally established (centralised data hubs). Further, such legacy approaches maintain a reliance upon a central broker/authority role which increasingly risks market failure through either security penetration and its associated calamities or administrative malfunction via being a single point of failure with cascading effects across all organisations that connect to the solution (e.g., a central hub).

Decentralisation via blockchain offers:

- Flexible service provision and resilience: participants host independent "nodes" or subscribe to existing ones, with such distributed infrastructure eliminating single points of failure.
- Single source of truth: data replication costs in many markets exceed millions of dollars annually. This is undertaken to enable data sharing of key market records between the central operator and participants; however, it is often ineffective over time, with multiple organisations separately managing multiple copies of the same data. With blockchain solutions, energy markets can avoid such costs and inefficiencies and utilise the decentralised ledger as the single source of truth for "standing data" – base registration information and metadata about people, organisations and devices.
- Self-managed identity: by anchoring digital and decentralised identifiers (DIDs), together with self-sovereign identities and verifiable credentials to the chain, each participant and consumer can manage their own identity and credentials and alleviate the need for central market operators to manage the sheer volume of registrations (and associated churn) of consumers, aggregators and devices that a DER-rich market will contain.
- Shared governance: rules, roles and responsibilities are defined via industry governance and can be enforced in code.
- Innovation potential: through utilising open-source technologies, participants can build custom applications on top of the shared infra, and new use cases can be established and provisioned, building network value for each market.

ENERGY ATTRIBUTE CERTIFICATES TRADING

Introduction

Energy Attribute Certificates (EACs) prove that a given unit of energy is generated from clean energy sources and act as a market-based instrument to incentivise clean energy rollout. An EAC owner can demonstrate their achievement of a regulatory mandate (e.g., an electricity supplier with a target share of renewables) or a voluntary commitment (e.g., RE100 companies with a renewables goal). Although EAC systems, particularly in the renewable electricity sector, are mature and widespread, there are various challenges faced by the industry:

- Lack of transparency and easily verifiable information throughout the entire EAC lifecycle.
- High complexity due to participation of numerous stakeholders.
- Manual processes inhibiting the ability to deal with high granularity and high volume of transactions.
- Barrier to entry for smaller-scale players since the systems were designed for large-scale utilities.

Blockchain brings significant advantages to address the aforementioned challenges, which is why there have been multiple initiatives at different stages of development implementing blockchain to improve the EAC markets.

Added value of blockchain for EACs

The benefits of using blockchain to improve EAC markets are increasingly recognised in the electricity industry because this technology allows:

- Accurate and verifiable tracking of every energy unit throughout its life cycle thanks to the decentralised nature and cryptography's capabilities.
- Real-time EAC issuance and transfer as generators produce electricity, instead of current monthly issuance.
- Automation of EAC trading due to the smart contracts and less dependence on a centralised entity to verify transactions.
- Cost-efficient handling of the ever-increasing number of small-scale generators and consumers with high granularity level and accuracy since blockchain makes any transaction financially viable.
- Creation of new market opportunities based on the digital acquisition of data and EAC issuance cost reduction.

Given this promising potential, it is not surprising to see an abundance of blockchain applications within the EAC market, which demonstrates a more mature adoption of the technology.

Existing applications and use cases

FlexiDAO, Foton, Powerledger, ReAcc, and TEO are among the most advanced and operational projects focusing on the two main use cases. Foton and ReAcc are growing voluntary renewables markets in developing countries by providing a blockchain-based marketplace with streamlined device registration, data collection, EAC issuance, trading and redemption in line with the I-REC Standard. FlexiDAO, Powerledger and TEO leverage blockchain to offer advanced functionalities for clean energy traceability, especially relevant in developed markets. There are, of course, many other similar projects and initiatives. Table 1 provides a brief non-exhaustive overview.

Table 1: Examples of blockchain applications for electricity attribute certificates.

Name	Type / use case	Description
Allinfra Climate by Allinfra	Sustainability management software	Allinfra covers environmental attributes, including EACs, allowing buyers and sellers to purchase and offer these products. The platform leverages Ethereum.
D-REC Initiative by South Pole and Positive Capital Partners	Registry and issuance platform for DERs	A pilot platform for tracking, issuing, transferring and redeeming EACs from thousands of small-scale DERs in developing economies such as Sub-Saharan Africa on a daily basis and at kWh granularity. The platform leverages the EWF's open-source tools such as EW Chain and EW Origin.
EcoGox by XM	EAC tracking platform	Managed by Colombia's electricity wholesale market operator (XM), EcoGox enables device registration, monthly issuance, transfer and redemption of EACs in line with XM's certification standard.

enerT by IBM	EAC tokenisation platform	enerT seeks to tokenise EACs and allow trading between suppliers and consumers. The solution leverages Hyperledger Fabric and Token SDK and is currently in development.
RESpring by FlexiDAO	Traceability dashboard and marketplace	FlexiDao traces the provenance of EACs and provides 24/7 traceability for renewable energy and CO2 accounting. FlexiDAO leverages EW Chain.
Foton	EAC tracking platform, marketplace and local Turkey I-REC issuer	Foton's I-REC marketplace registers generators and consumers in Turkey, issues I-RECs and allows trading and redemption. Foton is in the process of integrating with the I-REC Standard, which means the marketplace is compliant with the official standard present in Turkey. The marketplace leverages EW Chain and EW Origin.
Gaia-X	Green energy certification	Gaia-X is a European-wide initiative supported by several organisations seeking to develop a holistic EAC scheme based on blockchain to enable an end-to-end energy system that encompasses all products.
TraceX by Powerledger	EAC marketplace	TraceX lets generators track the creation, sale and transfer of RECs, while buyers can track the ownership, and hold and retire EACs against their targets. The platform is integrated with the U.S. Midwest Renewable Energy Tracking System (M-RETS) and leverages the Solana blockchain.
ReAcc by PTT	EAC marketplace	In addition to device registration, issuance, transfer and redemption of EACs, ReAcc also incorporates real-time generation data via smart meters and is planning to introduce long-term EAC purchases for buyers looking to support impactful projects. The marketplace leverages EW Chain and EW Origin.
REHash by T-RECs.ai	EAC tracking platform and marketplace	Users on REHash can register assets, buy, sell and cancel EACs. T-RECs.ai, REHash's operator, is an APX-TIGRs' registry system- approved independent verifier.
TEO by ENGIE	Traceability dashboard	TEO turns energy data into digital EAC assets leveraging blockchain. In addition to electricity, TEO works on tracking and certifying other products such as green gases. TEO leverages EW Chain and Ledger Origin.
Zero by Zero Labs	EAC dashboard	Zero Labs is a tech start-up that builds accessible and transparent tools to help businesses and individuals programme decarbonisation into their operations. Zero will make it easy for anyone anywhere to decarbonise and prove it with APIs that streamline the delivery of standard zero-carbon products such as EACs. This tool also leverages the proven decentralised technologies EW Chain and IPFS.

Emerging trends

These examples show that a predominant use of blockchain in the past years has been for streamlining EAC issuance and trading directly between buyers and sellers. There are, however, other trends emerging within the EAC and blockchain intersection:

- **Beyond electricity:** Blockchain can also be used to track other types of energy attributes (e.g., green hydrogen, biofuels). Similar to the electricity application, blockchain is leveraged to trace the life cycle of these energy products and issue transferable and redeemable attributes used by companies for their environmental performance.
- **Electric vehicle (EV) charging:** With the rise of e-mobility, EV owners (both large fleet and private owners) are seeking to ensure their cars are charged with green energy. Hence, there is an emerging use case for blockchain to track the energy used at specific charging points, automatically transfer the EACs to the EV owner and fractionalise the EACs into smaller units of energy (i.e., from MWh to KWh).
- **Move towards high granularity:** There is a move among corporate leaders towards 24/7 clean energy as opposed to matching net electricity consumption with annual EACs independently from what occurs on the grids. By using blockchain's granularity capabilities, EACs can be issued and matched with the consumption on a (sub-)hourly basis to allow generation and consumption to take place in the same grid and time interval as closely as possible.

Blockchain application for tracking renewable electricity is reaching its maturity as there are numerous actors and projects in place and already several operational platforms. Despite some challenges, proven use cases have helped transition blockchain applications for EACs from early-stage pilots towards commercially viable solutions. Moreover, given the emerging needs for traceability beyond traditional electricity-focused products and the push for higher granularity, the application of blockchain in the energy sector is likely to be further explored and advanced.

DIGITAL IDENTITIES FOR ENERGY ASSETS

Self-Sovereign Identity (SSI)

Self-Sovereign Identity is a growing paradigm that promotes individual control over identity data rather than relying on external authorities. This is in contrast to the current paradigm where most exchanges of identity data rely on communication and trust with an external, often centralised, authority.

Decentralised identifiers (DIDs) and verifiable credentials (VCs) are two of the most important components of SSI. Both DIDs and VCs are specifications of the W3C.

A DID is an identifier that can be generated and controlled by individuals or organisations without an external authority. It can be used to identify any subject, such as a non-tangible asset, a customer or an organisation. DIDs are typically generated and controlled via asymmetric (private/public key) cryptography. This allows the binding between public key and identifier to be verified without external certification. Though this reduces costs and provides self-sovereign control, it can present recovery challenges if the private key is lost.

A verifiable credential is a secure and machine-verifiable digital credential which respects a standard data model.

Together, they allow users and organisations to have control over their identities. Instead of an external authority maintaining control over an identifier and its associated identity data, any individual or asset can create an identity, and then establish credentials over time through interactions with peers or authorities on a trusted, decentralised network.

Though SSI provides a powerful and low-cost alternative to existing identity systems such as X509, it is important to note that it is relatively immature, and less tooling is available. The high-level benefits of SSI technology for energy assets are listed below:

- It is impossible to impersonate the asset. Every message the asset sends has a signature, and this signature can be verified by the receiver to check the correctness of the sender.
- It is impossible to impersonate the owner because the asset verifies the message's signature when it receives it.
- The asset can present its VCs to onboard itself; no need to have a centralised solution to store device identities.
- If using a blockchain for a registry of DID data, asset public key data (PKI) cannot be corrupted.

Energy sector use cases

Asset life cycle management

Monitoring assets through their life cycle in a verifiable way is very challenging when using a centralised solution, especially for assets that need more care when they reach their end of life (i.e., batteries) and assets that serve long years on the field (i.e., smart meters).

Self-sovereign identities can be easily used for life cycle management applications. For each life cycle event (i.e., manufacturing, installation, etc.), an issuer can issue a VC to track these events, and the asset itself or a VC custody service stores these VCs to present them to a verifier when necessary.

SSI for battery lifecycle management

To understand how and why an asset can take on a DID and acquire and use VCs, let's use the life cycle of a battery as an example. When the battery is manufactured, the manufacturer assigns a DID to the battery and issues claims about the battery's physical makeup (date of manufacture, model, serial number, battery capacity). The battery is sold. The installer of the battery adds new claims about the battery's purchaser and its new location. The new owner then adds claims about the battery's charge and discharge rate. The battery reaches the end of its life cycle. The final owner of the battery adds the date that it is retired and its final charge and discharge rate. Because we now have verified information on the battery, the battery can use this information to participate in various energy markets and provide services to the grid based on its confirmed attributes. This all happens without central oversight of the battery, and the battery is not restricted to participating in only one market.

Secure remote monitoring

The backbone for a grid flexibility application is to be able to receive real-time measurements from assets and be able to control them when necessary. Exposing this communication publicly online is very risky, and it will be a very easy target for hackers. However, hiding everything behind a VPN is also risky, because every system can be hacked, and when a hacker penetrates into the system, it means all the connected assets are vulnerable.

Self-sovereign identity is a perfect solution for securing the systems on the internet. Security relies on asymmetric cryptographic keys (known as public/private key cryptography); therefore, there is no need for establishing a VPN connection between the device and the system. All communication can happen over the internet because it is not possible to impersonate the device or the system. Furthermore, use of SSI for secure internet communication can be a lower-cost solution than existing public-key cryptography solutions such as X509 due to the elimination of certificate provisioning costs.

Asset onboarding

SSI can be used to enable the onboarding of assets in energy sector use cases. Similarly to the battery life cycle example previously discussed, asset data may be provided by asset manufacturers, asset installers or

asset owners themselves. Data may also be provided by asset certifiers or regulator bodies. In each case, issuing the asset data as VCs to the asset directly or to the asset owners provides flexibility on when and how the data will be shared for use-case onboarding and allows the source of data to be verifiable.

SSI for prequalification of electric vehicles and charge points

An example of asset onboarding is the prequalification of electric vehicles (EV) and charge points for flexibility use cases. In this example, EV and charge points are issued VCs containing information relevant to EV charging by their respective manufacturers. A grid balancing party, such as a transmission system operator (TSO), can verify the initial VCs and issue a further VC which prequalifies the assets for use in grid flexibility use cases. This example demonstrates how VCs can be issued based on other VCs to build a richer picture of an asset's eligibility for energy sector use cases.

Section 3: Case studies

CASE STUDIES

24/7 CPPA in NL: 100/100/0 becomes a reality

Project status: ongoing

Project partners: Eneco, Microsoft, FlexiDAO

Project location: Ypenburg, the Netherlands

About the project

Microsoft collaborated with energy supplier Eneco and software provider FlexiDAO in order to pilot a procurement arrangement that can truly eliminate emissions from the electricity it buys for its data centres. This pilot is matching one of Microsoft's Amsterdam data centres' hourly energy consumption with Dutch offshore wind. Microsoft is now a flagship customer of the integrated 24/7 solution, which is enabling Eneco's customers including Microsoft to have access to FlexiDAO's 24/7 renewable energy matching tools at scale.

In this pilot, Eneco is currently providing Microsoft with green energy not only on an annual basis but for every hour of the day. 24/7 green energy is essential to push the energy transition since it is about moving from offsetting greenhouse gas emissions to fully eliminating them from the grid. This pilot project was launched to demonstrate that 24/7 carbon-free energy is possible in compliance with official energy certification schemes and to enable more buyers to have access to 24/7 solutions.

In the context of the pilot, carbon-free power is produced by one of Eneco's offshore wind farms located off the Dutch coast. The generation is consumed by Microsoft Netherlands and is now being matched hourly at one of its data centres.

Following the guidelines defined by the EnergyTag initiative, FlexiDAO is providing its blockchain-based technology to monitor production and consumption 24/7, supported by measurement data made available by Eneco and Microsoft. This software is enabling the issuance, transfer and claim of granular certificates (i.e., hourly time-stamped energy attribute certificates) in order to monitor and certify the 24/7 synchronicity score of the Corporate Power Purchase Agreement (CPPA) while complying with the Dutch underlying certificate scheme – European Guarantees of Origin (GOs) – as implemented in Dutch law. CertiQ (Dutch GO issuing body) acts as the supervising party ensuring the compliance of the claims with the Dutch GO scheme.

In line with future energy systems

The current certification system, which uses GOs, does not support granular time-based certification. Using a more granular time indication can offer a guarantee that green electricity is produced and consumed within a single hour – or even within a quarter of an hour. Eneco has previously claimed that this is more in line with an energy system in which the balance between consumption and generation is becoming increasingly important as weather-dependent solar and wind power production increases.

A more transparent certification system gives private customers and companies like Microsoft more accurate insights into the sustainability of their electricity consumption. It allows them to make better-informed choices regarding which electricity they want to use, and companies can make their sustainability ambitions even more explicit towards a true decarbonisation.

The metering data used for the certification is third-party certified settlement data, provided to FlexiDAO by a Dutch regulated metering company after receiving permission from Eneco and Microsoft.

Thanks to FlexiDAO's 24/7 solution, Microsoft is now able to:

- monitor and calculate the 24/7 synchronicity score of its CPPA supported by the claim of granular certificates and GOs;
- obtain all the GOs needed to submit the yearly Scope 2 reporting;
- calculate the location-based and market-based CO2 emissions hour-by-hour in line with the GHG Protocol Scope 2 guidelines.

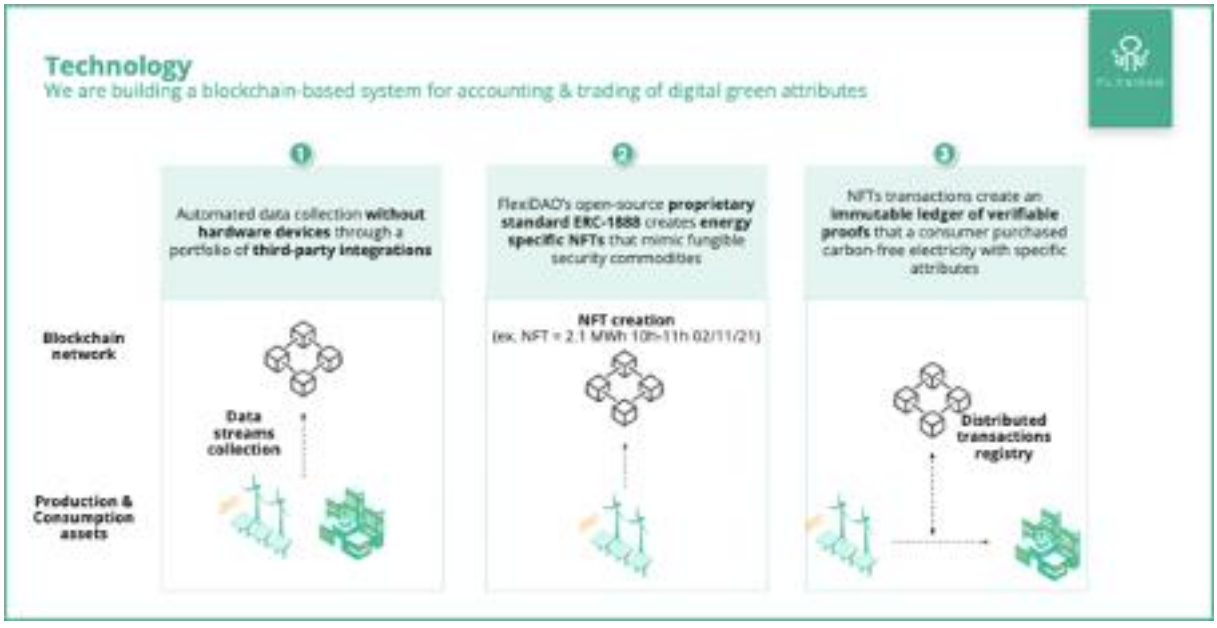
At the same time, the active participation of CertiQ ensures that the project is the first-of-its-kind since it has implemented a CPPA 24/7 certification mechanism backed by the first global guidelines on hourly certification (i.e. EnergyTag) together with the existing GO scheme.

The role of blockchain?

FlexiDAO's business model addresses one of the main barriers that companies face on their path to decarbonisation, which is the ability of energy consumers to access transparent energy data to gain control over where, when and how the renewable energy they consume is produced.

As mentioned before, the GO certification scheme is argued to be decoupled from time and, often, space of the production of energy units. This decoupling can create market inefficiencies because renewable energy sources aren't present everywhere and at every time in the same amount. It is important to keep track of the location of energy production to help determine the impact of transportation and storage while keeping track of the time of production. This is fundamental to the determination of the cost of energy since 1 kWh of solar energy in November won't have the same value of 1 kWh of solar energy on a sunny day in August.

To have a balanced grid, these factors must be taken into consideration. Blockchain is an effective technological enabler to solve these challenges. It not only increases the transparency and credibility of the actual reporting scheme, but it also provides efficiency in terms of automating a process that was previously done manually.



FlexiDAO's software solution, RESpring, is based on blockchain acting as a real-time digital notary that records the generated electricity, timestamps its origin and transforms it into a digital asset which is automatically transferred to consumers based on their consumption. It ensures the credibility and authenticity

of information shared with external or internal stakeholders. It also gives secure access to selected teams and third-party auditors and avoids simultaneous data entries and human errors.

The shift from monthly/annual energy data to hourly/sub-hourly energy data will require an immense increase in the amount of data that need to be tracked. To manage this, there will be a strong need for a fast, auditable and trusted system, as decentralised as possible to ensure that companies present in more than one country/region can interface directly with it.

Blockchain has the capabilities to take this vision of 24/7 renewable energy sourcing one step further. It could eventually uncover a marketplace for granular certificates, where buyers and sellers will be able to exchange clean energy on an hourly basis. An example could be the cross-selling of excess renewable energy instruments such as PPAs between parties based on the respective energy consumption and demand profiles identified through 24/7 hourly matching of renewable energy.

The early results of this project were presented last October at the Green Data Center Conference held in Rotterdam, and they are very promising. FlexiDAO have delivered proof of a working solution to a real-world use case by addressing Microsoft's 100/100/0 vision. This pilot is ready to shift from just signing PPAs even closer to true zero carbon. Microsoft has been able to develop a good understanding of the current time match and are ready to expand FlexiDAO's solutions from Sweden and the Netherlands to other countries. Not only has this pilot cleared the way for Microsoft, it also opens the door for others to manage their journey from nominally green to true zero carbon.

Eneco and Microsoft have recognised a market need for more transparency and credibility in renewable energy certification, and FlexiDAO are allowing that to happen through their innovative blockchain-based software solution.

EDGE: Energy Demand and Generation Exchange

Project status: ongoing

Project website: https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge

Project sponsor: Australian Renewable Energy Agency (ARENA)

Project partners: Australian Energy Market Operator (AEMO), AusNet (distribution network operator), Mondo (aggregator)

Project location: Victoria, Australia

About the project

Project Energy Demand and Generation Exchange (“Project EDGE”) will develop and test the concept of a distributed energy resources (DER) marketplace for DER services. Project EDGE is being undertaken by AEMO in partnership with AusNet Services (“AusNet”) and Mondo, with funding from the Australian Renewable Energy Agency (ARENA).

The DER marketplace in Project EDGE aims to optimally facilitate DER to participate at scale in the wholesale markets and deliver local (distribution) network support services. The trial will take place in the Victoria’s Hume Region, Australia, demonstrating the following key functions:

- Data exchange – providing a secure, efficient and scalable way for data exchange between Project EDGE participants.
- Wholesale integration of DER – trialling how aggregated DER might participate with progressive sophistication in the NEM wholesale dispatch process and operate within distribution network limits.

- Delivery of local network services using aggregated DER to meet requirements set by the distribution network service provider (DNSP) – providing DER owners and aggregators the opportunity to deliver new value streams.
- Understanding and defining the customer value proposition that market aggregators can offer their customers by developing and testing incentives for DER owners (customers) that promote active market participation.

Project EDGE aims to achieve the following:

- Demonstrate how DER fleets could participate in existing and future wholesale energy markets at scale.
- Demonstrate different ways to consider distribution network limits in the wholesale dispatch process.
- Demonstrate how to facilitate standardised, scalable and competitive trade of local network services.
- Demonstrate how data should be exchanged efficiently and securely between interested parties to support delivery of distributed energy services.
- Develop a proof-of-concept, integrated software platform to facilitate delivery of objectives 1–4 in an efficient and scalable way.
- Develop a detailed understanding of the roles and specific responsibilities of each industry actor.
- Conduct comprehensive cost–benefit analysis to provide an evidence base for future regulatory decision-making.
- Conduct a customer-focused social science study to understand customer opinions on the complexities of DER integration.
- Deliver best practice stakeholder engagement throughout the project with a commitment to knowledge sharing.
- Deliver recommendations, supported with evidence, on how and when the concepts demonstrated should be implemented operationally.

Platform

The digital infrastructure being built for the project is based on Energy Web's open-source stack and integrates with technology systems operated by the Australian market participants. It leverages third-party market intelligence software and uses Microsoft Azure cloud computing resources to integrate with AEMO and external partner systems.

Energy Web's blockchain (EWChain) is being utilised to establish the single trusted source of truth for the project's dynamic DER register, containing information about the DER devices and equipment being utilised, market metering and market participant information, and a host of other associated "standing data" used as reference for various market services and processes (e.g., portfolio constructions).

Energy Web's solution for the project includes the generation of decentralised identifiers (DIDs) for all assets and organisations, and the application of anonymisation techniques to enable data sharing between participants that also protects and secures consumer privacy.

In addition to market participants having access to agreed data sets registered using the EWChain, the project will trial third-party permissioning to access and write data to the source records. Such third parties may include DER installers, OEM manufacturers (updating firmware information) and certification authorities (validating capacity/service capabilities).

Project EDGE will include a key component – a local services exchange (LSE) – where the distribution system operator (DSO) will seek demand reduction and voltage management services from DER aggregators. The exchange will enable the solicitation and bidding for such services, and all aggregators awarded local service contracts will have their delivery assessed via network management tools in addition to being required to provide validation data to the DSO post delivery.

In addition to the LSE, the DSO will issue dynamic operating envelopes (DOEs) to all aggregators. Operating envelopes are the limits that a customer can import and export to the grid. At present, in most cases, operating envelopes have been fixed at conservative levels regardless of the capacity of the network because they are static and need to account for "worst case scenario" conditions. DOEs will allow import and export limits to vary over time and location, potentially enabling higher levels of energy exports from customers' solar and battery systems when there is more hosting capacity on the local network. Aggregators issued DOEs (which relate to local network infrastructure) will have their wholesale market bids/offers constrained/unconstrained in accordance with the DOEs settings.

BMIL: Blockchain Machine Identify Ledger

Project title: Blockchain Machine Identify Ledger (BMIL)

Project status: completed

Project website: https://future-energy-lab.de/piloten/blockchain-identity-ledger/

Project sponsor: German Federal Ministry for Economic Affairs and Energy

Project partners: German Energy Agency (dena), Project Group Business and Information Systems Engineering of the Fraunhofer FIT, Spherity, Oli Systems, Youki, Energy Web Foundation, Kilt, and 14 more project partners

Project location: Germany

About the project

The core of the Blockchain Machine Identity Ledger ("BMIL") project, led by the German Energy Agency (dena) and strongly represented by more than 20 project partners from different industries and application areas, aims to pilot a decentralised, device-specific and dynamic management of identities and properties of devices in the energy industry. It aims to provide the basis for autonomous, self-determined and flexible interaction with and between assets and stakeholders and markets in the energy system. Digital identities can form the basis for new and traceable market communication in the energy industry, for example by digitising master data and real-time data from decentralised generation plants and making them available and verifiable for automated use. In this way, different use cases such as renewable energy certificates or efficient CO2 footprint verification can be implemented with low effort and high data integrity guarantees. For this purpose, a blockchain- and certificate-based approach based on the paradigm of self-sovereign identities (SSI) was chosen to meet both the requirement of a decentralised, highly available and traceable solution and data protection and minimal data exchange requirements.

Simplified, the approach can be described as follows: each asset in the energy sector has its own, potentially self-managed, digital identity. Its cryptographic keys and digital certificates are stored in its local or cloud-based digital wallet. The certificates or "verifiable credentials" attest to attributes (sometimes also called "verifiable claims") of the asset and are issued by authorities (issuers) such as regulatory bodies and certified businesses in the energy sector. Selected attributes can be proved in the form of verifiable presentations. The verification of these verifiable presentations with regard to such a decentralised identity, characterised by one or more identifiers (DID), takes place bilaterally or can be conducted vis-à-vis a smart contract. Trust chains in the issuance of the certificates, as well as a revocation registry, can be used to determine at any

time whether the certificates issued are trustworthy and still valid. Thus, SSI-based digital identities form the foundation on which the BMIL is then built as the center of the project, enabling both discoverability and interfaces to on-chain use cases. By logging onto the blockchain using a temporary identity consisting of a changing identifier (pseudonym) and an application-specific subset of the certificates or the attributes validated in the certificates (selective disclosure), facilities can make selected attributes visible to other participants. Thus, for various use cases, for example, a targeted search of assets with certain attributes or an overview of currently registered assets can be provided to businesses and the regulator. Due to a high degree of automation with simultaneous control of the asset or its owner via the identity data, the system is highly flexible and represents a first step towards more complex on-chain logic (using smart contracts) in various use cases. An elementary feature here is that identity information is only published on the blockchain under use case-specific identifiers. In this way, sensitive data, e.g. personal data, which would otherwise be permanently visible on the persistent blockchain, can be pseudonymised to a high degree, and at the same time trust regarding the correctness of the attributes can be ensured.

The project has already been completed content-wise and is now in the finalisation phase of the closing report. As part of the project, the technical and legal hurdles to implementing the BMIL were analysed, possible solutions were designed and weighed against one other, and a proof-of-concept was implemented and tested. For this purpose, devices with complete trust chains, starting already in the supply chain of the manufacturing process, were installed in real laboratories, identities were assigned to them, and the feasibility of automatic transfer to registers was verified.

Possible use cases of the architecture developed within BMIL are manifold. Among others, the fields of application include the efficient issuance of renewable energy certificates and CO2 certificates as well as the simplification of prequalification procedures in flexibility markets. Currently, the correct identification of renewable energy in renewable energy certificate registries is associated with major inefficiencies and requirements, and in some cases it even necessitates plant inspections. The BMIL can considerably simplify these processes and at the same time facilitate easy registration in such a register, even for small plants and individual renewable energy assets. In the case of CO2 certificates, the efficient recording of all emissions along the entire value chain is currently not possible, or only possible at great expense. Here, too, the BMIL offers a starting point for circumventing this problem through the verification and tamper-resistant, decentralised storage of the data. Similarly, prequalification procedures for flexibility markets, which are usually cost- and time-intensive due to on-site inspection of the existing generators and devices, can be simplified. There are many other use cases that can be realised based on the project's results.

A Blockchain-Based Payment and Validity Check System for EV Services

Project title: A Blockchain-Based Payment and Validity Check System for (Electric) Vehicle Services

Project status: completed

Project sponsor: BMW Group

Project partners: Share&Charge Foundation (now Energy Web Foundation)

Project location: Munich, Germany

About the project

Self-driving cars rely on several services to operate, some of which require financial interactions, such as paying for battery charging in the case of electric vehicles. Providing these services demands the cooperation of several parties and organisations that do not necessarily trust each other. Over the past few years, several blockchain-based services were introduced to provide users with a safe and secure medium

for conducting business in a trustless environment. In this case study, we evaluate a blockchain-based solution to enable vehicles to consume and pay for services.

Case study

Drivers of conventional vehicles have to conduct many manual tasks such as charging, fuelling or parking. Most of these tasks require payment actions that are implemented in different manners (i.e., subscription model, cash or credit card payment, and contract-based payment). With the adoption of fully autonomous cars (level 4 or 5), it is necessary for these payments to be processed automatically since there won't be a driver to conclude the tasks. To prepare for the future of autonomous cars and also make the life of an everyday car owner easier, we implement an integrated electronic car wallet (eWallet), which enables the vehicle to generate value and act as an individual business unit. The eWallet connects to several ecosystems that handle the processing and communication with different service providers. The eWallet and ecosystem combination can be used to automatically pay all fees and costs the vehicle generates as well as handle the authentication process when communicating with infrastructure such as charging stations. Additionally, by benefitting from a blockchain-based environment, the solution provides a safe and secure approach where the users are not required to trust an individual organisation. Moreover, the system offers high transparency through tracking the vehicle-consumed resources on the blockchain and reduces the need for a payment service provider and, thus, the operational costs. The main objective of the integrated wallet is to provide a native ecosystem for enabling the car to connect to and consume services and to pay for the consumptions. To demonstrate the applicability of the solution, we focus on an electric vehicle charging use case. As soon as the charging cable is plugged in, we read the event from the vehicle bus. Then, we trigger the charging event at the charge point. To record the start of the charging process in a safe and trusted manner, we store a hash of the vehicle information, including the vehicle identification, timestamp, and state of charge of the battery on the Ethereum blockchain, through a transaction which is signed by the embedded device. To increase the users' privacy, we store the user data off-chain. Once the charging cable is unplugged, the charging process is terminated through the stop-charging event. Consequently, we store the hash of the updated vehicle data on the Ethereum blockchain. To ensure secure payment of the charging process that can be trusted by all involved parties, we use an Ethereum smart contract. This contract allows us to compare the data of the charge point with the data of the vehicle. Depending on the business model of the charge point operator, we either compare the charging duration or the charging consumption. If the respective values lie within a certain threshold, we trigger the payment automatically. Depending on the provider, the payment can be made using blockchain technology (e.g., through a stable coin to prevent the price fluctuation of the cryptocurrencies) or using conventional means like a credit card.

To evaluate the design, we compare the latency that the user experiences when using our designed automated system with an existing manual and not-automated platform which authenticates users via an NFC card at the charge point and accepts payment using the payment information provided beforehand. We also compare the cost of running the platform, especially regarding the transaction fees for Ethereum. Our evaluation shows that our solution based on the Ethereum test-net blockchain is, on average, 30% faster than the existing manually operated platform. Our solution can reduce the cost of using the system by almost 50%. Finally, our solution cuts the number of involved parties to half since many intermediaries (i.e., charge point aggregators or payment providers) are not required in this system.

In this work, we presented an integrated car wallet that enables the vehicle to pay for services automatically. The solution provides reliable storage for vehicle data, an automated plausibility check of the consumed energy through smart contracts, and payment using blockchain technology. Our approach could provide a solution for autonomous cars, which are required to pay for services without user interactions. It also shows how different parties in the energy sector interact and benefit on the basis of distributed ledger technologies.

Peer-to-Peer (P2P) energy exchange

Project title: Peer-to-Peer (P2P) energy exchange

Project partners: Powerledger

Project location: Uttar Pradesh, India

About the project

Access to energy is crucial in the development of emerging economies. Uttar Pradesh (UP), India's most populous state, houses nearly a third of the country's unelectrified population.

The Government of India set an ambitious goal of installing 40 GW of rooftop solar (RTPV) power by 2022. At the end of 2020, India had about 4 GW of RTPV capacity. Therefore, a P2P trading solution to benefit consumers, prosumers and electricity distribution companies was essential for a more interactive grid.

Powerledger's solution was to incentivise the uptake of distributed energy resources (DERs) in Uttar Pradesh through a market-based mechanism instead of relying on a subsidy-based mechanism (net metering).

Powerledger worked to provide valuable opportunities to Uttar Pradesh Power Corporation Ltd (UPPCL) to learn how to best implement all aspects of blockchain-enabled P2P electricity trading including defining network tariff to support the wider rollout of P2P electricity trading; and understand the impacts of P2P trading on the electricity distribution network.

These findings have enabled legislative changes to allow P2P trading in the state. In achieving this, affordable electricity can be distributed to the unelectrified population of the state.

Key features

Optimise electricity usage and provide prosumers more flexibility in price when carrying out trading of energy generated from rooftop solar systems, further incentivising the uptake of DERs.

Assist customers who want to buy green power by allowing them to purchase energy from rooftop solar systems through P2P trading.

Reduce distribution losses by encouraging local generation and facilitate decongestion in the distribution network.

Defer investment in distribution network expansion. Reduce transmission charges and generation capacity charges, which in turn reduces overall power procurement cost.

Blockchain allows transparency in transactions and negates the role of third parties in energy transactions.. Blockchain also ensures traceability of energy, allowing utility to trace prosumers and consumers to help in proper accounting and billing.

Location

Lucknow, Uttar Pradesh, India. The UP state is home to 90 million people. Despite being the fourth largest producer and second largest consumer of electricity, the state houses a third of India's unelectrified population.

Technology

- Powerledger xGrid application.
- Smart meters based on GPRS communication installed in 12 buildings, including 9 prosumers and 3 consumers.
- Head end system integrated with the blockchain platform and smart meters.
- CC&B system developed for this project and nitration of billing system within the blockchain platform.

Outcomes

- The P2P energy market buying price was 43% lower than the retail tariff; thus, further incentivising uptake of distributed energy resources.
- The Uttar Pradesh Electricity Regulatory Committee is the first regulatory body in India to create a tariff order that provides a directive to ALL the utilities in the state of UP to implement P2P energy trading.
- This allows greater opportunity for affordable energy to reach unelectrified rural areas, thus improving the economic welfare of the citizens of UP. The next steps being developed involve bringing P2P energy trading into a local energy market to drive grid efficiencies.

Energy Web Zero: a global renewables hub

Project title: Energy Web Zero: a global renewables hub

Project status: ongoing

Project website: https://www.energyweb.org/technology/applications/ew-zero/

Project sponsor: Energy Web Foundation, Good Energies Foundation, Protocol Labs

Project location: global

About the project

This section looks at how Energy Web Zero (“Zero”), a blockchain-based global renewables hub developed by the Energy Web Foundation (EW), aims at improving voluntary renewable energy searching, comparing and sourcing starting from renewable energy certificates (REC). An ongoing pilot with Protocol Labs (PL) is provided as a specific example of how the crypto industry can create significant additional renewables demand and set best practices for renewables procurement.

Energy Web Zero

The EW is a non-profit organisation building public, open-source decentralised software tools and blockchain infrastructure for the energy sector. EW’s software stack can be applied in different use cases including distributed energy resource (DER) integration into the grid, green EV charging, traceability and tradeability of low-carbon energy attributes, etc. With Zero, an example of EW’s work in the traceability and green proofs domain, EW aims at building a decentralised hub facilitating a two-sided market for carbon-free energy products such as renewable energy certificates (RECs).

Zero intends to tackle the opacity, fragmentation and lack of transparency in the markets of decarbonisation products (e.g., RECs, carbon removal credits, green gas attributes, etc.). The means of achieving this is by streamlining processes around both the i) supply and ii) demand.

Supply: Zero aims at enabling suppliers of any size, especially in developing countries, to post their decarbonisation products, starting from RECs, in an easy and verifiable manner and increase exposure to different types of buyers. Examples of suppliers from EW's ecosystem already include Foton, PTT, Singapore Power Group (SPG), 3Degrees, South Pole, and others.

Zero's vision is to provide full visibility on the life cycle of decarbonisation products (e.g., where exactly the renewable energy unit was generated, what the impact story is, etc.), offer easy discovery and comparison of these products to help buyers make informed decisions, and simplify the procurement.

A new wave of buyers with the Crypto Climate Accord

EW's mission is to decarbonise the energy sector with the help of innovative technology such as blockchain. The same objective is now extended towards the crypto industry, which presents a vast opportunity for the energy sector in terms of renewable energy demand and providing grid flexibility. In this spirit, EW co-launched the Crypto Climate Accord (CCA) along with the Rocky Mountain Institute (RMI) and the Alliance for Innovative Regulation (AIR). The CCA is a private sector-led initiative – inspired by the 2015 Paris Climate Accord – with the objective of powering the crypto industry with 100% renewable energy by 2030. Since its launch in April 2021, it has quickly gathered the support of more than 150 companies, including PL, who is actively contributing with technology development that aims at meeting this objective.

Zero is being designed to help different types of actors with renewables sourcing, including the crypto industry. Hence, Zero presents a forward-looking solution for numerous technically savvy crypto companies (e.g., blockchains, exchanges, dApps, etc.) to search for and source decarbonisation products starting from RECs. This additional demand for renewable energy from the crypto industry will hopefully scale the markets, especially in developing countries, and showcase how open-source blockchain technology can be leveraged to establish transparency and trust in the REC markets.

Protocol Labs: setting best practices for crypto decarbonisation

PL is a fully distributed open-source research, development and deployment laboratory aiming to upgrade the internet through the development of decentralised technologies. PL's projects include IPFS, libp2p and Filecoin, the world's largest decentralised storage network.

EW and PL recently partnered together to decarbonise the Filecoin blockchain and turn it into a new source of demand for renewable energy. The first leg of this partnership resulted in a showcase where selected Filecoin miners, better known as storage providers (SPs), purchased RECs through Zero from 3Degrees and SPG.

This exercise exemplified how crypto miners can cover their energy consumption by purchasing RECs, supporting renewable energy deployment. PL encourages the replication of this, not only among FIL's SPs but also by any other miners from any other blockchain.

In addition to the rewards SPs receive for providing storage, by covering their energy consumption with purchased RECs, they will be recognised for doing so in Filecoin's reputation system (FilRep). Zero feeds data into the FilRep and highlights whether an SP has purchased renewables or not. Clients seeking to store data or investors in search of clean investment opportunities are now able to verify whether a given SP has covered their energy consumption with RECs or not. This solution makes it possible to trace environmental attributes

several levels throughout the value chain of distributed file storage: from clients storing data, to the SP, to the specific renewables generator producing the energy used to store the data.

As of now, Zero displays a verification page linked to FilRep where these customers and investors are able to review where the energy came from, the type of energy (e.g., solar or wind) and the redemption statements that entitle SPs to claim ownership over the purchased RECs. Once fully developed, Zero will integrate additional functionalities that will automate, democratise and bring transparency to REC markets. Leveraging on the work that PL spearheaded, EW intends to replicate this for the wider crypto ecosystem.

This first iteration between EW and PL is paving the way to further develop Zero. Future work will focus on anchoring SPs' REC purchases on the EWC, which will ensure full traceability and transparency throughout the REC life cycle. EW's and PL's final objective is to have a full cross-chain solution where any type of miner will have a unique decentralised identifier (DID) on the EWC, which will then link REC purchases to an SP's DID.

Call for action

Both EW and PL have open-source and decentralisation deep-rooted into their core. Throughout this partnership, both organisations have realised that more work needs to be done and collaborative initiatives such as this one can help accelerate the decarbonisation path.

Therefore, crypto and energy companies are invited to collaborate. Crypto companies and other renewables buyers interested in purchasing renewable energy to cover their electricity consumption and REC suppliers that want to further deploy renewables have the opportunity to be a part of this project.

If the crypto industry wants to meet the CCA's objective – 100% renewable energy by 2030 – coming together to work towards this target is the best way forward.

Section 4: Insights from the industry

ETIENNE GEHAIN, ENGIE

Question 1: The expansion of renewable energies throughout Europe is leading to a decentralisation of the energy industry. For ENGIE, what are the most important use cases of blockchain that will transform the energy value chain towards addressing the challenges of the decentralised modern grid?

Response: The two main use cases are:

- the tokenisation of renewable energy production, leading to the issuance and exchange of certificates,
- the automatic sharing of value creation, leading to P2P or energy community management.

Both rely on a trusted source of shared information between different actors of a value chain. Many cumbersome exchanges of information and redundant verifications are avoided if all actors use the same source of information.

The trust issue is in fact not totally cancelled. It is moved to the “edge” (where the data is collected). The different actors still need to agree and trust the “edge” source of data (a meter or a sensor). However, this issue seems easier to solve than that of trusting a centralised database owned by a single actor.

An important part of the trust in the “edge” is the ability to verify the identity of these sources of data. Decentralised identities and verifiable credentials are good instruments to promote that trust.

Paradoxically, blockchain infrastructure can be slower and more complicated to set up than centralised systems. The number of transactions per second can be smaller with a blockchain. However, the gains come from the human need for redundant verification of the data exchanged between the IT systems of the different actors.

The ability of any actor in a value chain to independently audit a data trail at will is the key to simplifying processes that are more complex in a decentralised modern grid than before.

Question 2: What is the key characteristic of blockchain that is motivating you to use this technology?

Response: Its potential for decentralised governance. This provides a higher degree of trust in the recorded information and its automatic processes. With the possibility of programmable transactions (“smart contract”), a blockchain becomes a parameterised “open data” source. If well parameterised, it is as easy to implement as a cloud data storage, but with simpler processes attached to that data. It opens the possibility of self-managed wallets of information about assets and their user, which should simplify many processes.

Question 3: Are there any pilot projects in the field of energy and blockchain that ENGIE is currently working on?

Response: A DeFi project to crowd-fund the deployment of local renewable energy in Africa by our subsidiary ENGIE Energy Access. The aim is to lower the cost of financing the development of renewables in countries with low investment capabilities. By simplifying and automating lending and repayment processes, the number of intermediaries is decreased and the risk premium attached to these operations can be lowered. It requires leveraging an existing ecosystem of owners of tokens that hold some kind of value.

The pilot is implemented with the Energy Web Foundation, which fosters the ecosystem of Energy Web Token (EWT) owners. These will be able to stake their EWT and be rewarded for it according to the value created in the field by ENGIE Energy Access. This is the first example that links a value creation in the real world (i.e. renewable energy deployment) with value creation in crypto money (staking).

Question 4: What were the main lessons from these projects?

Response: The most difficult part is no longer the blockchain technology itself but the business model and the user experience associated with the use case. Using blockchain technology does not remove all financial risks from projects. Nor does it automatically signify success in attracting participants. But it does provide new financial instruments at a global scale as well as access to a vibrant and motivated community of users.

Question 5: What were the most important challenges and barriers observed in blockchain projects in the energy sector?

Response: The biggest barrier is the integration with legacy systems. Blockchain is a new infrastructure that can rarely be deployed on its own. It must connect with existing systems. The correct choice of which part of the solution must be managed with the chain and which part must be done with existing components is not always easy.

The choice of “on-chain” versus “off-chain” governance must be made carefully at the design stage of the project. It can be difficult to modify once the project is launched.

Another challenge is the fast pace of evolution in blockchain technology. Code maintenance can become difficult by the lack of motivated skilled resources. A technology lifecycle of 2 years does not fit well with the energy project payback period of time, which can be 10 times longer.

KAI SCHMIED, ELIA GROUP

Question 1: The expansion of renewable energies throughout Europe is leading to a decentralisation of the energy industry. For Elia Group, what are the most important use cases of blockchain that will transform the energy value chain towards addressing the challenges of the decentralised modern grid?

Response: We expect a huge potential in decentralised identification (DID) and verifiable credentials (VC). In the future, we will have to integrate decentralised energy resources such as electric vehicles, heat pumps and home storage devices. Today, we are lacking standards for expressing, exchanging and validating digital credentials across organisational boundaries, which lead to data silos and prevent interoperability. If we want to efficiently integrate said devices within our domain as well as in cross-sector (e.g., power and mobility) applications, we need standardised protocols for the exchange of credentials to make them work everywhere in an interoperable way. Blockchain can be a ledger to store DIDs and/or serve as a revocation registry to check the validity of credentials. Storing such information on a decentralised ledger ensures its interoperability, trust and availability.

The second use case is payment services. We are currently building a new consumer-centric market design that allows prosumers to participate in the energy market (react to real-time prices and trade energy P2P). This requires the settlement of micro transactions. With token-based systems and smart contracts we hope to reduce payment fees and create trust in settlement systems (up-to-date balance between accounts receivable & payable).

Question 2: What is the key characteristic of blockchain that is motivating you to use this technology?

Response: Immutability of data, accessibility and availability. We expect that the operation of a decentralised ledger is much lower than that of a centralised system with comparable rates of availability.

Immutability creates trust e.g., when using the above-mentioned revocation registry. This also requires an accessible ledger, which is provided by blockchain.

Question 3: Are there any pilot projects in the field of energy and blockchain that Elia Group is currently working on?

Response: We are actively testing the concept of decentralised asset registries and how we can enable interaction between assets, market participants and authorities. Together with industry partners, start-ups and blockchain technology providers we create DID for electric vehicles and test the concept of verifiable credentials. This concept can simplify prequalification processes (authorisation for balancing power participation). We demonstrated how this process could work: Elia Group issues a VC to the vehicle (or the holder of the vehicle) that can in return create a verifiable presentation for a third party (e.g. a flexibility service provider). This party can now independently verify that the credentials have been issued by Elia Group to the specific asset (or holder of the asset).

Another project is about retailer roaming for EV charging. Today EV drivers are bound to the supplier of the charge point operator (CPO). We are working on a solution to enable a free choice of retailers or even the option to select your own PV panel as a source of electricity for your charging process. In order to make this happen, several pieces of information are required: a) proof of a contract between EV driver and selected retailer, b) identifier of the user and c) charge point, d) supplier information e) consent.

This concept is urgently required in plenty of use cases: consent management for customers to provide data, proof of contractual relationships, etc. All this information and data need to be portable across use cases and applications.

Question 4: What were the main lessons from these projects?

Response: Instead of putting blockchain in the centre as the solution to everything, we can now better assess where the technology makes sense. One example: transparency can be an issue for granular certificates of origin, for instance, because it discloses consumption and production profiles. For such use cases, a public ledger is not the right choice from our point of view. Furthermore, we need to carefully evaluate the source and the way we write data on the ledger. Disintermediation works very well for decentralised finance, but in energy, where we interact with hardware, trusted entities are still required. Hence, we cannot easily disintermediate authorities or entities while providing the same level of trust.

Question 5: What were the most important challenges and barriers observed in blockchain projects in the energy sector?

Response: Resistance to applying new technology: There is resistance when it comes to replacing existing standards and technologies with technologies such as blockchain. Especially in the energy sector, where security is of high importance, it is quite a challenge to propose a technology that has not proven its maturity. Going beyond proof-of-concept is a big hurdle also because it usually affects many stakeholders (including regulators) with high technical requirements. Moreover, the traditional time horizon for developing, testing and approving new IT standards, e.g. in market communication, is long.

Solving current issues: the technological benefits of blockchain are promising for a decentralised energy system. Today we are not there yet, which makes it very difficult to test and prove its potential since a lot of assumptions need to be made (decentralisation, number of decentralised devices, etc.). Without tangible or monetary proof, it is difficult to become convinced to switch to a new technology.

Complexity of the energy sector: the energy sector is very complex in its structure, processes and governance. Therefore, understanding challenges and offering a better solution requires a deep understanding of the sector, which is difficult for tech start-ups without an energy background.

ARJEN ZUIJDERDUIJN, STEDIN

Question 1: The expansion of renewable energies throughout Europe is leading to a decentralisation of the energy industry. For Stedin, what are the most important use cases of blockchain that will transform the energy value chain towards addressing the challenges of the decentralised modern grid?

Response: For Stedin, there are two main use cases under investigation. The first is onboarding DSO and prosumer IOT assets, ensuring security, connectivity and interconnectivity. This allows Stedin to have a clearer audit trail of its own assets and enables interaction with prosumer assets (e.g., batteries, heat pumps and EV) to address imbalances and congestion in the near future. Besides, blockchain can enable a low(er) barrier and vendor lock in a free environment to start interacting between prosumers and sustainable monetary services.

Question 2: What is the key characteristic of blockchain that is motivating you to use this technology?

Response: The decentralisation characteristic. The customers in our grid all have their own tailored ambitions and needs in their sustainable growth and thus energy management. Blockchain helps this ecosystem to facilitate all these tailored actions in a democratic, social and technical manner. In other words, everybody can interact and improve the ROI on sustainable investments in their own way, with their own suppliers, etc.

Question 3: Are there any pilot projects in the field of energy and blockchain that Stedin is currently working on?

Response: Stedin is working on two pilot projects in the field of energy and blockchain. The first is an energy community in Hoog Dalem, Gorinchem, in the Netherlands. Stedin has jointly developed, with i.LECO and ABB, a blockchain-based local energy community. In this community residents can use and sell their own generated energy among their neighbours. This enables a system in which local generated energy is stored and consumed locally. First outlook is showing a ~22% increase in local self-consumption.

The second pilot is on creating digital identifiers (DIDs) for Stedins IOT devices. This enables an audit trail for our installing challenge for the years to come. Moreover, our assets can be interpreted as legal entities, thus enabling local interaction with prosumer-owned assets for balancing and/or congestion services. Lastly, by onboarding our assets to the blockchain, Stedin creates a more secure environment for its IOT asset base.

Question 4: What were the main lessons from these projects?

Response: We've had several lessons, the main two being the following:

- Blockchain is as good as its use case. An open door. However, the second pilot was started after several academic claims were made on blockchain as a mitigation for security risks on IOT devices. Also, the market model of the local energy community is the main value creator, not the blockchain.
- Decentralised, bottom-up thinking. The energy sector is historically top-down focused. This way of thinking is trusted, proven and technically logical. However, the energy transition is not only a transition in energy sources but also a transition from centralised to decentralised energy management. Blockchain is decentralised, and it helps the energy sector to understand this transition from centralised to decentralised energy management. Besides the technicalities, the prosumer is now leading design decisions. I strongly believe that top-down (forced) designs have only a limited stretch in succeeding in the energy transition.

Question 5: What were the most important challenges and barriers observed in blockchain projects in the energy sector?

Response: Overall distrust regarding blockchain. Internal and external stakeholders often have an initial distrust regarding blockchain; it is often mistaken with the volatility of e.g., bitcoin, mostly because of a lack of information and knowledge. But also because of the character of blockchain projects, which are most often in a pilot stage. A scalable, widely recognised blockchain solution is needed to bypass this distrust in the future. Alternative solutions should be objectively not logical to consider. E.g., we see other solutions being used for the replication of energy communities. Reasons: time to market, lower complexity and supplier adaptation.

Lastly, projects often mistake blockchain as a means to an end. This has eliminated a lot of fortune-seeking industry cowboys in the last years. This seems a logical one; however, in the last years we've seen that this challenge is often underestimated by many.

MARVIN SCHRIEDER, VOLKSWAGEN

Question 1: The expansion of renewable energies throughout Europe is leading to a decentralisation of the energy industry. For Volkswagen, what are the most important use cases of blockchain that will transform the energy value chain towards addressing the challenges of the decentralised modern grid?

Response: Blockchain in general can help us reduce the complexity of complex systems, such as a more and more decentralised energy sector. Further, it can achieve a much more efficient usage of the available energy and thereby reduce carbon emissions.

Question 2: What is the key characteristic of blockchain that is motivating you to use this technology?

Response: The use of smart contracts to ensure that the execution of contracts with value transfer without any further interaction enables a new dimension of intelligent linked systems.

Question 3: Are there any pilot projects in the field of energy and blockchain that Volkswagen is currently working on?

Response: At Volkswagen Group, blockchain is currently being investigated to create and redeem certificates for renewable energies at current time intervals. This will enable a more efficient use of energy, leading to a reduction in CO2 emissions.

Question 4: What were the main lessons from these projects?

Response: There were many, and (hopefully) there will be many more. Personally, I was surprised that conversations about disruptive technologies – such as blockchain – often end in a philosophical argument between scientists.

Question 5: What were the most important challenges and barriers observed in blockchain projects in the energy sector?

Response: One of the greatest intellectual challenges in the project is turning a highly optimised and established market – such as the energy sector – on its head and implementing a completely new system in which blockchain is the key element.

INTERVIEW WITH MICHA ROON, FORMER CIO, ENERGY WEB FOUNDATION

Q: Micha Roon, how did you become involved in blockchain and what is your current role?

I was raised and educated in Switzerland and spent most of my career creating solutions for the financial industry. But Switzerland is this really stable, secure and rich country so the usefulness of the value part of blockchain did not solve a problem I had personally.

In 2015, however, I discovered Ethereum, courtesy of my brother who was studying decentralised systems at the time, and the possibility to have a consensus-driven state machine with programmable state transitions piqued my interest. This was a solution to a problem I had as a developer: increasing trust in processes, making it impossible to rewrite history. These were things I could relate to, and thus I learned how to develop smart contracts and how to integrate them into applications.

I've been working full time on blockchain projects since 2016. In August 2019, the EWF hired me as their chief technical officer, and my first task was to answer the question, "What do we do with the energy web chain?" I lead the effort to architect the tech stack that would help the EWF deliver on its mission to build the

decentralised infrastructure to decarbonise the grid. Since September of last year, I have transitioned to the chief innovation officer role, and now I get to do research on the evolution of the decentralised eco system, in order to find the gems that will accelerate our mission.

Q: Blockchain is still a very young field, but where do you see the most need for improvement?

Looking back at the last five years, I am blown away by the progress that has been made in the field of decentralised computing. Many of the issues which I set out to solve with the EW-DOS have been at least partially solved.

- We have a working trust layer with the EWC, and the efficiency and ease of deployment of new blockchains is astonishing.
- There are multiple messaging or publish–subscribe solutions which can scale and be used in production.
- Decentralised databases are making huge progress too, but their querying capabilities are still lagging behind their centralised brethren.
- While decentralised identifiers allow users to authenticate with their private keys, the authorisation management part has not been solved in a satisfactory manner yet.
- Data privacy is still a big problem on blockchains. As enterprises are more aware of privacy issues, our work is more impacted than might be the case for decentralised user-facing projects.

To summarise: databases, authorisation management and privacy are the three fields where I would like to see more innovation. Not that there is no development going on. I know of four production-grade decentralised database systems (Ceramic, GunDB, CondensationDB and ThreadDB). We are working on a decentralised roles system – switchboard – at EWF, and I know of iden3. There are also some very promising ZK smart-contract frameworks under development, for example Partisia, Mir and Mina.

Q: What is your expectation of the blockchain ecosystem's development in the next 10 years?

It is impossible to see 10 years into the future from my current vantage point. But what I expect to happen in the next 5 years is that the basic infrastructure will solidify and become much easier to use.

I see the most promise in generic technology projects such as Polkadot/Substrate and Cosmos SDK because these frameworks allow developers to create more or less whatever they want. It can be a smart contract-enabled chain with some off-chain workers for assistance (Moonriver and Secret Network come to mind) or a specialised network that performs only one task (Kilt for DID or ChainProof for data anchoring). They also enable mixing and matching network functionality through their communication protocols: IBC for Cosmos and XCMP for Polkadot.

The tools and frameworks to create truly decentralised applications that don't require a central server at all will start to appear in this timeframe. It is not possible with current technology to create a decentralised hotel-booking app, for example. I see this changing in the next 5 years. There are protocols emerging that would allow such services to be created. The Graph Protocol is one of them and so is ThreadDB, which will allow the creation of decentralised query services. Once the tooling around projects like Waku and Ethereum Hive improves, clients will be able to communicate freely. And then there are generic approaches such as Holochain, which solves many of the issues as well.

We see more and more projects popping up, which do not try to solve all the problems themselves but are using other projects to provide parts of the functionality. I hope this trend will accelerate and pick up momentum. That's what decentralisation is all about: permissionless usage of functionality, which can be audited and trusted not to change. This might seem like a minor issue, but it is actually a huge thing: when

your app uses Firebase as a platform, Firebase can decide to upgrade the software that is running in the back-end, and you would never know. This is harmless in most cases, but it can be nefarious.

One of the things that drew me to decentralised applications is the transition from the intention “Don’t be evil” to the proof “Can’t be evil without being discovered.”

Q: What do you see as the biggest hurdle for the adoption of blockchain?

The loss of control! Many processes rely on the fact that an admin can intervene and fix errors. While fixing is still technically possible, it is impossible to cover your tracks and make everyone believe that no mistakes have happened. Organisations are keen on auditability and transparency when it applies to their partners but don’t like it all that much when it applies to them.

The technical issues have mostly been solved. It is not particularly easy to integrate your application with a blockchain, but it is already possible. And creating a successful software project has never been easy in the first place.

I am actually surprised that regulators have not jumped on the blockchain train yet. It is a regulator’s dream come true to be able to prove backdating of events and discover that things have changed. Imagine auditing the books of a company and being able to verify that they have not been cooked. Today, most audits rely on the fact that the company is telling the truth about its intentions and processes. This has been shown to be untrue on many occasions.

I explicitly think that transactions per second is not the hurdle that needs to be overcome. You don’t need all of your data to reside in a blockchain. It makes no sense, actually, and it is expensive and cumbersome. Blockchains will never replace databases; that is not their purpose. A much bigger issue is that not enough engineers know how to build efficient blockchain-based solutions. That might actually be the second biggest adoption hurdle to overcome: training and education.

Q: Let’s talk a bit about EW-Labs: what are your most exciting projects?

EW-Labs has been created to make novel uses of the resources of the EWF. We are focusing on financing renewable energy projects and creating a DAO for the management of the EWT Community Fund.

On the first topic, we have a very fruitful collaboration with ENGIE Energy Access and their African subsidiary Mobisol. Together, we are using blockchain to improve access to solar energy for millions of Africans who live in underserved or even off-grid villages. The project is more about token economics than blockchain technology, but it is fascinating work. For example, we are working with partners to create a euro-pegged stable coin to reduce the currency risk of the loans and reduce the sell pressure on EWT when some EWT grant is made from the community fund. The result should be that the cost of the loans is reduced and at the same time the value of EWT is maintained.

On the DAO part, we are building the governance tools to enable handing over the management of the community fund to the community itself. The technology involved mainly exists, but it is a matter of getting the right balance between on-chain and off-chain processes. For example, we don’t want the voting to be done on-chain because that would involve too many transactions and it would be slow. But at the same time, we need to have the assurance that the process is censorship-resistant while remaining privacy-preserving.

We are also involved in the EW-Relay-Chain project, which was started with Parity. In a nutshell, we want to create a blockchain consortium chain for the energy industry based on Polkadot and Substrate. This will allow our members to run their own blockchains but inherit the security from the EW-Relay-Chain. This should lower the barriers to entry for our corporate members as they’ll be able to run their own chains and keep everything as transparent or opaque as they like while still being able to prove to the world that the rules are not being broken.

Q: You mentioned stable coins. Is EWF entering the fintech space?

No; EWF, as a mission-driven organisation, sticks to its mission to create the digital infrastructure to decarbonise the grid. However, nothing can be achieved without financial resources, and we need to make sure that we protect the value of the EWT. Partnering with fintech projects to achieve both financing and value protection makes good sense.

The EWF will not be involved in the funding or development of the stablecoin, but it might provide liquidity to the DEX in order to make it easy to swap EWT for KES (Kenyan shilling) and back, in order to provide loans in local currency for the buyers of photovoltaic equipment.

Q: Some final thoughts?

In conclusion, I would like to say that even though the crypto ecosystem is still very young, it is not going away. Cryptocurrencies have gained enough traction that it will be impossible for lawmakers in western countries to outlaw them. This happens for many reasons, but the most important one is that too many people are invested and that people tend to get very angry if they perceive that their assets are being attacked. And angry voters don't vote for the politicians that made them feel that way.

Also, I am very hopeful as to the future of the software industry as a whole. It will take a few more years, but the industry is being decentralised, and users are waking up to the fact that they should not give up their data to the big corporations. What will take most time and effort is reaching the same level of usability in decentralised apps as in centralised ones. Convenience wins over privacy, sadly. But there are many projects working on solutions, and I am confident that a few will succeed.

In the near future, we will be able to store our identities privately on our smartphones and thus remove the need for usernames and passwords. This will make tracking our activities much harder as we will be leaving fewer tracks when using connected services. Companies are adopting digital identities too, with initiatives such as the vLEI from GLEIF. Combine corporate and private identity systems, and we will get a fully decentralisable infrastructure. The next step will be to build the infrastructure in such a way that it remains permissionless and open.

Section 5: Policy recommendations

In a recent joint report by ENTSO-E and the European associations representing DSOs (CEDEC, E.DSO, Eurelectric, GEODE) dated June 2021 under the title “Roadmap on the Evolution of the Regulatory Framework for Distributed Flexibility,” several key principles of flexibility markets were proposed that are highly related to the applications at the crossroads of blockchain and energy. These principles are:

- easy access and registration of assets for all customers,
- technology-agnostic access,
- access to all markets for all assets either directly or aggregated,
- equal access for DSOs and TSOs to markets and services,
- optimal use of available flexibility (no lock-in, hoarding),
- complete and transparent DSO–TSO interaction and collaboration,
- strive for uniform/similar market access in EU countries, and
- visibility and transparency of networks and flexibility of asset data.

One can observe that several principles are highly related to the advantages that come along with the introduction of blockchain-based solutions in the energy sector. Having these key principles as a starting point and taking into account the analysis presented throughout this report, we conclude with the following policy recommendations for the application of blockchain technology in the energy sector.

RECOMMENDATIONS

- **EU level**
    - Standardisation should be promoted at a European level, especially on the topic of digital and self-sovereign identities.
    - The European Commission may consider including energy-related use cases for evaluation in the context of the European Blockchain Services Infrastructure (EBSI).
    - It is also highly recommended that a systematic exploitation of the results of the various research projects under the Horizon 2020 and Horizon Europe frameworks should be promoted for projects using blockchain applications for the energy sector. Such a systematic exploitation could be part of the activities of the EU Blockchain Observatory and Forum, in a similar manner to BRIDGE for the energy-related projects funded under Horizon 2020 and Horizon Europe.
    -
- **Member State level**
    - It is recommended that national regulatory authorities should allow small-scale (less that 1 MW) flexibility assets to participate in flexibility markets either indirectly, via an aggregator, or directly.
    - The regulatory framework should also allow the visibility of energy assets connected to the distribution grid by the Transmission System Operator by means of digital and self-sovereign identities.
    - National regulatory authorities should provide regulatory sandboxes, where regulated entities such as transmission and distribution system operators are able to test and evaluate blockchain solutions that implement market design currently not supported by the existing regulatory framework. This is expected to radically accelerate the adoption of new technologies by transmission and distribution system operators, and it will also allow blockchain solution providers to evaluate (and subsequently optimise) their products.
    - Taking into account the uptake of e-mobility and the increased penetration rates of electric vehicles (EVs), policies should be in place that will allow regulated entities to work with car manufactures and charging-point OEMs to leverage the benefits of the EVs' flexibility assets and their use in different and innovative market designs.

- **Other**
    - It is recommended that blockchain technologies leveraging the notions of digital identities should also be used to support the secure and trusted exchange of data between the different market participants. This can be achieved by leveraging the relevant advantages offered by digital identities and verifiable credentials. Such a secure and trusted data exchange will also provide an efficient data exchange framework to further promote the transmission and distribution system operators' cooperation and coordination, in addition to supporting the various European initiatives in building data spaces across the EU for the different sectors, with the energy sector being one of the most important ones.
    - Public blockchains should be used in order to promote collaboration between the various energy market stakeholders and limit the possibility of creating vendor lock-in.

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Annex I: Status of R&D and innovation in Europe

R&D ACTIVITIES AND FUNDING

Projects

INTERRFACE

Project acronym: INTERRFACE
Project full name: TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system
Start date: 1 January 2019
End date: 31 December 2022
Overall project budget: EUR 21M
Project website: www.interrface.eu
Project coordinator: European Dynamic

Project relation to blockchain technology: within the INTERRFACE project, EMAX takes the lead to develop a Blockchain TSO-DSO Flexibility Trading Platform. We test the platform with the network operators and partners in Romania and Bulgaria.

With higher and higher renewable energy sources (RES) integration into the power system, both TSOs and DSOs need to have different flexibility means to maintain grid operation and stability.

In the last few years, blockchain technologies have been developed and applied in many sectors, including energy. Blockchain enables a set of members, in this case TSOs, DSOs, FSPs and prosumers, to safely transact with each other without investing trust in a central governing authority, such as a platform provider. Unlike central databases, blockchain has **no single point of failure**. Since every new transaction is recorded, checked and saved on many distributed computers, this level of transparency not only generates trust but also makes it possible to document processes and call them up at any time.

Currently, the platform provides visualisations for TSOs and DSOs where they can see the evolution of their local energy grids' congestion and availability of local flexibility assets 5 years ahead. In this way, the platform aims to help them plan in advance how to ensure the stability of the grid and find out where they can buy flexibility services to balance energy demand on their networks. Moreover, the platform has created a full onboarding experience for DSOs as well as TSOs to register on the platform and indicate their specific needs for grid flexibility. To match this demand, flexibility service providers, such as renewable energy generators and prosumers, can set up their profiles on the platform to submit their bids to DSOs and TSOs.

Once the market players indicate their needs and offering, eFlex allows them to trade flexibility services with each other. These transactions are based on blockchain, providing smart contract and smart billing solutions. Finally, thanks to the use of a blockchain ledger, transactions are communicated to the market players in real time. This helps TSOs and DSOs to immediately see how the local grid reacts to the trading and how it affects the grid congestion.

ACCEPT

Project acronym: ACCEPT
Project full name: ACtive Communities & Energy Prosumers for the Energy Transition
Start date: 1 January 2021
End date: 31 May 2024
Overall project budget: EUR 7,571,716
Project website: https://www.accept-project.com/
Project coordinator: Hypertech

Project relation to blockchain technology: The ACCEPT project offers a community-level P2P energy/flexibility exchange platform. This is a blockchain-based and smart contract enabled platform that facilitates the exchange of energy or flexibility for community-level optimisation (e.g., balancing, self-consumption, congestion management) between the community members with an option to assign credits to the transactions. This will become the foundation for optimally sharing energy generated by common renewable resources in a fair and transparent manner. The blockchain will record the individual member consumption share/offering in a trustworthy manner for later reconciliation and settlement. The P2P platform's main goal is to reduce the transaction costs by eliminating intermediaries and minimising billing and administrative costs. It will also promote local energy production and consumption by allowing aggregation and trading in wholesale markets in a seamless and transparent way. Blockchain in general is a technology that fits almost naturally in the P2P energy trading schemes as it offers immutable registration and recording of assets, recording the generation and consumption of data in complex energy systems with many subsystems' interactions and intersections. The other innovative aspect of the blockchain technology that is implanted in ACCEPT is the concept of smart contracts, immutable contracts between a service provider and a client that monitor service level agreements without the need of a third party. With the use of smart contracts, the delivered service will be evaluated through a number of well-chosen measurable and quantifiable key performance indicators.

BD4NRG

Project acronym: BD4NRG
Project full name: Big Data for Next geneRation enerGy
Start date: 1 January 2021
End date: 31 December 2023
Overall project budget: EUR 11,883,025.00
Project website: https://www.bd4nrg.eu/
Project coordinator: ENGINEERING INGEGNERIA INFORMATICA SPA
Project partners: NATIONAL TECHNICAL UNIVERSITY OF ATHENS – NTUA, RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN

Project relation to blockchain technology: BD4NRG put DLT, blockchain and smart contracts centre stage to deliver i) an innovative data governance layer compliant with the International Data Space Association ii) a P2P digital marketplace for heterogeneous tokenised asset compensation.

As for the first topic, BD4NRG has been developing and deploying an IDSA-compliant DLT/blockchain-based implementation for a decentralised data sovereignty and governance architecture for cross-entity data sharing, which integrates IDSA conceptual architecture and truly extends the FIWARE NGSI vs ETSI Standard Context Broker to seamlessly integrate with hybrid IoT/blockchain off-chain data sharing solutions from the H2020 eDREAM, H2020 INTERRFACE and H2020 SOFIE projects. Scalability of the planned infrastructure will be achieved through utilising the blockchain for hash storing, which will uniquely refer to the information content that is managed off-chain in a decentralised way (e.g. IPFS). Hence, we will be gaining the immutability, traceability, accountability and notarisation/time stamping benefits offered by distributed ledgers and blockchain technologies, at the same time effectively managing DLTs' intrinsic difficulty in scaling up.

As for the second topic, BD4NRG adapts, matures and deploys a TRL 7–8 flexible and adaptable P2P marketplace, which leverages and combines tokenisation inspiring principles from value networks,

DLT/blockchain and smart contracts to enable the value- and incentive-based sharing, exchange and financial and non-financial compensation of data resources (data sets, data services, AI ML models/algorithms, data storage and computing resources) with energy services. In particular, we will make available a flexible, adaptable and configurable DLT- and blockchain-based technology backbone able to optimally support tailored vertical mono-commodity or horizontal cross-commodity marketplace implementations.

BRIGHT

Project acronym: BRIGHT
Project full name: Boosting DR through increased communIty-level consumer engaGement by combining data-driven and blockcHain technology Tools with social science approaches and multi-value service design
Start date: 1 November 2020
End date: 31 October 2023
Overall project budget: EUR 5.88 M
Project website: https://www.brightproject.eu
Project coordinator: Vincenzo Croce (ENGINEERING)

Project relation to blockchain technology: The BRIGHT project will leverage recent advancements in blockchain technologies to deliver many-fold applications in order to support new community-enabled ways for engaging consumers in DR. Specifically, it will be provided four integrated software tools for the management of energy communities:

- Community-level blockchain-based flexibility market – it allows the users from a community to trade their energy flexibility in a P2P manner. Different types of flexibilities are considered, such as electrical, thermal, comfort services, etc. The matching between the flexibility bids and offers is done using services integrated with the blockchain via oracles providing both cooperative and competitive (price-driven) trading models for matching.

- Blockchain management and settlement of flexibility-driven DR – it allows the injection of energy goals in smart contracts, the tracking of flexibility delivery and energy, and financial settlement. The implemented self-enforcing smart contracts will aim at tracking and checking the compliance of each prosumer enrolled in DR programmes with the desired demand energy profiles, to calculate associated rewards and penalties and to detect grid energy imbalances requiring the definition of new DR events.

- Community self-governance to deliver flexibility services – it allows the creation and decentralised management of coalitions in a community to deliver flexibility services on demand to the main grid. The smart contracts will have the ability to consider by means of direct injection the output of the hybrid optimisation heuristics for cross-sector combination of services. In this way, prosumers will be empowered to dynamically participate in coalitions by considering optimisation targets and energy profiles outputted by the optimisation heuristics.

- Edge metering infrastructure and interoperable gateway – it allows monitoring and control of the home environment, integrating various home sensors/controllers/appliances belonging to different vendor ecosystems and making them interoperable. The tool will be integrated with smart contracts for flexibility actions' automation.

CoordiNet

Project acronym: CoordiNet
Project full name: Large scale campaigns to demonstrate how TSO-DSO shall act in a coordinated manner to procure grid services in the most reliable and efficient way
Start date: 1 January 2019
End date: 30 June 2022

Overall project budget: EUR 19,191,479.11 (EUR 15,077,587.57 funded by the European Commission – Horizon 2020)
Project website: https://coordinet-project.eu/
Project coordinator: ENEL

Project relation to blockchain technology: In the CoordiNet project a blockchain-based platform has been implemented as part of the CoordiNet Swedish demonstration campaign. The platform aims to develop a blockchain-based system that is integrated with the Swedish P2P market to validate trading capacity after a marketplace session, ensuring that energy transactions between parties can take place in a transparent, traceable and immutable way. The P2P market was applied in the Västernorrland/Jämtland and Gotland pilot sites to manage congestion because of capacity limitation due to maintenance and investments in the grid. The blockchain infrastructure provides the use of a private network, capable of supporting programmable smart contracts. The reference platform is based on Ethereum blockchain, identified as the most suitable one for the Swedish demonstrator (it supports smart contracts and is Turing-complete programmable). The Ethereum private network has been leveraged because it is faster, has lower costs and is more scalable. Two kinds of smart contracts were developed and deployed in the private blockchain:

- Energy measures smart contract: readings from meters are associated with an Ethereum portfolio and are stored in the blockchain with an array of timestamp/value pairs.

- Value transaction smart contract: An ERC-20 token has been exploited for the economic transaction once the energy transaction has been verified.

BD4OPEM

Project acronym: BD4OPEM
Project full name: Big Data for OPen innovation Energy Marketplace
Start date: January 2020
End date: June 2023
Overall project budget: EUR 9.9 M
Project website: https://bd4opem.eu
Project coordinator: Universitat Politècnica de Catalunya

Project relation to blockchain technology: The P2P Energy Trading Service aims to facilitate the implementation of the Clean Energy Package enabling prosumers, consumers and small producers to trade energy between them as part of a Citizen Energy Community (CEC) and at the same time help provide a more optimal control of the distributed renewable energy sources (DRES).

As such, the service enables the trading of energy directly between local community end users (prosumers, consumers and small-scale producers) over a transactive grid. End-user communities that register with the P2P Energy Trading Service will allow the hourly real-time reading of their smart meters over the BD4OPEM platform to a smart contract which will monitor their energy flow and execute the trading algorithm. The trading algorithm runs in an automatic fashion according to the type of trading algorithm selected by the community (e.g. fair trading with no user settings, competitive trading with user settings).

The smart contract implementation provides a notarisation function storing the hashes of the energy traded against the pseudonymous identities of the members' smart meter IDs participating in the CEC. This provides immutable trust in the service amongst the parties involved. To add greater privacy, the pseudonymous IDs can be rotated at the end of a trading period, which will be managed by the service.

To develop these solutions, the use of a modular architecture that allows a private network such as Hyperledger Fabric is being considered, whilst other solutions are considered as well, such as developing on Ethereum.

FEVER

Project acronym: FEVER
Project full name: Flexible Energy Production, Demand and Storage-based Virtual Power Plants for Electricity Markets and Resilient DSO Operation
Start date: 1 February 2020
End date: 31 July 2023
Overall project budget: EUR 9,847,839.82
Project website: https://fever-h2020.eu
Project coordinator: Intracom Telecom SA

Project relation to blockchain technology: The project will implement a blockchain-based software platform for P2P flexibility trading. The solution targets energy communities (ECs) where active electricity consumers and/or producers (prosumers) have a need to transact energy and/or flexibility as well as monetary and (other) communal assets in the P2P fashion without a fully trusted marketplace operator. It offers a novel concept of a pseudo-currency (FlexCoins) and an auction-based P2P marketplace solution, which allows electricity consumers and/or producers to offer/request advanced energy and flexibility products to/from the members (peers) of an EC. A set of distributed applications running on top of the Hyperledger Fabric (HLF) are developed:

- FlexCoin DAPP: provides a common value system for all participants in the trading system and acts as a building block to trade products and services. FlexCoin is designed as a secure, verifiable and privacy-preserving smart contract ecosystem that can also be used to provide a so-called stable coin (i.e., a digital currency that is pegged to a real-world fiat).

- Community Management DAPP: allows EC administrators to create trusted and secure ecosystems – managing the digital identities of their consortia – following a federated identity model which is employed by the HLF.

- FlexTrading DAPP: provides a P2P marketplace in scenarios when no trusted market operator can be assumed. Different products (i.e., energy product, flexibility product) are supported by the P2P marketplace, through selling and buying bids (following/adapting FlexOffer specification).

TwinERGY

Project acronym: TwinERGY
Project full name: Intelligent interconnection of prosumers in positive energy communities with twins of things for digital energy markets
Start date: 1 November 2020
End date: 1 November 2023
Overall project budget: EU 7,093,910
Project website: https://www.twinergy.eu
Project coordinator: University of Patras

Project relation to blockchain technology:

- Transactive Energy Module

  The TwinERGY project is a provider of a transactive energy (TE) ERC-20 Ethereum token-based blockchain global framework that provides energy consumer transactions, energy generation access, and participation in decentralised and wholesale energy markets. TwinERGY's TE framework consists of multiple permissioned TE sidechains as part of the global Ethereum network.

  The first federation of sidechains and smart contract settlements of the token provides a unique energy loyalty and reward to those who participate in energy savings, demand response (DR) energy curtailment, energy settlements, micro-renewables and other energy programmes. TwinERGY's implementations for energy sidechains are projected to be among the most energy-

efficient, encrypted blockchain platforms in the market today, in some cases 100x to the competition, 10x to most, and more energy-efficient than any other energy blockchain proposal. The TwinERGY permissioned sidechain TE architecture will make energy consumption for blockchain processing a non-factor.

The Transactive Energy Platform will use the Ethereum network and technology to create a thrustless auction house where flexible capacity and demand from DERs will be auctioned off, through encrypted, shared, immutable and publicly auditable smart contracts. A cryptocurrency ecosystem is created, which reserves the cryptocurrency asset value, solves volatility problems and ensures high transaction-processing speed.

- TwinEV Module

  TwinEV is the module that allows electric vehicle (EV) charging in public and private charging points considering grid restrictions. Its goal is to provide the required and optimised state of charge, considering minimum charging prices and the delivery of green electricity supply to EVs. Since this module allows the charging of EVs in public infrastructures, it will make use of the Transactive Energy Module and blockchain technology to permit the financial transaction that may be required. Furthermore, the TwinEV module intends to allow V2G functionalities for energy transaction between the EV and the grid. This transfer will be allowed by the Transactive Energy Module and blockchain technology.

SENDER

Project acronym: SENDER
Project full name: Sustainable consumer ENgagement and DEmand Response
Start date: 1 October 2020
End date: 30 September 2024
Overall project budget: EUR 6,759,618.69
Project website: https://www.sender-h2020.eu
Project coordinator: Smart Innovation Norway

Project relation to blockchain technology: In SENDER, Trialog will develop a smart-charging EMS. It is an innovative energy management system exploiting the flexibility capabilities of electro-mobility and EVs through smart charging and V2G, e.g., to support public grid, private grid, local energy communities, energy markets and local balancing. This EMS integrates the evaluation of flexibility, its provision to the flexibility market, and also the assurance and traceability of both flexibility offers and activations. This assurance and traceability are based on blockchain and smart contracts, allowing the movement from flexibility activation "blindness" (i.e., an activation signal is sent without any feedback) to flexibility activation assurance (i.e., guarantee that the flexibility will be activated) and traceability (i.e., proof that the flexibility has been activated). This assurance is essential to system operators (DSO, TSO) as the non-activation of a flexibility requested by the SO can lead to severe grid issues.

PEAK

Project acronym: PEAK
Project full name: Integrierte Plattform für Peer-to-Peer Energiehandel und Aktive Netzführung
Start date: 8 March 2021
End date: 29 February 2024
Overall project budget: EUR 4,000,000
Project website: https://www.hsu-hh.de/startschuss-fuer-peer-to-peer-energiehandel-auf-blockchain-basis
Project coordinator: Helmut-Schmidt-Universität Hamburg

Project relation to blockchain technology: A blockchain is used for the PEAK platform, which acts as an access manager and thus represents a central element of the system's security architecture. The blockchain used is based on the principle of self-sovereign identity. Self-sovereign identities or decentralised digital

identities have the potential to reinvent our understanding and management of data and identities in digital space. The energy industry needs a secure and scalable way to identify the growing number of clean energy resources, review their attributes (such as location, capacity and financial relationships) and manage permissions and behaviours based on these attributes. PEAK creates a cryptographically secure distributed ledger that records transactions that prevent any change. Individual market participants can authenticate themselves via the general ledger and receive verifiable credentials that enable them to participate in the market. Instead of a manual email data exchange between PEAK participants or participants and the platform, the origin of address data, bank data, and supplier and consumer certificates can be verified cryptographically.

HESTIA

Project acronym: HESTIA
Project full name: Holistic dEmand response Services for European residenTIAl communities
Start date: 1 November 2020
End date: 31 October 2023
Overall project budget: EUR 7,514,042.50
Project website: www-hestia-eu.com
Project coordinator: Sinloc - Sistema Iniziative Locali SpA

Project relation to blockchain technology: HESTIA will lay the foundation for an open marketplace and a new grid reality, as part of which the residents will be able to exchange the produced energy and demand flexibility while interacting within the community as well as with the grid. Such a marketplace will be deployed on the HESTIA platform based on the integration of the layered energy system (LES) from i.LECO (with its first proof-of-concept implementation in 2019, in NL) with the Zenroom VM implementation of PROSUME (by Grid Ability) acting as a layer of interoperability between common databases, distributed ledgers and blockchains (like the Ethereum-based one from EWF or the Hyperledger-based one from PROSUME), which will allow for decentralised management and automated demand response settlement procedures to be performed in a secure manner. HESTIA will enable liberalised energy flows within entire communities while steering consumer engagement according to grid requirements and promoting renewable energy systems and sustainable behaviour. HESTIA will foster technological solutions such as distributed management, smart billing and market integration by ensuring secure energy and flexibility exchange within the community, at the same time enabling human understandable “smart contracts” to execute automated settlement procedures and process fair remuneration business logics.

IANOS

Project acronym: IANOS
Project full name: IntegrAted SolutioNs for DecarbOnisation and Smartification of Islands
Start date: 1 October 2020
End date: 30 September 2024
Overall project budget: EUR 8.8 M
Project website: https://ianos.eu
Project coordinator: EDP

Project relation to blockchain technology: In IANOS the blockchain technology will be exploited by the engineering partner to implement a DLT-based transactive platform inside the iVPP framework. The DLT-based transactive platform aims to develop a P2P market that enables prosumers in a local network to directly trade energy with each other, avoiding RES curtailment and future grid transport costs. The P2P trading system is based on Ethereum blockchain that guarantees the transparency and security of the transaction, which remains permanently recorded in the platform, allowing all parties to audit the results. Fungible tokens based on the ERC-20 standard will be exploited as payment for the purchase of energy between prosumers.

The expected impact is greater awareness, improved local quality of life and a boost in local employment, but also energy efficiency.

Main advantages of the DLT component are:

- Neutrality of the market: the absence of a central owner of the market guarantees the satisfaction of all stakeholders' interests without any catalysation around big players. Moreover, the adoption of an open mechanism for price calculation (everybody knows the algorithm) is another way to engage prosumers by reducing their worries about system fairness.
- Trustworthiness, transparency and immutability: by design, the transactions in the blockchain are transparent and immutable. This can help resolve any disputes among the market participants and ensure non-repudiation for transactions performed.
- Self-enforceability of smart contracts: self-enforceable means that once the smart contract is configured and running, the execution of its code is automatic and will not require specific approval. In the proposed system the transfer of tokens between prosumers is performed automatically by a smart contract after the validation of the energy transaction. No central authority can interfere with the transaction.

InterConnect

Project acronym: InterConnect
Project full name: Interoperable Solutions Connecting Smart Homes, Buildings and Grids
Start date: 1 October/2019
End date: 30 September 2023
Overall project budget: EUR 35,793,191.38
Project website: https://interconnectproject.eu/
Project coordinator: INESC TEC

Project relation to blockchain technology: The InterConnect project provides an interoperability framework as a set of tools for enabling trusted and secured semantic interoperability of digital systems from different domains. The framework includes blockchain technology in two main directions:

First, blockchain is used as the basis for building P2P marketplace enablers for energy and data trading and trusted data transactions in smart energy communities. The P2P marketplace enablers include: 1. blockchain network configuration which includes actors, their roles, relationships and blockchain access rules; 2. a set of smart contract templates for facilitating all transactions, settlements, process management and integration requirements of smart energy community use cases; 3. white-labelled web application for demonstration of the marketplace operation; 4. order matching engine which can be configured in line with specific business logic and regulatory constraints. The data models in marketplaces are based on SAREF ontology, and exposed integration REST APIs correspond to the interoperability framework-unified communication interface provided by generic adapters. Four project pilots will deploy P2P marketplace enablers in their community-based use cases.

The second application of the blockchain technology goes towards enabling an automated interoperability compliance certification mechanism, which is part of the project's service store. Each semantically interoperable service needs to pass an interoperability compliance test before being onboarded to the service store. After a successful compliance check, the service is provided with a digital certificate that is written in project-level blockchain. This process is executed each time service is restarted or updated. The compliance certification provides a level of trust for integrators looking to deploy interoperable services in their use cases.

The project applies Hyperledger Fabric technology and smart contracts in both of these cases.

PARITY

Project acronym: PARITY
Project full name: Pro-sumer AwaRe, Transactive Markets for Valorization of Distributed flexibilITY enabled by Smart Energy Contracts
Start date: 1 October 2019
End date: 31 March 2023
Overall project budget: EUR 9,388,829.88
Project website: https://parity-h2020.eu
Project coordinator: CERTH

Project relation to blockchain technology: The smart contract-enabled market platform of PARITY implements a local electricity market (LEM), which facilitates automated P2P energy/flexibility trading among prosumers and implicitly integrates a local flexibility market (LFM) for facilitating selling of flexibility to smart grid actors such as the DSO. Energy/flexibility tokens are used to stimulate liquidity in the local market and to provide the means for market coupling with national energy and ancillary service markets. By delivering a market for automated flexibility exchange based on smart contracts and blockchain, PARITY facilitates efficient and transparent local flexibility transactions and rewards flexibility in a cost-reflective and symmetric manner, through price signals based on grid status and operational constraints as well as the available DER flexibility. From the implementation point of view, the blockchain agent is the component that holds the market mechanism and provides a sidechain platform, where the LEM with implicit LFM market represented by the market engine (ME) can run and interact with the PARITY components. An automated market making (AMM) mechanism was proposed to generate the LEM energy prices. The market engine performs the computation of the automated market making energy tariffs. Multiple blockchain agent instances are running, one per market participant. The main actions that are regulated through smart contracts are: new clients (any actor, e.g. energy prosumer) registration into the marketplace; payments/penalties settlement for each provider of energy/flexibility; and acquisition of attributes through permissioned-handling management from the relevant responsible party.

PHOENIX

Project acronym: PHOENIX
Project full name: Electrical Power System's Shield against complex incidents and extensive cyber and privacy attacks
Start date: 1 September 2019
End date: 31 August 2022
Overall project budget: EUR 10,738,867.44
Project website: https://phoenix-h2020.eu
Project coordinator: Capgemini Technology Services

Project relation to blockchain technology: PHOENIX adopts a data-centric approach based on federated DLTs, as part of its secure and persistent communications (SPC), to achieve a higher degree of persistency, traceability, availability, integrity and interoperability in the context of data communications. The SPC Layer benefits from the Interledger (IL) component, which is implemented on the basis of protocol bridging, for interconnecting varying ledger networks, which are also suitable for critical EPES assets and data. More precisely, the IL component triggers transactions on multiple ledgers (so-called responder ledgers) when it receives an event from one ledger (so-called initiator ledger). It is noteworthy that all cross-ledger operations performed by IL are atomic. The implementation of the IL component enables connection between various DLTs including Quorum, Hyperledger Fabric, Hyperledger Indy, Ethereum and KSI, and can easily be extended to support other ledger networks.

IL facilitates the integration of multiple ledgers, which results in cohesive storage platforms where different types of ledgers can be used simultaneously to benefit from the strengths of every ledger and overcome its downsides. The IL component can be utilised for the following application scenarios:

- Storing data hashes. Writing complete sets of data records on a public ledger is a relatively expensive and time-consuming process due to its demanding consensus mechanism. Thereby, typically the full data blocks are stored in a private ledger while a public ledger stores only a hash of the data to assure the highest level of trust.
- Transferring data among different ledger types.
- Exchanging digital assets. To achieve this, IL benefits from hashed timelocked contracts (HTLCs) to automate the process of trading value between DLTs.

Platone

Project acronym: Platone
Project full name: Platform for Operation of distribution NEtworks
Start date: 1 September 2019
End date: 31 August 2023
Overall project budget: EUR 9,600,957.58
Project website: https://www.platone-h2020.eu
Project coordinator: RWTH Aachen University

Project relation to blockchain technology: Blockchain technologies and smart contracts play a key role in the Platone Open Framework architecture since it is present in both layers: the Blockchain Access Layer and the Blockchain Service Layer.

Blockchain Access Layer: this layer adds a further level of security and trustworthiness to the framework. It is an extension of the physical infrastructure and performs multiple tasks, among which are data certification and automated flexibility execution through smart contracts.

Blockchain Service Layer: this layer enables the deployment of different blockchain-based components, providing a blockchain infrastructure and smart contracts services. In the context of Platone, the Platone market platform is an example of a blockchain-based platform deployed on it.

The usage of blockchain technology brings several interesting advantages:

- New coordination schemes among customers are possible such as P2P trading.
- Transparent unmodifiable data management and sharing is preserved and guaranteed.
- Multi-party data sharing can be seamlessly extended to data collected in the field for operational purposes and not for market reasons.

The Platone Open Framework offers multi-value functionalities based on blockchain technology and smart contracts, covering economic transactions, business logic (e.g., grid control) and data management.

- Economic transactions: Ethereum smart contracts can directly manage economic transactions between two or more actors on a blockchain, being completely self-enforcing. It is possible to transact cryptocurrency or customised tokens. Platone will implement the usage of tokens as a way of rewarding or penalising users involved in market operation.
- Grid control: Platone provides mechanisms, based on smart contracts, for ensuring that the flexibility aggregation and local energy exchange are trackable and tamper-proof.
- Data management: all the data are registered at the level of an individual prosumer or individual market operator and then stored as immutable transactions. This allows the provision of two important features: data provenance and data immutability.

ROBINSON

Project acronym: ROBINSON
Project full name: Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands
Start date: 1 October 2020
End date: 30 September 2024
Overall project budget: EUR 6,994,901.01
Project website: https://www.robinson-h2020.eu
Project coordinator: European Turbine Network (ETN)

Project relation to blockchain technology: Blockchain technology will be considered for cybersecurity-related activities. This is an important task (mainly managed by the partner FUNDITEC) for the protection of the integrated system by cyber attacks. A blockchain network will be developed considering sophisticated cryptography mechanisms to provide security and ensure confidentiality of the data. This technology is expected to reach TRL 7 and to ensure good protection of the components to be managed by a real-time energy management system. So, after some preliminary tests in a laboratory environment, the technology will be demonstrated on the island of Eigerøy, Norway, considering the integration with the fish industry of Prima Protein (PRIMA – partner in the project). As planned in the ROBINSON proposal, the replication of this technology will be considered for other applications, for example on the Western Isles of Scotland and Crete.

TRINITY

Project acronym: TRINITY
Project full name: TRansmission system enhancement of regIoNal borders by means of IntellIgenT market technologY
Start date: 1 October 2019
End date: 30 September 2023
Overall project budget: EUR 13.1 M
Project website: http://trinityh2020.eu
Project coordinator: ETRA I+D (Spain)

Project relation to blockchain technology: TRINITY is developing Guarantees of Origin issuing, transfer and cancellation modules based on blockchain technology. Currently, there is no issuing body using blockchain for these purposes. Thanks to blockchain, the project will provide more agile, secure and reliable tracking of Guarantees of Origin. The modules follow the EECS Rules.

VPP4ISLANDS

Project acronym: VPP4ISLANDS
Project full name: Virtual Power Plant for Interoperable and Smart isLANDS
Start date: 01 October 2020
End date: 31 March 2024
Overall project budget: EUR 7,223,108.75
Project website: https://www.vpp4islands.eu
Project coordinator: Université d'Aix-Marseill

Project relation to blockchain technology: Blockchain technology as a distributed ledger has the potential to improve efficiencies for utility providers by tracking the chain of custody for grid materials.

VPP4ISLANDS, as a complex system including multiple actors such as energy producers, transmission system operators, local energy producers and business–household consumers, has the opportunity to benefit from blockchain technology.

The ultimate goal is to create a database where digital information can be recorded and distributed without being altered or edited, yet remaining completely accessible.

Entering and re-entering personal information, verifying identities, interacting with different intermediaries, and unnecessary fees and commissions at every step are entirely removed using the mechanism that smart contracts provide to the blockchain framework.

VPP4ISLANDS constitutes the ideal field for blockchain and smart contracts to demonstrate how they can facilitate the operation of P2P electricity distribution network transactions between energy consumers and energy generators.

What we are trying to achieve through this project is to maximise efficiencies, reduce costs, improve timelines and drive industry transformation through collaboration with peer companies.

Moreover, the smart contracts used in blockchain can provide automatic control over the energy storage installations and energy transmission within the network. The purpose of the utilisation of smart contracts in VPP4ISLANDS is to keep a balance between energy supply and demand.

Distributed accounting provided in VPP4ISLANDS is another benefit of blockchain technology as it improves network functioning and energy storage. Distributed accounting would allow keeping a decentralised, secure and tamper-proof register of all energy flows and transactions.

Therefore, blockchain technology makes it possible to establish a distributed energy supply system, much cheaper and more efficient than the traditional one. Shortly, blockchain will directly connect suppliers to energy consumers and simplify today's energy system, where each party in the energy sector operates at different levels.