Climate-KIC

Distributed Ledger Technology

for Climate Action Assessment

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Introduction

A letter from **Dr. Harald Rauter**,
Innovation Lead - DACH, EIT Climate-KIC.

Over the past decade the world has witnessed a myriad of milestones that that have put the vision of a prosperous, climate-resilient society on the main stage of the world's attention. From the UN's Sustainable Development Goals to the Paris Agreement, there is overwhelming global consensus that collective action is needed to meet the 2° target. The painful truth, however, is that Europe and the world are not on track to reach the 2° target.

At EIT Climate-KIC, as Europe's largest public-private partnership focused on climate innovation, more than 300 world-class partner organisations across business, academia, the public sector and NGOs are committed to the shared vision of taking a systemic approach across technology, infrastructure, economic models, capital flows and policy to turn innovation into climate action. The shared ambition is to deploy the innovation that is needed for the deep decarbonisation that will put Europe and the world on the path towards a truly zero-carbon economy.

Digital transformation in the context of climate action

However, time is running out and climate innovation initiatives must be accelerated, scaled more quickly and must lead to more systemic climate impact. Digitalisation is, and will be even more so in the future, a powerful means of effectively responding to the complexity of the climate change challenge. Digitalisation in its current form already affects our way of living. More than that, it bears the potential to create new social- and market dynamics, helps develop new and innovative ways of doing business and brings unprecedented transparency to capital flows. Bringing powerful technologies of data sensing and -collection (Internet of Things), data analysis (Artifical Intelligence and Machine Learning) and data encryption and transaction (Distributed Ledger Technology) to climate action opens a new opportunity window for highly impactful climate action initiatives that lead to the deep decarbonisation that is needed to reach the 2° target.

How to read this report

In the ever-changing and evolving world of digital transformation, keeping up with the most recent developments and their respective impact potential can seem a daunting and almost impossible task.
EIT Climate-KIC is happy to make this report available to all who are interested in the nexus of digital technologies and climate action; to all who share the strong belief that collaboration and knowledge exchange is critical in the common effort to tackle climate change. The publication shall be understood as a starting point for discussion and as an invitation to collaborate. Come, innovate with us!

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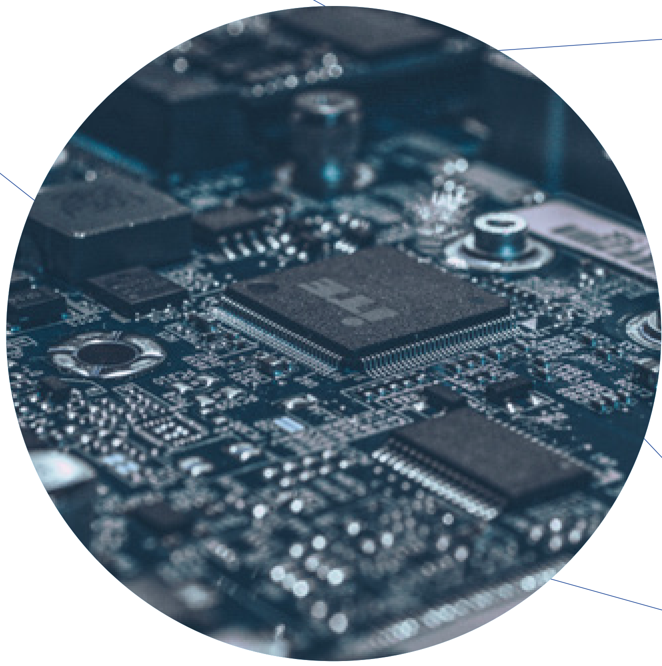
1. Executive summary

A summary from **Robin Born**,
researcher and author of this report.

Humanity is not on track to reach the 2 °C goal set out by the Paris Agreement, hence there is a need to look and invest into disruptive solutions to transform our economy. Distributed Ledger Technology (DLT), also referred to as "Blockchain", has the potential to be such a disruptive solution.

While climate change is a truly global problem, it is well recognised that it requires a decentralised, multi-stakeholder, bottom-up approach to be solved, along with an open and transnational platform of existing (carbon markets, taxes, pricing) and evolving climate action instruments (Nationally Determined Contributions). Furthermore, the approach needs to allow for a high level of measurement, reporting, and verification (MRV) and enforce high levels of trust and transparency. DLT is a technology that optimally aligns with these requirements. ▶



Definition of Distributed Ledger Technology (DLT)

DLT is the term to collectively describe IT systems that replicate, share, and synchronise digital data geographically spread across multiple sites, countries, or institutions. Put simply, DLT is a technology to manage a database, without a central administrator or centralised data storage.

Benefits of DLT

First, **DLTs increase the level of decentralisation,** which allows the shortcomings of today's centralised systems to be addressed. Decentralisation leads to higher levels of fault tolerance, attack resistance, resistance to collusion and abuse of power, permission-less innovation, efficiency in inherently decentralised systems, and immutability. Decentralisation is borderless, transnational and neutral. Second, **DLTs enable new open markets** for tasks that today are coordinated by the state or corporations (e.g. energy industry). Third, DLTs **enable smart networks based on the Internet of Things (IoT) and Artificial Intelligence (AI)** to develop their full potential without exposing humanity to the risk associated with centralised approaches as mentioned above. Fourth, **DLTs increase social scalability** by sacrificing computational efficiency. As researcher Nick Szabo elegantly puts it: "Scaling human traditional institutions in a reliable and secure manner requires increasing [the number of] accountants, lawyers, regulators, and police, along with the increase in bureaucracy, risk, and stress that such institutions entail."[1]

Smart contracts are often mentioned as one of DLT's main benefits, however, they are not as smart as touted. Instead, they are rule-based computer code without a "spirit of the agreement", which creates new vulnerabilities. Nonetheless, even if smart contracts are difficult to secure and rely on external dependencies to work, they could still be powerful tools.

Drawbacks of DLT

First, **DLT is a highly inefficient database technology** that is up to 1 million times less efficient than a centralised database. Second, **developing and updating DLT-based systems is much slower and stricter** than developing a centralised IT system, because updates and patches work on a voluntary basis. Third, **the design of incentives required to coordinate action in DLT-based systems is a big challenge**, especially given the difficulty of changing the system once it is launched. Fourth, **DLTs do not allow to refuse service to a misbehaving or malicious user**, if the coded rules and incentives are insufficient. Some of these drawbacks might decrease as the technology is further developed. However, with these costly drawbacks, some DLT projects try to get the best of both the centralised and decentralised world, but often end up with the worst of both worlds: the cost and difficulty of decentralisation with the failure modes of centralisation.

When to use DLT

To determine whether DLT is the right tool to solve a given problem, **it should be validated that DLT is the only solution to a given problem**. The six-step flowchart presented in this report helps in answering this question (see chapter 3.6). When answering this question, it should be kept in mind, that many companies looking to use DLT do not really need a DLT-based solution, but rather IT upgrades, which could also have a climate-positive impact.

Energy efficiency criticism

While the DLT community is working on considerably improving DLT's energy efficiency, addressing the trade-off between low energy efficiency and higher levels of decentralisation is and remains a key question in the DLT for climate action ecosystem for now. As of August 2018, it is estimated that Bitcoin consumes 73.1 TWh of electricity per year (0.33% of global annual electricity consumption) and Ethereum 20.8 TWh per year (0.1% of global annual electricity consumption). Furthermore, it is estimated that Bitcoin has an annual carbon footprint of 35,830 $ktCO_2$, or 451.62 $kgCO_2$ per transaction.

Ecosystem assessment

As of August 2018, **222 actors have been identified in the global DLT for climate action ecosystem**. The number grew from 114 actors as identified in the first ecosystem assessment in January 2018. While most actors are active in entrepreneurial ventures, there are also actors working on knowledge development (e.g. R&D), knowledge diffusion (e.g. events), financing, education and lobbying. Within entrepreneurial ventures, the largest group of actors focuses on the energy use case (74 actors), followed by the supply chain use case (12 actors) and carbon trading (10 actors) (see box below). DLT is still a young technology and thus **most actors are still in the exploration and understanding phase**. In terms of the innovation curve, the financial sector is the most advanced, followed by the energy sector.

Adoption barriers

Twelve main barriers were identified to the further adoption and diffusion of DLT for climate action. Six of these barriers were identified within the DLT community, three in "climate relevant industries" and three at the intersection of these two communities. Many of the 222 identified actors work on overcoming these identified barriers. However, **the barriers at the intersection are the least deliberately worked on.** Intersection barriers require an understanding of both the DLT community and the "climate relevant industries". Overcoming these barriers is a task of coordinating effective collaboration, translating between the different jargons and educating both sides about each other's needs and capabilities. Furthermore, as DLT is still young, **technological barriers and uncertainties are a major barrier.** These uncertainties are especially challenging for climate applications as they use DLT as their underlying technology layer. Therefore, any shortcoming of DLT directly affects climate applications. For example, to be an effective tool for many of the discussed use cases, Ethereum would need to scale its current transaction throughput (20 transactions per second) to compete with traditional systems (e.g. Visa can handle up to 24,000 transactions per second).

Involvement timing

The analysis suggests that **now might be a good moment to get involved**, even though the DLT for climate action ecosystem is still in its early development stage. In addition, the analysis suggests limiting risk exposure according to DLT's early stage and diversifying engagements in line with the four typical technology adoption phases (single use, localisation, substitution and transformation). Alternatively, a different approach could be to postpone engagement to a later phase when key technological challenges have been solved and adoption rates have increased. However, the following four arguments favour an engagement now rather than later:

- **Missing actor addressing intersection barriers:** The barriers at the intersection of DLT and the "climate relevant industries" are unlikely to be deliberately addressed by any of the identified actors in the ecosystem.

- **Climate-friendly direction:** The DLT community is already invested and developments will continue in any case. The trajectory that DLT will take is not predetermined and thus a strong actor can direct it towards climate-friendly developments and ensure that its developments do not increase climate impact.

- **Learning curve and capacity building:** Before value-added solutions can be expected, people and organisations need to gain experiences about what works, what are valuable contributions and about potential partners.

- **Linear thinking bias:** The human brain struggles to understand nonlinear relationships, which are most often how technological revolutions behave. Short-term developments are generally overestimated, while long-term developments are underestimated.

Use cases of DLT for climate action

Across the "DLT for climate action" ecosystem, the following use cases have been identified:

Energy: The shared vision of energy DLT projects is to decarbonise the energy system by decentralising, democratising and digitalising it. Decentralisation focuses on increasing the share of renewable energy sources, and a better management of consumption and storage, all of which are inherently decentral. Democratisation focuses on enabling peer-to-peer energy trading. Digitalisation focuses on the "Uberisation", i.e. the usage of under-utilised capacity of existing assets like fridges.

Supply chain management: DLT could reduce fraud and errors, improve inventory management, minimise courier costs, reduce delays from paperwork, speed up issue identification, and increase brand trust among consumers and partners.

Carbon trading: DLT could create a more liquid and transparent carbon marketplace, which would allow more participants to use it and would enable direct integration with other business processes (e.g. integration with eCommerce payments) through Application Programming Interfaces (APIs).

Transportation: DLT could enable a wider diffusion of electric cars and increase the usability and reach of low-carbon public transportation including a shared mobility system.

Other climate action: This use case category includes cases that incentivise climate-positive behaviors like recycling or conscious consumption. A noteworthy type of use case in the "other climate action" category is forestry, especially in combination with the UN's REDD+ programme.

Open government: Projects in this category seek to increase overall transparency and accountability of public leaders and agencies and by that create a more inclusive society.

Philanthropy: Philanthropic actors seek to increase transparency and accountability in the non-profit sector, which could improve the effectiveness of donations and might even increase donations overall due to improved public perception.

Measurement Reporting and Verification (MRV): MRV is an overarching theme across all use cases. When it comes to climate action, effective measurement, reporting and verification is critical to take and assess action. Furthermore, MRV is central to effectively implementing the Nationally Determined Contributions (NDCs) submitted under the Paris Agreement.

Climate finance: Green finance also is an overarching theme across all use cases. By improving data availability and MRV, new ways of financing climate projects are enabled. The Paris Agreement represents a USD 23 trillion green investment market between now and 2030. Finance DLT projects aim at reducing costs of developing new green finance products, reducing information asymmetry and improving certification systems.

1.1. Terminology used in this report

The terminology around Distributed Ledger Technology (DLT), blockchain and Bitcoin is confusing and different actors use names differently. This report uses the following terminology which aligns with general terminology used.

- **Bitcoin (upper case)** is the well-known cryptocurrency. Ticker symbols to represent Bitcoin are BTC and XBT. 1 Bitcoin consists of 100,000,000 Satoshi (like how 1 USD consists of 100 cents).

  Example: "The price of Bitcoin has decreased lately."

- **bitcoin (lower case)** is the specific collection of technologies used by Bitcoin. Bitcoin, the cryptocurrency, is itself one of these technologies as it is the incentive for miners to create new blocks.

  Example: "Satoshi Nakamoto invented bitcoin."

- **cryptocurrency (or crypto token or native coin)** is a digital asset that uses cryptography to secure financial transactions, control the creation of additional units, and verify the transfer of assets. A cryptocurrency exists within a specific DLT system (e.g. Bitcoin is the cryptocurrency of bitcoin, Ether is the cryptocurrency of Ethereum, Lumen is the cryptocurrency of Stellar).

  Example: "Bitcoin is generally considered the first decentralised cryptocurrency. The biggest cryptocurrencies by market capitalisation are Bitcoin, Ethereum, Ripple, Bitcoin Cash, EOS and Litecoin."

- **blockchain (or blockchain technology)** is a database technology that is a continuously growing list of records, called blocks, which are linked and secured using cryptography. Blockchain technology is one of the components that powers bitcoin.

  Example: "This application uses a blockchain as its database."

- **distributed ledger technology (or DLT)** is the term to collectively describe the family of technologies that allow geographically spread ledgers to reach consensus and replicate, share, and synchronise digital data.

  A distributed ledger is a database that is spread across several nodes or computing devices. Each node replicates and saves an identical copy of the ledger. Each participant node of the network updates itself independently. Blockchain is one component of distributed ledger technology. However, not all DLT systems employ a chain of blocks (see chapter 3.3.1.1)

  Example: "DLT can be used to create new types of markets that do not require a central agent to control it."

- **ledger (or digital ledger)** is the medium of accounting. In the context of DLT, the ledger is the term used to describe a database. It is called "ledger" because the first application (i.e. Bitcoin) was a financial application, where the database tracked financial data.

  Example: "Ethereum uses a blockchain as its ledger."

2. Not on track to reach the 2°C goal

The World Bank states that "Scientific consensus is that rapid and aggressive reductions in greenhouse gas (GHG) emissions are needed if significant climate disruption and irreversible environmental impacts are to be averted. The changes required necessitate large-scale investment and governments at all levels are responding with combinations of regulatory mandates, incentives and market-driven solutions."[2]

At the current rate however, the global 2°C target of the Paris Agreement is not possible. PWC's Low Carbon Index 2017[3] shows that the global carbon intensity, i.e. the emissions per dollar of GDP (tCO2/USDmGDP) needs to fall by 6.3% every year until 2100 to stay within the 2°C carbon budget. In 2016, the global carbon intensity fell by only 2.6%, and the average decarbonisation rate pledged in the G20 NDCs implies a rate of only 3%.

The fact that current efforts are not enough is, among others, shared by the International Energy Agency[4] and the Climate Action Tracker[5].

The Mercator Research Institute on Global Commons and Climate Change estimates that the world can emit a maximum of up to 700 gigatons (Gt) of CO2 between mid-2018 and 2100 to reach the 2°C target with a medium probability[6]. The world is currently emitting 40 Gt of CO2 per year, leaving 17 years and 6 months of the maximum carbon budget remaining. The budget for reaching the 1.5°C target with medium probability runs out in mid-September 2018. According to Carbon Brief, the budgets last a bit longer, 25.6 years for staying below 2°C, and 6.8 years for staying below 1.5°C[7]. Other institutions use different modelling assumptions and thus base projections on different carbon budgets (an overview of different carbon budgets is available from Carbon Tracker[8]).

Current climate action approaches have not yet lead to the substantial carbon reductions needed. While following the path of further incremental improvements should be continued, humanity needs to look and invest into more disruptive approaches. This report investigates one of these options, namely Distributed Ledger Technology (DLT), also referred to as "Blockchain".

3. Distributed Ledger Technology assessment

3.1. DLT assessment summary

While climate change is a truly global problem, it is well recognised that it requires a decentralised, multi-stakeholder, bottom-up approach to be solved. It requires an open and transnational platform of existing (carbon markets, taxes, pricing) and evolving climate action instruments (Nationally Determined Contributions). Furthermore, the approach needs to allow for a high level of measurement, reporting, and verification (MRV) and enforce high levels of trust and transparency. Distributed Ledger Technology is the technology that optimally aligns with these requirements.

Definition of Distributed Ledger Technology (DLT)

Distributed Ledger Technology (DLT) is the term to collectively describe IT systems that replicate, share, and synchronise digital data geographically spread across multiple sites, countries, or institutions. Put simply, DLT is a technology to manage a database, without a central administrator or centralised data storage. As of August 2018, there are 1833 cryptocurrencies, i.e. DLT projects, being traded online. The five main components of DLT systems are the ledger, peer-to-peer network, consensus mechanism, Sybil control mechanism and cryptography.

The term "smart contract" is often used in relation to DLTs and smart contracts are often mentioned as one of DLT's main benefits, however, they are not as smart as touted. Instead, they are rule-based computer code without a "spirit of the agreement", which creates new vulnerabilities (e.g., as witnessed by the USD 150 million DAO smart contract hack). While smart contracts are difficult to secure, hard to make trustless and rely on many external dependencies to work, they could still be powerful tools to increase the level of decentralisation.

Benefits of DLT

The key feature of DLTs is that they increase the level of decentralisation, allowing some of the shortcomings of today's centralised systems to be addressed. Specifically, decentralisation offers the following benefits:

- Fault tolerance: DLT systems are more resilient against accidental failures and networks and data remains reliably available even if a large portion of the network is offline.
- Attack resistance: In a world where malicious hackers and IT vulnerabilities will remain a persistent reality, decentralisation offers one of the only truly effective means to improve system security and resilience.
- Resistance to collusion and abuse of power: In decentralised systems it is much harder for colluding participants to act in ways that benefit them at the expense of other participants, like censoring, disrupting, blacklisting, restricting, seizing or freezing transactions or preventing users from participating in the network.
- Permissionless innovation: As nobody needs to ask for permission to launch an application on DLT-based systems (like on the internet), competition and thus the rate of innovation increases.
- Efficiency of inherently decentralised systems: DLT is more efficient at dealing with inherently decentralised systems, e.g., P2P energy trading or the sharing economy than more centralised approaches.
- Borderless, transnational and neutral: On DLT-based systems, there are no good/bad or

legal/illegal transactions, only valid or invalid transactions based on the consensus rules. It does not matter who or where the sender and receiver are or what is transacted.

- Immutability: Once a DLT transaction has received a sufficient level of validation (e.g. roughly 60 minutes in Bitcoin), the transaction can never be replaced or deleted, not even by a "system administrator".

- Option of Exit and increased power of Voice: If users of a given DLT system are not happy with it, they can simply "copy" and change the parts they do not like (this is called a "hard fork"). By that process, there are always options to exit a given system. Furthermore, the threat of users exiting also increases the power of the users willing to stay and change the system from within.

- DLTs enable new market networks: Among humanity's five network types, the market network is the most powerful. DLTs enable new market networks as they do not require money (e.g. USD) to coordinate and motivate the network, but their own native coin (e.g. Bitcoin). For example, where today the energy industry is organised by the state and corporations, it could be organised by a DLT enabled market in the future.

- Infrastructure for smart networks: IoT & AI: DLT enables smart networks based on IoT and AI to develop their full potential without exposing humanity to the risk associated with centralised approaches.

- Social scalability: DLTs buy social scalability by spending a lot of resources and computational scalability, i.e. they sacrifice computational efficiency. Scaling computational resources requires "cheap" additional resources. As researcher Nick Szabo elegantly puts it: "Scaling human traditional institutions in a reliable and secure manner requires increasing [numbers of] accountants, lawyers, regulators, and police, along with the increase in bureaucracy, risk, and stress that such institutions entail."[1]

Drawbacks of DLT

This higher level of decentralisation made possible by DLT also has its drawbacks.

- Highly inefficient database: DLT is a factor of up to 1 million times less efficient than a centralised database, which in turn leads to much higher energy consumption and GHG emissions.

- Stricter and slower development: Changes, updates and patches to DLTs work on a voluntary basis. Forced updates are not an option. This makes developing and updating DLT-based systems much slower and stricter than developing a centralised IT system.

- Difficulty of incentive design: DLTs create new market networks, which are coordinated by incentives. In traditional market networks the incentive is money. In DLTs the incentive is the DLT's native coin. Creating the right incentive structures and making sure that all actors in the system cannot abuse or corrupt the ledger, is a big challenge.

- Cost of parallelisation: In DLTs, parallelisation is unavoidable. It is a key component of peer-to-peer networks which themselves are a key component of DLTs. Writing into a centralised database needs to be done once, writing into a distributed ledger needs to be done as many times as there are nodes that carry a copy of the ledger

- No control over misbehaving users: In a centralised service, it is easy to refuse service to a misbehaving or malicious user. In decentralised services, it is only the rules defined in the software that can refuse service. If the rules and incentive structures are insufficient, it takes a lot of time to make the desired adjustments.

Some of these drawbacks might decrease as the technology is further developed, making DLT more attractive. However, as the drawbacks are currently big, some DLT projects are trying to get the best of both the centralised and decentralised world. Yet this approach might lead to systems that get the worst of both worlds: the cost and difficulty of decentralisation with the failure modes of centralisation.

When to use DLT

DLT is a tool that offers unique benefits, but these come with big drawbacks. To determine whether DLT is the right tool to solve a given problem, it should be validated that DLT is the only solution to the given problem. If DLT is not the only solution, also a more efficient centralised database can solve the problem. To facilitate answering whether DLT is the only solution, this report presents a six-step flowchart by the Swiss Federal Institute's Department of Computer Science. Generally suitable use cases are in disintermediation, cross jurisdiction and reporting & compliance applications.

Furthermore, many companies and projects looking to use DLT do not really need a DLT-based solution, but rather just IT upgrades, which could also have a climate positive impact. Most companies resist upgrading because of the risks involved. While using the terms "blockchain or distributed ledger technology" to sell these upgrades more easily works well, it is a practice that should be questioned.

Energy efficiency criticism

An often-raised criticism of Bitcoin and DLTs in general, is their energy consumption and levels of GHG emission. As of August 2018, it is estimated that Bitcoin consumes 73.1 TWh of electricity per year (0.33% of global annual electricity consumption), Ethereum 20.8 TWh per year (0.1% of global annual electricity consumption). This compares to the annual consumption of Austria and Azerbaijan respectively. Furthermore, it is estimated that Bitcoin has an annual carbon footprint of 35,830 kt CO2, or 451.62 kg CO2 per transaction.

The DLT community is working on improving DLT's energy efficiency by looking into four directions: improving the Proof-of-Work mechanisms, switching away from Proof-of-Work to Proof-of-Stake, switching from a ledger based on blockchain to Directed Acyclic Graph and using green energy sources to power mining. These developments can considerably increase DLT's energy efficiency.

However, for now the trade-off between low energy efficiency and higher levels of decentralisation is the key question in the DLT for climate action ecosystem and needs to be addressed for each potential DLT solution. For some DLT projects it might be worth expending the energy, for others not.

3.2. DLT might accelerate climate action

While climate change is a truly global problem, it is well recognised that it requires a decentralised, multi-stakeholder, bottom-up approach to be solved, along with an open and transnational platform of existing (carbon markets, taxes, pricing) and evolving climate action instruments (Nationally Determined Contributions). Furthermore, the approach needs to allow for a high level of measurement, reporting, and verification (MRV, see chapter 4.4.8) and enforce high levels of trust and transparency.

DLT is the technology that optimally aligns with these requirements: it is open to everyone, decentralised, transnational, immutable and allows to reach the social scalability required to solve climate change (see chapter 3.4.11). DLT enables new market networks to coordinate climate action through incentives (see chapter 3.4.9), and it can serve as the secure infrastructure for smart networks based on IoT and AI (see chapter 3.4.10). Chapter 4.4 describes DLT applications in climate relevant industries like energy and transportation in detail.

As Prof. Marco Iansit and Prof. Karim R. Lakhani write in their Harvard Business Review article: "Contracts, transactions, and the records of them are among the defining structures in our economic, legal, and political systems. They protect assets and set organisational boundaries. They establish and verify identities and chronicle events. They govern interactions among nations, organisations, communities, and individuals. They guide managerial and social action. And yet these critical tools and the bureaucracies formed to manage them have not kept up with the economy's digital transformation. They're like a rush-hour gridlock trapping a Formula 1 race car. In a digital world, the way we regulate and maintain administrative control has to change. DLT promises to solve this problem." [9]

While decentralisation's benefits (see chapter 3.4) indicate a strong potential for systemic change and disruption in technology, regulation, governance, values and mindsets, it is difficult to predict whether that potential will materialise and if so, how it will materialise.

Regardless of technological scope, predictions about the future level of disruption are always hard. However, in DLT's case, there is an additional difficulty caused by the two-stage product-market fit process required in decentralised platforms. "At launch centralised platforms come bundled with compelling applications (e.g. Facebook had its core socialising features and the iPhone had several key apps). By contrast, decentralised platforms launch half-finished and without clear use cases. As a result, they need to go through two phases of product-market fit. The first product-market fit needs to happen between the platform and the developers and entrepreneurs who will finish the platform and build out the ecosystem."[10]

3.3. Introduction to Distributed Ledger Technology

Distributed Ledger Technology (DLT) is the term to collectively describe IT systems that replicate, share, and synchronise digital data geographically spread across multiple sites, countries, or institutions. Put simply, DLT is a technology to manage a database, without a central administrator or centralised data storage.

With the creation of Bitcoin in 2008, Satoshi Nakamoto pioneered the space of DLT by combining five core components: a ledger, peer-to-peer network, consensus mechanism, Sybil control mechanism and cryptography (see chapter 3.3.1). Each of these components precede bitcoin (e.g. Proof-of-Work was first discussed in 1997 and developed for the first time in 1999[11]).

The concept was proposed in October 2008 in the paper, "Bitcoin: A Peer-to-Peer Electronic Cash System"[12]. "The first Bitcoin was minted on January 4th, 2009, the first payment occurred on January 11th, 2009 and the software was released as open source software on January 15th, 2009, enabling anyone with the required technical skills to get involved."[13]

Considering the technologies behind Bitcoin (see chapter 3.3.1) for additional applications started in 2013 when Vitalik Buterin released the Ethereum White Paper[14], which eventually launched the Ethereum network[15] in July 2015 (see chapter 0). In 2014 consortia-type DLTs started launching, As of 14 August 2018. there are 1833 cryptocurrencies being traded online[16].

Top 100 Cryptocurrencies By Market Capitalization

Cryptocurrencies ▾ | Exchanges ▾ | Watchlist | USD ▾ | Next 100 → | View All

#	Name	Market Cap	Price	Volume (24h)	Circulating Supply	Change (24h)	Price Graph (7d)
1	Bitcoin	$104,478,362,400	$6,071.19	$5,288,051,835	17,208,875 BTC	-6.36%	
2	Ethereum	$27,053,110,171	$267.01	$2,087,237,872	101,317,038 ETH	-17.10%	
3	XRP	$10,450,354,286	$0.265423	$297,875,942	39,372,399,467 XRP *	13.96%	
4	Bitcoin Cash	$8,578,213,427	$496.08	$405,507,947	17,291,913 BCH	-15.60%	
5	Stellar	$4,056,189,736	$0.216080	$115,527,952	18,771,733,350 XLM *	-9.78%	
6	EOS	$3,979,604,280	$4.39	$659,531,822	906,245,118 EOS *	-14.90%	
7	Litecoin	$3,009,319,312	$52.03	$251,246,768	57,839,034 LTC	-13.51%	
8	Cardano	$2,424,618,709	$0.093517	$111,029,611	25,927,070,538 ADA *	-18.53%	

Figure 1: Top 8 cryptocurrencies by market capitalisation as of 14 August 2018. Source: CoinMarketCap [16].

3.3.1. Components that enable DLT

Any peer can add data to the database of a DLT system. However, data are only accepted when the group of peers agrees that all the DLT requirements, i.e. its rules, are met. Since there is no central agent making sure that the rules are adhered to, DLTs rely on five main components.

These components decrease the level of trust required by a peer to believe in the correctness of the ledger, thus DLTs are often referred to as "minimising trust".

The following chapters describe the five components of DLTs to give readers fundamental background information. This chapter does not provide deep technological explanations and summarises concepts at the cost of generalisation: there are many more nuances to the technology.

3.3.1.1. Ledger: Blockchain or Directed Acyclic Graph

DLTs require a ledger that stores data. The term "ledger" describes a database but is called ledger because the first application (i.e. Bitcoin) was a financial application, where the database tracked financial data.

While most DLT systems use blockchain as their ledger structure, Directed Acyclic Graphs are also used.

In Wikipedia, blockchain is described as: "A blockchain, originally block chain, is a continuously growing list of records, called blocks, which are linked and secured using cryptography. Each block typically contains a cryptographic hash of the previous block, a timestamp, and transaction data."[17]. Blocks contain multiple transactions and are added in more-or-less regular, discrete time intervals. Most DLTs run on a blockchain, including Bitcoin and Ethereum.

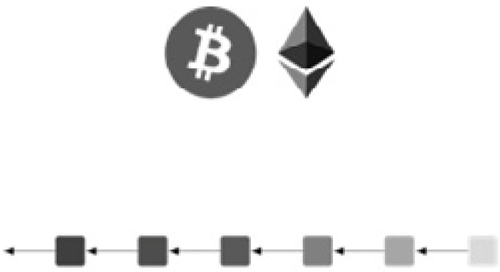


Figure 2: The blockchain structure is a sequential chain of blocks. Source: [18].

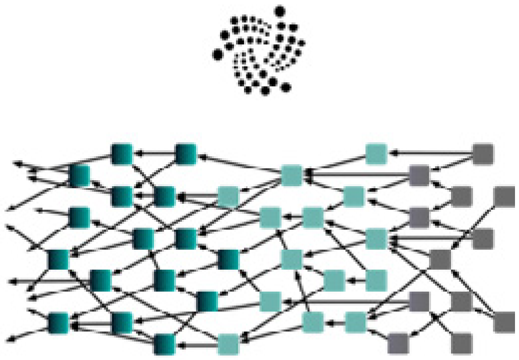


Figure 3: The Directed Acyclic Graph structure is a complex web structure. Source:[18].

For interested readers: The videos and demos by Anders Brownworth[19], a software developer, explain very well how a blockchain works.

Alternatively, the ledger can be built via a complex web structure known in mathematics as a Directed Acyclic Graph for short. IOTA[20] or Hedera hashgraph[21] use a Directed Acyclic Graph as their ledger structure. In a Directed Acyclic Graph each transaction (rather than a block of transactions) references to two previous transactions. "A Directed Acyclic Graph structure allows transactions to be issued simultaneously, asynchronously, and continuously, as opposed to the discrete time intervals and linear expansion of a Blockchain."[18].

3.3.1.2. Peer-to-peer network

DLTs run on a set of nodes, which may be owned and controlled by a company, individual or organisation. Nodes hold a replicated copy of the ledger and can have varying roles depending on the type of DLT. These nodes connect to each other in a dense peer-to-peer (P2P) network. In a P2P network there are no central points of control or failure (see chapter 3.4.1).

"Nodes can typically generate and digitally sign transactions which represent operations in in a database, and these transactions rapidly propagate to other nodes across the network in a gossip-like way. Nodes independently verify every new incoming transaction for validity, in terms of (a) its compliance with the DLT's rules, (b) its digital signature and (c) any conflicts with previously seen transactions. If a transaction passes these tests, it enters that node's local list of provisional unconfirmed transactions (the 'memory pool') and will be forwarded on to its peers."[22].

At periodic intervals, a new block is generated by one of the "validator nodes" on the network (see chapter 3.3.1.4), containing a set of new confirmed transactions. As soon as a new block is generated, it is propagated through the whole network, effectively updating the ledger of all peers, i.e. nodes.

As all nodes have the same copy of the ledger, any tampering with the ledger will be evident. P2P networks ensure there is evidence of any tampering, but do not prevent tampering. It is the consensus mechanism (see chapter 3.3.1.3) and the Sybil control mechanism (see chapter 3.3.1.4) that prevent tampering and create thereby create data immutability (see chapter 3.4.7).

3.3.1.3. Consensus mechanism

The consensus mechanism is the method of authenticating and validating a value or transaction on a distributed ledger without the need to trust or rely on a central authority. Consensus mechanisms are central to the functioning of a distributed ledger[12]. The consensus mechanism is the algorithm that is used to solve the Byzantine General's Problem (see box below).

The Byzantine General's Problem

Computer scientists have long concerned themselves with the problem of maintaining a consistent and accurate set of records in a large and complex computer system where malfunctioning components give conflicting information to different parts of the system, or where hacked components deliberately lie in an attempt to subvert the system[14].

Bitcoin is subject to this problem because the integrity of the distributed ledger must be maintained in an environment where some of the miners may be actively working to subvert the ledger. This problem is called the Byzantine Generals' Problem[24].

"Several divisions of the Byzantine army are camped outside an enemy city, each division commanded by its own general. The generals can communicate with one another only by messenger. After observing the enemy, they must decide upon a common plan of action. However, some of the generals may be traitors, trying to prevent the loyal generals from reaching agreement. The generals must decide on when to attack the city, but they need a strong majority of their army to attack at the same time. The generals must have an algorithm to guarantee that (a) all loyal generals decide upon the same plan of action, and (b) a small number of traitors cannot cause the loyal generals to adopt a bad plan. The loyal generals will all do what the algorithm says they should, but the traitors may do anything they wish. The algorithm must guarantee condition (a) regardless of what the traitors do. The loyal generals should not only reach agreement, but should agree upon a reasonable plan."[24]

Depending on the type of Sybil protection (see chapter 3.3.1.4) used, two different validator nodes might simultaneously generate new and conflicting blocks, both of which point to the same previous one. When such a "fork" happens, different nodes in the network will see different blocks first, leading them to have different opinions about the ledger's recent history. These "forks" need to be automatically resolved by the DLT software to establish network-wide consensus about which "fork" is valid.

Currently, the most used consensus mechanisms in public DLTs is the "heaviest chain", i.e. "longest chain" rule. Once a fork happens, some validator nodes will try to add a new block to one fork, while other validator nodes will work on the other fork.

Consensus is regained once a new block arrives on one of the forks, making that fork the longer chain. Nodes that were on the shorter branch automatically rewind their last block and replay the two blocks on the longer one. It might happen that both forks are extended simultaneously. In this case the conflict will be resolved after the third block on one fork, or the one after that, and so on. The probability of a fork persisting drops exponentially as its length increases[22] (see Figure 4). The longest chain is the chain which has the greatest Proof-of-Work effort invested in it[12].

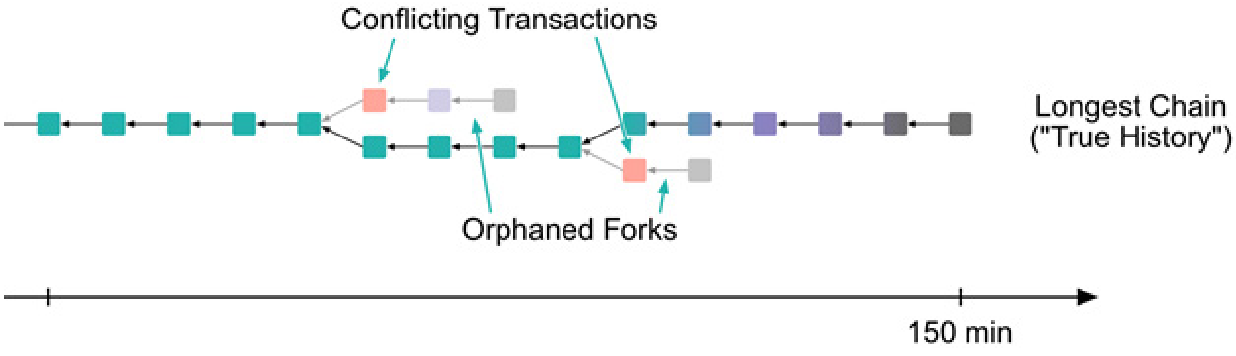


Figure 4: The "longest chain" rule consensus mechanism. Source: IOTA FAQ[18].

Other consensus mechanisms are PBFT, Ben-or, Tendermint/Cosmos or Avalanche[24].

3.3.1.4. Sybil control mechanism: Proof-of-Work, Proof-of-Stake and more

In a Sybil attack, the attacker subverts the reputation system of a peer-to-peer network by creating a large number of fake entities, using them to gain a disproportionately large influence on the network. A network's vulnerability to a Sybil attack depends on how cheaply entities can be generated, the degree to which the reputation system accepts inputs from entities that do not have a chain of trust linking them to a trusted entity, and whether the reputation system treats all entities identically[25].

DLT systems need to control Sybil attacks without relying on a central actor that, for example, validates trusted entities. The most notable Sybil control mechanism in DLT is Proof-of-Work. Other mechanisms are Proof-of-Stake, Delegated Proof-of-Stake, Proof-of-Authority and Proof-of-Replication.

Proof-of-Work

Proof-of-Work expends electricity to solve a pointless cryptographic puzzle. The puzzle consists of finding a 'nonce', that together with the previous block hash and all block transactions, creates a hash that meets certain predefined criteria. A hash is the output of a hashing function, which takes an input (or 'message') and returns a fixed-size alphanumeric string[26]. The current (June 2018) criterion of a valid block header hash is a hash starts with 19 leading zeroes. Interested readers can find a helpful visual explanation of hashing in a video by Anders Brownworth[27]. The only way to solve this cryptographic puzzle, i.e. finding the nonce, is by brute force, also known as "guess and check"[18].

The process of finding the nonce, is called mining, because whoever finds the nonce creates a new block that is added to the blockchain and receives a reward of "new, freshly mined" Bitcoins (the reward currently is 12.5 Bitcoin per new block[28].

Finding that nonce uses a lot of energy (see chapter 3.7). All that energy expenditure has an important purpose: it secures Bitcoin from Sybil attacks by requiring a big investment in equipment and electricity to sustain the attack. In fact, carrying out an attack to a Proof-of-Work network has higher costs than what an attacker could steal[29]. Therefore, the computers that make up the Bitcoin backbone (i.e. the mining infrastructure) are constantly ensuring security and verifiability. Those who participate in this network maintenance, i.e. the miners, are rewarded in Bitcoin, incentivising them to upgrade their machines so they can secure and mine more efficiently[30].

"As two or more miners may find the answer to this puzzle at almost the same time, thus simultaneously creating new blocks which may contain conflicting transactions, the network needs a consensus-building rule to determine which chain should be accepted as valid"[18]. This is where e.g. the "longest chain" rule is applied (see chapter 3.3.1.3).

Proof-of-Stake

Proof-of-Stake was first developed in 2012[11]. "Unlike the proof of work system, in which the user validates transactions and creates new blocks by performing a certain amount of computational work, a proof of stake system requires the user to show ownership of a certain number of cryptocurrency units and to stake a predefined amount of cryptocurrency. In the proof of stake system, blocks are said to be "forged" or "minted", not mined. […] In order to validate transactions and create blocks, a forger must first put a predefined amount of owned cryptocurrency at "stake", similar to putting money in an escrow account. Forgers that validate a fraudulent transaction, lose their stake, as well as their rights to participate as a forger in the future. As a forger puts owned cryptocurrency at risk, they are incentivised to validate the right transactions"[31].

The advantage of Proof-of-Stake over Proof-of-Work is that it requires a lot less laborious computations, which in turn uses a lot fewer energy. Furthermore, as Proof-of-Work computations are expensive, their reduction lowers the cost of the system and the barriers to entry[11].

However, as noted on the Proof-of-Stake Wikipedia site: "Some authors argue that proof of stake is not an ideal option for a distributed consensus protocol. One issue that can arise is the "nothing-at-stake" problem, wherein block generators have nothing to lose by voting for multiple blockchain histories, thereby preventing consensus from being achieved. Because unlike in Proof-of-Work systems, there is little cost to working on several chains."[32]

While some DLT systems already run on Proof-of-Stake, the most eagerly anticipated deployment is within Ethereum. Ethereum plans to switch from Proof-of-Work to Proof-of-Stake in the near future[33].

Readers interested in learning more about other mechanisms like Delegated Proof-of-Stake, Proof-of-Authority and Proof-of-Replication, can find an overview and short description in an article from Zane Witherspoon[34].

3.3.1.5. Cryptography

Cryptography protects privacy and anonymity in decentralised networks. It allows to share only the information that is needed for transactions and ensures that only those who need to see that information can see it, while still allowing all users to be sure, that the transaction happened and was valid. The two main techniques used are public-key cryptography[35] and hashing functions[36].

While cryptography is a key pillar that enables DLTs, and led to the definition of the term "cryptocurrencies", it is not of central importance to understand the DLT for climate action ecosystem and will not be further discussed here. This article by Jorn van Zwanenburg[37] offers a good introduction to cryptography in DLTs.

3.3.2. DLT increases decentralisation

The key feature of DLTs is that they increase the level of decentralisation, specifically the level of architectural and political decentralisation. Decentralisation consists of three types[38]:

- Architectural decentralisation: describes on how many physical "objects" a system depends (e.g. does a system depend on one or multiple root servers?).

- Political decentralisation: describes how many people or entities control the decision-making of a given system.

- Logical decentralisation: describes whether the outcome of a system (e.g. law as the outcome of government, or database as the outcome of software) is a singleton or is more like an amorphous swarm (i.e. many similar but different outcomes).

Different problems require different combinations of these decentralisation types.

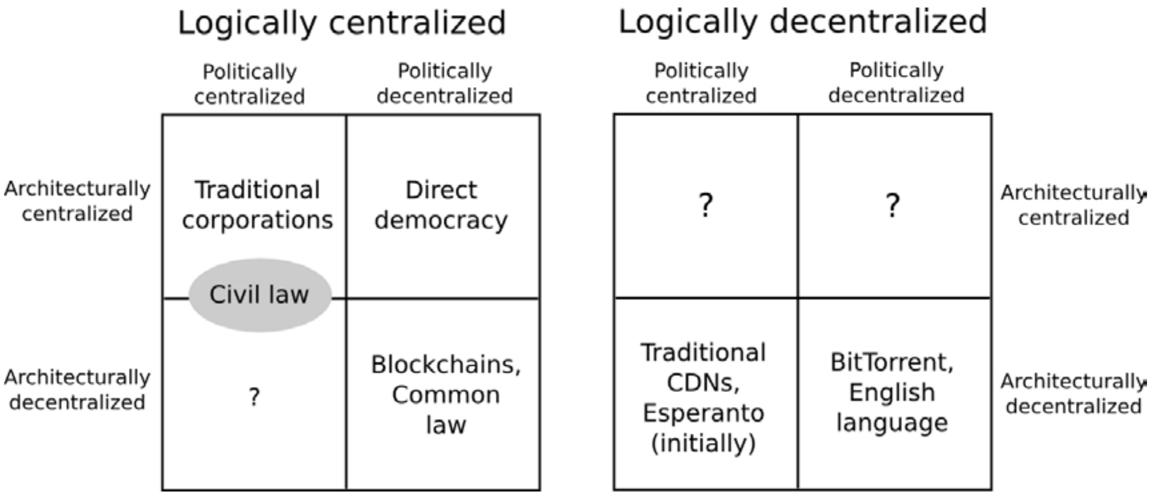


Figure 5: Architectural, political and logical decentralisation in combination. Source: Buterin, Vitalik [38]

Direct democracy
Direct democracies are architecturally centralised by having many singular entities that keep it running: one parliament, one police, one military, etc. They are however politically decentralised as decision making is widely spread among many people and entities. It is logically centralised, because it creates one set of outcomes: one law, one government, etc.

English language
The English language is architecturally decentralised: it is taught and created in many different locations and by many different entities. It is politically decentralised as no one entity controls the language. Also, it is logically decentralised as the English language creates many different outcomes of the language: American English is different from British English is different from Australian English.

DLT
DLTs systems are designed so that they are architecturally and politically decentralised and logically centralised. Logical centralisation is an advantage: contrary to the current model where every entity has its own database and it takes a lot of effort to reconcile all of these different databases with each other, DLTs create one single database that contains all transactions.

3.3.3. Smart Contracts

The term "smart contract" is often used in relation to DLTs. Smart contracts are not as smart as touted. Instead, they are rule-based computer code that follows the rules written in code perfectly. There is no "spirit of the agreement" in smart contracts. By this, smart contracts create new vulnerabilities, e.g. as witnessed by the USD 150 million DAO smart contract hack[39]. While smart contracts are difficult to secure, hard to make trustless and rely on many external dependencies to work, they are still powerful tools to increase the level of decentralisation.

The following article by Jimmy Song, a DLT developer and venture partner at Blockchain Capital, is a comprehensive description of smart contracts and the common misconceptions around their prowess and use cases. The article is shown in its full length. Images from the original article have been excluded.

The Truth about Smart Contracts, by Jimmy Song[41]

Much like the words "blockchain", "AI" and "cloud", "smart contract" is one of those phrases that get a lot of hype.

After all, what could be better than being able to trust what will happen instead of using the judicial system? The promises of smart contracts include:

- Enforcing contracts automatically, trustlessly and impartially
- Taking out the middle men in contract construction, contract execution and contract enforcement
- (By implication) Removing lawyers

I sympathise with the hype. After all, how much more efficient could things be if we could just remove the need for trusting the other party to execute?

What the heck is a smart contract, anyway? And isn't that the domain of Ethereum? Isn't this the way of the future? Why would you stand in the way of progress?

In this article, I'm going to examine what smart contracts are and the engineering reality that goes with it (spoiler: it's not so simple and very hard to secure).

What is a Smart Contract?
A normal contract is an agreement between two or more parties that binds them to something in the future. Alice may pay Bob some money in return for use of Bob's house (AKA rent). Charlie may agree to repair any damage to Denise's car in the future in return for a monthly payment (AKA car insurance).

What's different about a "smart" contract is that the conditions are both evaluated and executed by computer code making it trustless. So if Alice agrees to pay Bob $500 for a couch for delivery 3 months from now (AKA couch future), some code can determine whether the conditions are true (has Alice paid Bob? has it been 3 months yet?) and do the execution (deliver the couch from escrow) without giving either party the ability to back out.

The key feature of a smart contract is that it has trustless execution. That is, you don't need to rely on a third party to execute various conditions. Instead of relying on the other party to make good on their word or even worse, relying on lawyers and the legal system to remedy things should something go wrong, a smart contract executes what's supposed to happen timely and objectively.

Smart Contracts are Pretty Dumb
The use of the word "smart" implies that these contracts have some innate intelligence. They don't. The smart part of the contract is in not needing the other party's cooperation to execute the agreement. Instead of having to kick out the renters that aren't paying, a "smart" contract would lock the non-paying renters out of their apartment. The execution of the agreed-to consequences are what make smart contracts powerful, not in the contracts' innate intelligence.

A truly intelligent contract would take into account all the extenuating circumstances, look at the spirit of the contract and make rulings that are fair even in the most murky of circumstances. In other words, a truly smart contract would act like a really good judge. Instead, a "smart contract" in this context is not intelligent at all. It's actually very rule-based and follows the rules down to a T and can't take any secondary considerations or the "spirit" of the law into account.

In other words, making a contract trustless means that we really can't have any room for ambiguity, which brings up the next problem.

Smart Contracts are Really Hard

Because of a lot of centralised marketing from Ethereum, there's a mistaken belief that Smart Contracts only exist in Ethereum. This is not true. Bitcoin has had, from the very beginning in 2009, a pretty extensive smart contract language called Script[42]. In fact, smart contracts existed before Bitcoin as far back as 1995. The difference between Bitcoin's smart contract language and Ethereum's is that Ethereum's is Turing-complete. That is, Solidity (ETH's smart contract language) allows for more complicated contracts at the expense of making them more difficult to analyse.

There are some significant consequences of complexity. While complex contracts can allow for more complicated situations, a complex contract is also very difficult to secure. Even in normal contracts, the **more** complicated the contract it is, the harder it gets to enforce as complications add more uncertainty and room for interpretation. With smart contracts, security means handling every possible way in which a contract could get executed and making sure that the contract does what the authors intend.

Execution in a Turing-complete context is extremely tricky and hard to analyse. Securing a Turing-complete smart contract becomes the equivalent of proving that a computer program does not have bugs. We know this is very difficult, as nearly every computer program in existence has bugs.

Consider that writing normal contracts takes years of study and a very hard bar exam to be able to write competently. Smart contracts require at least that level of competence and yet currently, many are written by newbies that don't understand how secure it needs to be. This is very clear from the various contracts that have been shown to be flawed.

Bitcoin's solution to this problem is to simply not have Turing-completeness. This makes the contracts easier to analyse as the possible states of the program are easier to enumerate and examine.

Ethereum's solution is to place the burden on the smart-contract writers. It is up to the contract writers to make sure that the contract does what they intend.

Smart Contracts Aren't Really Contracts (at least on ETH)

While leaving the responsibility of securing contracts to the writers sounds good in theory, in practice, this has had some serious centralising consequences.

Ethereum launched with the idea that "code is law". That is, a contract on Ethereum is the ultimate authority and nobody could overrule the contract. The idea was to make clear to smart contract developers that they're on their own. If you screwed up in making your own smart contract, then in a sense, you deserve it. This came to a crashing halt when the DAO event happened.

DAO stands for "Decentralised Autonomous Organisation" and a fund was created in Ethereum as a way to show what the platform could do. Users could deposit money to the DAO and get returns based on the investments that the DAO made.

The decisions themselves would be crowd-sourced and decentralised. The DAO raised $150M in ETH when ETH was trading at around $20. This all sounded good in theory, but there was a problem. The code wasn't secured very well and resulted in someone figuring out a way to drain the DAO out of money.

Many called the person draining the DAO of money a "hacker"[43]. In the sense that the "hacker" found a way to take money from the contract in a way not intended by the creators, this is true. But in a broader sense, this was not a hacker at all, just someone that was taking advantage of the quirks in the smart contract to their advantage. This isn't very different than a creative CPA figuring out a tax loophole to save their clients money.

What happened next is that Ethereum decided that code no longer is law[44] and reverted all the money that went into the DAO. In other words, the contract writers and investors did something stupid and the Ethereum developers decided to bail them out.

The fallout of this incident is well documented. Ethereum Classic was born, preserving the DAO as written and conserving the "code is law" principle. In addition, developers began shying away from using the Turing-completeness property of Ethereum as it's proven to be hard to secure. ERC20 and ERC721 standards are the most frequently used smart contract templates in Ethereum and it's important to point out that both types of contracts can be written without any Turing-completeness.

Smart Contracts Only Work with Digital Bearer Instruments

Even without Turing-completeness, smart contracts sound really good. After all, who likes having to go to court to get something that rightfully belongs to them trustlessly? Isn't using a smart contract much easier than normal contracts?

For example, wouldn't real estate benefit from smart contracts? Alice can prove she owns the house. Bob can send money for the house and get the house in exchange. No questions of ownership, trustless, fast execution by machine, no need for judges, bureaucrats or title insurance. Sounds amazing, right?

There are two problems here. The first is that smart contract execution by a centralised party is not really trustless. You still have to trust the centralised party to execute. Trustlessness is the key feature, so centralised execution doesn't really make sense. To make smart contracts really trustless, you need a platform that's actually decentralised.

That leads us to the second problem. In a decentralised context, smart contracts only work if there's some definitive link between the digital version and the physical version. That is, whenever the digital version of the house changes ownership the physical version has to also change ownership. There's a need for the digital world to "know" about the physical world. This is known as the "Oracle problem"[45].

When Alice transfers the house to Bob, the smart contract needs to know that she actually transferred the house to Bob. There are several ways of doing this but they all have the same essential problem. There has to be some trust in some third party to verify the events in the physical world.

For example, the house could be represented as a non-fungible token on Ethereum. Alice could transfer the house to Bob in an atomic swap for some amount of ETH. Here's the problem. Bob needs to trust that the token actually represents the house. There has to be some Oracle that ensures the transfer of the house token to him actually means that the house is his legally.

Furthermore, even if a government authority says that the token actually represents the house, what then happens if the token is stolen? Does the house now belong to the thief? What if the token is lost? Is the house not available to be sold anymore? Can the house token be re-issued? If so, by whom?

There is an intractable problem in linking a digital to a physical asset whether it be fruit, cars or houses at least in a decentralised context. Physical assets are regulated by the jurisdiction you happen to be in and this means they are in a sense trusting something in addition to the smart contract you've created. This means that possession in a smart contract doesn't necessarily mean possession in the real world and suffers from the same trust problem as normal contracts. A smart contract that trusts a third party removes the killer feature of trustlessness.

Even digital assets like ebooks, health records or movies suffer from the same problem. The "rights" to these these digital assets are ultimately decided by some other authority and an Oracle needs to be trusted.

And in this light, Oracles are just dumbed down versions of judges. Instead of getting machine-only execution and simplified enforcement, what you actually get is the complexity of having to encode all possible outcomes with the subjectivity and risk of human judgment. In other words, by making a contract "smart", you've drastically made it more complex to write while still having to trust someone.

The only things that can work without an Oracle are digital bearer instruments. Essentially, both sides of the trade need to not just be digital, but be bearer instruments. That is, ownership of the token cannot have dependencies outside of the smart contracting platform. Only when a smart contract has digital bearer instruments can a smart contract really be trustless.

Conclusion

I wish smart contracts could be more useful than they actually are. Unfortunately, much of what we humans think of as contracts bring in a whole bunch of assumptions and established case law that don't need to be explicitly stated.

Furthermore, it turns out utilising Turing completeness is an easy way to screw up and cause all sorts of unintended behavior. We should be labeling smart contract platforms Turing-vulnerable, not Turing-complete. The DAO incident also proved that there's a "spirit" of the contract which is implicitly trusted and helps resolve disputes more so than we realise.

Smart contracts are simply too easy to screw up, too difficult to secure, too hard to make trustless and have too many external dependencies to work for most things. The only real place where smart contracts actually add trustlessness is with digital bearer instruments on decentralised platforms like Bitcoin.

Original article by Jimmy Song[41].

3.3.4. Decentralised application (DApp)

The definition of a decentralised application given by Wikipedia is: "A decentralised application (Dapp, dApp or DApp) is an application that is run by many users on a decentralised network with trustless protocols. They are designed to avoid any single point of failure. They typically have tokens to reward users for providing computing power."[46].

DApps run on DLT-based protocols, similar to the apps that run on the internet protocol (TCP/IP) like Gmail, Facebook or Amazon. Ethereum[15] is such a platform and acts like "decentralised appstore" where anyone can publish their DApp. Other platforms include EOS[47] or NEO[48].

The definition of a DApp is still in development and under debate. Typical definitions include the attributes that the code is open-source and that DApps are unstoppable as there is no intermediary that controls the code or platform it runs on (see also chapter 3.4.3).

Examples of DApps are CryptoKitties[49] or Augur[50]. State of the DApps[51] lists 1802 DApps built on Ethereum (as of August 2018).

3.4. Benefits of DLTs

The key feature of DLTs is that they increase the level of decentralisation. This feature offers better ways of dealing with the shortcomings, i.e. costs, of humanity's current centralised systems.

While there are seen costs of centralisation (faults, attacks, collusion, abuse of power, low levels of innovation, soft promises), there are also unseen costs: centralisation is a barrier that hinders market networks, new technologies like IoT and AI and digital solutions like online voting and digital IDs to develop their full potential (e.g. centralised online voting is much less difficult to compromise than traditional paper-based voting).

Decentralisation offers solutions to these seen and unseen costs of centralisation. The following chapters show and describe the benefits of decentralisation, which can be gained through DLTs. However, the level of decentralisation of a DLT strongly depends on its design (e.g. being the most decentralised systems, Bitcoin has much higher collusion resistance than EOS, a top 10 DLT project measured by market capitalisation).

3.4.1. Fault tolerance

DLT systems are typically designed with a lot of redundancy through peer-to-peer networks (see chapter 3.3.1.2). Consequently, DLT systems are more resilient against accidental failures and networks and data remain reliably available even if a large portion of the network is offline.

A source of error often missed is time: e.g. as the internet is ever growing, it is also changing, and links will stop working. This is a problem for all types of documents that rely on links (e.g. this report), but is more troublesome when the justice system is built on links (49% of the Links Cited in the US Supreme Court Decisions Are Broken[52].

3.4.2. Attack resistance

Centralised services become points of centralised data collection. These centralised databases become very valuable, which attracts people and entities willing to use this data to their own benefit by stealing or corrupting the data (see also chapter 3.4.3). In centralised systems, the rewards of attacks are superlinear: the more data is added, the more valuable it gets.

Centralised services are constantly attacked and hacked, affecting large corporations (e.g. Equifax[53], PlayStation, eBay) and governments (Aadhaar[54], Stuxnet, NSA hacking tools leakage) alike. The interactive graph "World's Biggest Data Breaches" by Information is Beautiful illustrates the large number of attacks since 2004[55].

Centralisation reduces the number of points of failure. By decreasing the number of points of failure, the costs of attacks in centralised systems become sublinear: spending 100x more on security, does not lead to a 100x higher cost of attacks.

Decentralisation splits systems into components and thus increases the number of points of failure, thus increasing security[56]. In decentralised systems, the points of failure are roughly equivalent to the number of users[56]: in Bitcoin, every user exclusively controls his/her private key. It is not possible to hack into Bitcoin, like hacking into a bank, and steal all funds from all users. In Bitcoin, an attacker needs to hack one user to access this user's (and only this user's) funds. However, there are centralised services running on top of decentralised networks (e.g. trading exchanges like Coinbase[56] and these centralised services are prone to hacks (e.g. in the Mt. Gox hack 850,000 bitcoins, worth at the time USD 450 million (now USD 5.5 billion) were stolen[58].

In a world where malicious hackers and IT vulnerabilities will remain a persistent reality, decentralisation offers one of the only truly effective means to improve system security and resilience.

3.4.3. Resistance to collusion and abuse of power

Valuable centralised services and databases create incentives for sub-groups of a community to act in their own benefit at everyone's else's expense. Put more generally, centralisation creates quasi-monopolies that concentrate power. Over 100 years ago Lord Acton said that "Power tends to corrupt and absolute power corrupts absolutely", a statement that seems to be backed by scientific findings[59].

Vitalik Buterin, founder of Ethereum writes: "Collusion is difficult to define; perhaps the only truly valid way to put it is to simply say that collusion is "coordination that we don't like". There are many situations in real life where even though having perfect coordination between everyone would be ideal, one sub-group being able to coordinate while the others cannot, is dangerous."[38]. Collusion can lead to all types of financial fraud (e.g. Libor scandal[60]) and price fixing (e.g. Roche and other vitamin makers fined USD 755 million for price fixing[61]). Furthermore, collusion and monopolies cause decreased levels of innovation by creating barriers for new entrants and by becoming lazy themselves[62]. Large network companies like Facebook (e.g. Cambridge Analytica scandal[63]), Apple (e.g. censorship on iTunes App Store[64]), Google (e.g. Google's €2.42 billion antitrust fine for manipulating search results in favour of its own services[65]) and Twitter (API restrictions[66]) continually abuse their power.

Collusion can also take the form of censorship. In their current centralised forms, networks are powerful tools for censorship, ranging from totalitarian (e.g. China's internet censorship[67]) to relatively moderate (e.g. content censorship on YouTube[68]). Furthermore, digital networks plague consumers with algorithmic abuse instead of fulfilling their intended use (e.g. engineering of purposely addictive and time-wasting social media to increase engagement and thus being able to sell more advertisements[69]).

In decentralised systems it is much harder for participants to collude to act in ways that benefit them at the expense of other participants. As Andreas M. Antonopoulos, bestselling author and advocate of open DLTs, puts it: "In Bitcoin, it is near impossible for any actor or even multiple colluding actors to censor, disrupt, blacklist, restrict, seize or freeze transactions or prevent users from participating in the network."[70]. To collude, it requires control over 51% of the network (a so called 51% attack[71]).

Decentralisation means lower levels of control. This can also be a drawback as it is harder to control users that "misbehave" (e.g. the online black-market Silk Road used Bitcoin as its payment system[72]).

However, even though DLTs offer a technological solution for decentralisation, also these systems are subject to the trend towards more centralisation as can be observed in mining power, equipment and within DLT governance (see chapter 4.5.1.2).

3.4.4. Permissionless innovation

Nobody needs to ask for permission to launch an application on the internet. Similarly, nobody needs to ask for permission to launch a new financial application (instruments, payment system or other service) on Bitcoin. The same is true of DLT-based systems, e.g. for energy or CO2 certificate trading.

Furthermore, there are no switching costs between DApps on a decentralised DLT (e.g. if a user does not like the UX of a certain cryptocurrency exchange, she can just switch to a different exchange still dealing with the same underlying DLTs). The analogy to the internet would be if a user could seamlessly switch all social media data (profile, picture, conversations, contacts, etc.) from one platform to another (e.g. porting everything from Myspace to Facebook to "the next thing"). This would drastically increase competition for monopolistic network companies and lead to higher rates of innovation. Additionally, upcoming interoperability protocols[73] would allow users of different DApps and DLTs to transact across different systems.

Future leaders within these DLT enabled services will have to constantly innovate and increase consumer value or lose market share to more insightful competitors.

3.4.5. Efficiency in inherently decentralised systems

In cases of decentralised problems, decentralised solutions like DLT may be more efficient than centralised ones. For example, spreading restaurants widely is more efficient than if all restaurant were located in only one place.

Decentralised energy sources like solar and wind are among the most effective solutions against climate change[74]. DLT enabled systems could increase the efficiency of an energy grid that integrates more of these decentral sources[75]. Furthermore, decentral approaches for managing spare capacity are also more efficient than central approaches (Airbnb is efficient at managing widely spread spare room capacity).

3.4.6. Borderless, transnational and neutral

As DLTs are hard to control they are borderless, transnational and neutral. DLTs do not follow the goals of one actor, they just follow the consensus rules neutrally. There are no good/bad and legal/illegal transactions, only valid or invalid transactions based on the consensus rules. It does not matter who the sender and receiver are or what is transacted.

DLT is a truly global technology that is ideally suited for solving global problems like climate change. Given these properties, Bitcoin and other cryptocurrencies are often referred to as the native money to internet. Bitcoin and its DLT revolution are often termed as the "Internet of Money", as proponents argue that Bitcoin will do to money what the internet did to media (e.g. Netflix eroding Hollywood's power).

3.4.7. Immutability

DLTs create higher levels of data immutability. Data immutability describes the concept that once a DLT transaction has received a sufficient level of validation (e.g. roughly after 60 minutes in Bitcoin), the transaction can never be replaced or reversed, not even by a "system administrator".

The levels of immutability vary based on DLT designs. It is important to note, that the DLT component "blockchain" (see chapter 3.3.1.1) does not create immutability, it creates tamper evidence: if someone tampers with past transactions, all the nodes on the P2P network will see that a transaction has been tampered with. However, "blockchain" does not prevent tampering with transactions. Proof-of-Work and the longest chain consensus rule (see chapters 3.3.1.3 and 3.3.1.4) create immutability in DLTs like Bitcoin[70].
These designs require a minimum of 51% of mining power to change past transactions. To

execute a successful 51% attack, it must be sustained over long periods of time, where the cost of controlling 51% of mining power can be as high as USD 510,935 per hour for Bitcoin to USD 6 per hour for DNotes[76].

However, there is a big difference between changing past transactions and controlling future transactions. Having the mining majority on Bitcoin allows it to be decided what gets recorded in the future but it is not as easy to change the past. The reason the past cannot be changed is because every node on the P2P network is still validating every block and it is going to demand Proof-of-Work.

Changing past transactions requires a continued and long sustained attack that is impossible to pay for. As Andreas M. Antonopoulos, bestselling author and advocate of open DLTs, states:

"Let's say we want to go back and change history three weeks ago. Three weeks doesn't seem like a long time. In Bitcoin it's an eternity. Everyday 500 megawatts of electricity are used continuously to feed the mining process, just a ballpark figure it might be more, it might be less right now, let's use that as a ballpark figure. Five hundred megawatts in 24 hours is 12 gigawatts of electricity, 12-gigawatt hours of electricity expended per day. 12-gigawatt hours of electricity over 30 days is 360-gigawatt hours of electricity over 12 months that's 3.6-terawatt hours of electricity in a year.3.6-terawatt hours of electricity is a lot of electricity. But it's only a lot of electricity if you take it all at once. If you take it on a daily basis on a 500 megawatts basis running forth it's enough to keep the Bitcoin network secure. But here's the thing, if you try to go change Bitcoin it starts adding up pretty fast. You go back three weeks with 51% of the hashing power how long will it take to remine the blocks of the last three weeks, anyone? [..]The first week of blocks will take you two week to mine and then in two weeks you're going to have difficulty chains which is going to drop your difficulty and then it's going to take another two weeks to mine the next two weeks of blocks so you're going to end up approximately a four weeks total to mine three weeks worth of blocks. Here's the problem. The other side didn't stop mining, right? At 49% how long is it going to take then to mine? So by the time you get to where you were when you stopped mining the majority chain and you tried to rewrite the history they've also mined at least two weeks ahead. If they got the difficulty chains too they've mined even further so now you've to mine a bit more to overtake them. Meanwhile, the miners who are doing this exercise are earning nothing, presumably they're part of the same hashing power that mined the first time around. Presumably they already had 51% of the power when they were mining the first time around and now that they're trying to remine the last three weeks of blocks well, they've already banked the rewards but they banked them on the other chain which they're making invalid. So now, they're going to get rewards on the new chain but only if they give up the rewards that they bank on the other chain which means effectively they're going to spend three to four weeks at 500 megawatts mining for free. Meanwhile what happens on the other chain, on the minority chain? You are a 49% miner and you're now mining a minority chain. It's going to be hard. First two weeks it's going to be slow you're going to be doing blocks every 20 minutes but your share of the mining capacity just doubled which means your profitability just doubled. So, you're getting more reward for the same amount of mining. And if that chain still has value you're making quite a bit of money because you now have a bigger market share. In fact the more people abandoned the chain the more profitable it is for the minority. All you have to do is peel off 2%. All you have to do is persuade 2% of the people who are mining for nothing to come mine on the chain where we're mining for double rewards. How hard is that going to be? Which means that actually sustaining a 51% attack for four weeks is brutally hard. Now, of course, that means you probably only do it if you have 75%, 80%. Ethereum was starting with 90, at some point they went as low as 70% on the majority chain when they did their fork. That's a pretty big drop. So, you have these economic incentives that make it very difficult."[70,77]

3.4.8. Option of Exit and increased power of Voice

Albert Hirschman's "Exit, Voice and Loyalty: Responses to Decline in Firms, Organisations and States"[78] proposed a framework for understanding how stakeholders, such as shareholders in a firm or citizens in a nation, respond to an unsatisfactory status quo. Stakeholders can either voice dissent, exit the relationship, or loyally remain. The unavailability of the option of an exit, severely restricts the power of voice (e.g. while exiting the political systems of a nation is possible, it comes with a lot of cost and is seldomly pursued).

While Bitcoin created an exit option out of the current financial and nation-focused system, the decentralised nature of Bitcoin and DLT, also ensures that the exit option remains open in the future. If users of Bitcoin are not happy with Bitcoin, they can simply "copy" Bitcoin and change the parts they do not like. This process is called a "hard fork" and already occurred several times. Most notably, the Bitcoin Cash hard fork created a spin-off of Bitcoin that is similar to Bitcoin, except for the increased block sise[79].

While the exit option for current financial systems is a big and potentially revolutionary feature, the always-open exit option will be powerful for future network-enabled solutions. As there is no exit option to Facebook, Facebook does not act with the user's benefits in mind. If Facebook could be exited simply by copying what's good and changing what's bad including all the past data, then Facebook would be much more concerned about user's privacy. The exit option is a major contributor to the feature of permissionless innovation (see chapter 3.4.4).

Seth Godin, entrepreneur, bestselling author and speaker, summarises the concept of "Exit, Voice and Loyalty" in the following way: "In commerce, if we don't like a brand, we leave. The always-present choice to stay or to go drives bosses, marketers and organisations to continually be focused on earning (and re-earning) the attention and patronage of their constituents.

"Sometimes, instead of leaving, people speak up. For most of my life, the biggest separation between government and economics was this distinction.

"In many cases, government has generally taken the idea of exit off the table. If you don't like your country, you could consider leaving it, but that's an extraordinarily disruptive act. Not voting may express your apathy or disgust, but you're still a member of the society.

"Capitalism ceases to be an efficient choice when those served have no ability to exit. For-profit prisons, for example, or cable monopolies. If you can't exit, you're not really the customer, and you are deprived, as a result, of voice.

"In the case of effective government, voice is built in on behalf of those that have no ability to exit. A well-functioning representative democracy opens the door for people to be heard and action to be taken.

"Suddenly, it's easier than ever for rich people to exit instead of speak up. They can wire funds (when wealth was held only in real estate, that wasn't an option, you can't take land with you) and they can live an almost post-national existence. As a result, since they're not tied down and often pay little or nothing in taxes, they're less inclined to work hard to make their place better for everyone. The same applies to private school (for the few) compared to public school (for the rest).

"Voice matters. Loyalty, then, could be defined as the emotion that sways us to speak up when we're tempted to walk away instead.

"When your loyal customers speak up, how do you respond? When you have a chance to speak up but walk away instead, what does it cost you? What about those groups you used to be part of? I've had the experience several times where, when my voice ceased to be heard, I decided it was easier to walk away instead.

"Voice is an expression of loyalty. Voice is not merely criticism, it might be the contribution of someone who has the option to walk away but doesn't."[80]

3.4.9. New network markets

The following chapter is a summary of Naval Ravikant's perspective on the power of DLTs. Naval Ravikant is the CEO and co-founder of AngelList. He has invested in more than 100 companies, including Uber, Twitter, Yammer, and many others. He is a strong supporter of DLTs. The original article can be found here: Social Capital[81]. Humans are organised around networks to coordinate and motivate progress: money, religion, corporations, roads, electricity, beliefs are all networks. Because networks have a "network effect", they grow very powerful as participants join. Networks require rules and rulers to enforce these network rules. The rulers are the most powerful entities in society. Humanity knows five types of networks and rulers.

The market networks are the most powerful networks, but they currently have limited application as they require a commitment of money, like the US dollar, for coordination and motivation. DLTs widen the application range of market networks as they are governed in their own native coin (i.e. do not require money like USD) and without a ruler.

DLTs allow the market model to be applied to networks currently run by states, corporations, elites and democracies. This includes many of the most climate-relevant networks like energy, mobility, NDCs and financing. Where today the energy industry is organised by the state and corporations, it could be organised by a DLT-enabled market in the future.

Just as today's market networks are more powerful than the other network types (e.g. the money market can take down the state network by hyperinflation), these new DLT-based market networks will probably be more powerful than current state, corporation, elites and mob networks and disrupt the way humanity deals with problems such as climate change. However, while market networks are powerful, humanity still requires the other network types. For example, if a problem requires extreme coordination (e.g. building a new highway tunnel), the firm and state model will outperform the market network. Building these new DLT-enabled market networks is hard and takes time. Adoption will be slow at first, but will eventually outperform many of today's solutions.

3.4.10. Secure infrastructure for smart networks

The Internet of Things (IoT) is a network of physical devices embedded with electronics, software, sensors, actuators and connectivity. It includes but is not limited to cars, factory machines, building sensors, environmental sensors, personal health sensors, satellites, parking spots, computers and data centres.

With IoT, potentially everything is a generator of data. IoT enables a more direct integration of the physical world into computer-based systems resulting in efficiency improvements, economic benefits, and reduced human exertions[82].

Ruler	Network characteristic	Examples
State, King, Priest	Closed networks based on power.	The powerful chose and enforce what is money, religion, etc.
Corporation	Closed and initially meritocratic networks.	Social, search, phone, or energy networks.
Elite, Aristocracy	Somewhat open and somewhat meritocratic networks.	Medical, banking or university networks.
Mob	Open and non-meritocratic networks.	Democracy, the internet or the commons.
Market	Open and meritocratic networks.	Credit, stock, money and commodity networks

Table 1: Five types of networks and their rulers. Based on: Social Capital[81].

It requires Artificial Intelligence (AI) to process and learn from the immense amount of data created by IoT networks. The learnings from AI then feed back into the IoT network which then can adapt to reach its goals effectively. Consequently, everything surrounding humans becomes a smart network: everything from buildings, cars, cities, factories and agriculture to personal health.

Combining IoT and AI can already have big impacts on the climate. E.g. Google achieved a 15% energy reduction for its servers by combining sensor data from its servers with its AI Deep Mind[83].

As these smart networks are becoming more valuable, they will constantly face challenges related to errors, security, collusion and abuse of power. If these smart networks are owned and operated by central actors, the challenges will be near impossible to manage successfully. Consequently, the risks of deploying smart networks without DLT is too large (e.g. online voting on standard centralised cloud infrastructure could easily be compromised, rendering the complete system not only useless but harmful). DLT offers the only security solution that can effectively mitigate the risk of centralised approaches and is thus the only solution capable of enabling these smart networks (see Figure 6). Furthermore, DLT allows these networks to be opened to all users interested in joining and creates new market platforms (see chapter 3.4.9). These are platforms with shared ownership, democratic governance and free and anonymous access without the need for a central, trusted third party. These platforms enable permissionless innovation (see chapter 3.4.4), similarly to the levels of innovation introduced by the internet protocols (Google, Facebook, Airbnb and many more are based on TCP/IP) applied to systems like the energy system.

These platforms could be used to manage cities or the energy market. They could give open access to interested parties that want to, for example, conduct research, write a new DApp (see chapter 3.3.4) for grid balancing, carbon accounting or traffic routing. This offers countless currently unrealised efficiency gains (e.g. connected fridges could be used to add flexibility to the electricity grid for near zero additional investment costs: 1 million fridges with each 100 W capacities would amount to a 100 MW asset that could be shifted to a period of high solar PV electricity generation, for example).

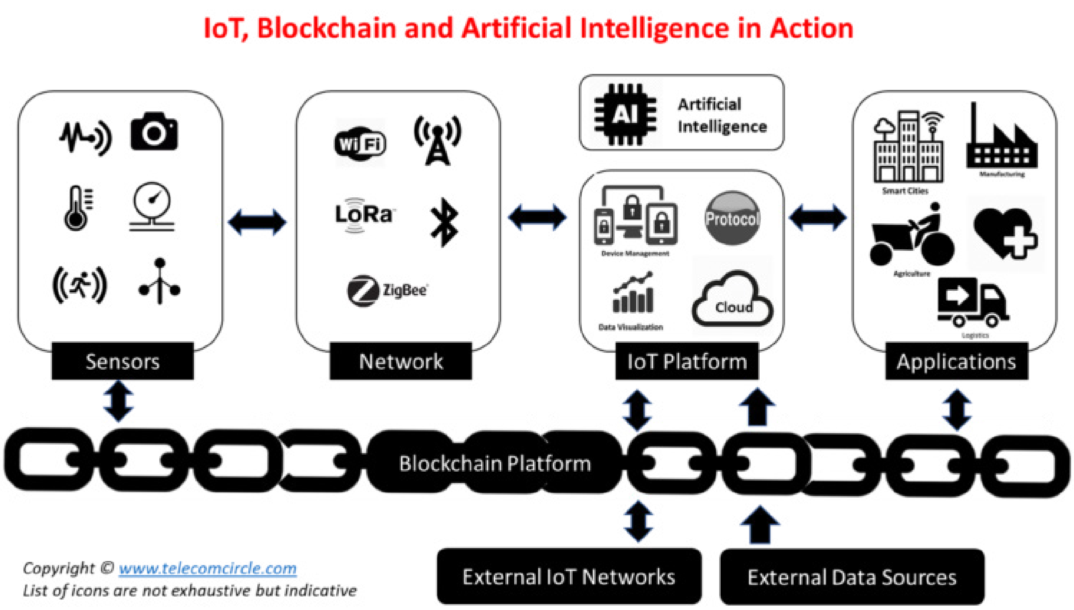


Figure 6: IoT, Blockchain and Artificial Intelligence in Action. Source: Wikipedia. "Internet of things."[84].

These platforms could also automate transactions from human to machine (e.g. human pays car for its rental), machine to machine (e.g. electric car pays directly to charging station) and machine to human (e.g. car pays human for cleaning).

3.4.11. Social scalability

Humanity needs more socially scalable institutions to solve global problems like climate change. DLTs are a tool of increasing social scalability at the cost of efficiency. Social scalability is "the redundancies and inefficiencies that protect a system from being inadvertently ruined by idiots or villains."[85]

Nick Szabo, computer scientist, legal scholar and leading researcher in digital money and smart contracts, describes social scalability in more detail: "The secret to Bitcoin's success is that its prolific resource consumption and poor computational scalability is buying something even more valuable: social scalability. Social scalability is the ability of an institution—a relationship or shared endeavor, in which multiple people repeatedly participate, and featuring customs, rules, or other features which constrain or motivate participants' behaviors—to overcome shortcomings in human minds and in the motivating or constraining aspects of said institution that limit who or how many can

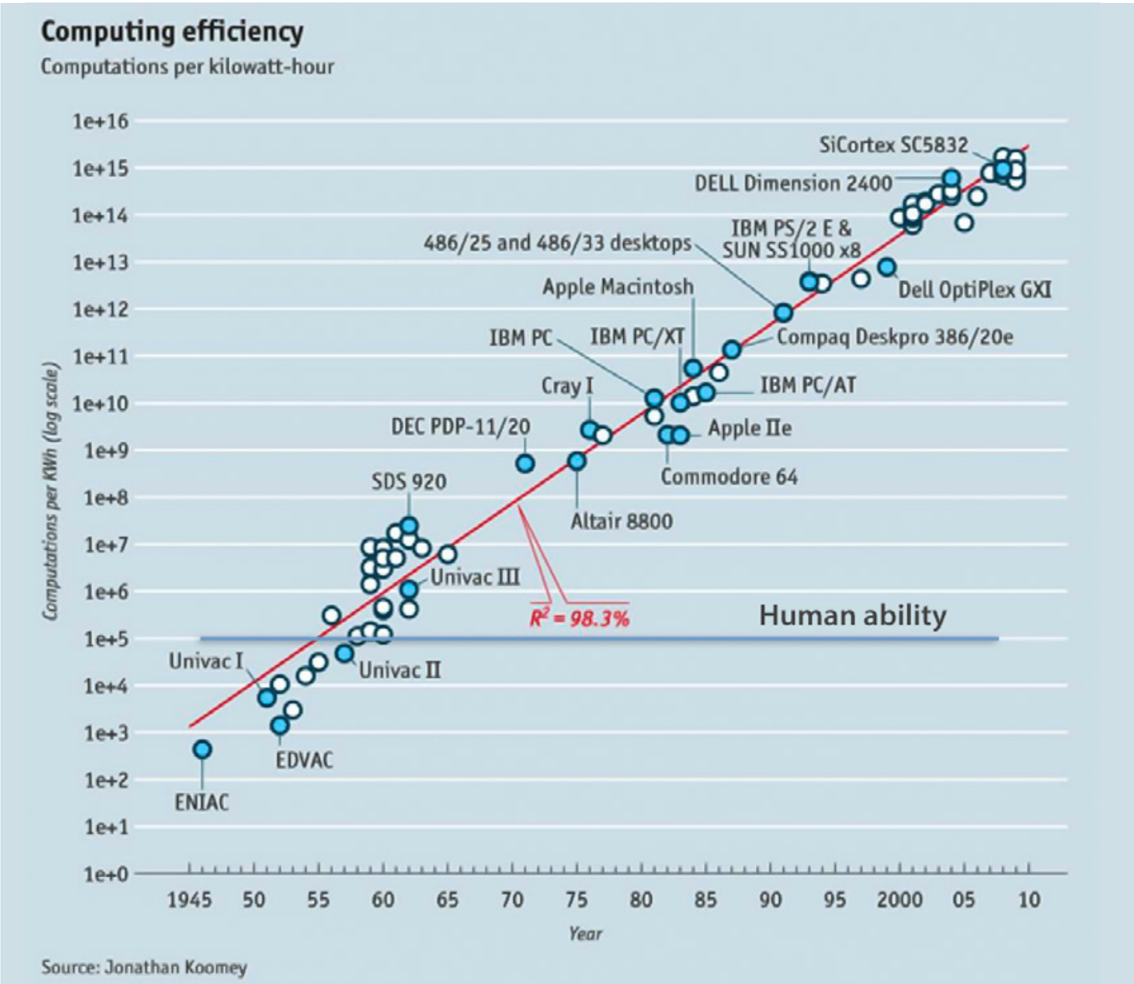


Figure 7: Since the mid-20th century computing has increased in efficiency by many orders of magnitude, but humans are using the same brains. This has created plenty of possibility for overcoming human limitations, and institutions based solely on human minds, with computational capabilities, including in security, doing what they do best, with human minds doing what they still do best. Source: Agrawal, Mohit. "IoT, Blockchain & Artificial Intelligence – New Holy Trinity."[86].

successfully participate. Social scalability is about the ways and extents to which participants can think about and respond to institutions and fellow participants as the variety and numbers of participants in those institutions or relationships grow. It's about human limitations, not about technological limitations or physical resource constraints.

"[...] Computers and networks are cheap. Scaling computational resources requires cheap additional resources. Scaling human traditional institutions in a reliable and secure manner requires increasing [the number of] accountants, lawyers, regulators, and police, along with the increase in bureaucracy, risk, and stress that such institutions entail. Lawyers are costly. Regulation is to the moon. Computer science secures money far better than accountants, police, and lawyers."[86].

3.5. Drawbacks of DLTs

The higher level of decentralisation offered by DLT, also has its drawbacks. Decentralised IT systems are inefficient databases, costly to maintain, slow and hard to develop, difficult to design and difficult to control. While these drawbacks are prohibitive compared to centralised IT systems, some of DLT's drawbacks might decrease as the technology is further developed (see also chapter 4.5.1.2), making DLT more attractive.

As the drawbacks are currently big, some DLT projects are trying to get the best of both the centralised and decentralised world. However, often these systems get the worst of both worlds: the cost and difficulty of decentralisation with the failure modes of centralisation.

Furthermore, many companies and projects looking to use DLT do not really want a DLT at all, but rather IT upgrades (e.g. supply chain management software is difficult to use and hard to install), which could also have a climate-positive impact. Most companies resist upgrading because of the risks involved. While using the terms "blockchain" or "distributed ledger technology" to sell these upgrades more easily works well, it is a practice that should be questioned.

3.5.1. Highly inefficient database technology

DLT is up to a factor of 1 million times less efficient than a centralised database[87], which in turn leads to much higher energy consumption and GHG emissions (see chapter 3.7).

With efficiency losses of DLTs as high as they are right now, only applications that really need one or more of the benefits of decentralisation (see chapter 3.4), ought to use DLT. The current efficiency levels are enough to enable some DLT usage, but it is mostly limited to cryptocurrency trading and early-stage testing.

The cost-benefit trade-off of many of the solutions in the DLT for climate action ecosystem are not yet in favour of DLT. To enable these solutions, the cost of DLTs must come down. Technology developing, especially scaling solutions, is one of the major technological barriers to the whole ecosystem (see chapter 4.5.1.2).

3.5.2. Stricter and slower development

Changes, updates and patches to DLTs work on a voluntary basis. Forced updates are not an option. Nodes on the network have no obligation to change to updated software. "The whole point of DLTs is, that it's not under the control of a single entity, which would be violated with the option of forced updates"[88].

While this is a problem for the integration of new features, it is an even bigger problem for testing and bug fixing. "Creating a provably consistent system is not an easy task. Bugs will remain a persistent reality in any IT system. Even a small bug could corrupt the entire ledger or cause some ledgers to be different from others. Once a ledger is corrupted or split, there are no longer any consistency guarantees. Consequently, DLT systems have to be designed from the outset to be consistent. There is no "move fast and break things" in DLT. If things break, consistency is lost and the DLT becomes corrupted and worthless."[88].

While developing and updating DLT systems is not impossible, it is certainly much slower and stricter than developing a centralised IT system. Many industries require new features, updates and the freedom to change and expand as necessary. Given that DLTs are hard to update, hard to change and hard to scale, their application is more cumbersome than using a centralised approach.

3.5.3. Difficulty of incentive design

In market networks, coordination and motivation are organised with incentives. In traditional market networks the incentive is money (see chapter 3.4.9). In DLTs the incentive is the DLT's native coin (the native coin of Bitcoin is Bitcoin, Etherium's is Ether, Cardano's is Ada). By doing that, DLTs give participants coins for giving the network what it wants. Different networks require different work: Bitcoin pays for securing the ledger, Ethereum pays for executing and verifying computation, Filecoin pays for providing storage[88].

Creating the right incentive structures and making sure that all actors in the system cannot abuse or corrupt the ledger is a big challenge. A distributed ledger "may be consistent, but that's not very useful if it has a lot of frivolous, useless data in it because the costs of putting data into it are very low. Neither is a consistent ledger useful if it has almost no data because the costs of putting data into it are very high"[88].

Creating sustainable incentive structures that solve specific problems remains a key challenge for the DLT ecosystem (see also chapter 4.5.1.2).

3.5.4. Costs of parallelisation

In DLTs, parallelisation is unavoidable. It is a key component of peer-to-peer networks which themselves are a key component of DLTs. Writing into a centralised database needs to be done once, writing into a distributed ledger needs to be done as many times as there are nodes that carry a copy of the ledger (as of 06 July 2018, Bitcoin has 9,384 reachable nodes[89]). The same applies to data validity checks and storage space: in centralised systems these operations prompt one actions, in DLTs as many as there are nodes.

Furthermore, this also applies to hardware. Centralised services run on one or a small number of redundant servers, while DLTs run on as many servers or computers as there are nodes. Consequently, this leads to higher maintenance costs and physical space requirements.

3.5.5. No control over "misbehaving" users

In DLTs there is no way to control users. While this can be a good thing (e.g. no liability of having user data in the first place), it can be bad if users are "misbehaving": e.g. the online black market Silk Road72 used Bitcoin as its payment system and no entity could stop the Silk Road from doing that. Similarly, if users are spamming the ledger with useless data, or if they figure out how to profit in a way that causes inconvenience to other users, there is no way to stop this.

In a centralised service, it is very easy to refuse service to a misbehaving or malicious user. In decentralised services, it is the rules defined in the software that can refuse service. If the rules and incentive structures are insufficient, it takes a lot of time to make the adjustments (see chapter 3.5.2). In DLT, there is no "spirit" of the law. To prevent users from misbehaving, DLTs introduce incentives that if designed correctly ensure that users do not want to misbehave. Consequently, DLT systems need to be designed from the onset to disincentivise unwelcomed behaviour.

3.6. When to use DLT and when not to use DLT

DLT is just a tool to solve problems. It is therefore crucial to first have a high level of certainty about the problem that needs to be solved. Once the problem is well defined and validated, the following question needs to be answered: "**Is DLT the only solution to this problem?**". The question should not be "Is DLT a solution to this problem?".

DLT is a highly inefficient database, which is costly to maintain, slow and hard to develop, difficult to design and difficult to control (see chapter 3.4.11). In return for these costs, DLTs gain higher fault tolerance, attack resistance, collusion resistance, rate of innovation, openness, immutability, social scalability, and they could enable new market networks and serve as the secure infrastructure for smart networks based on IoT and AI (see chapter 3.4).

If these DLT benefits are not required to solve the problem, DLT is just a highly inefficient and wasteful database, and "traditional" centralised databases can solve the problem in a much more elegant, cost-effective and climate-friendly way.

The flowchart by Karl Wüst and Arthur Gervais of the Department of Computer Science at the Swiss Federal Institute of Technology (ETH Zurich) facilitates answering whether DLT should be considered as a solution tool[90].

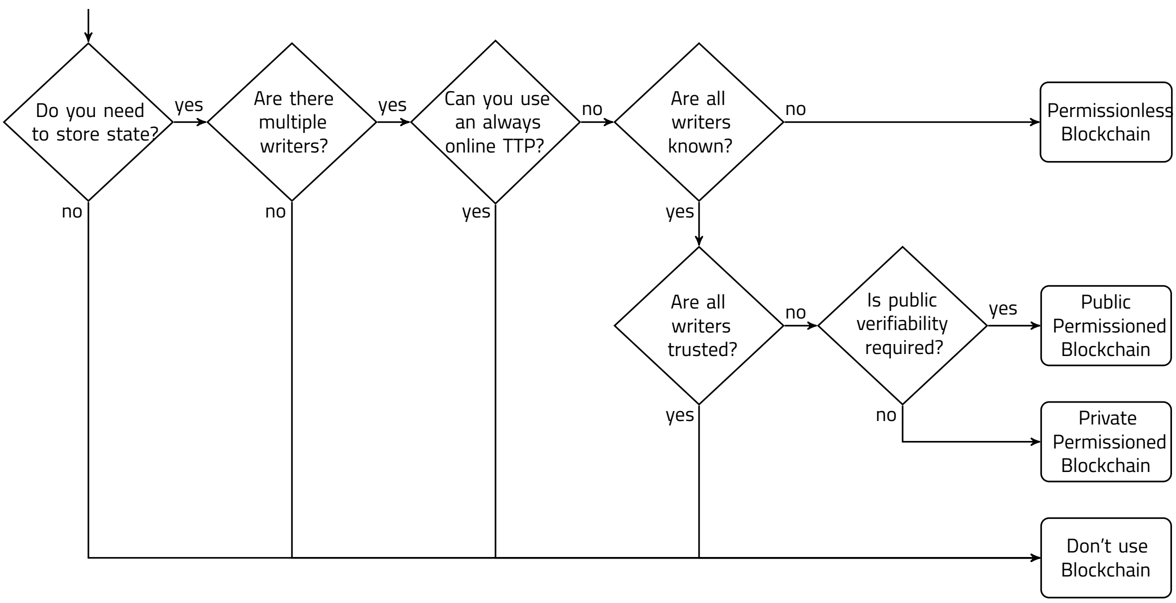


Figure 8: Flowchart to determine whether DLT is the appropriate technology to solve a problem. Source: Karl Wüst and Arthur Gervais. "Do you need a Blockchain?" [90].

For interested readers the World Economic Forum presents a more detailed flowchart here: Mulligan, Cathy. "These 11 questions will help you decide if blockchain is right for your business."[91].

In the context of Figure 8, "blockchain" and "DLT" can be used interchangeably. DLT includes private-permissioned blockchains, public-permissioned blockchains and permissionless blockchains. Readers interested in learning more about the differences between these types of blockchains can find a comprehensive introduction can find a comprehensive introduction at Digiconomist[93].

"State" refers to the action of writing and storing information to a database. If no data needs to be stored, then it does not require DLT.

"Writers" refers to entities with write access to the database, i.e. ledger (in DLT a writer corresponds to a validator node [see chapter 3.3.1.3]). If there are not multiple writers, a standard centralised database is much more efficient.

If the system can use Trusted Third Party (TTP) which is always online, write operations can be delegated to it and it does not require a blockchain. If the TTP is usually offline, it can function as a certificate authority in the setting of a permissioned blockchain, i.e. where all writers in the system are known. In the case of the TTP, it is not only a question of availability, but also design requirements: bitcoin was specifically created so that no trusted third party controls the currency Bitcoin, even though TTPs are available in the form of central banks.

If the writers all mutually trust each other, i.e. no participant is malicious now now or in the future, a database with shared write access is likely the best solution, and it does not require DLT. If the writers do not trust each other a permissioned blockchain makes sense. Depending on whether public verifiability is required, anyone could be allowed to read the state (public-permissioned blockchain) or the set of readers may also be restricted (private-permissioned blockchain). In a permissioned blockchain, a central entity decides and attributes the write and read rights to individual peers. To provide encapsulation and privacy, readers and writers can also run in separate parallel blockchains that are interconnected.

If the number of writers is not fixed and they are not known, a permissionless blockchain, also called public blockchain, such as Bitcoin is the only suitable solution.

The following three use case scenarios are generally suitable use cases for DLT-based systems[13]. The use cases generally make sense following the logic of the flowchart and gain from the trade-off between decentralisation and centralisation.

- **Disintermediation:** cutting out trusted third parties could increase overall efficiencies, especially in cases where the underlying problem is not centralised in nature (see chapter 3.4.5).
- **Cross Jurisdiction:** in this scenario it might not be possible to find or create a trusted third party, or it might also be too inefficient to go through a trusted third party.
- **Reporting & compliance:** reporting, especially with regards to regulatory compliance reporting, can be moved from time-discrete (usually annually) reporting to a continuous consensus process through permissionless or public permissioned blockchains.

3.7. Energy consumption of DLTs

Bitcoin, Ethereum and many DLTs prevent Sybil attacks by using Proof-of-Work. Proof-of-Work expends electricity to solve a pointless cryptographic puzzle (see chapter 3.3.1.4).

The following table shows the energy consumption of the two largest public DLTs, Bitcoin and Ethereum as of August 2018.

	Bitcoin	Ethereum
Current estimated annual electricity consumption, in TWh	73.1	20.77
Closest country in terms of electricity consumption	Austria	Azerbaijan
Electricity consumed per transaction, in kWh	922	87
Electricity consumption as percentage of global consumption	0.33 %	0.1 %
Annual carbon footprint, in ktCO2	35,830.00	n/a
Carbon footprint per transaction, in kgCO2	451.62	n/a

Sources: Bitcoin[93], Ethereum[94]
Table 2: Energy consumption of Bitcoin and Ethereum as of August 2018.

To add perspective with comparable assets, Table 3 compares the costs and maintenance resources between Bitcoin, gold mining, gold recycling, paper currency and the banking system.

	Gross yearly cost USD billion / relation to Bitcoin	**Annual electricity consumption** TWh / relation to Bitcoin	**Annual carbon footprint** kt CO2 / relation to Bitcoin	**Emission Trend**
Bitcoin mining	3.65	73.10	35'830	Increasing
Gold mining	105 / 3.4%	131.95 / 53.9%	54,000 / 64.5%	Increasing
Gold recycling	40 / 8.9%	6.94 / 1023%	4,000 / 871.3%	Decreasing
Paper currency & minting	28 / 12.7%	11.00 / 646%	6,700 / 520.2%	Increasing
Banking system	1870 / 0.2%	650.01 / 10.9%	390,000 / 8.9%	Increasing

Sources: Bitcoin[93]; Gold, currency, minting, banking values[95]
Table 3: Comparison of costs, electricity consumption and carbon footprint between Bitcoin, gold mining, gold recycling, paper currency & minting, and the banking system.

While the numbers for gold mining, gold recycling, currency, minting and the banking systems give an indication of the difference to Bitcoin, these are hard to calculate and should be consumed with caution. Furthermore, it is hard to compare these industries/technologies 1-to-1 with each other: the banking system executes orders of magnitudes more transactions than Bitcoin.

As Christopher Malmo, journalist at Vice's Motherboard, states: "Unfortunately for Bitcoin, if user adoption spikes, so will price - and so must public-permissioned. Bitcoin mining leads to an arms race among miners to grab a slice of the fixed rewards doled out by the network. The higher the financial rewards, the more miners will invest in powerful equipment to keep up with the competition. The Bitcoin protocol will continue to increase the difficulty of the cryptopuzzles to keep rewards constant, continuing the arms race until the last block is mined"[30].

There are ways to make Bitcoin and DLTs in general more energy efficient and reduce GHG emissions. Currently, the following four directions are pursued and might lead to considerable energy efficiency increases.

- **Direction 1: Keeping and improving Proof-of-Work,** as it is considered a key pillar in increasing decentralisation in DLTs. The main type of improvements pursued are scaling solutions (see chapter 4.5.1.2), as these would allowmore transactions to be put through the system.

- **Direction 2: Switching to different Sybil control mechanisms.** Ethereum is preparing a switch to a Proof-of-Stake system that would result in much lower energy consumption[97]. However, Proof-of-Stake designs are in their early stage and it is not yet clear what the practical implications for decentralisation will be once these systems run on scale.

- **Direction 3: Switching to a different ledger type.** DLTs like IOTA[20] or Hedera hashgraph[21] employ a Directed Acyclic Graph as their ledger, which ought to be much more energy efficient (see chapter 3.3.1.1).

- **Direction 4: Using green energy in Proof-of-Work mining operations.** While using clean energy does not make DLTs more energy efficient, it considerably lowers their GHG emissions. Simultaneously, mining hardware developers are developing more energy efficient equipment.

While DLTs running on PoW Sybil control mechanisms use a lot of energy, Proof-of-Work is also the mechanism that enables decentralisation and with it all of decentralisation's benefits (see chapter 3.3.1.4).

The trade-off between high energy consumption for higher levels of decentralisation is a key question in the DLT for climate action ecosystem and needs to be addressed for each potential DLT solution. For some DLT projects it might be worth expending the energy, for others not.

As Nick Szabo, computer scientist, legal scholar and leading researcher in digital money and smart contracts, puts it: "That is what Proof-of-Work and broadcast-replication are about: greatly sacrificing computational scalability to improve social scalability. That is Bitcoin's brilliant trade-off. It is brilliant because humans are far more expensive than computers and that gap widens further each year. And it is brilliant because it allows one to seamlessly and securely work across human trust boundaries (e.g. national borders), in contrast to "call-the-cop" architectures like PayPal and Visa that continually depend on expensive, error-prone, and sometimes corruptible bureaucracies to function with a reasonable amount of integrity"[1].

4. Ecosystem assessment

4.1. Ecosystem assessment summary

As of August 2018, there are 222 actors active in the DLT for climate action ecosystem. The number grew from 114 actors as identified in the first ecosystem assessment in January 2018. These actors are active in five different system functions that collectively shape and move the ecosystem.

- The **"entrepreneurial activity"** function describes actors that translate knowledge into business opportunities, and eventually innovations[214].
- The "**knowledge development**" function involves learning activities, mostly on the emerging technologies, but also on markets, networks, and users[214].
- The "**knowledge diffusion**" function involves partnerships between actors, for example technology developers, but also meetings like workshops and conferences, where knowledge is shared in the community[214].
- The "**resource mobilisation**" function refers to the allocation of financial, material and human capital[214].
- The "**advocacy support**" function describes political lobbies and advice activities on behalf of interest groups[214].

While most actors are active in the entrepreneurial activity function, the other four system functions are also filled with active actors. Within the entrepreneurial activity, the largest group of actors focuses on the energy-use case (74 actors), followed by the supply-chain-use case (12 actors) and carbon trading (10 actors). While most actors are active in one system function, there are 14 actors who position themselves in multiple functions. These actors could be interesting candidates for initial partner network building as described in the recommendations.

DLT for climate action use cases

DLT is still a young technology and thus most actors are still in the exploration and understanding phase. In terms of the innovation curve, the financial sector is the most advanced, followed by the energy sector. Across the DLT for climate ecosystem, the following use cases have been identified:

Energy: The shared vision of energy DLT projects is to decarbonise the energy system by decentralising, democratising and digitalising it. Decentralisation focuses on increasing the share of renewable energy sources, and better management of energy consumption and storage, all of which are inherently decentralised. Democratisation focuses on enabling peer-to-peer energy trading. Digitalisation focuses on the "Uberisation", i.e. the usage of under-utilised capacity of existing assets like fridges, in the energy market.

- **Supply chain management:** The use cases focus on the reduction or elimination of fraud and errors, improvements in inventory management, minimisation of courier costs, reduction of delays from paperwork, faster issue identification and increased brand trust by consumers and partners.
- **Carbon trading:** DLT could create a more liquid and transparent carbon marketplace, which would allow more participants to use

it and would enable direct integration with other business processes (e.g. integration with eCommerce payments) through Application Programming Interfaces (APIs).

- **Transportation:** The two major trends observed in the transportation DLT ecosystem are enabling a wider diffusion of electric cars and increasing the usability and reach of a low-carbon public transportation including a shared mobility system.

- **Other climate action:** This use case category includes cases that incentivise climate-positive behaviours like recycling or conscious consumption. A noteworthy type of use case in the "other climate action" category is forestry, especially in combination with the UN's REDD+ programme.

- **Open government:** Projects in this category want to increase overall transparency and accountability of public leaders and agencies and by that create a more inclusive society.

- **Philanthropy:** Philanthropic actors want to increase transparency and accountability, which could improve the effectiveness of donations and might even increase donations overall due to improved public perception.

- **Measurement Reporting and Verification (MRV):** MRV is an overarching theme across DLT for climate action use cases. When it comes to climate action, effective measurement, reporting and verification is criticalin taking and assessing action.Furthermore, MRV is central to effectively implementing the Nationally Determined Contributions (NDCs) submitted under the Paris Agreement.

- **Green finance:** Green finance is another overarching theme across DLT for climate action use cases. By improving data availability and MRV, new ways of financing climate projects are enabled. The Paris Agreement represents a USD 23 trillion green investment market between now and 2030. Finance DLT projects aim at reducing costs of developing new green finance products, reducing information asymmetry and improving certification systems.

Adoption barriers

Twelve main barriers were identified to the further adoption and diffusion of DLT for *climate action*. Six of these barriers were identified within the DLT community, three in "climate-relevant industries" and three at the intersection of these two communities.

Many of the 222 identified actors work on overcoming these identified barriers. However, from the qualitative research and interviews with stakeholders it seems that the barriers at the intersection are the least deliberately worked on. These intersection barriers require an understanding of both the DLT community and the "climate-relevant industries". Overcoming these barriers is a task of coordinating effective collaboration, translating between the different jargons and educating both sides about each other's needs and capabilities.

Furthermore, as DLT is still young, technological barriers and uncertainties are a major barrier. These uncertainties are especially challenging for climate applications as these use DLT as their underlying technology layer. Therefore any shortcoming of DLT directly affects climate applications. For example, to be an effective tool for many of the discussed use cases, Ethereum would need to scale its current transaction throughput (20 transactions per second) to compete with traditional systems (e.g. Visa can handle up to 24,000 transactions per second).

4.2. Ecosystem landscape map

Figure 9 and Figure 10 show the 222 actors active in the DLT for climate action ecosystem as of August 2018. The actors are mapped onto five system functions: entrepreneurial activities, knowledge development, knowledge diffusion, resource mobilisation and advocacy support (described in more detail below).

Figure 9: Landscape map of actors in the DLT for climate action ecosystem as of August 2018; part 1 of 2. The full list of actors, including a description and URL is available in chapter 8.3.

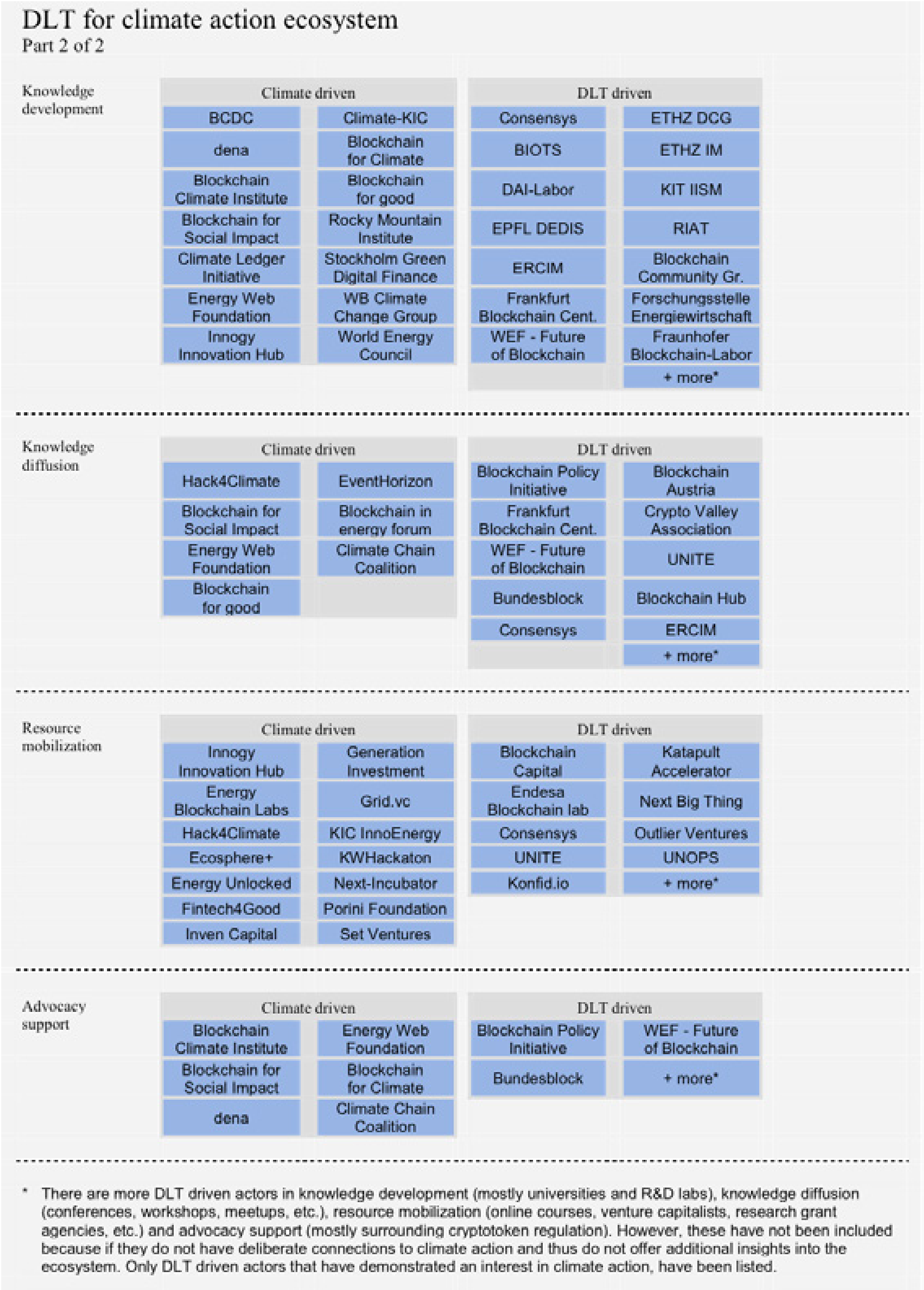


Figure 10: Landscape map of actors in the DLT for climate action ecosystem as of August 2018; part 2 of 2. The full list of actors, including a description and URL is available in chapter 8.3.

Often the mapped actors focus on their work on one system function but are still active in other functions where it is required to achieve their mission. A few actors however, are deliberately active in multiple functions. These types of actors have been mapped onto all the system functions where they are active. For example, Innogy Innovation Hub is active in entrepreneurial activities, knowledge development and resource mobilisation.

Actors in knowledge development, knowledge diffusion, resource mobilisation and advocacy support are organised into either climate-driven or DLT-driven to differentiate between these actor's motivations. There are more DLT-driven actors in knowledge development (mostly universities and R&D labs), knowledge diffusion (conferences, workshops, meetups, etc.), resource mobilisation (online courses, venture capitalists, research grant agencies, etc.) and advocacy support (mostly surrounding cryptotoken regulation). However, these have not been included because they do not have connections to climate action and thus do not offer additional insights into the ecosystem. Only DLT-driven actors that have demonstrated an interest in climate action have been listed.

The numbers and actors mapped in the landscape map should be taken as an indication of the overall direction in the ecosystem. The exact numbers are flawed in as much as the map does not claim completeness. Actors might have been missed. Also, there is a portion of unknown actors in this space also (e.g. internal working groups that explore and test DLT-based solutions without going public).

The use cases mapped in entrepreneurial activities are descried in chapter 4.4. A detailed list of all actors is available in chapter 8.3.

Description of entrepreneurial activity
The role of an entrepreneurial activity is to translate knowledge into business opportunities, and eventually innovations[214]. It does this by performing market-oriented experiments that establish change, both to the emerging technology and to the institutions that surround it. Entrepreneurial activities involve projects driven by start-ups, SME's, big corporations and consortia.

Entrepreneurial activities should be understood as market experiments. A large proportion of these experiments will fail, but those that survive will create a lot of economic value. Also, some of the experiments that fail financially, might still contribute significant value to the overall development in terms of learnings.

Description of knowledge development
The knowledge development function involves learning activities, mostly on the emerging technologies, but also on markets, networks, and users[214]. There are various types of learning activities, the most important categories being learning-by-searching and learning-by-doing. The former concerns R&D and patenting activities in basic science, whereas the latter involves learning activities in a practical context, for example in the form of laboratory experiments or adoption trials.

Description of knowledge diffusion
Knowledge diffusion activities involve partnerships between actors, for example technology developers, but also meetings like workshops and conferences. The knowledge diffusion function is mapped, because innovation happens mostly where actors of different backgrounds interact.

Description of resource mobilisation
Resource mobilisation refers to the allocation of financial, material and human capital. The access to such resources is necessary for all developments as an emerging technology cannot be supported in any way if there are no financial or natural means, or if there are no actors present with the right skills and competences[214].

Description of advocacy support
The rise of an emerging technology often leads to resistance from actors with interests in the incumbent systems. For an emerging technology innovation system to develop, other

actors must counteract this inertia. This can be done by urging authorities to reorganise the institutional configuration of the system. This function includes political lobbies and advice activities on behalf of interest groups. Advocacy coalitions do not have the power, like for example governments, to change formal institutions directly. Instead, they employ the power of persuasion[214].

4.3. Ecosystem observations

	Version 1 – Jan 2018		Version 2 – Aug 2018	
	# of actors	Share	# of actors	Share
Entrepreneurial activity	72	63.2%	144	64.9%
Knowledge development	14	12.3%	28	12.6%
Knowledge diffusion	12	10.5%	18	8.1%
Resource mobilisation	10	8.8%	23	10.4%
Advocacy support	6	5.3%	9	4.1%
Total	114		222	

Table 4: Growth of number of actors across five system functions.

Fast ecosystem growth
Figure 9 and Figure 10 were first created in January 2018[97]. In the 7 months since then, the map grew from 114 to 222 actors (i.e. an increase of 108 actors). Table 4 shows the growth of the number of actors across the five system functions.

Five system functions sufficiently filled
Table 5 shows how actors are spread across the five system functions. While the largest group is in entrepreneurial activities, all five functions contain active actors.

The research activities (online research and interviews) leading to the creation of the landscape map gave the impression that overall the five functions are sufficiently filled. However, the knowledge diffusion function could benefit most from additional actors as the DLT for climate action ecosystem is still young and growing better networks would facilitate the ecosystem's further growth. The barrier analysis comes to a similar conclusion, namely that the intersection between the DLT and "climate-relevant industries" is the least worked on (see chapter 4.5).

There are many more DLT-driven actors involved in knowledge development, knowledge diffusion, resource mobilisation and advocacy support. However, these have not been included because they do not have connections to climate action and thus do not offer additional insights into the ecosystem. Only DLT-driven actors that have demonstrated an interest in climate action have been listed.

System function	Climate-driven	DLT-driven
Knowledge development	14	14
Knowledge diffusion	7	11
Resource mobilisation	14	9
Advocacy support	6	3

Table 5: Amount of climate or DLT-driven actors across four system functions.

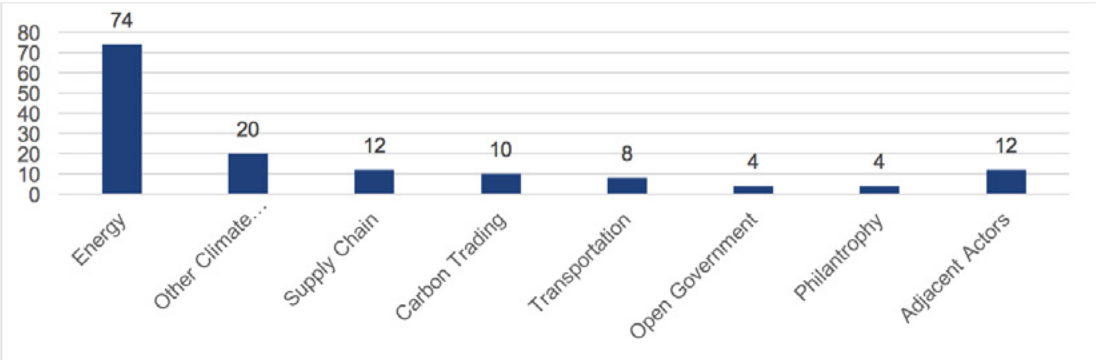


Figure 11: Number of actors in the 8 sub-groups in entrepreneurial activities. Each actor is mapped to only one sub-group, even if it is active multiple sub-groups.

Most actors in the energy use case
There are 144 actors in the entrepreneurial activities system function. Within this function, the energy sector is by far the biggest (Figure 11).

Additional to the 74 entrepreneurial actors in the energy DLT ecosystem, the investigation identified 145 observers: energy companies, mostly incumbents, that observe DLT developments or run pilot projects with some of the identified entrepreneurial actors (see list of energy DLT observers in chapter 8.4).

A recurring theme across all entrepreneurial actors is that of increased data integrity and transparency and thus enhanced capabilities in measurement, reporting and verification (MRV) (see chapter 4.4.8). MRV could be one of the biggest contributors to climate action, notably as it will enable new carbon market with better emissions certification, trading and accounting (see chapter 4.4.9).

Key actors active in multiple system functions
Table 6 shows actors that are active in more than two system functions. These actors could be ideal partners to connect with as part of dedicated partner network building (see also chapter 6.1).

Actor Name	Entrepreneurial activities	Knowledge development	Knowledge diffusion	Resource mobilisation	Advocacy support
BCDC	active	active			
Blockchain Climate Institute		active			active
Blockchain for Social Impact	active	active	active		active
Blockchain Policy Initiative			active		active
Bundesblock			active		active
Climate Ledger Initiative	active	active			
Consensys	active	active	active	active	
dena		active			active
Energy Web Foundation		active	active		active
Frankfurt Blockchain Center		active	active		
Hack4Climate			active	active	
Innogy Innovation Hub	active	active		active	
UNITE			active	active	
WEF - Future of Blockchain		active	active		active

Table 6: List of actors that are active in more than two system functions.

Most actors are in the exploration and understanding phase

DLT is a young technology that exists since 2008 (see chapter 0). Bitcoin is the first, most widely spread and furthest developed DLT. Considering the technologies behind Bitcoin for additional applications started in 2013 when Vitalik Buterin released the Ethereum white paper, which eventually launched the Ethereum network in July 2015. In 2014 consortia-type DLTs started launching. The first industry to pick up on DLT was the financial sector, the second is the energy sector. The World Energy Council and PwC believe that the financial sector is in transition between the "explore" and "growth" stages, while the energy sector is following closely (see Figure 12). Other industries, such as those mapped in Figure 9 and Figure 10, are believed to be further back. The research conducted for this report, confirms these beliefs.

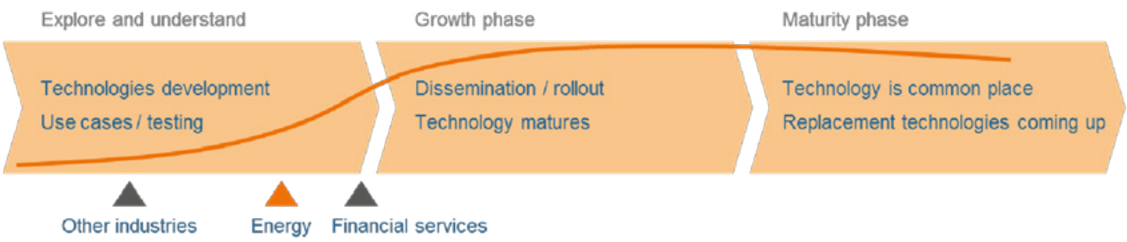


Figure 12: DLT applications on the innovation curve. Source: World Energy Council, and PwC. "The Developing Role of Blockchain." [98]

Difference between climate and DLT-driven projects
The actors mapped in Figure 9 and Figure 10 are driven by climate action (i.e. climate action is the goal, using DLT might make sense) or by DLT (i.e. applying DLT as a tool is the goal, applying it to climate change might make sense).

The impression gained from online research and interviews is that climate-action-driven actors often miss the truly transformative capability of DLT and thus design pointless solutions. In many of these cases, "DLT or blockchain" could just be replaced by "centralised database", making the solution just as feasible, and potentially even more cost-effective (see chapter 3.5.1). On the other hand, DLT-driven approaches often lack industry specific knowledge resulting in suboptimal problem-solution fits.

Furthermore, the impression is that the different mindsets of these two groups create some mistrust among each other. Bitcoin and many early DLT projects originate from the open source community and are still developed by many loosely organised individuals, working groups and "teenagers dabbling with their computer". Many of the early developers and supporters of Bitcoin and DLT are contrarians, libertarians and/or part of the cypherpunk community. As such, many of these people are skeptical of governments and corporations, also of those who are interested in using DLT for their own purposes. This is especially true in situations where permissioned and private DLTs (see chapter 3.6) are proposed. In contrast, organisations looking to make use of DLT, do seldomly align with these principles, and mostly serve the needs of investors, that are generally interested in proprietary technologies.

4.4. DLT for climate action use cases

4.4.1. Energy

Reducing GHG emissions in the electricity sector could be powerful in terms of climate action as energy is responsible for 72% of emissions globally. The primary sources of are electricity and heat (31%), transportation (15%), manufacturing (12%), agriculture (11%) and forestry (6%).

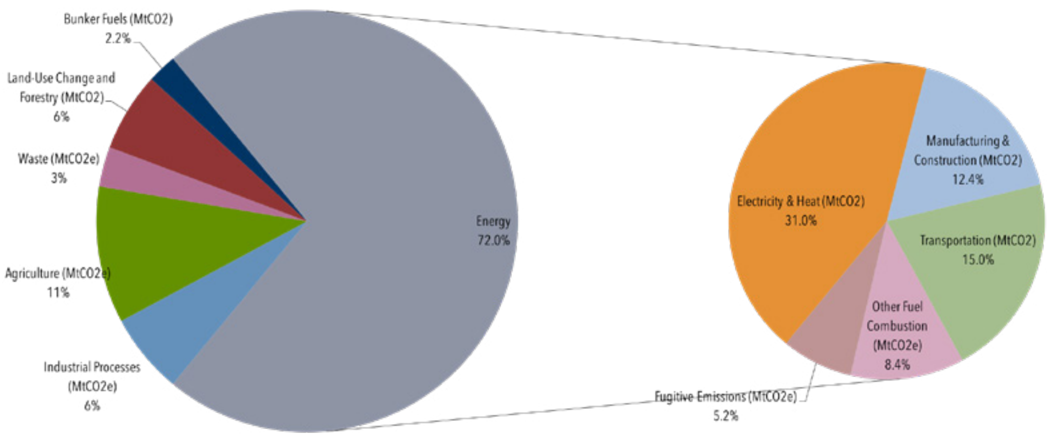


Figure 13: Global man-made greenhouse gas emissions by sector in 2013. Source: : Center for climate and energy solutions. "Global Manmade Greenhouse Gas Emissions by Sector, 2013."[99].

The first energy DLT transaction was done in April 2016 in a microgrid in Brooklyn, a project developed by LO3Energy[100]. As shown in Figure 11, there are 74 actors in the energy sector. Concurrent with the growth of energy DLT actors, financing of energy DLT projects is also accelerating: since Q2 2017, USD 300m has been invested and 33 new projects have been launched[102].

The shared vision of energy DLT projects is to decarbonise the energy system by decentralising, democratising and digitalising the energy system.

Decentralisation focuses on increasing the share of renewable energy sources, and better management of energy consumption and energy storing, all of which are inherently decentral (and intermittent)[75].

Democratisation focuses on enabling peer-to-peer energy trading markets with unstoppable DApps (see chapter 3.3.4) which allow every person, company and device to participate in the network.

Digitalisation of new and existing energy infrastructure focuses on the "Uberisation"[102] in the energy market: the idea is to use under-utilised capacity of existing assets. For example, the digitalisation of fridges would allow their energy consumption to be shifted to a time when excess energy is produced at e.g. peak solar energy production (1 million 100-watt fridges equals a thermal storage capacity of 100MW). The Uberisation of fridges could add 100MW of grid flexibility at virtually no investments in new assets.

According to research by the Cleantech Group, the energy DLT ecosystem has the following characteristics as of April 2018:

- European actors are leading the energy DLT ecosystem. European actors jointly hold USD 723m, Asia USD 251m and North America USD 140m in investments[103].
- Deal-making in energy DLT keeps accelerating[103].
- The global top three investments were USD 337m in P2P and retail trading, USD 134m in green mining, USD 19m in smart home and energy efficiency[103].

	Generation	Transmission	Distribution	Trading	Sales	Metering	Other areas
B2C energy trading / peer-to-peer systems							
Microgrids (peer-to-peer)	●	●	●		●	●	
Grid management systems	●	●	●			●	
Trading based on BC/Smart Contracts				●			
Mobility							
Charging process mgmt./payment							●
Charging station handling							●
Ride sharing							●
Asset management							
Data collection/integration for individual assets ("provenance")	●						
Other energy use cases							
Certificate handling (e.g. for renewable energy usage)				●	●		
Payment of invoices with crypto-currencies				●	●		
Blockchain-based supplier switching management			●		●	●	

Source: World Energy Council, PwC

Figure 14: DLT use cases along the energy value chain. Source: World Energy Council and PwC. "The Developing Role of Blockchain."[98].

Interested readers can consult the comprehensive energy DLT market overview by Jules Besnainou from the Cleantech Group[103].

While energy DLT projects are generally looking to decentralise the energy system, it should be noted, that these digitalisation projects need to interact with the physical grid to unlock the full potential. For that, they need the support of (centralised) incumbents which own the grid and thus it seems that the disruptive DLT potential might not be fully utilised.

The impression gained from research activities and interviews (see chapter 8.1.4) indicates that the following use cases seem most relevant in the context of climate change:

- **Peer-to-peer (P2P) energy trading:** Enabling P2P energy trading would enable possibilities to make the energy grid more resilient and cost effective. It wouldallow the building of a transactive grid based on multiple microgrids (i.e. a neighbourhood), which aggregate into minigrids (e.g. a city district), which aggregate into city grids, which aggregate into region grids and so forth. Such a system could achieve high levels of local energy generation and consumption. Furthermore, grid stability could be improved by automated micromanagement of the smallest grid units.

- **Real-time grid management systems:** Improving availability and frequency of energy production and consumption data, could increase efficiencies in grid balancing and introduce additional grid flexibility which in turn could be used to add more intermittent renewable energy sources.

- **Automated energy trading and settlement:** Shared trusted data enhances automation of trading, settlement and reconciliation among wholesale energy traders. Automated trading and settlement are furthermore a feature which might increase the number of prosumers as it would facilitate their management processes. Additionally, this feature could enable simple electric vehicle charging which eventually could lead to the payment of electricity from machine to machine, i.e. from vehicle to sharing station (see chapter 4.4.4).

- **Certificates of origin:** DLT-based systems can greatly enhance provenance capabilities and reduce erroneous or fraudulent double spending of certificates.

Overall however, the farthest-reaching implication of energy DLT is the potential creation of an open energy data platform that is connected to the physical grid.

Such a platform could accelerate climate action through permissionless innovation on the energy network itself: anyone and any organisation would be able to create a new type of DApp (see chapter 3.3.4), e.g. for energy trading, renewable energy certificates or even self-managed neighbourhood grids with neighbourhood-owned renewable energy generation. Furthermore, it would allow participants to add any type of energy-relevant machine (i.e. energy generation, storage or consumption machine) to the platform and manage it through a DApp. Such a platform could lead to new business models, increased efficiencies in the energy grid and higher levels of renewable energy sources. It could increase citizen autonomy and create a more climate-friendly energy sector.

However, this type of platform is still many years away from reality and will face a lot of technological (see chapter 4.5.1.2), societal (see chapter 4.5.2.3) and political (see chapter 4.5.3.2) challenges.

Overall, the blief in DLT's high potential to transform the energy sector is shared by 93% of senior energy executives interviewed by the World Energy Council[98].

Energy DLT example: Enerchain

Enerchain[104] is a project focused on wholesale energy trading and consists of 38 energy trading firms. Enerchain aims at becoming the operating system of Energy Trading covering the entire trade cycle from end to end. Currently, the Enerchain distributed marketplace already enables: reduced market access cost without transaction fees, lower entrance barriers for smaller players and new products and the opportunity to trade self-defined, non-standard products.

The project started in May 2017 with a consortium of 23 participants, which increased to 38 as of August 2018. The consortium consists of energy companies like Alpiq, Centrica, Eon and is developed by Ponton.

Energy DLT example: Energy Web Foundation (EWF)

The Energy Web Foundation[105] is building the shared digital infrastructure of the energy sector (i.e. open energy data platform) on which anyone could run their solutions (decentralised applications, i.e. DApps). Additionally, EWF is building some of the first DApps for their platform. Their current DApp lighthouse project is called EW Origin[106], which is a customisable, open-source decentralised application for renewable energy and carbon markets that wants to simplify and enhance the way in which customers procure renewable energy. EWF's test network, named Tobalaba, is open for the public.

As of August 2018, EWF is built by a consortium of 46 companies, comprising of energy companies like Shell, Eon and Engie and DLT developers like Innogy, Share&Charge and Electron.

Furthermore, EWF organises an annual summit for the energy DLT community, called Event Horizon[107]. The summit showcases EWF's latest developments, hosts speakers from climate researchers, DLT developers and energy executives, and offers multiple energy start-ups to pitch their ideas in a highly vibrant atmosphere. The event suggests that the energy industry is finally innovating again[108].

It seems like EWF is motivated equally by innovating the energy system and by fighting climate change (e.g. the keynote at the 2018 Event Horizon was Sebastian Copeland, an adventurer and environmental advocate[109]).

4.4.2. Supply chain management

Traceability and transparency are some of the most important foundations of logistics. DLT offers a tool to increase today's levels of these factors. It enables equal visibility of activities and reveals where an asset is at any point in time, who owns it and what condition it's in. The benefits of DLT in supply chains are the reduction or elimination of fraud and errors, improvements in inventory management, minimisation of courier costs, reduction of delays from paperwork, faster issue identification and increased trust among consumers and partners.

Overall, these benefits mean better abilities for measurement, reporting and verification (MRV, see chapter 4.4.8). While MRV is useful to drive any type of goal, it is also especially helpful in decreasing the carbon footprint of supply chains and products and enabling better approaches to circular economy.

Supply chain DLT example: Provenance

Provenance[110] is a platform that empowers brands to take steps toward greater transparency by tracing the origins and histories of products. Provenance's mission is to help make opaque supply chains that are devastating environments and compromising the well-being of people, animals and communities more transparent.

Supply chain DLT example: Xpansiv

Xpansiv[111] authenticates commodity production data and refines it into a new, standardised data format to power the digital migration of commodities from production to consumption. This approach is sensible as commodities are at the heart of global supply chains and their production has a disproportionate impact economically, operationally and environmentally. Furthermore, commodities are not created equal.

4.4.3. Carbon trading

Purchasing "high quality" carbon credits is a process that must be done in over-the-counter transactions, which slows down the market for them. DLT could help to creating a more liquid and transparent marketplace, which would allow more participants to use and automatically connect to it, through APIs (Application Programming Interfaces), for example.

Furthermore, better MRV capabilities due to DLT-based systems – used in companies, but also cities, regions and nations – would allow better tracking of environmental impacts and how much carbon credits are needed to sufficiently offset a given process. This could also lead to reputation systems based on a company or brand's carbon footprint.

DLT-based systems could be especially interesting in the context of climate markets post 2020. As The World Bank notes: "Blockchain, Big Data, the Internet of Things (IoT), smart contracts and other disruptive technologies hold out the promise of addressing the needs of new generation climate markets post-2020."[2]. In such a climate market, DLT could act as the national registry for countries wishing to participate in Article 6 of the Paris Agreement, could act as the settlement platform for tracking of trades and for reconciliation and avoidance of double counting, or could act as the common language to communicate across countries.

Carbon trading DLT example: Veridium
Veridium[112] tokenises carbon offset credits using the Stellar blockchain. This token is backed by a basket of different carbon assets verified by third parties according to international standards. Veridium works with IBM to take advantage of their expertise in industry-specific DLT networks, particularly those it has developed for the energy sector, where companies also happen to be looking to offset their carbon emissions.

4.4.4. Transportation

The two major trends observed in the transportation DLT ecosystem are the enabling of a wider distribution of electric cars and the increase in the usability and reach of a low-carbon public transportation system, including a shared mobility system.

Electric cars powered by renewable energy sources are seen as a major contributor to decarbonisation. DLT actors working on electric car challenges have a lot of commonalities with energy DLT actors and often work together.

A study by the International Transport Forum at the OECD[113] found that shared mobility can greatly reduce GHG emissions by up to 40 percent and reduce the need for vehicle material, without requiring any change of vehicle technologies. "Likewise, congestion would strongly decrease leading to greater traffic fluidity in vehicle mileage (30 percent reduction).) Additionally, [due] to the savings due to higher vehicle occupancy, under all tested scenarios, vehicles are used much more intensely than before – rising from approximately 50 min to 12 h per day and daily travel will increase from approximately 30 kilometers to nearly 250 kilometers. This will reduce operating life-cycles and with it allow for a quick renewal of fleets and thus a younger and environmentally cleaner fleet on average."[113]

Transportation DLT example: Share&Charge
Share&Charge[114] is an open network enabling mobility companies to offer a seamless, secure and smart charging experience. Furthermore, their DApp allows for private charging stations to participate in the network and the network could thus be considered like the "Airbnb of Charging Stations".

In May 2017, Share&Charge launched in Germany with what it says is the first deployment of DLT technology around e-mobility providing a registration platform for electric car owners and charging station operators. Additionally, they are currently running pilot projects in the UK and California.

Transportation DLT example: Open Mobility System (OMOS)
OMOS[115] is working on an open platform similar to the Energy Web Foundation's platform (see chapter 4.4.1), that aims at interconnecting existing and potentially new transportation providers (trains, public transportation, car renting companies, taxi, private car sharing, bicycles, etc.) and DApp (booking agents, insurance streaming, etc.) developers on one platform.

OMOS aims at building an open system that will not create lock-in effects and information monopolies. Rather, it encourages creative and fair competition within a communal and democratically governed digital transaction infrastructure. Furthermore, it should allow a high level of data sovereignty for customers and companies. It facilitates secure, controlled, use-case-specific, and real-time data sharing. The system should also encourage participants to co-create with one another and thus leverage the expertise and skills of people and companies from around the globe.

4.4.5. Other climate action

This sub-group contains actors that primarily focus on bringing climate-positive initiatives through DLT to market, but do not fall into any of the other DLT for climate use cases. It includes actors that incentivise recycling, reducing emissions, and more climate friendly behaviour in general.

A noteworthy type of use case in the "other climate action" sub-group is forestry. The UN's programme for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) was launched in 2008 as a measure to distribute income from those who had most benefited from the exploitation of forests, to those who needed funds to counter balance the loss of leaving the remaining forests untouched.

However, one of the largest barriers to the diffusion of REDD+ has been an inability to set up credible financing mechanisms and a lack of trusted MRV systems. DLT offers key features to solve these problems.

Forestry DLT example: Gainforest

Gainforest[116] fights rainforest deforestation by rewarding and empowering caretakers with a system based on a DLT system and a suite of AI-powered conservation tools. Caretakers take responsibility for ensuring a certain patch of the Amazon is protected against deforestation. To do that, they stake an amount of money. After a conservation period and the forest still stands (verified by satellite), caretakers get the back their initial stake plus a reward. The reward is paid for by donors.

Other climate action DLT example: Regen network

The Regen Network[117] was conceived of as a balance sheet for the earth. It is a community of actors engaging with ecological regeneration, ecological measurement, verification, distributed computing and technology development. Network members track specific changes of land, oceans and watersheds. By improving the understanding of the ecosystem and enabling rewards for verified positive changes, Regen Network catalyzes the regeneration of the earth's ecosystems.

Other climate action DLT example: Poseidon

Poseidon's[118] DLT-based platform makes purchases climate positive by empowering users to participate in climate action. It links climate-negative purchases to an equally climate-positive carbon credit, which creates an immediate offset.

4.4.6. Open government

Open Government actors want to increase overall transparency and accountability of public leaders and agencies and by doing so create a more inclusive society. These actors are listed in this map as it is assumed that this will improve public climate change perception and action.

Open government example: Bitnation

Bitnation[119] (is the world's first Decentralised Borderless Voluntary Nation (DBVN). Bitnation started in July 2014 and hosted the world's first blockchain marriage, birth certificate, refugee emergency ID, World Citizenship, DBVN Constitution and more. The website proof-of-concept, including the blockchain ID and Public Notary, is used by Bitnation Citizens and Embassies around the world.

4.4.7. Philanthropy

Philanthropic actors want to increase transparency and accountability, which could improve the effectiveness of donations and might even increase donations overall due to improved public perception. DLT could allow tracking of whether donations were used for their intended use, allow the release of donations only upon reaching specific goals via smart contracts, allow micropayments without going through intermediaries and thus saving on the costs of these.

Philanthropy DLT example: BitGive

BitGive's[120] flagship project GiveTrack is a donation platform for nonprofits to provide transparency and accountability to donors by sharing financial information and direct project results in real time.

4.4.8. Measurement Reporting and Verification (MRV)

An overarching theme across DLT for climate action use cases is Measurement Reporting and Verification (MRV).

When it comes to climate action, effective measurement, reporting and verification (MRV) is critical in taking and assessing climate action. Furthermore, MRV is central to effectively implementing the Nationally Determined Contributions (NDCs) submitted under the Paris Agreement, which describe countries' mitigation goals and policies.

"Measurement" is needed to identify emissions trends, determine where to focus greenhouse gas (GHG) reduction efforts, track mitigation-related support, assess whether mitigation actions planned under NDCs or otherwise are proving effective, evaluate the impact of support received, and monitor progress achieved in reducing emissions.

"Reporting and Verification" are important for ensuring transparency, good governance, accountability, and credibility of results, and for building confidence that resources are being utilised effectively.

In the context of climate action, there are three main types of MRV as noted by the World Resources Institute[121].

- MRV of GHG emissions, conducted at national, organisational, and/or facility level to understand an entity's emissions profile and report it in the form of an emissions inventory.
- MRV of climate actions (e.g., policies and projects) to assess their GHG effects and sustainable development (non-GHG) effects as well as to monitor their implementation.
- MRV of support (e.g., climate finance, technology transfer, and capacity building) to track provision and receipt of climate support, monitor results achieved, and assess impact.

DLT, especially in combination with IoT and AI, is an optimal tool to automate and improve the effectiveness of MRV in the climate action ecosystem.

Many of the described DLT for climate action use cases in some way improve MRV of existing systems and by that allow better resource allocations and enable additional investments in climate action.

4.4.9. Climate finance

The overarching MRV theme (see chapter 4.4.8) observed in all identified use cases, also enables better ways for climate finance as it increases availability, trust and transparency in finance.

As Alastair Marke, the founder of the International Core Group on Blockchain Climate Finance, and Bianca Sylvester, an associate director at the Clean Energy Finance Corporation note:

"The Paris Agreement alone represents a USD 23 trillion green investment market between now and 2030. The emerging demand for green investment requires significant investment in social capital – the networks of "trusting" relationships among investors and enterprises that facilitate finance flows to climate/ green projects. Despite green finance being a priority in many governments' agendas, it has not been developed at a pace expected because: (a) the cost of developing green finance products (e.g. green bonds) is higher than traditional ones; (b) information asymmetry is greater; and (c) third-party certification and regulatory system have been inadequate. These are exactly the pain points to which DLT technology can provide innovative, far reaching solutions. Its key features – distributed data, cross-sector process cooperation, and low-cost third-party certification platform – could turbo-boost global climate finance and green investment"[122].

4.5. Barriers to DLT for climate action adoption

Barriers predominant in DLT	Barriers predominant at intersection of DLT and "climate-relevant industries"	Barriers predominant in "climate-relevant industries"
▪ Business model uncertainty ▪ Technological barriers and uncertainties ▪ Shortage of DLT talent ▪ Neglect of combination with IoT and AI ▪ Internal disputes ▪ Shady image	▪ Poor collaboration ▪ Start-up challenges on steroids ▪ Laws & regulations	▪ Lack of DLT knowledge ▪ Lack of vision for DLT projects ▪ Resistance to change by DLT

Table 7: Main DLT for climate action barriers, grouped by predominance in either the DLT community, in "climate-relevant industries", or at their intersection.

The investigation of the barriers to the further adoption and diffusion of DLT for climate action solutions and industries identified 12 main barriers. These barriers have been found to be either predominant in the DLT community, at the intersection of DLT and "climate-relevant industries" or in "climate-relevant industries" (see Table 7).

Barriers are organised into three layers (see Table 7). On the first layer, barriers are assigned as being predominant either in DLT, at the intersection of DLT and "climate-relevant industries" or in "climate-relevant industries" ("climate-relevant industries" refers to industries that are relevant to climate action [see Figure 13]). On the second layer, barriers are grouped into main barriers, while the third layer shows further aspects of these barriers.

Many of the DLT for climate action actors (see Figure 9 and Figure 10) work on overcoming these barriers. However, from the qualitative research and interviews with stakeholders it seems that the barriers at the intersection are the least deliberately worked on. These intersection barriers require an understanding of both the DLT community and the "climate-relevant industries". Overcoming these barriers is a task of coordinating effective collaboration, translating between the different jargons and educating both sides about each other's needs and capabilities.

Furthermore, as DL technology is still young, technological barriers and uncertainties are a major barrier, especially for climate-relevant applications that rely on the underlying technology as an enabler for their application. For example, to be an effective tool for many of the discussed use cases, Ethereum would need to scale its current transaction throughput (20 transactions per second) to compete with traditional systems (e.g. Visa can handle up to 24,000 transactions per second).

The relevance of the found barriers varies depending on specific industries, problems and geographies. For example, on the international level energy DLT projects are well supported by the industry (e.g. in the energy industry, EWF (see chapter 4.4.1) has created an international consortium of 46 companies including some of the biggest energy actors like Shell and Eon. However, the support of the energy industry on a more regional level, like that of the local distribution system operators, is rather low and companies are rather skeptical of DLT solutions).

The findings are based on observations from interviews, workshops, conferences, reports and articles (see chapter 8.1). While the list of barriers has been created to give the broadest possible sense of the ecosystem, it does not claim completeness.

4.5.1. Barriers predominant in the DLT ecosystem

4.5.1.1. Business model uncertainty

Many DLT initiatives, including those aimed at climate action, are built around a native cryptocurrency (see chapters 1.1, 3.4.9 and 3.5.3), they work as a platform (e.g. Energy Web Foundation as described in chapter 4.4.1) and are often run by a foundation (e.g. Ethereum is run by the Ethereum Foundation). For the foundations and developers of these systems, it is often unclear or not validated how they will earn an income.

Some approaches to monetising DLT platforms are discussed and elaborated among the community already[123]. However, a large part of early-stage projects run without a clear and/or validated monetisation strategy (as "traditional" start-ups like Google, Facebook and Twitter did as well). This is mostly a barrier for institutional supporters to enter that space, because it requires a leap of faith that the project will eventually be financially sustainable.

4.5.1.2. Technological barriers and uncertainties

DLT is still in the infrastructure stage (see chapter 4.3) and there are many unsolved technological challenges. DLTs run on and are governed by protocols. DApps run on top of these protocols (see chapter 3.3.4). These protocols are still developing, transforming and competing against each other. This is especially difficult for DApps because they rely on the underlying technologies, i.e. protocols, as enabling tools for their business model.

In the context of climate action, most projects are building DApps and standard business processes around these DApps. Also, the feasibility and disruptive potential of these DApps depends on their underlying protocol's ability to solve the technological challenges described below.

Scaling

DLTs suffer from a trilemma, that states that a DLT system can only at most have two of the following three properties: decentralisation, scalability and security[123].

Bitcoin and Ethereum were built around the idea of sacrificing scalability for decentralisation

Network	Transactions per second
Bitcoin	7
Ethereum	20
Dash	48
Litecoin	56
Bitcoin Cash	60
PayPal	193
Iota	600
Ripple	1,500

Sources: [127,128]

Table 8: Transactions per second comparison of decentralised and centralised services.

and security. There are projects sacrificing decentralisation or security for scalability (e.g. Ripple). Transaction speeds of DLT solutions are currently not competitive with centralised services. In the same vein, transaction fees are higher on DLT-based systems[125].

Scalability is a major barrier to further adoption of DLT and one of the main development topics in the DLT community. The three main scenarios regarding scalability are, that (1) the communities with the largest network effects and developer mindshare (i.e. Bitcoin and Ethereum) will solve scalability, (2) new networks emerge that are fundamentally built to be scalable and users gravitate to them (e.g. Iota) or (3), DLT networks don't scale[126].

Scalability developments are very important and touch on issues regarding governance, incentives, energy consumption as discussed below. Interested readers can find more information about scalability issues and potential solutions here:

- Introductory: "Blockchain Scalability: The Issues, and Proposed Solutions"[129]
- Intermediate: "On the Scalability of Blockchains"[126]
- Intermediate: "The State of Scaling Ethereum"[130]

- Advanced: "Sharding FAQ on Ethereum GitHub wiki"[131]

Decentralised governance in a centralised (physical) world
DLT's main power lies in decentralisation (see chapter 3.4). It currently is unclear how the physical centralised world can be decentralised. Not only is it a question of resistance by central authorities (see chapter 4.5.3.3), it is also a question of how to design a system that might require control (e.g. the electricity network is mission critical, especially hospitals, for example), and how to handle the oracle problem (see chapter 3.3.3). As many climate action solutions are more valuable when synchronised with the physical world, this barrier is a key barrier to overcome.

EWF (see chapter 4.4.1) is currently pioneering work in this field in their decentralised energy market design[132]. However, it will take time to validate if their approach is suitable to bring decentralisation to the centralised physical energy world.

Incentive structures
Creating sustainable incentive structures that solve a specific problem is a key challenge of the DLT ecosystem. As incentive structures also play a large part in climate action, this topic is relevant to climate action specifically.

In the process of designing incentive structures, the following questions need to be answered:

- What gives the data finality?
- How can you ensure that the rewards are aligned with the network goals?
- Why do nodes keep or update data and what makes them choose one piece of data over another when they are in conflict?

These incentive questions need good answers and they need to be aligned not just at the inception of a DLT solution, but at all points in the future as technology and companies change. Furthermore, as the development of DLT systems is stricter and slower than in traditional IT systems (see chapter 3.5.2), it is crucial to design sensible systems from the beginning.

Incentive systems are notoriously difficult to design[133]. Mechanism design is a sub-discipline of economics dedicated to studying how to design protocols that incentivise rational actors to behave in socially desirable ways[134].

Energy consumption
Bitcoin, Ethereum and most altcoins run on Proof-of-Work consensus algorithms that consume a lot of electricity (see chapter 3.7). To credibly and sustainably use DLT as lever for climate action, energy efficiency must be improved. This barrier is an interrelated technological problem, where the Sybil control mechanism (see chapter 3.3.1.4) plays a crucial role.

In the absence of future energy efficiency improvements, the trade-off between high energy consumption for higher levels of decentralisation is a key question in the DLT for climate action ecosystem and needs to be addressed for each potential DLT solution. For some DLT projects it might be worth expending the energy, for others not (see chapter 3.4.11).

Centralisation within decentralised networks
DLTs like Bitcoin and Ethereum are the most decentralised networks that were ever created. However, Bitcoin and Ethereum are still quasi-controlled by central actors[135].

Centralisation in decentralised networks is achieved by one of three options options (centralisation of mining equipment manufacturing, of mining power [i.e. hash power] or of governance), which are described below.

Centralisation of mining equipment manufacturing
Most mining software is run on ASICs (Application-Specific Integrated Circuit) or GPUs (Graphics Processing Unit). ASICs have a much higher efficiency than GPUs, but as they are application-specific, can mine only one cryptocurrency. GPUs can mine several different cryptocurrencies[136].
GPU mining chip manufacturing is dominated by NVIDIA and AMD. ASIC chip manufacturing is dominated by Bitmain[137]. Furthermore, Bitmain

also manages and controls the two biggest Bitcoin mining pools BTC.com and AntPool, accounting for 40.6% of the Bitcoin mining power[138].

Many DLT developers see ASIC and Bitmain dominance as a threat to decentralisation and are developing plans to make ASIC equipment obsolete (e.g. Monero hard fork[139]). Other projects like Ethereum want to move off Proof-of-Work which also makes mining equipment largely obsolete[140].

Centralisation of mining power

Currently, the top 4 mining operations control 60.9% of Bitcoin's mining capacity[141], in Ethereum the top 4 mining operations control 71.5%[142]. Furthermore, 56% of Bitcoin nodes and 28% of Ethereum nodes (not all nodes engage in mining) are located in data centres, which might indicate that these networks are more corporatised than assumed. In the case of Ripple, a privately-owned company oversees the distribution of coins and still holds more than half of all in existence[135].

Centralisation in governance

Bitcoin is an open-source project. Open-source projects largely fall into two types of governance: "democratic-organic" or "autocratic-mechanistic". The former is a "meritocratic governance system". The latter, instead, has no formal governance structure, only implicit, with the project often relying on a "benevolent dictator." As researchers from Harvard University and ParisTech note, "Bitcoin definitely falls into the second category."[143]. Furthermore, they note: "There is a discrepancy between those who can provide input to the project (the community at large) and those who have the ultimate call as to where the project is going. Indeed, while anyone is entitled to submit changes to the software (such as bug fixes, incremental improvements, etc.), only a small number of individuals (the core developers) have the power to decide which changes shall be incorporated into the main branch of the software."[143]. Additionally, miners have vetoing power in that they can refuse to run updated code. Users have vetoing power in the form of exiting the system (see chapter3.4.8). Any group that is not willing to support updates or wants to force updates, has the opportunity to hard fork the code and apply its own features, as has happened with e.g. the Bitcoin Cash hard fork[144]. While other DLT projects suffer from similar issues, they mostly formalised governance in especially created foundations (e.g. Ethereum foundation).

In Ethereum, there currently is a hot debate about EIP 867[145], a proposal to standardise the process of recovering funds on the platform. Recovering fund on the platform would in effect mean, that a centralised agent can rewrite historic transactions if they serve the greater good of the network. This goes against the principles of decentralisation and immutability but solves the problem of cybersecurity (see chapter "Cybersecurity and custodianship" below). The debate stems back from the DAO hack in 2016, when Ethereum developers decided to give victims their funds back[146]. The controversial decision lead to a hard fork of Ethereum into Ethereum (where the DAO hack has been reversed) and Ethereum Classic (where the DAO hack has not been reversed).

Furthermore, Ethereum suffers from deeper technical centralisation trends caused by its block size[147] and developments around sharding[148].

User experience

The climate and societal impact envisioned by DLT for climate action will only be realised when DLT is widely adopted. User-centric design that creates intuitive user experience (UX) is essential to drive adoption and success of companies (Design-driven companies have outperformed the S&P 500 by 228% over ten years[149]). Thus, UX design will ultimately have a big impact on the widespread adoption of DLT-based solutions.

"User experience (UX) design is the process of creating products that provide meaningful and personally relevant experiences. It focuses on the design of both a product's usability and the pleasure users feel when using it. Aside from usability and desirability, it is also concerned with the entire process of acquiring and interacting with the product. Including aspects of branding, visual design, and function."[150].

Today, UX of DLTs is cumbersome and complicated, especially compared to incumbent services (see Figure 15). Just like the cloud is not the product, nor

is DLT. A product needs to be focused on delivering value to or solving a need for real people and organisations – financial transactions, energy trading, supply chain, tracking IoT devices, etc. DLT just happens to be the underlying technology to enable the required product features[150].
DLT-based products need to be able to compete with incumbent services. To do that, these key challenges need to be solved.

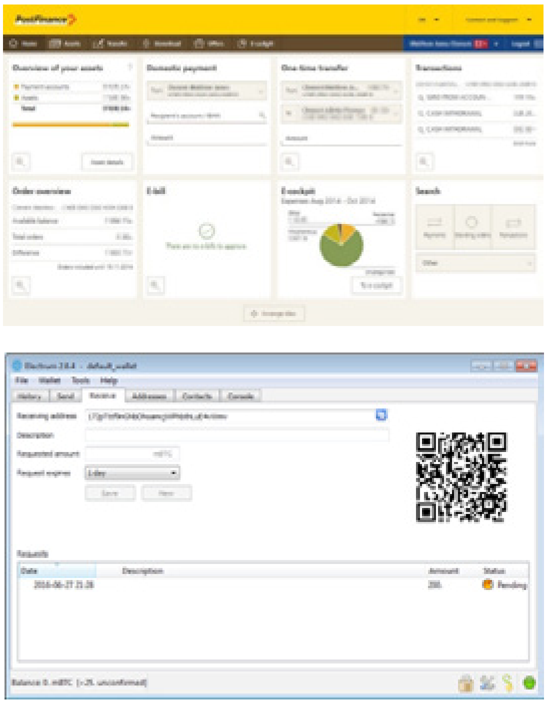


Figure 15: UX comparison between a financial incumbent service (Switzerland's Postfinance[151] ebanking site) and Electrum[152] (one of the most widely used Bitcoin Desktop wallets).

- Immutability: erroneous and malicious transactions cannot be reversed (see chapter "Cybersecurity and custodianship" below), which places a huge burden on users.
- Forgetting passwords: only users know their passwords. If users forget or lose their password, there is no way to access the account anymore (see chapter "Cybersecurity and custodianship" below), which also places a huge burden on users.
- Transaction times & feedback: users are used to instant feedback of transactions (via email or notifications). In DLT-based systems, transaction confirmations take up to 60 minutes (see chapter "Scaling" above). Users need transparent and trustworthy feedback about transaction status.
- Usability: many DLT systems are designed by engineers for engineers, making navigation too complicated for average users.

Cybersecurity and custodianship

Decentralised systems require that each network participant manages its own account through a private key (see chapter 3.4.2). Consequently, this means that each user is fully responsible for protecting the private key and using the key without errors. The implications of private key protection and management failures are[153]:

- Private key lost/forgotten: access to funds is gone forever. No one can retrieve the funds anymore. It is estimated that 3.79 million bitcoins (23% of total bitcoin supply) are lost forever[154].
- Erroneous transaction: if a rightful private key owner makes an erroneous transaction (by e.g. sending to a different address), there is no way to get the funds back.
- Private key hacked: the hacker has full control over the funds and will most likely steal everything. The funds are gone forever, there is no police or other central authority to get the money back, unless the hacker can be personally identified.

Depending on the climate action application, these cybersecurity requirements can manifest in different forms. For example, in the energy industry an error by a wholesale energy trader could lead to the loss of millions of USD to an unknown address, decreasing the financial stability of the company and even disrupting energy supply. Technologies like multi-signature transactions could alleviate some of these problems[155].

As billions of IoT devices are set to be managed on DLT systems (see chapter 3.4.10), where each device has its own private key, custodianship becomes more important. Custodianship and multi signature transactions are equally important if large fund managers (e.g. pension funds) are expected to enter the crypto market.

4.5.1.3. Shortage of DLT talent

The whole DLT ecosystem needs talented coders and product managers, especially to solve technological uncertainties (see chapter 4.5.1.2) hindering further diffusion.

Driven by the hype and the expanded set of use cases, the demand for DLT talent has risen dramatically (e.g. 6000% demand increase in Q1 2018 makes DLT development the hottest skill in the job market today[156,157]).

Coding DLTs is relatively simple for experienced developers as coding approaches, languages and architecture are similar to traditional IT environments. The top skills demanded by most positions are[158]:

- Hyperledger Fabric
- Ripple
- Solidity (Ethereum programming language)
- Multiple programming languages: C++, Python, JavaScript
- Cryptography
- Networks
- Cybersecurity

However, there is still a stark shortage of DLT talent overall[159] and finding good talent is hard[160]. Furthermore, the DLT for climate action ecosystem suffers even more from this shortage, as many developers gravitate to industries that are perceived to be more lucrative and/or famed. This cause is heavily linked to the general perception that climate change is framed as a problem rather than an opportunity.

Finding a good DLT developer is a challenge. They're busy, they're rich[161] and they're idealistic. They neglect their LinkedIn page, stand oblivious to job postings, are not interested to move to the cities with high demands (San Francisco, London, New York, Berlin and Singapore[158]) and are obsessed with their own vision and mission. However, good DLT developers exist, but it might require walking an unconventional path to find and recruit them[160].

4.5.1.4. Neglect to combine with IoT and AI

DLT is a crucial part of the technology triangle discussed in chapter 3.4.10. Many DLT projects lack the vision, funds, knowledge or collaborators to make use of the synergies among these technologies. As for the reasons discussed in chapter 3.4.10, combining all three technologies can unlock much more potential.

However, there are also projects that treat the three technologies in combination and can thus create powerful solutions. For example, EWF's origin DApp (see chapter 4.4.1) includes sensory data from power plants, feeds the data on EWF's distributed ledger and allows analysis through machine learning. Interestingly, EWF sells the "DLT" part of their solution heavily, which shows that DLT currently is seen as a bit of a sliver bullet when it comes to marketing. Projects using DLT, Blockchain or AI generally raise more awareness and sometimes it is even enough to raise funds, even if the project is pointless (e.g. FitVitalik[162]).

4.5.1.5. Internal disputes

The DLT community is host to many disputes: coin maximalists (e.g. "Bitcoin Cash is the only true DLT!"[163]) fight for their opinion, infighting leads to community separations (e.g. the Bitcoin Cash hard fork[144] and feuds on Twitter).

The resources spent on infighting would be better spent advancing projects and educating incumbents about the implications and opportunities of decentralisation (see chapters 3.4 and 3.4.11).

4.5.1.6. Shady image

DLT suffers from a predominantly negative public image which hinders further adoption and investment in the ecosystem. While DLT can have both negative or positive outcomes, fair and balanced discussions are rare in public media, industry media, climate action industries and within the DLT community itself.

The shady image is caused by actual scams (e.g. ICO exit scams[164] hacks (e.g. Mt. Gox Hack[59]), past criminal activities (e.g. Silk Road[165]), uninformed public discussions (see chapter 4.5.3.1), uninformed (e.g. Warren Buffet[166]) or ill-intended (e.g. Jamie Dimon[167]) public statements.

Many of the climate-positive development will happen through connecting DLT with the physical world (see chapter "Decentralised governance in a centralised (physical) world" in chapter 4.5.1.2). As such, these developments need support from decision-makers in the climate-relevant industries and positions. Without their support, DLT-based solutions will not have access to underlying infrastructure. It is therefore crucial, that these decision-makers can make positive decisions without being scrutinised for supporting shady actors.

4.5.2. Barriers predominant at the intersection of DLT and "climate-relevant industries"

4.5.2.1. Poor collaboration

Difficulties combining DLT with industry insights: Creating real added value with a realistic shot at disruptive innovation requires deep understanding of a specific industry and its problems and, at the same time, a fresh set of eyes to propose solutions based on new technological capabilities gained from DLT. In the DLT for climate action ecosystem, creating this combination is challenging, costly and not many actors have yet achieved it. In the "entrepreneurial activity" function the wrong start-ups are built and invested in. Hence, many DLT projects do not solve industry needs. While DLT-community-driven initiatives are often disruptive in their design and make use of the full potential of the technology, they often lack industry-specific knowledge (trends, problems, rules of the game) or partners to create real value-adding solutions.

Furthermore, both fields (climate action and DLT) are perceived as big risks on their own, so developing at or investing in the intersection is perceived as an even bigger risk, that most people and organisations shy away from.

Poor collaboration within the DLT for climate action community

Many actors in the DLT and DLT for climate action ecosystem are poorly connected with each other or do not want to collaborate, especially actors who work on similar projects.

Sooner or later interoperability protocols will force collaboration by enabling seamless conversion from one DLT system to another. However, it will take time until these interoperability protocols are up and running, and in the meantime the DLT for climate action would greatly benefit from better collaboration to coordinate tasks and create more specific and value-adding niches.

The lack of collaboration and learning becomes more apparent as the DLT for climate action ecosystem is steadily growing and many initiatives focus on startup building. Initiatives often have large overlapping areas of work (e.g. SolarCoin[168] and KWHCoin[169]) are basically the same, a tokenised version of a kWh of green electricity), and it is often not clear how they differentiate from each other. Instead of many projects doing the same thing, similar projects could develop solutions that contribute to each other and create systems where the complete system is more valuable than the sum of its parts.

DLT developers have limited interest in climate action

To many DLT developers (entrepreneurs and coders) climate change is not the most interesting issue. Moving climate action higher up on the priority list would unlock a lot of resources and talent to bring about the change that is needed to reach the 2°C goal.

While most developers know about climate change and believe in its existence, they are seldomly aware of the economic opportunities, the extent of the threat and the expected time horizon to reaching 2°C (see chapter 2). Informing developers could be one lever to alleviate this barrier. One cause is that climate action is often framed as a problem that, if you are a socially conscious person, you should try to solve. While this guilt motivated pitch works for some people and organisations, it fails to attract enough momentum to reach the 2°C goal.

This suboptimal perspective is often shared by many non-DLT companies and some of the biggest GHG emitters, that see climate as an economic burden and a threat to their existence. This leads to unnecessary resistance. Most people are "good people" and want to contribute to a positive society, but with this perspective, investing in climate action is a risk to an individual or organisation's existence.

Climate action is one of the major economic opportunities of this century: the estimated cost of meeting the 1.5°C target is USD 0.5 trillion, while the savings are expected to be USD 30 trillion[170].

4.5.2.2. Start-up challenges on steroids

Building initiatives in DLT for climate action is essentially start-up development on top of an ever-changing technological foundation. Start-ups are always challenging. Frameworks (Lean Startup), supporting entities (incubators, VCs) and platforms (e.g. AngelList[171], crowdfunding) address many challenges, but still 60% of start-ups fail[172].

The main reasons for start-up failure are a missing product-market fit, funding, team and poor execution[173]. These reasons also apply to the DLT for climate action ecosystem.

Apart from these general startup challenges, DLT startups face highly dynamic technological developments and high costs linked to the IoT, DLT and AI technology stack.

Highly dynamic technological developments in DLT

The rate of technological developments is high and it is impossible to keep track of all trends[174]. Certain developments have far-reaching consequences and might make initial project plans obsolete. For example, Directed Acyclic Graph by IOTA[20] and Hedera hashgraph[21] are more scalable, have lower or no transaction fees and use less energy than "traditional" DLT systems based on blockchain type ledgers (see chapter 3.3.1.1). Upcoming developments like interoperability protocols (e.g. Polkadot[175]) and sharding on Ethereum will also have consequences that are hard to predict at present.

Many of the current technological uncertainties, such as scaling (see chapter 4.5.1.2), have multiple different solutions that are being worked on. Ethereum currently has four individual, non-mutually-exclusive scaling proposals[130]. Building business models on this dynamic technological landscape is hard.

The costs of IoT, DLT and AI management

Effective DLT for climate action solutions need to work within the technology triangle of IoT, DLT and AI (see chapter 3.4.10). Managing all three technologies, or just keeping track of their developments challenges a team's skills and resources. While some teams have resources to deal with this internally or rely on partners, the majority do not have these resources and thus cannot deal with it effectively.

4.5.2.3. Laws & regulations

While DLT regulations start to take shape on an international and national level, the following top challenges remain unanswered[176,177,178].

- How to classify cryptocurrencies? Traditionally, regulators classify assets as either a security or a commodity. For now, it seems that the general view is that cryptocurrencies form a new asset class.
- How to treat Initial Coin Offerings (ICOs)?
- How to tax cryptocurrencies?
- How to deal with AML and KYC requirements?
- How to regulate decentralised and thus uncontrollable cryptocurrencies?

Apart from these DLT-specific regulatory uncertainties, there are also regulatory uncertainties in the industries that will be affected by disruption from DLTs. For example, is it unclear how energy regulators will respond to the emergence of trading in the energy distribution network (grid codes were created under the assumption that the distribution network is used for wholesale trading only[179]). Regulation in these affected industries need to be smart to foster climate action without risking adverse societal effects.

While there is a general lack of clear and smart DLT for climate action requirements being communicated to policy makers, there are regulators who proactively engage in the discussion. For example, Chile's energy regulator wants to use DLT to check how energy data are complying with the country's renewable energy law[180].

As Prof. Dr. Knut Blind from the Chair of Innovation Economics at TU Berlin notes: "Regulatory framework conditions have been identified as important factors influencing the innovation activities of companies, industries and whole economies. However, in the empirical literature, the impacts of regulation have been assessed as rather ambivalent for innovation. Different types of regulations generate various impacts and even a single type of regulation can influence innovation in various ways depending on how the regulation is implemented."[181].

As Kevin Werbach, associate professor of legal studies and business ethics at The Wharton School notes: "Regulating nascent technologies requires a balanced approach that fosters innovation and reduces harm to society. Just as in the dotcom era, the policy debate has become a fight over whether new enterprises should be regulated under the old regime or left unregulated, despite the problems of such artificially sharp divisions. The oft-repeated mantra that law and regulation move more slowly than technology should not be the end of the discussion. The celebration of innovation also should not obscure that law exists to protect core societal values precisely because values generally do not change. Between ill-fitting legacy regulations and none at all, targeted compromise facilitated by the eager participation of a proactive government is the best strategy for navigating the controversies produced by DLTs."[182].

Within the DLT ecosystem, approaches to regulation develop fast, and encompass various topics from monetary policy, security and exchange law, to financial crimes, taxation, and treasury.

Regulation is often seen as bad by innovators and it is especially true in the DLT community, as the community was born from the cypherpunk movement, which is anti-governmental. However, for a surprising amount of time it was government action facilitating innovation, and the emerging start-ups pushing for that government intervention to help create a more innovative marketplace (e.g. the Federal Communications Commission in the 1990s deliberately left open the door for Voice over IP and helped services like Skype, which was illegal in most countries at that time, to develop, or the antitrust case against Microsoft that allowed start-ups to innovate software on the PC[183]).

Additionally, DLT investors are in need of regulation, as the industry is plagued by multi-million dollar ICO exit scams (e.g. Pincoin token ICO team raised USD 660 million and then disappeared[184]), Ponzi schemes (BitConnect going from a USD 2.6 billion market cap to USD 22 million in 30 days, to now USD 4.7 million after Class Action and abruptly shutting down[185]), Hacks of exchanges (in the Mt. Gox hack 850,000 bitcoins, worth at the time USD 450 million – now USD 5.5 billion – were stolen[58]), pump and dumps (e.g. SaluS (SLS) token pump and dump on Bittrex of 950% within 20 minutes[186]), and Twitter scams (e.g. ETH giveaway scams tricked people out of USD 4.3 million[187]).

4.5.3. Barriers predominant in "climate-relevant industries"

4.5.3.1. Lack of DLT knowledge

Lack of knowledge and understanding in affected industries

Many industries and GHG emitters will be affected and possibly disrupted by new technologies. DLT is one of those technologies, and so are IoT and AI. While DLT is surrounded by a lot of hype (even though the hype is decreasing since February 2018), which generates media coverage and exposure to DLT and the benefits of decentralisation, the information is mostly superficial, trivialised and overly bearish or bullish.

DLT is a new set of technologies which brings about many technological, economic and societal implications (see chapters 3.4 and 3.4.11). Understanding these concepts and applying them to one's industry and experience is hard work and takes time.

While some industry actors are early DLT movers, still a large portion of actors remain at the superficial and bearish level. For example, in the energy industry, EWF (see chapter 4.4.1) has created an international consortium of 46 companies including some of the biggest energy actors like Shell and Eon. However, the support of the energy industry on a more regional level, like that of the local distribution system operators, is rather low and companies are rather skeptical of DLT solutions.

While the uneven distribution of knowledge is generally unfavourable, it is especially adverse in the case of industry groups and in industry media.

Lack of understanding in industry groups

Industry groups and lobbies often act as defenders of the status quo. It is not surprising that lobbying organisations do not fully recognise and advocate for a more inclusive approach to disruptive technologies like DLT.

For example, while the International Energy Association (IEA) recognises the potential of digitalisation in the energy industry and supply a sensible tech trend analysis, the report still falls short of giving bold recommendations and recognising the disruptive potential of DLT[188].

Lack of understanding in media, industry media

Traditional media houses are still relevant influencers of opinions and the general direction of public discussions. As media groups remain superficial in their DLT knowledge, their articles are mostly either aggressively positive or negative.

Many DLT projects do not need DLT

Many DLT projects do not require DLT (see chapter 3.6). In many instances, centralised databases with access controls offer the same functionality needed by these projects, but at a fraction of the (see chapter 3.5.1).

While technologically DLT is not needed, these proposed IT solutions might still add considerable value, even with centralised databases. This is especially the case if IT projects aim at upgrading industries that have old and inefficient infrastructure, such as in the financial and energy industries.

For these types of projects adding "DLT" or "blockchain" to the marketing mix adds value by increasing visibility and potentially helps selling these projects more easily. However, this is a practice that should be questioned.

4.5.3.2. Lack of vision for DLT projects

Lack of top management vision & support

While the people working in DLT initiatives and innovation teams usually understand the technology and its implications, large parts of their organisations, especially in the executive level and board, are unaware or wholly dismissive of DLT and decentralisation and the implications it has. As pilot projects and field tests move to the next phase, this situation constitutes a strong barrier to further DLT dissemination.

Industry projects do not make full use of DLT
Industry-driven projects often miss the disruptive potential of DLT, or more specifically the power of decentralisation (see chapter 3.4). These projects then typically run on a private DLT network and are controlled by the project developer. However, while omitting decentralisation as a feature renders the reason to apply DLT in the first place useless, it might be a deliberate act to defend an incumbent's position.

Industry demand is not articulated well enough
While the DLT community lacks industry knowledge or might not be willing or capable of gaining DLT knowledge, the industry communities do not have well-articulated demands to DLT developers. Consequently, it is not clear for DLT developers which are the main problems in need of solutions.. While most industries have interest groups that could enable that discussion and communicate demands, they often lack DLT knowledge to formulate sensible demands.

4.5.3.3. Resistance to change by DLT

Resistance to innovation from incumbents
Resistance to or the inability to embrace innovation by established corporations is well documented (e.g. Blackberry and Apple[189] or Google[190]). Some of the key characteristics hindering innovation in incumbents are: confidence in status quo, a sense of invincibility, fear of risk-taking and a focus on competitors, not customers.

Just as there is general resistance to innovation by incumbents, there is also resistance to DLT, even though many incumbents need to be transformed to ensure sustainable and ambitious climate action.

As discussed in the chapter "Decentralised governance in a centralised (physical) world" (see chapter 4.5.1.2), implementation speed and outcome of DLT for climate action also depend on the cooperation with the owners of the physical assets (e.g. electricity grid) that DLT aims to transform. Resistance from asset owners constitutes a big barrier to DLT adoption.

Resistance once DLT's decentralisation implications are clear
Consequent implementations of DLT, namely public chains, are decentralising existing systems at the cost of power concentrating actors and might remove control over a system by a central agent (see chapter 3.5.4).

Once an actor who currently has power understands these implications, it seems logical to start actively fighting further public DLT developments.

Since the financial industry is the furthest along in terms of adoption, this is also where most resistance has been observed (e.g. Jamie Dimon, chairman and CEO of JPMorgan Chase, calling Bitcoin a fraud[191] or Stripe shutting down businesses that are in any way related to DLT because of their banking partners), but it happens in other industries as well. Interestingly, most critics of DLT are people who stand to lose power (see Bloomberg's "Bitcoin Bulls and Bears" list[192]).

While it is understandable that actors who stand to lose power from DLT fight its deployment, it is nonetheless a major barrier for DLT for climate action that needs be removed. Also, within the climate action ecosystem, it remains to be seen if organisations like UNFCCC and The World Bank are willing to let go of their power over finance and carbon markets for the overall system benefit.

While conserving power for the sake of conserving power is negative for society, losing all control over a mission-critical system (e.g. the electricity grid) is a valid reason of concern and ought to be addressed through developments in governance (see chapter "Decentralised governance in a centralised (physical) world" in chapter 4.5.1.2).

5. Involvement timing

Five different types of assessment have been used to determine the optimal timing to get involved in the DLT for climate action ecosystem. Table 9 summarises the findings of these different types of assessments.

Assessment type	Conclusion	Findings
Four adoption stages: single use, localisation, substitution, transformation	Now seems to be a good time to get involved.	▪ DLT is mainly in the single use phase and just recently moved into the localisation and early substitution phase. ▪ Now seems to be a good time to get involved and shape and guide these early DLT developments towards climate-friendly outcomes. ▪ Development potential lies in single, localisation and substitution use cases. ▪ Email was the driver for TCP/IP, "internet money" is the driver for DLT.
User adoption rate	Now seems to be a good time to get involved.	▪ DLT is in its early adoption phase. ▪ While adoption is increasing, valuations are probably overvalued and a crash similar to the dot-com crash is to be expected in the near future or is already going on.
Market capitalisation	Now seems to be a good time to get involved, but with caution.	▪ It is most likely that the DLT market is in its crash phase now. ▪ The crash will most likely be followed by more realistic and longer-term developments, ▪ It might make sense to limit exposure to DLT as it is currently in its crash phase.
Gartner Hype Cycle	Now seems to be a bit early to get involved.	▪ "Blockchain" moved from the "Peak of Inflated Expectations" to the "Through of Disillusionment". ▪ While expectations could still fall lower from here, long-term DLT is approaching the Slope of Enlightenment.
Benchmark with other international organisations	Now seems to be a good time to get involved.	▪ Organisations like the UNFCCC and the World Bank's Climate Change Group see DLT as a potent accelerator for climate action. ▪ Both organisations support developments and could be ideal partners to fund and/or scale solutions.

Table 9: Assessment of involvement timing based on five different types of assessment.

Overall, the assessments suggest that now might be a good moment to get involved, even though DLT for climate action ecosystem is still in its early development stage. In addition, the assessments suggest limiting risk exposure according to DLT's early stage and diversify engagements in line with the four typical technology adoption phases (single use, localisation, substitution and transformation) (see chapter 5.1.2).

Alternatively, a different approach could be to postpone engagement with the DLT ecosystem to a later phase when some of the key technological challenges have been solved and adoption rates of value adding climate change applications have increased. However, considering the following four arguments favors an engagement now rather than later:

- **Missing actor addressing intersection barriers:** The barriers at the intersection of DLT and the "climate-relevant industries" (see chapter 4.5.2) are unlikely to be deliberately addressed by any of the identified actors in the ecosystem (see chapter 4.2).
- **Climate-friendly direction:** The DLT community is already invested and developments will continue in any case. The trajectory that DLT will take is not predetermined. DLT is just a technology and as such does not have its own will. Society needs a strong actor directing the community towards climate-friendly developments. It is not only a task of using DLT for climate action, but also ensuring that DLT developments do not lead to an increased climate impact (e.g. energy consumption of mining (see chapter 3.7)).
- **Learning curve and capacity building:** Before value-added solutions can be expected, people and organisations need to gain experiences about what works, what are valuable contributions and who the potential partners are, and to increase an organisation's influence over the ecosystem[193]. Climate-KIC has started the process of acquiring technological capacity and increasing its influence over the ecosystem. Pausing that process risks resetting the progress and the gained competencies. Waiting for "perfect" environment to get involved means missing the opportunity to help shape the DLT for climate action ecosystem. To understand how DLT can address climate-related challenges both research and real-life applications are needed.
- **Linear thinking bias:** The human brain struggles to understand non-linear relationships[194], which are most often how technological revolutions behave. Short-term developments are generally overestimated, while long-term developments are underestimated.

5.1. Comparison with TCP/IP

DLT belongs to the family of distributed computer networking technology, and it is just as foundational as TCP/IP (transmission control protocol/internet protocol), which laid the foundation for the development of the internet.

Like email enabled bilateral messaging, Bitcoin enables bilateral financial transactions. "The development and maintenance of Bitcoin is open, distributed, and shared—just like TCP/IP's. A team of volunteers around the world maintains the core software. And just like email, Bitcoin first caught on with an enthusiastic but relatively small community."[9].

It is therefore sensible to compare the development of DLT with the development of TCP/IP, which is an opinion shared by many[195].

There is however a minority of people who think that this comparison does not hold true, and rather think that DLT should be compared to the telegraph instead[196]. They argue that the telegraph and Bitcoin are the first example of a new technology: while the telegraph was the first telecommunications technology, Bitcoin was the first distributed consensus technology.

This report focuses as on the comparison with TCP/IP, rather than with the telegraph, as these two technologies resemble each other more, especially with regard to their effect on decentralisation.

5.1.1. The history of TCP/IP adoption

The history of the Internet begins with the development of electronic computers in the 1950s. Initial concepts of wide area networking originated in several computer science laboratories in the United States, United Kingdom, and France. The US Department of Defense awarded contracts as early as the 1960s, including for the development of the ARPANET project. The first message was sent over the ARPANET in 1969[197].

The history of TCP/IP adoption, *Summarised and reformatted from original article by Prof. Marco Iansit and Prof. Karim R. Lakhani[10].*

Single use

One of the initial applications of the earliest networks, including ARPANET, was email. Email started in 1965 as a way for multiple users of a time-sharing mainframe computer to communicate. TCP/IP was introduced in 1972 and became the standard networking protocol on the ARPANET. TCP/IP gained traction in a single-use case as the basis for email among the researchers on ARPANET. TCP/IP is a protocol that allows packet switching, that created an open, shared public network without any central authority or party responsible for its maintenance and improvement.

Localisation

Traditional telecommunications and computing sectors looked on TCP/IP with skepticism. Few imagined that robust data, messaging, voice, and video connections could be established on the new architecture or that the associated system could be secure and scale up. But during the late 1980s and 1990s, a growing number of firms, such as Sun, NeXT, Hewlett-Packard, and Silicon Graphics, used TCP/IP, in part to create localised private networks within organisations. To do so, they developed building blocks and tools that broadened its use beyond email, gradually replacing more-traditional local network technologies and standards. As organisations adopted these building blocks and tools, they saw dramatic gains in productivity.

TCP/IP burst into broad public use with the advent of the World Wide Web in the mid-1990s. New technology companies quickly emerged to provide the "plumbing" – the hardware, software, and services needed to connect to the now-public network and exchange information. Netscape commercialised browsers, web servers, and other tools and components that aided the development and adoption of internet services and applications. Sun drove the development of Java, the application-programming language. As information on the web grew exponentially, Infoseek, Excite, AltaVista, and Yahoo were born to guide users around it.

Substitution

Once this basic infrastructure gained critical mass, a new generation of companies took advantage of low-cost connectivity by creating internet services that were compelling substitutes for existing businesses. CNET moved news online. Amazon offered more books for sale than any bookshop. Priceline and Expedia made it easier to buy airline tickets and brought unprecedented transparency to the process. The ability of these newcomers to get extensive reach at relatively low cost put significant pressure on traditional businesses like newspapers and brick-and-mortar retailers.

Transformation

Relying on broad internet connectivity, the next wave of companies created novel, transformative applications that fundamentally changed the way businesses created and captured value. These companies were built on a new peer-to-peer architecture and generated value by coordinating distributed networks of users. eBay changed online retail through auctions, Napster changed the music industry, Skype changed telecommunications, and Google, which exploited user-generated links to provide more relevant results, changed web search.

Ultimately, it took more than 30 years for TCP/IP to move through all the phases—single use, localisation, substitution, and transformation—and reshape the economy. Email was not only the first application of TCP/IP, it was also the key adoption driver: first people and organisations migrated to email, and from there slowly began exploring other applications of TCP/IP.

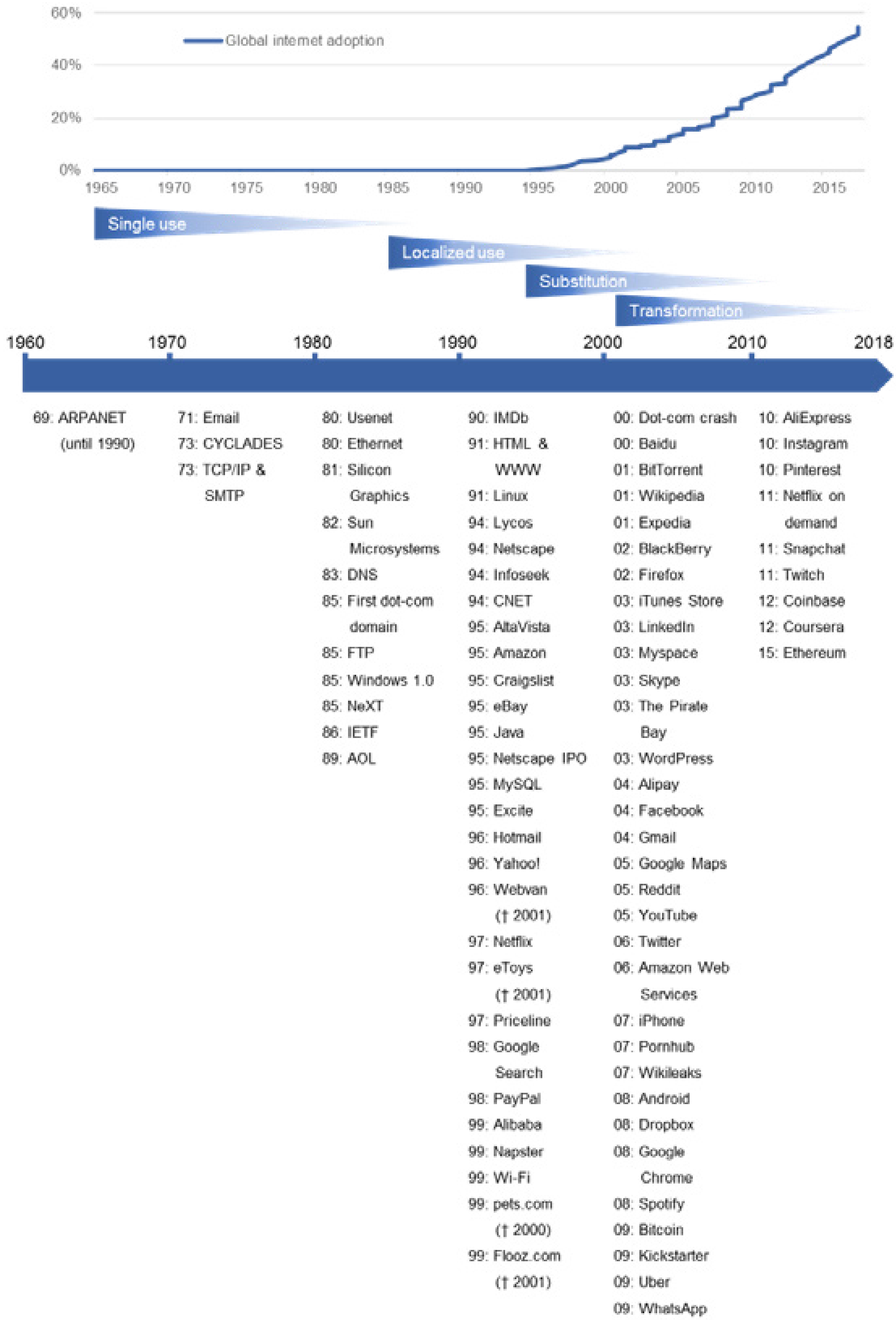


Figure 16: The history of the internet. Compiled from: Wikipedia. "History of the Internet." [197].

5.1.2. Assessment by four adoption phases

Potentially foundational technologies go through four phases to reach their full potential: single use, localisation, substitution and transformation (definitions cited from: Iansiti, Marco, and Karim R Lakhani. "The Truth About Blockchain." [9])

- **Single use:** In the first quadrant (see Figure 17) are low-novelty and low-coordination applications that create better, less costly, highly focused solutions.

- **Localisation:** The second quadrant (see Figure 17) comprises innovations that are relatively high in novelty but need only a limited number of users to create immediate value, so it's still relatively easy to promote their adoption.

- **Substitution:** The third quadrant (see Figure 17) contains applications that are relatively low in novelty because they build on existing single-use and localised applications but are high in coordination needs because they involve broader and increasingly public uses. These innovations aim to replace entire ways of doing business. They face high barriers to adoption, however; not only do they require more coordination but the processes they hope to replace may be full-blown and deeply embedded within organisations and institutions.

- **Transformation:** Under the last quadrant (see Figure 17) fall completely novel applications that, if successful, could change the very nature of economic, social, and political systems. They involve coordinating the activity of many actors and gaining institutional agreement on standards and processes. Their adoption will require major social, legal, and political change.

Two dimensions affect how a foundational technology and its business use cases evolve[10].

- **Degree of novelty:** The more novel a solution is, the more effort will be required to ensure that users understand which problems it solves.

- **Amount of complexity and coordination:** The more complex an application is, the more effort is required to coordinate diverse parties and processes to make a solution function.

While TCP/IP adoption has been driven by email (see chapter 5.1.1), DLT developments and applications are driven by "internet money", i.e. Bitcoin. Most of the other DLT applications are in the localisation (permissioned DLTs, i.e. private ledgers, to increase efficiency of supply chains) and substitution phase (e.g. tracking certificates of origin of renewable energy on DLT instead of conventional approaches). See chapter 4.4 for more examples of DLT for climate action use cases.

While DLT for climate action is still in its single use and early localisation and substitution phase, now is a good time to get involved and shape and guide these developments. When deciding about the extent and type of involvement, it is crucial to keep the four adoption phases in mind (see chapter 6.3). An alternative to focusing on climate action applications, might be to focus activities on the proliferation and adoption of internet money, as this is the main driver for further DLT adoption which will eventually also enable new and disruptive climate action applications based on DLT.

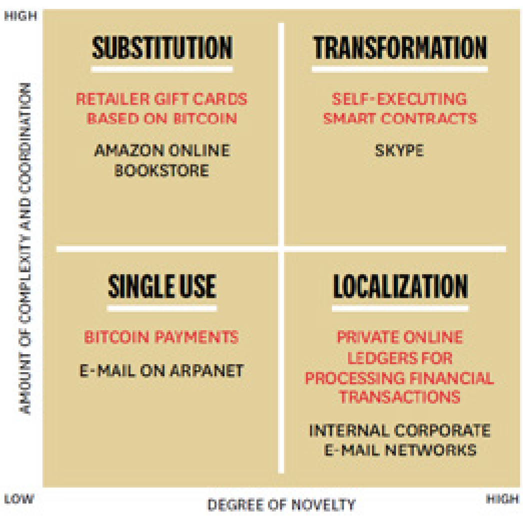


Figure 17: Comparison of DLT with TCP/IP along the four adoption phases single use, localisation, substitution and transformation. Source: Iansiti, Marco, and Karim R Lakhani. "The Truth About Blockchain."[9]

5.1.3. Assessment by user adoption rate

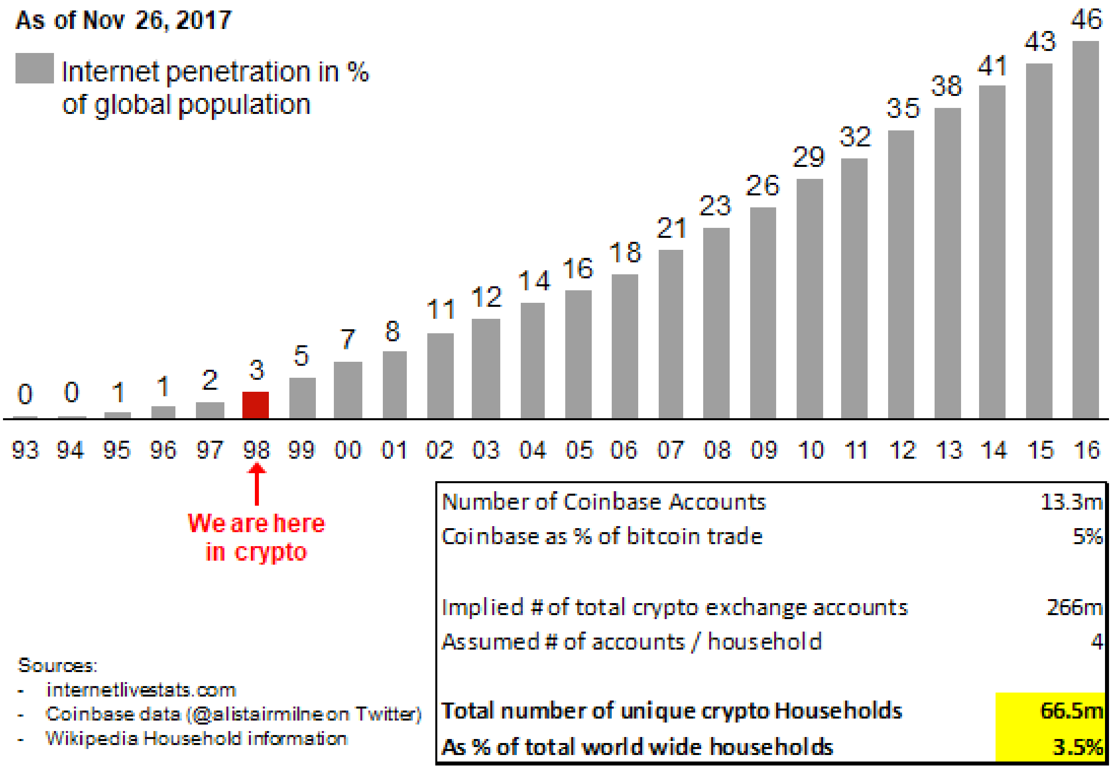


Figure 18: Comparison of TCP/IP and DLT by user adoption rate. Source: Paul, Ari. "It's 1994 In Cryptocurrency." [199]

Many comparisons of DLT with the internet, i.e. TCP/IP, compare user adoption rates to determine at which moment in time DLT is relative to the internet[198].

The above analysis places DLT adoption at the 1998 mark in relation to internet adoption, three years past the Netscape moment. The Netscape moment refers to Netscape's 1995 IPO, when an 18-month-old company that wasn't yet profitable electrified the public markets generating one of the biggest first day stock openings in history[200]. The Netscape moment symbolises two moments in the internet adoption: unlocking increasing adoption rates by user friendly UX that allowed non-technical people to enter the internet and starting an exuberant investment cycle that eventually ended in the dot-com crash in 2000.

While comparison by adoption rate gives indications about DLT's status, it might be misleading as BlackRock's Investment Institute notes: "inventions are moving from the drawing board to widespread use faster than ever before."[201] (see Figure 19).

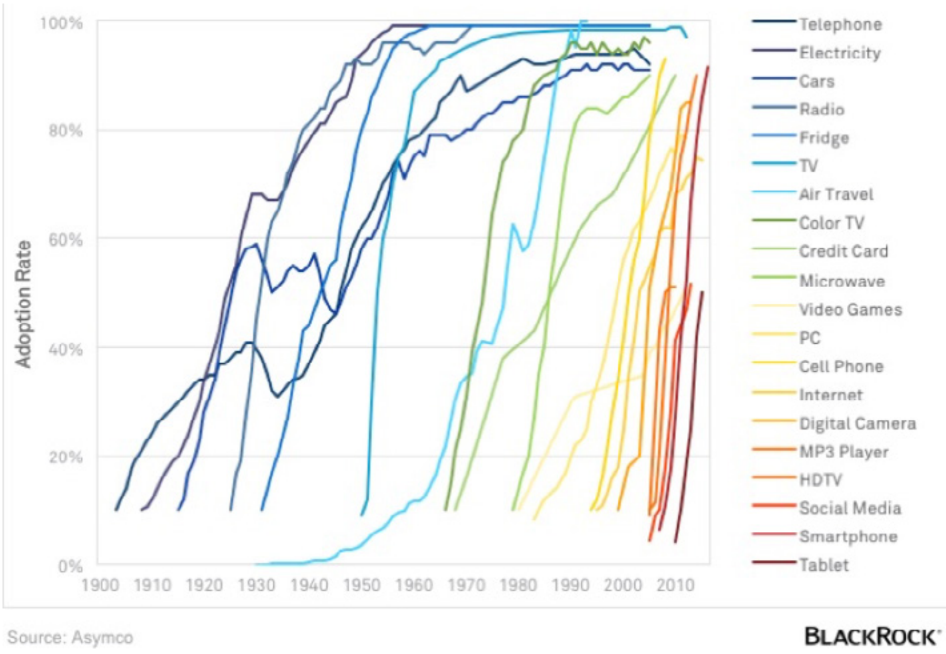


Figure 19: Adoption of technology in the US since 1900. Source: Rieder, Rick. "The Topic We Should All Be Paying Attention to (in 3 Chart)." [202]

The assessment by user adoption rate indicates that while DLT is in the early adoption phase, now is a good time to get involved. It is however important to keep in mind, that the market is exuberant. Valuations for most projects are probably overvalued and a crash similar to the dot-com crash is to be expected in the near future or is already going on. While DLT-related speculation is often labelled as a negative process, it is important to keep in mind that speculation is often the engine of technological adoption[203].

5.1.4. Assessment by market capitalisation

Figure 20 compares the market capitalisations of the "internet market" at the time of the dot-com bubble with the DLT market capitalisation as of 28 November 2017.

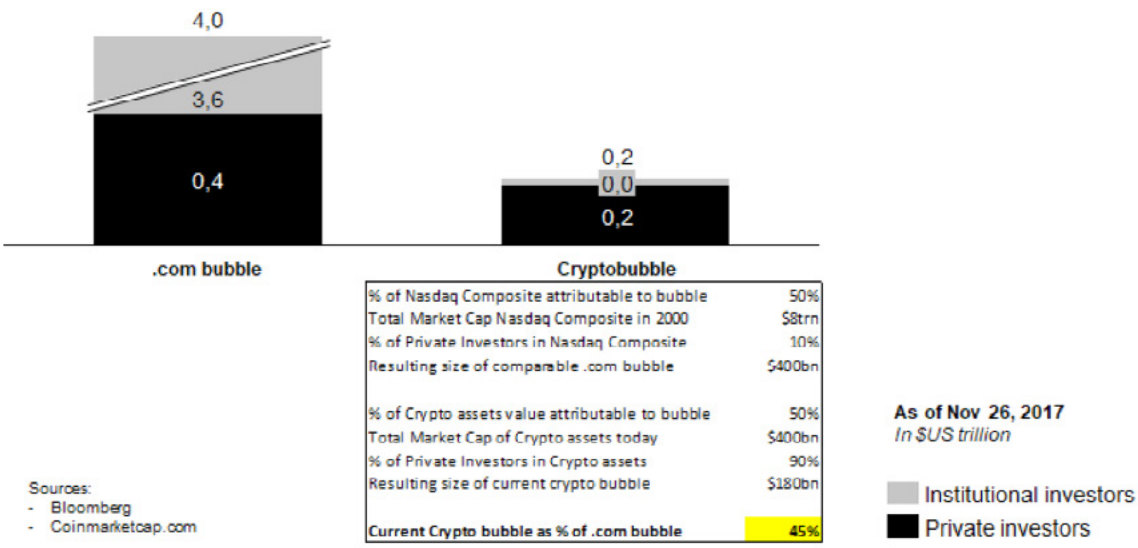


Figure 20: Comparison of the market capitalisation of TCP/IP (at time of the dot-com crash in 2000) with the market capitalisation of DLT. Source: DK. 2017. "Crypto and bitcoin adoption—How far along are we really in this rally?." [199]

Since the publication of this comparison in November 2017, the market cap increased from USD 400 billion to USD 750 billion in early January 2018, and since then continually fell (USD 244 billion in August 2018)[204]. Considering these recent developments, it can be argued that the dot-com bubble was matched by the crypto market cap in early 2018, and since then the crash is ongoing.

It is most likely that the DLT market is in its crash phase now, and presumably will be followed by more realistic and longer-term developments. This assessment indicates, that now is a good time to get involved in the DLT for climate action ecosystem.

5.2. Garnter Hype Cycle

As of July 2017, the Gartner Hype Cycle places "blockchain" at the intersection of the Peak of Inflated Expectations and Through of Disillusionment (Figure 21). They assess that "blockchain might seem like it's just around the corner. However, most initiatives are still in alpha or beta stage. Enterprises are still deciding how to navigate this technology, but the lack

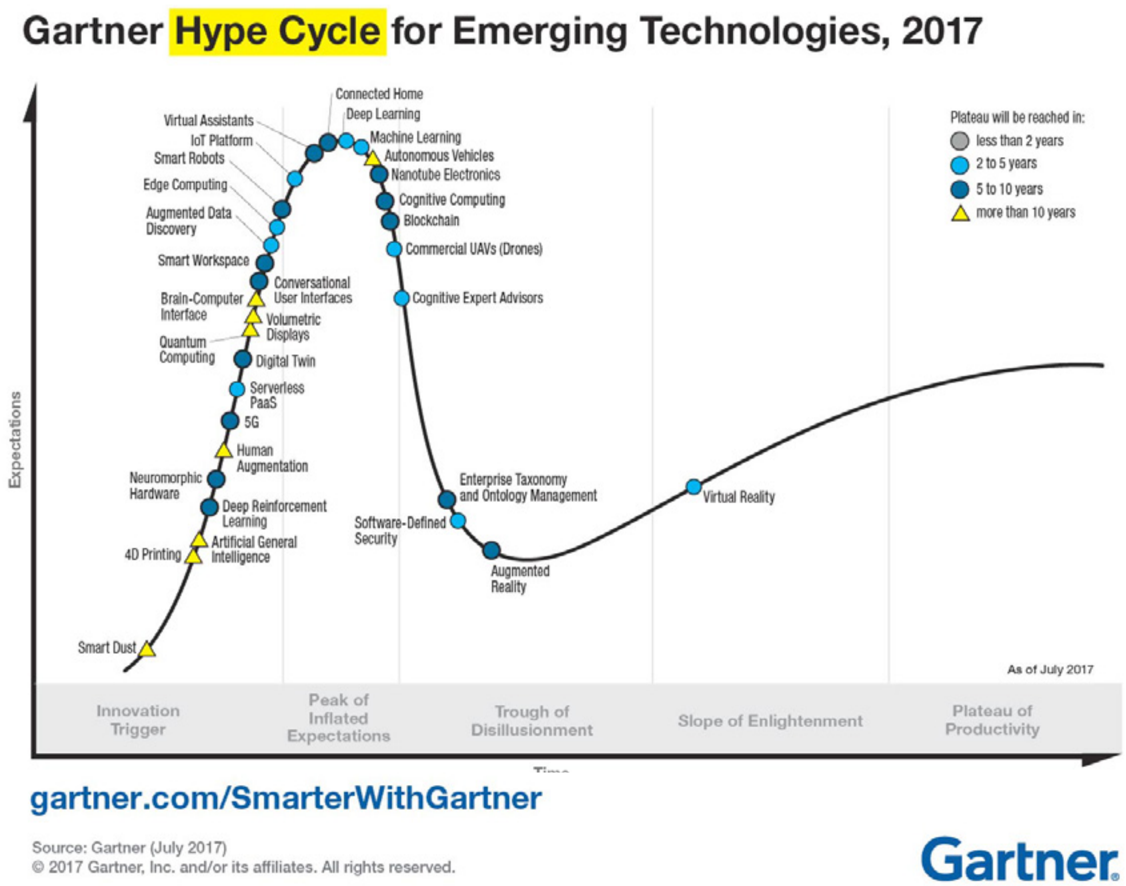


Figure 21: Gartner Hype Cycle for emerging technologies places "blockchain" at the intersection of the Peak of Inflated Expectations and Through of Disillusionment. Source: Gartner Hype Cycle. "Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017."[205]

of proven use cases and the volatility of bitcoin have created concerns about the viability of the technology. Long-term, Gartner believes this technology will lead to a reformation of whole industries"[205].

Since the publication of Gartner's hype cycle in July 2017, interest and hype has increased and peaked in January 2018. Since then, interest and the overall exuberance in the DLT community decreases. Additionally, DLT projects start to fail (e.g. EOS main net launch). These overall developments indicate that DLT needs to be placed further into the Trough of Disillusionment. While expectations could fall lower from here (as of August 2018), DLT is approaching the Slope of Enlightenment, at which point it will start to deliver long-term value. The assessment by Gartner indicates that getting involved in DLT for climate action might be a bit early but still a sensible decision long-term.

5.3. Benchmarking with the UNFCCC & The World Bank

The UNFCCC[207] and The World Bank[2] are both supporting activities in the DLT for climate action ecosystem.

The UNFCCC supports DLT for climate action through the Climate Chain Coalition[208]. The Climate Chain Coalition (CCC) is an open global initiative launched by 12 organisations working on DLT in 2017. As of August 2018, over 100 organisations have joined the CCC. The CCC seeks to align its efforts with the long-term goals of the Paris Agreement and advance DLT for better climate change solutions[208].

The World Bank's Climate Change Group published the report "Blockchain and Emerging Digital Technologies for Enhancing Post-2020 Climate Markets"[2] in 2018. They note that: "Scientific consensus is that rapid and aggressive reductions in greenhouse gas (GHG) emissions are needed if significant climate disruption and irreversible environmental impacts are to be averted. [..] The new generation of climate markets is thus likely to develop as a network of decentralised markets, linking at regional, national and subnational levels. [...] To facilitate larger, more liquid and resilient trading across heterogeneous climate markets, a new architecture is needed. [...] Blockchain, in particular, provides data sharing and transaction management elements well aligned with the requirements of climate markets."

The report concludes that DLT is ideally suited to address climate market challenges, specifically:

- the increasing diversity of regulations, MRV systems, climate assets, and values of mitigation outcomes, within and across jurisdictions;
- the increasing size and scale of post-2020 climate markets, as well as linkages with related climate actions and other markets; and
- the expectation of new cross-jurisdictional trading arrangements (e.g., clubs, regional trading schemes, sectoral trading schemes), and greater financial flows and types of transactions, such as peer-to-peer and results-based finance.

The fact that the UNFCCC and the World Bank's Climate Change Group are venturing into the DLT for climate action ecosystem supports the general assessment that now is a good time to get involved.

6. Scope & methodology

6.1. Snowball sampling

Findings in this report have been guided by the overall approach of snowball sampling: an approach where a piece of information is used to identify the next piece of information and so forth. The information presented in this report has been informed and cross-referenced by a combination of the following approaches:

- Literature research in academic journals, non-fiction books and industry reports.
- Google search.
- Unstructured interviews and workshops with stakeholders.
- Participation in industry fairs/events.

The information sources of this report are listed in chapter 8.1.

6.2. Landscape map actor identification

Actors were also identified by using snowball sampling (see chapter 7.1): a Google search revealed one actor. Then the partners and investors of that first actor revealed many more actors, and so forth. The DLT start-up tracker from Outlier Ventures[211] offers the most comprehensive lists of DLT start-ups. The start-up tracker has also been used and mined for the identification of actors. Further sources used are OnchainFX[212] and CoinMarketCap[16].

6.3. Thematic scope

This report focuses on actors and developments at the intersection of DLT and climate action. While the scope is focused on actors that display both characteristics (i.e. actors that use DLT to enable climate action), it also includes actors and developments exclusive of each other (i.e., only DTL, or only climate action) where deemed necessary to gain a better overview of the intersection itself.

DLT (Distributed Ledger Technology) is the term to collectively describe IT systems that replicate, share, and synchronise digital data geographically spread across multiple sites, countries, or institutions. Put simply, DLT is a technology to manage a database, without a central administrator or centralised data storage. A more detailed description of DLT can be found in chapter 3.3. Climate action includes all industries, actors and projects that aim at decreasing GHG emissions. A list of identified use cases can be found in chapter 4.4.

6.4. Geographical scope

No geographical scope was chosen. However, as information was identified through online resources and interviews, there exists a bias against information that does not use Western information channels and the English language.

While this is a flaw, it is negligible in the case of DLT. DLT ultimately draws its power from its decentralised and transnational nature. While geographic clustering occurs, the DLT space is still rather remotely set up and thus often communicates in English.

"Modern clustering in the tech industry usually happens around universities. However, the DLT courses are not yet widely taught at universities. The DLT community is one of the first to grow from the Internet and therefore is inherently distributed. Networks are global, expertise is shared globally on GitHub, suppliers are cloud-based and distributed over the Internet, and customers can be anywhere in the world."[213].

At this moment, it is safe to assume that players who cannot be identified easily through Western information channels, are either in their early stage or are focused on a regional scope. Early stage DLT actors will eventually have to broaden activities to the Western sphere. Regionally focused DLT actors will ultimately not be able to survive competition from more international DLT actors in a similar fashion to how the intranet was not able to compete against the internet. To balance the bias towards Western actors, research into Russian, Asian and African actors was emphasised to the extent possible.

6.5. Technological Innovation System (TIS)

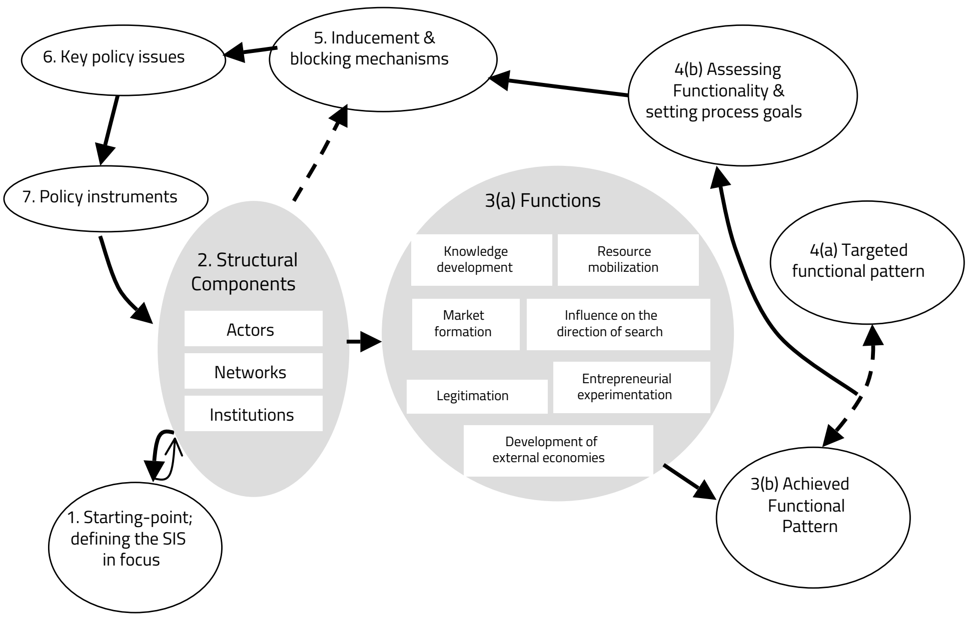


Figure 22: Technological Innovation System. Source: Bergek, Anna, Staffan Jacobssonb, Bo Carlsson, Sven Lindmark, Annika Rickne. "Analysing the functional dynamics of technological innovation systems: A scheme of analysis."[215]

The report uses the Technological Innovation System (TIS) framework to define and asses the status of the DLT for climate action ecosystem[214].

The intersection of DLT and Climate Action is a nascent innovation system. The TIS is a practical approach to analysing innovation system dynamics. The TIS framework is based on broad academic research and is used mostly by policy makers to identify the key policy issues and to set policy goals[215]. In the context of this report, TIS is applied because it is an effective and practical tool to understand and describe innovation dynamics, and because it will help deriving barriers and opportunity recommendations. There are different definitions of the TIS framework in the literature. The definition by Anna Bergek et. al.[216] is one of the more frequently cited definitions and is used as the basis for this report.

This report focuses on the dynamics in the DLT for climate action ecosystem, as it emerged in 2014 (Bitcoin, the first DLT was created in 2009, but exploration of other applications, including for climate action, started around 2014). The functions that are investigated in this report are described in chapter 4.2.

7. References & Appendix

7.1. References

7.1.1. List of references

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7.1.2. List of figures

7.1.3. List of tables

7.1.4. List of interview partners and events

The findings in this report have additionally been informed by interviews at

- Blockchain Summit Crypto Valley, November 22, 2017, https://blockchainsummit.ch/home-2017/
- Blockchain Strategy Dialog, Frankfurt, November 27, 2017, http://www.cintona.com/ger/practices/blockchain-strategiedialog-14-november-2017/
- AI Strategy Dialog, Frankfurt, November 28, 2017, http://www.cintona.com/ger/practices/ai-strategiedialog-15-november-2017/
- Event Horizon, Berlin, April 17. – 19, 2018, https://eventhorizon2018.com/
- Innovate4Climate, Frankfurt, May 22. – 24, 2018, http://www.innovate4climate.com/

Unstructured interviews have been conducted with representatives of the following actors:

ABB	Energy Web Foundation	Poseidon
AMAG AG	ETH Computational Social Science	PostFinance
Axpo	ewz	Power Ledger
BIOTS	Fraunhofer Blockchain-Labor	Research Institute for Future Cryptoeconomics
BKW Energie	Future ICT 2.0	South Pole
BLOC	GIZ	Stadtwerke Schwäbisch Hall
Blockchain Climate Institute	Green Energy Wallet	Stockholm Green Digital Finance
Climate Ledger Initiative	Hack4Climate	SUSI & James GmbH
Climate-KIC	HCASH	UNFCCC
cpb-lab	Hewlett Packard Enterprise	Validity Labs
DASH	Hive Power	Via Blockchain
Datum	Innogy Innovation Hub	WePower
Dennemeyer Group	Mainzer Stadtwerke AG	Western Engineering
Deutsche Bank	MunichRe	Wiener Börse AG
Dezentrum	OLI Systems GmbH	World Economic Forum
elblox	Partake AG	Xpansiv

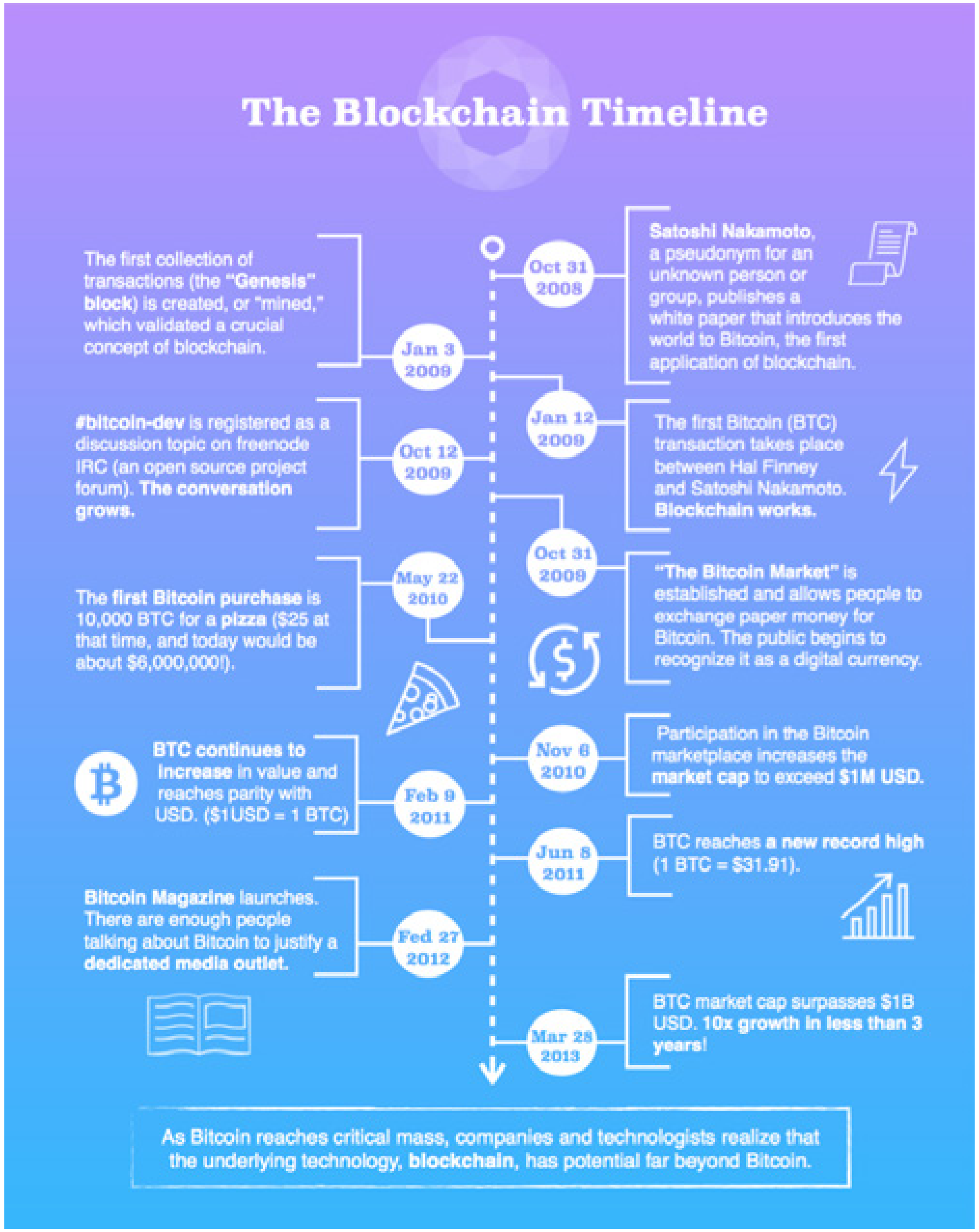

Figure 23: Blockchain historical timeline part 1 of 2.

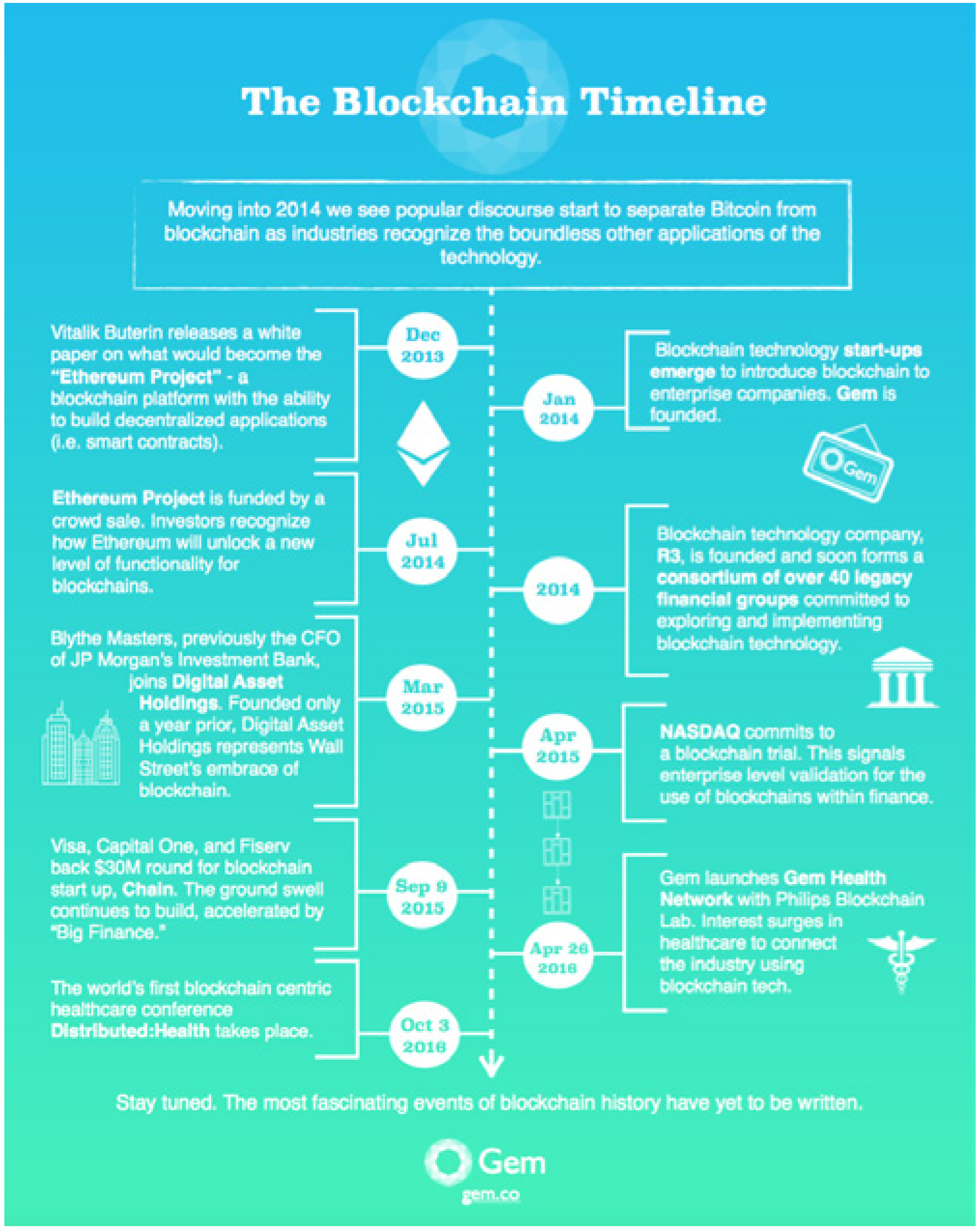

Figure 24: Blockchain historical timeline part 2 of 2.

Image source (part 1 and 2): Mann, Madeline. 2016. "The Blockchain Timeline." Medium. Accessed June 01, 2018. https://blog.gem.co/the-blockchain-timeline-3fdffe281378.

7.2. List of all mapped actors

Actor name	System function	Sub-group	Description / Pitch	URL
Air Products & Engie project	Entrepreneurial activity	Energy	ENGIE and AIR PRODUCTS have signed a contract that will allow AIR PRODUCTS to maximise, trace and certify the green energy used in its manufacturing process, using blockchain technology.	https://www.engie.com/en/journalists/press-releases/air-products-blockchain-technology-traceability-green-electricity/
AMPERE ENERGY	Entrepreneurial activity	Energy	Taking an innovative approach to the environment, we created the Ampere project to encourage the use of clean energy and help our customers to reduce their carbon footprint. Smart Ampere Energy batteries are the real engine of self-consumption, since they get to use 95% of the solar energy production.	http://www.ampere-energy.eu/
Aurora Network	Entrepreneurial activity	Energy	Self-sustaining Microgeneration Network & Decentralised Smart Grid.	http://auroranetwork.co/
BiotaSphere	Entrepreneurial activity	Energy	BiotaSphere facilitates the commercialisation of IOTA applications and to educate stakeholders in North America and globally about the value of the DAG based Tangle to solve some of the world's large and complex problems. Also, it facilitates a Net-Zero emission world through the application of IOTA in the energy and carbon markets.	http://www.biotasphere.com/
Bitlumens	Entrepreneurial activity	Energy	BitLumens is building a decentralised, blockchain-based micro power-grid for the 1.2 billion people without access to electricity and banking.	https://www.bitlumens.com/
BTL Group	Entrepreneurial activity	Energy	Interbit is a blockchain development platform designed for business innovators and developers to quickly and easily incorporate the best of blockchain capabilities into enterprise applications. Successful completion of European energy trading pilot with BP, Eni Trading & Shipping and Wien Energie.	http://btl.co/
Conjoule	Entrepreneurial activity	Energy	Peer-to-peer marketplace for renewable energy. Currently piloting in Essen & Mülheim. Part of Innogy.	http://conjoule.de/de/start/
Co-tricity	Entrepreneurial activity	Energy	CO-TRICITY is a partnership with Innogy Innovation aiming to create a market between homeowners who produce solar powered energy and local businesses. CO-TRICITY presents solar energy producers with the choice to sell their solar surplus to a local business or organization such as a supermarket or school.	http://www.the-blockchain.com/docs/Energy%20meets%20Blockchain%20-%20Consensys.pdf

Actor name	System function	Sub-group	Description / Pitch	URL
Daisee	Entrepreneurial activity	Energy	Provide the conditions for shared governance of energy by the grid stakeholders.	http://daisee.org/
DAJIE!	Entrepreneurial activity	Energy	Peer-to-peer Energy exchange platform redeem carbon credits and pay for energy.	https://www.dajie.eu/
Drift Marketplace	Entrepreneurial activity	Energy	Drift is the first energy provider that gives you access to premium clean energy without the premium price tag. We're using smart software to keep your costs down by connecting you to the people who make power.	https://www.joindrift.com/
EcoChain	Entrepreneurial activity	Energy	EcoChain is a blockchain based investment hub and central project comparison tool, which directly connects investors to renewable energy projects around the world, allowing them to gain long-term ROI. Power Ledger will run on EcoChain.	https://www.bcdc.online/ecochain
elblox	Entrepreneurial activity	Energy	Elblox bietet regionalen Endverteilern von Strom eine Plattform, auf welcher Verbraucher aus der Region ihren Strom-Mix digital selbst zusammenstellen können. Der Herkunftsnachweis wird mittels Blockchain sichergestellt. Regionalen Betreibern von Solar-, Windkraft-, Wasserkraft- und Biomasseanlagen bietet sich die Möglichkeit, ihren selbst produzierten Strom direkt an die lokalen Endverbraucher zu verkaufen.	http://www.electricchain.org/our-projects/project-13/
ElectraSeeD	Entrepreneurial activity	Energy	ElectraSeed is a concept for a modular smart micro-grid, which can supply rural areas with solar energy and storage. ElectraSeed installations features a ± 5kWp photovoltaic power plant with energy storage capacity deployed as a micro-grid. Collaboration between ElectraSeed is a concept for a modular smart micro-grid, which can supply rural areas with solar energy and storage. ElectraSeed installations features a ± 5kWp photovoltaic power plant with energy storage capacity deployed as a micro-grid.	http://www.electricchain.org/our-projects/project-13/
ElectriCChain	Entrepreneurial activity	Energy	The ElectriCChain is an Open Solar energy generation data project with an initial focus on verifying and publishing data from the seven million solar energy generators globally on an open Blockchain.	https://www.electricchain.org/

Actor name	System function	Sub-group	Description / Pitch	URL
Electrify.Asia	Entrepreneurial activity	Energy	ELECTRIFY plans to develop a decentralised energy marketplace that runs on the blockchain.	https://electrify.asia/#home
Electron	Entrepreneurial activity	Energy	Platform for meter registration, trading and community energy projects with the goal of decarbonising and distributing the energy sector.	http://www.electron.org.uk/
EltriCChain	Entrepreneurial activity	Energy	ElectriCChain is an Open Science project based on the SolarCoin blockchain. Originally intended to verify and publish near real-time production data of some 7 million solar plants, it is designed to help advance knowledge and enable Climate Change analysis for scientists and researchers and has recently published the first node on the SolarCoin blockchain, the ElectriCChain. Runs a large collection of collaboration projects.	http://www.electricchain.org/
Enerchain	Entrepreneurial activity	Energy	Creation of a decentralised European market place for energy trading, comprised of 33 partner organisations (Eon, Alpiq, Axpo, BWK, Engie, RWE, etc.)	https://enerchain.ponton.de/
enosi	Entrepreneurial activity	Energy	Enosi is at the forefront of disrupting existing energy landscapes and supporting P2P energy exchange.	https://enosi.io/
Envion	Entrepreneurial activity	Energy	Highly profitable, global crypto-mining-infrastructure - Hosted in mobile, modular CSC containers - Decentralised placement directly at the energy source.	https://enosi.io/
FlexiDao	Entrepreneurial activity	Energy	Our software facilitates the aggregation and control of distributed flexible energy resources in order to deliver transparent, secure, reliable, and timely energy flexibility to grid operators.	http://flexidao.com/
Fortum	Entrepreneurial activity	Energy	Hazardous waste treatment services.	https://www3.fortum.com/
Fsight	Entrepreneurial activity	Energy	FSIGHT's Energy AI system is the first-ever fully automated AI agent that predicts, optimises and trades energy produced "behind-the-meter" . Energy AI achieves a better utilisation of distributed electricity grids for smart homes, communities, service providers and energy aggregators.	https://www.fsight.io/
fury.network	Entrepreneurial activity	Energy	fury network is the boutique blockchain for the energy industry! This online IDE (integrated development environment) can be used to design and test applications based on the STROMDAO using html or JavaScript.	https://fury.network/

Actor name	System function	Sub-group	Description / Pitch	URL
GPX Energy	Entrepreneurial activity	Energy	The GPX Platform enables simple Peer-to-Peer energy trading. Producers can easily pre-sell their power at a better rate while allowing consumers to buy their power directly for significantly less. We are creating a hyper-efficient renewable energy market place to turbocharge clean energy deployment and push out fossil fuels. Be on the right side of history.	https://gpx.energy/
Green Energy Wallet	Entrepreneurial activity	Energy	Green Energy Wallet connects electric vehicle and home batteries to a large energy storage system for renewable energies to balance the power grid.	http://www.greenenergywallet.com/
Green Running	Entrepreneurial activity	Energy	Green Running are a London-based team of Data Scientists and Machine Learning experts specialising in high-frequency disaggregation and data analytics in the energy sector.	https://www.greenrunning.com/
Greeneum	Entrepreneurial activity	Energy	Greeneum is a decentralised platform that rewards you for supporting an eco-friendly future.	https://www.greeneum.net/greeneum-home/
Grid Singularity	Entrepreneurial activity	Energy	Decentralised energy data platform for analysis, benchmarking, smart grid management, trade of green certificates, investment decisions, energy trade validation. Hosted by Energy Web Forum (EWF).	http://gridsingularity.com/
Grid+	Entrepreneurial activity	Energy	Created by Consensys. Grid+ functions as a commercial utility in select deregulated markets in the United States. Grid+ agent devices pay for all electricity bills automatically and in real-time. All payments are done over state channels using BOLT tokens. For transparency, all fees from these payments are held by a fee vault smart-contract called Karabraxos.	https://gridplus.io
GridX	Entrepreneurial activity	Energy	GridX provides the financial operating system to enable utilities, Retail Energy Suppliers, DER Providers, Energy Service Providers and their customers to operate and otherwise participate in decentralised energy markets. GridX technology enables these market participants to develop better products, services and business models; understand the financial implications of participating in energy-related transactions; and efficiently settle transactions with their trading partners.	https://gridplus.io
Hive Power	Entrepreneurial activity	Energy	Hive Power provides anyone with the possibility to create and manage energy communities on the Ethereum blockchain.	https://www.hivepower.tech/

Actor name	System function	Sub-group	Description / Pitch	URL
ImpactPPA	Entrepreneurial activity	Energy	ImpactPPA is an Ethereum-based decentralised energy platform that will transform the global energy finance industry. ImpactPPA uses the power of the blockchain to bring together capital and consumers in a way that is direct, responsive, and expedient. ImpactPPA solves the problem created by legacy financial institutions of too much bureaucracy, cost and infrastructure to effectively and efficiently provide solutions that work!	https://www.impactppa.com/
Innogy Innovation Hub	Entrepreneurial activity	Energy	Subsidiary of RWE. Focused on innovating the energy industry through key focus areas: machine economy, urban exponentials, smart & connected, disruptive digital and cybersecurity ventures.	https://innovationhub.innogy.com/
Interbit / BTL	Entrepreneurial activity	Energy	Can be used for different application types. Interbit has been piloted for energy trading confirmations.	http://btl.co/
Jouliette at de Ceuvel	Entrepreneurial activity	Energy	Spectral and Alliander have launched a new blockchain-based energy sharing token at De Ceuvel in Amsterdam. Named the 'Jouliette', the new token aims to empower individuals and communities to easily manage and share their locally produced renewable energy.	https://spectral.energy/news/jouliette-at-deceuvel/
Kiwi New Energy	Entrepreneurial activity	Energy	KiWi is a blockchain-based Green Energy Sharing Platform company that connects billions of future new energy consumers with millions of premium renewable energy suppliers around the world, through KiWi platform, our contributors can have privileged access to our smart microgrid projects which empowered by the most advanced smart inverter technologies that will make a big impact to future smart grid networks and our environment!	http://www.kiwinewenergy.com/
Kiwigrid	Entrepreneurial activity	Energy	Wir helfen Energieunternehmen, die Herausforderungen eines Energiesystems zu meistern, das für immer "auf den Kopf" gestellt sein wird. Hierfür entwickeln wir innovative und energiewirtschaftlich leistungsfähige Softwarelösungen auf der Basis einer hochsicheren und iMSys-konformen Infrastruktur.	https://www.kiwigrid.com/

Actor name	System function	Sub-group	Description / Pitch	URL
KWHCoin	Entrepreneurial activity	Energy	KWHCoin is a blockchain-based community, ecosystem and cryptocurrency backed by units of clean, renewable energy. Physical units of kWh energy are leveraged from multiple sources including smart meters, sensor readings and green button data. This measurable output is tokenised on the blockchain to create KWH tokens.	https://kwhcoin.com/#/
Landau Microgrid Project	Entrepreneurial activity	Energy	Pilot project with LO3 Energy based on the Brooklyn Microgrid pilot project. In Partnership with Karlsruher Institut für Technologie.	https://im.iism.kit.edu/news_2098.php
Leap	Entrepreneurial activity	Energy	Leap enables automated trading on energy markets for anyone, regardless of capacity and availability. Get access to wholesale markets through a single API and help build the flexible renewable grid of the future.	https://leap.ac/
Lition Energie	Entrepreneurial activity	Energy	Mit Lition vernetzen Konsumenten und Erzeuger auf direktem Wege über unsere Energiebörse - zu außergewöhnlich günstigen Preisen. Mit 100% Ökostrom. Werde Teil davon und revolutioniere mit uns den Energiemarkt!	https://www.lition.de/
LO3Energy	Entrepreneurial activity	Energy	Energy generation, conservation, trading and sharing. Creator of Brooklyn Microgrid pilot project.	https://lo3energy.com/
Lumenaza	Entrepreneurial activity	Energy	Lumenaza is the software provider for the new, decentralised and digitised energy world. The software can offer virtually all the functions that are needed in the energy market in a modular form as a "utility-in-a-box".	https://www.lumenaza.de/
Magnefico GmbH	Entrepreneurial activity	Energy	If you own a solar power plant or plan do implement such an asset, consider SolarCoin. You can potentially generate additional income or improve the cost structure of your solar power plant.	http://www.magnefico.com/en/solar-blockchain/
More Solar	Entrepreneurial activity	Energy	MORE token solar lets you get rewards for using solar, earning MORE tokens automatically for all the SunJoules you use. Use more solar, get more MORE!	https://www.moresolar.io/

Actor name	System function	Sub-group	Description / Pitch	URL
M-PAYG	Entrepreneurial activity	Energy	M-PAYG is a provider of high-quality prepaid solar energy systems for the developing world. Our systems allow off-grid low-income households and businesses to access solar energy through small-scale mobile repayments. To use the system, you unlock it through weekly or monthly mobile repayments.	http://www.mpayg.com/
NRGcoin	Entrepreneurial activity	Energy	The NRGcoin mechanism replaces traditional high-risk renewable support policies with a novel blockchain-based Smart Contract, which better rewards green energy.	https://www.nrgcoin.org/
OLI Systems GmbH	Entrepreneurial activity	Energy	OLI turns consumers and prosumers with decentralised generation into active players of the Energiewende. By employing Blockchain technology, they form a scalable network and share electricity within neighbourhoods, districts, regions and entire countries.	http://www.my-oli.com/de/
Omega Grid	Entrepreneurial activity	Energy	Peer to Peer Energy Platform: Blockchain based grid balancing and settlement for electric utilities.	http://www.omegagrid.com/
Power Ledger	Entrepreneurial activity	Energy	Peer-to-peer marketplace for renewable energy. Currently piloting in Australia with solar PV.	https://powerledger.io
Power-ID	Entrepreneurial activity	Energy	Pilot project from Clean Ledger Initiative. Small project in Walenstadt linking 10 households, including 1-2 prosumers to a blockchain. The idea is to show how a prosumer-based energy generation and sharing system could work. Still early phase with many technical difficulties (e.g. smart meter).	https://www.climateledger.org/en/Innovation/Use-Cases.33.html
Powerpeers	Entrepreneurial activity	Energy	Energy trading of renewable energy.	https://www.powerpeers.nl/
PowerToShare	Entrepreneurial activity	Energy	PowerToShare is a blockchain based energy information exchange that will act as the nerve system in transformed energy markets. Markets based on renewable energy sources where energy providers, companies and consumers will work together in a variety of traditional and non-traditional business models.	http://www.powertoshare.eu/

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Prosume	Entrepreneurial activity	Energy	PROSUME is a blockchain-based platform that, thanks also to its own decentralised and self-regulated monitoring system, guarantees an autonomous, independent and digitised smart place that will permit users to exchange different energy sources, promoting and accelerating new energy community models.	https://prosume.io/
Pylon Network	Entrepreneurial activity	Energy	P2P Distributed Green Energy Market including own Hardware to add Electricity data to platform.	https://pylon-network.org
ReWatt Power	Entrepreneurial activity	Energy	Using Automation and Blockchain technology, we reduce operating and transaction costs for large and small generators.	https://www.rewattpower.com/
Solar Bankers	Entrepreneurial activity	Energy	By creating a freely accessible marketplace for renewable energy trading, Solar Bankers is challenging the dominance of the large energy companies. With Solar Bankers, consumers can produce their own electricity and sell any excess at competitive prices to their neighbours via local marketplaces.	https://solarbankers.com/
SolarChange	Entrepreneurial activity	Energy	Get more value from your solar system with SolarCoin - a revolutionary digital currency that is coupled to the production of clean solar energy. Solar owners get 1 SolarCoin for every 1 MWh they produce. A simple 5 minute registration is all that is needed.	https://m.solarchange.co/#/
SolarCoin	Entrepreneurial activity	Energy	A global rewards programme for solar electricity generation.	https://solarcoin.org/en/node/6
Solshare	Entrepreneurial activity	Energy	Our decentralised peer-to-peer microgrids deliver solar power to households and businesses, and enable them to trade their (excess) electricity for profit.	https://www.me-solshare.com/
sonnen/TenneT	Entrepreneurial activity	Energy	sonnen and TenneT run the first European pilot project which aims at stabilising the electricity grid with home batteries. TenneT has the grid, sonnen the batteries, IBM the blockchain.	https://www.tennet.eu/news/detail/europes-first-blockchain-project-to-stabilize-the-power-grid-launches-tennet-and-sonnen-expect-res/
Spectral	Entrepreneurial activity	Energy	Spectral offers a data analytics platform which enables energy utilities, real-estate and facility managers, businesses, and smart energy communities to extract unique business intelligence from the vast amounts of data that they generate every day.	https://spectral.energy/

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Spread.Energy	Entrepreneurial activity	Energy	SPREAD allows digitalisation of green energy assets such as Solar PVs, Wind Turbines, Energy Storage Devices, EV Charging Units etc. and allows automation of project data room for the due diligence process.	http://positiveenergy.community/
StromDAO	Entrepreneurial activity	Energy	Decentral autonomous organisation which develops new electricity products.	https://stromdao.de
Stromhaltig.de	Entrepreneurial activity	Energy	Die Digitalisierung des Strommarktes erlaubt es den privaten Stromkunden direkt die Kostenersparnisse der Energiewende zu nutzen, ohne dabei auf einen nachhaltigen Umgang mit unserer Umwelt verzichten zu müssen. Der Stromanbieter Stromhaltig basiert auf der digitalen Infrastruktur der Tarifmanufaktur von STROMDAO.	https://stromhaltig.de/
SUNCHAIN	Entrepreneurial activity	Energy	Grâce aux technologies de la blockchain, l'ambition de Sunchain est de faire circuler l'énergie solaire sur les réseaux publics de distribution d'électricité.	http://www.sunchain.fr/
Suncontract	Entrepreneurial activity	Energy	The SunContract platform empowers individuals, with an emphasis on home owners, to freely buy, sell or trade electricity.	https://suncontract.org
The Sun Exchange	Entrepreneurial activity	Energy	The Solar Panel Sharing Economy platform.	https://thesunexchange.com/
The Sun Protocol	Entrepreneurial activity	Energy	Providing electricity, internet access and the purification of water - all from decentralised hubs. Measuring productive energy use and using Crypto Economics to create sustainable infrastructures of modern life.	https://thesunprotocol.io/
Volt markets	Entrepreneurial activity	Energy	Volt Markets disintermediates traditional energy markets and enables monitoring, managing, originating and trading energy and energy attributes in a peer-to-peer market on the Ethereum blockchain.	https://voltmarkets.com/
Wattcoin Labs	Entrepreneurial activity	Energy	Wattcoin Labs is solving the global energy problems of access, efficient use, and carbon reduction by building a platform as a service where energy and its value can come together.	https://wattcoin.com/index.html
WePower	Entrepreneurial activity	Energy	A blockchain based green energy trading platform that enables green energy producers to raise capital by issuing tradable energy tokens. Currently a pilot running in Estonia (100% smart meter coverage). Raised 40Mio USD in ICO.	https://wepower.network/

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BCDC	Entrepreneurial activity	Other Climate Action	A UK based start-up committed to developing DLT and leveraging them to make a positive impact on the world. Developers of FoodTrax, EcoChain, Recycle to Coin and Plastic Foodprint.	https://www.bcdc.online/
BLOC	Entrepreneurial activity	Other Climate Action	Blockchain Labs for Open Collaboration. Focusing on Projects in Energy (Feasibility, pilot project local energy generation and consumption) and Maritime.	https://www.un-bloc.com/
Blockchain for Social Impact	Entrepreneurial activity	Other Climate Action	Blockchain for Social Impact Coalition (BSIC) incubates, develops, and implements confederated blockchain products and solutions that can address social and environmental challenges across the United Nation's Sustainable Development Goals. We aim to inspire, federate, and create bridges between NGO's, and government agencies, foundations, impact investors, philanthropists and technologists.	https://www.blockchainforsocialimpact.com/
CleanCoin	Entrepreneurial activity	Other Climate Action	Pilot project from Clean Ledger Initiative. Project shows electricity and climate impacts of cryptocurrencies BTC and ETH.	http://www.cleancoins.io/#/info
Climate Ledger Initiative	Entrepreneurial activity	Other Climate Action	CLI is an international, multi-stakeholder initiative at the intersection of climate change and distributed ledger technology (DLT, 'Blockchain'). The mission of CLI is to accelerate #ClimateAction in line with the Paris Climate Agreement and the Sustainable Development Goals (SDGs) through blockchain-based innovation applicable to climate change mitigation, adaptation, and finance. CLI is supported by governments, major international organisations, companies and foundations.	https://www.climateledger.org/
ClimateCoop	Entrepreneurial activity	Other Climate Action	ClimateCoop is a blockchain based platform for the SDG ecosystem, allowing decentralised collaboration, governance & community development.	https://www.dcentra.io/climatecoop/
Energimine	Entrepreneurial activity	Other Climate Action	Decentralising global energy markets by rewarding energy efficient behaviour.	https://www.energimine.com/

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Gainforest	Entrepreneurial activity	Other Climate Action	We fight rainforest deforestation by intelligently rewarding and empowering caretakers with a cutting-edge proof-of-care consensus system and suite of AI-powered conservation tools.	https://gainforest.org/
Green Asset Wallet	Entrepreneurial activity	Other Climate Action	Throughout 2018, the consortium is building a ground-breaking blockchain platform to help accelerate the market for green investments in support of the United Nations' Sustainable Development Goals and the objectives of the Paris Agreement.	https://stockholmgreenfin.tech/gaw/
Green List Standard Token	Entrepreneurial activity	Other Climate Action	A blockchain based Smart Contract platform to implement the IUCN Green List Programme for nature conservation.	https://gls.porini.foundation/de/
IXO Foundation	Entrepreneurial activity	Other Climate Action	Count what matters. ixo provides a trusted global information network that is owned by everyone. Enabling anyone to become the creators of their own impact projects and a stake-holder in the projects they believe in.	https://ixo.foundation/
Origin Protocol	Entrepreneurial activity	Other Climate Action	Origin is a protocol for creating sharing economy marketplaces using the Ethereum blockchain and IPFS.	https://www.originprotocol.com/
Oxyn	Entrepreneurial activity	Other Climate Action	Oxyn is a fast and secure technology for the GREEN COMMUNITY. It enables us to exchange value between CSR driven business corporations, conscious consumers and environmental organisations.	https://oxyn.io/
Poseidon	Entrepreneurial activity	Other Climate Action	Poseidon will simplify the carbon credit market with the creation of an ecosystem built on Stellar.org's blockchain technology.	https://poseidon.eco/
RecycleToCoin	Entrepreneurial activity	Other Climate Action	RecycleToCoin is a world-first system providing the public with a cutting edge incentive to recycle waste. Aimed at 'single-use' plastic bottles and aluminum cans, this revolutionary solution leverages a blockchain based mobile app to help inspire environmental change.	https://www.recycletocoin.com/

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Regen Network	Entrepreneurial activity	Other Climate Action	Balance Sheet for Earth: Regen Network is a community of actors engaging with ecological regeneration, ecological monitoring, verification, distributed computing and technology development, centered around Regen Ledger. Network members track specific changes of land, oceans and watersheds. By improving our understanding of ecosystems and enabling rewards for verified positive changes, Regen Network catalysis the regeneration of the earth's ecosystems.	https://www.regen.network/
Swytch	Entrepreneurial activity	Other Climate Action	Swytch is a blockchain-based platform that tracks and verifies the impact of sustainability efforts and actions on the worldwide level of CO2 emissions.	https://swytch.io/
Terra0	Entrepreneurial activity	Other Climate Action	terra0 is a scalable framework built on the Ethereum network that provides automated resilience systems for ecosystems. Via instantiating a Decentralised Autonomous Organisation atop areas of land to manage them, terra0 aims to create technologically-augmented ecosystems that are more resilient, and able to act within a predetermined set of rules in the economic sphere as agents in their own right.	https://terra0.org/
TerraFina	Entrepreneurial activity	Other Climate Action	The Terrafina Framework aims to create the conditions for farmland being treated as a commons all over the world.	https://terrafina.org/
Treepex	Entrepreneurial activity	Other Climate Action	Treepex is an easy-to-use platform to plant trees, either for yourself or as a gift. And we do this with an innovative tracking system and follow up care.	https://treepex.com/
Adaptation Ledger	Entrepreneurial activity	Carbon Trading	Adaptation Ledger is advancing climate Adaptation solutions and Mobilising Finance through the integration of Blockchain, smart standards and a unified metric for vulnerability reduction.	https://www.adaptationledger.com/
CarbonX	Entrepreneurial activity	Carbon Trading	CarbonX enables enterprise companies to satisfy the growing consumer demand for sustainable business practices. We source and recast carbon offsets as tokens on a private blockchain, thereby validating provenance and ensuring the security and immutability of all transactions.	https://www.carbonx.ca
Climate Coin	Entrepreneurial activity	Carbon Trading	Climatecoin launched a peer to peer decentralised carbon credits portal.	https://climatecoin.io/

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DAO IPCI	Entrepreneurial activity	Carbon Trading	Blockchain technology for carbon markets, environmental assets and liabilities	http://ipci.io/
Earth token	Entrepreneurial activity	Carbon Trading	Market place for the exchange of natural assets like: waste to energy, solar, wind, carbon sequestration, avoided emissions projects. Demand side is existing Climate Action solutions (mitigation, adaptation). Piloting with REDD+ projects	https://earth-token.com/
Market-Chain	Entrepreneurial activity	Carbon Trading	Pilot project from Clean Ledger Initiative. The project demonstrates a distributed and supra-national emission trading scheme based on blockchain.	https://www.climateledger.org/en/Innovation/Use-Cases.33.html
REDD-Chain	Entrepreneurial activity	Carbon Trading	Pilot project from Clean Ledger Initiative. MRV service for REDD+ (forests) linking finance to verified climate mitigation measures.	https://www.climateledger.org/en/Innovation/Use-Cases.33.html
Veridium	Entrepreneurial activity	Carbon Trading	Market place for carbon sequestration and avoided emissions projects. Piloting with REDD+ projects.	http://veridium.io/
WPO	Entrepreneurial activity	Carbon Trading	Always faithful to its pioneering spirit, WPO plans to issue the first secure and irrefutable renewable energy production certificates on the world market. These blocks of data certified directly on the production sites by our own care will be valuable, auditable, tradable, exchangeable, and usable anywhere in the world.	https://wpo.eu/wpo-3-0/
Zero Carbon Project	Entrepreneurial activity	Carbon Trading	The Zero Carbon Project is tackling climate change using the blockchain and international carbon credits.	https://www.zerocarbonproject.com/
Bext360	Entrepreneurial activity	Supply Chain	Complete coffee supply chain solution.	https://www.bext360.com/
Chronicled	Entrepreneurial activity	Supply Chain	Chronicled is the first company to leverage IoT, AI, and Blockchain technologies to power end-to-end smart supply chain solutions.	https://chronicled.com/
Everledger	Entrepreneurial activity	Supply Chain	Diamond provenance tracking on blockchain.	https://www.everledger.io/
eWINGZ GmbH	Entrepreneurial activity	Supply Chain	eWINGZ is a platform for the aviation industry basically to make life easier, simple and connected. It is a plug and play solution which offers a flexible way to manage your aircraft fleet, parts and related maintenance with interlinked manuals.	http://www.ewingz.aero/
Mineral Track	Entrepreneurial activity	Supply Chain	Mineral Track is an application that will reshape supply chains and incentivise responsible sourcing.	https://vimeo.com/237332708

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Plastic Footprint	Entrepreneurial activity	Supply Chain	Customers (companies & individuals) around the world can calculate and then offset their entire annual plastic footprint with the help of partners like the Plastic Disclosure Project.	https://www.globalplasticoffsetscheme.com/
Provenance	Entrepreneurial activity	Supply Chain	Blockchain to make supply chains more transparent. Focus on food.	https://www.provenance.org/
SKUchain	Entrepreneurial activity	Supply Chain	At Skuchain, we empower enterprise supply chains with blockchain to extract maximum value from the $18 trillion dollar market for global trade.	http://www.skuchain.com
Vechain	Entrepreneurial activity	Supply Chain	leveraging on blockchain technology, VeChain strives to build a trust-free and distributed business ecosystem, which is self-circulating and scalable.	https://www.vechain.com/#/
Walton	Entrepreneurial activity	Supply Chain	Blockchain + RFID for IoT and supply chain.	https://www.waltonchain.org/
Wave	Entrepreneurial activity	Supply Chain	WAVE connects all members of the supply chain to a decentralised network and allows them a direct exchange of documents. WAVE's application manages ownership of documents on the blockchain eliminating disputes, forgeries and unnecessary risks.	http://wavebl.com/
Xpansiv	Entrepreneurial activity	Supply Chain	We authenticate commodity production data and refine it into Digital Feedstock™. Digital Feedstock is a new, standardised data format to power the digital migration of commodities from production to consumption.	https://www.xpansiv.com/
Arcade City	Entrepreneurial activity	Transportation	Sharing platform analogous to Uber but running on DLT to eliminate central intermediary (like Uber).	https://arcade.city/
Car eWallet	Entrepreneurial activity	Transportation	We enable cars to become business entities on their own to autonomously pay for services like parking or charging.	https://car-ewallet.zf.com
Demos	Entrepreneurial activity	Transportation	An open mobility platform, still in development. The idea is to link all mobility offerings (train, cars, bikes), fuel providers (conventional, renewable, battery) onto one database (DLT). Demos is a co-development with slock.it and innogy and it seems that it did not go forward, especially given OMOS which is also supported by innogy	https://www.youtube.com/watch?v=IuAoNlnHYkw
La'Zooz	Entrepreneurial activity	Transportation	Get anywhere with collaborative transportation. save money while making new friends	http://lazooz.org/

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LET-Chain	Entrepreneurial activity	Transportation	Pilot project from Clean Ledger Initiative. Software to offer incentives for sustainable transport.	https://www.climateledger.org/en/Innovation/Use-Cases.33.html
MotionWerk	Entrepreneurial activity	Transportation	A blockchain platform to support an open and secure infrastructure for mobility business. The goal is to build a strong B2B-network based on green and shared electricity. The platform makes electric vehicle charging easier. They develop Share&Charge, Oslo2Rome, eMotorWerks, OMOS. Partnered with some of the biggest mobility and energy players in Europe. Supported by Innogy.	https://motionwerk.com/
OMOS	Entrepreneurial activity	Transportation	An open mobility platform, still in development. The idea is to link all mobility offerings (train, cars, bikes), fuel providers (conventional, renewable, battery) onto one database (DLT). This would greatly enhance customer experience and system efficiency. It would open up new potentials for AI pattern recognition, etc. Supported by Innogy.	https://www.omos.io/
Share&Charge	Entrepreneurial activity	Transportation	E-vehicle charging network in Europe. Integrates private and institutional e-charging stations. An additional subsidiary runs in California. Supported by Innogy.	https://shareandcharge.com/en/
Bitnation	Entrepreneurial activity	Open Government	On Pangea you can create your own Decentralised Borderless Voluntary Nation (DBVN). Choose your Code of Law, Economic Model, Decision Making Mechanism, write a Constitution and provide Governance Services to Citisens.	https://tse.bitnation.co/
Democracy Earth	Entrepreneurial activity	Open Government	A borderless peer to peer democracy. For everyone, anywhere.	https://www.democracy.earth/
Flux	Entrepreneurial activity	Open Government	Flux is your way to participate directly in parliament. Empowering people in government decisions directly through technology.	https://voteflux.org/
Wien Open Government	Entrepreneurial activity	Open Government	Wien as a pioneer in open government data.	https://open.wien.gv.at/site/
BitGive	Entrepreneurial activity	Philantrophy	Financial transparency of donations and project outcomes.	https://www.bitgivefoundation.org/
Bithope	Entrepreneurial activity	Philantrophy	Financial transparency of donations and project outcomes.	https://bithope.org
Giveth	Entrepreneurial activity	Philantrophy	Giveth is an Open-Source Platform for Building Decentralised Altruistic Communities.	https://giveth.io/

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PinkCoin	Entrepreneurial activity	Philantrophy	The world's most advanced blockchain based donation platform for social impact.	https://getstarted.with.pink/
Blockchain for Humanity	Entrepreneurial activity	Adjacent Actors	The World Identity Network (WIN), the United Nations Office for Project Services (UNOPS), and the United Nations Office of Information and Communications Technology (UN-OICT) are partnering to launch a pilot initiative that will use the blockchain technology to help combat child trafficking in Moldova.	http://www.b4h.world/
Melonport	Entrepreneurial activity	Adjacent Actors	Melonport is a technology regulated investment fund. Projects have been proposed to feed directly from power plant data and thus greating green energy funds. This vehicle could be used for green finance, but still has some way to go.	https://melonport.com/
SatoshiPay	Entrepreneurial activity	Adjacent Actors	Nanopayment infrastructure with API. If nanopayments start to work, a huge number of business models opens up.	https://satoshipay.io/
Spherity	Entrepreneurial activity	Adjacent Actors	Bridging the physical, biological and digital spheres. Spherity gives any entity, a unique identifier linked to a digital twin with access to a scalable and self-sovereign transaction layer.	http://spherity.com
ETHZ IM	Entrepreneurial activity	Adjacent Actors	Combining Computer Science with Social Science. Blockchain technology is treated as an interesting driver for innovation.	http://www.im.ethz.ch/research.html
Consensys	Entrepreneurial activity	Adjacent Actors	ConsenSys is a global formation of technologists and entrepreneurs building the infrastructure, applications, and practices that enable a decentralised world. They offer labs, consulting, capital, and events. Additionally, they are co-developing the Ethereum blockchain.	https://new.consensys.net
Helios Wire	Entrepreneurial activity	Adjacent Actors	Helios is democratising IoT to make blockchain technology accessible, secure and affordable for small, medium, and large organisations, worldwide.	https://helioswire.com/
RIDDLE&CODE	Entrepreneurial activity	Adjacent Actors	RIDDLE&CODE combines the security of smart cards with the potential of Bitcoin Technology and the Internet of Things (IoT). This is achieved by extending smart card chips in form and function. This way the sophisticated security measures known from the credit card industry get transferred into the Blockchain world and the physical internet.	https://www.riddleandcode.com/

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WIN - World Identity Network	Entrepreneurial activity	Adjacent Actors	Linked to UNITE & UNOPS & Blockchain for Humanity. WIN is a network that wants to build ID solutions to improve the world.	https://win.systems/
Artis	Entrepreneurial activity	Adjacent Actors	ARTIS enables and is a system for real-life, sustainable business cases.	https://artis.eco/
slock.it	Entrepreneurial activity	Adjacent Actors	Decentralised infrastructure for sharing economy. With this platform, sharing of apartments, cars, basically anything becomes easier with smart contracts.	https://slock.it
Metr	Entrepreneurial activity	Adjacent Actors	METR's IoT Backbone is an infrastructure for tenement buildings and public facilities. It works like a digital backbone, which interconnects smart devices and technical systems of different producers through the building. Connectivity for everything!	http://metr.systems/
BCDC	Knowledge development	Climate driven	A UK-based start-up committed to developing DLT and leveraging them to make a positive impact on the world. Developers of FoodTrax, EcoChain, Recycle to Coin and Plastic Foodprint.	https://www.bcdc.online/
Blockchain Climate Institute	Knowledge development	Climate driven	Building a decentralised climate economy in the blockchain era. Blockchain Climate Institute (BCI) is a not-for-profit entity combining the functions of a think-and-do tank, an advocacy group, and a chamber of commerce.	https://www.blockchainclimateinstitute.org/
Blockchain for Climate	Knowledge development	Climate driven	Helping mint successful climate initiatives on the blockchain.	https://www.blockchainforclimate.org/
Blockchain for good	Knowledge development	Climate driven	Blockchain For Good is a think tank which brings together the greatest minds around the world to explore and debate the development of blockchain, for the greater good of humanity, society, economy and our environment.	https://www.blockchainforgood.com/

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Blockchain for Social Impact	Knowledge development	Climate driven	Blockchain for Social Impact Coalition (BSIC) incubates, develops, and implements confederated blockchain products and solutions that can address social and environmental challenges across the United Nation's Sustainable Development Goals. We aim to inspire, federate, and create bridges between NGOs, and government agencies, foundations, impact investors, philanthropists and technologists.	https://www.blockchainforsocialimpact.com/
Climate Ledger Initiative	Knowledge development	Climate driven	CLI is an international, multi-stakeholder initiative at the intersection of climate change and distributed ledger technology (DLT, 'Blockchain'). The mission of CLI is to accelerate #ClimateAction in line with the Paris Climate Agreement and the Sustainable Development Goals (SDGs) through blockchain-based innovation applicable to climate change mitigation, adaptation, and finance. CLI is supported by governments, major international organisations, companies and foundations.	https://www.climateledger.org/
Climate-KIC	Knowledge development	Climate driven	Supported by the European Institute of Innovation and Technology, Climate-KIC identifies and supports innovation that helps society mitigate and adapt to climate change.	http://www.climate-kic.org/
dena	Knowledge development	Climate driven	dena is the German competence center for energy efficiency, renewable energy and smart energy systems. They contribute to reaching Germany's environmental goals. Among others, they published a report about applications of blockchains in energy.	https://www.dena.de
Energy Web Foundation	Knowledge development	Climate driven	The Energy Web Foundation is a global non-profit organisation focused on accelerating blockchain technology across the energy sector.	energyweb.org
Innogy Innovation Hub	Knowledge development	Climate driven	Subsidiary of RWE. Focused on innovating the energy industry through key focus areas: machine economy, urban exponentials, smart & connected, disruptive digital and cybersecurity ventures. Innogy Innovation Hub supports many start-ups in the blockchain for Climate area (e.g. OMOS).	https://innovationhub.innogy.com/

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Rocky Mountain Institute	Knowledge development	Climate driven	RMI engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. We employ rigorous research, analysis, and whole-systems expertise to develop breakthrough insights. We then convene and collaborate with diverse partners—business, government, academic, nonprofit, philanthropic, and military—to accelerate and scale solutions.	https://www.rmi.org/
Stockholm Green Digital Finance	Knowledge development	Climate driven	Stockholm Green Digital Finance is a not-for-profit Centre tasked to accelerate Green Finance and Investment through Fintech Innovations.	https://stockholmgreenfin.tech/
The World Bank Climate Change Group	Knowledge development	Climate driven	Report: Blockchain and emerging digital technologies for enhancing post-2020 climate markets.	https://www.worldbank.org/en/topic/climatechange
World Energy Council	Knowledge development	Climate driven	The World Energy Council is the principal impartial network of leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.	https://www.worldenergy.org/
BIOTS	Knowledge development	DLT driven	Blockchain and IoT School. Funding through corporates who define challenges. Most challenges in energy systems.	http://biots.org/
Blockchain Community Group	Knowledge development	DLT driven	The mission of the the Blockchain Community Group is to generate message format standards of Blockchain based on ISO20022 and to generate guidelines for usage of storage including torrent, public blockchain, private blockchain, side chain and CDN. Lead by W3.	https://www.w3.org/community/blockchain/
Consensys	Knowledge development	DLT driven	ConsenSys is a global formation of technologists and entrepreneurs building the infrastructure, applications, and practices that enable a decentralised world. They offer labs, consulting, capital, and events. Additionally, they are co-developing the Ethereum blockchain.	https://new.consensys.net
DAI-Labor	Knowledge development	DLT driven	The DAI-Labor and the chair "Agent technologies in business applications and telecommunication" at the Technische Universität Berlin, headed by Prof. Dr. Sahin Albayrak, perform research and development in order to provide solutions for a new generation of systems and services – "smart services and smart systems".	http://www.dai-labor.de/en/

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EPFL DEDIS	Knowledge development	DLT driven	The DEDIS team is working on a number of projects related to large-scale collective authorities (cothorities), that distribute trust among a number of independent parties.	https://dedis.epfl.ch/
ERCIM	Knowledge development	DLT driven	ERCIM - the European Research Consortium for Informatics and Mathematics - aims to foster collaborative work within the European research community and to increase co-operation with European industry.	https://www.ercim.eu/contact
ETHZ DCG	Knowledge development	DLT driven	Research focused on distributed computing and networks.	https://disco.ethz.ch/
ETHZ IM	Knowledge development	DLT driven	Combining Computer Science with Social Science. Blockchain technology is treated as an interesting driver for innovation.	http://www.im.ethz.ch/research.html
Forschungsstelle für Energiewirtschaft	Knowledge development	DLT driven	The FfE is an independent research institute that focuses on energy technology and energy management issues on a scientific basis. It draws up its research results across all energy carriers and represents them free of political directions - on the basis of scientific methods and analyses.	https://www.ffe.de/themen-und-methoden/digitalisierung
Frankfurt Blockchain Center	Knowledge development	DLT driven	The Frankfurt School Blockchain Center is a think tank and research centre which investigates implications of the blockchain technology for companies and their business models.	http://www.frankfurt-school.de/home/research/centres/blockchain.html
Fraunhofer Blockchain-Labor	Knowledge development	DLT driven	A multidisciplinary group for conception, development and evaluation of blockchain solutions. They focus on bringing academic knowledge for the DLT space into actionable solutions. Application focus is IoT, IP, stock trading, wealth management but also open for other applications.	https://www.fit.fraunhofer.de/de/fb/cscw/blockchain.html
KIT IISM	Knowledge development	DLT driven	In einem interdisziplinären Team und Netzwerk forschen wir an einer innovativen Gestaltung des Energiesystems der Zukunft.	https://im.iism.kit.edu/1093_2058.php
RIAT	Knowledge development	DLT driven	RIAT is an institute for research, development, communication and education in the fields of cryptoeconomics and the blockchain. We work with experimental artistic technology and open hardware.	https://riat.at/

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WEF - Future of Blockchain	Knowledge development	DLT driven	This WEF council explores how the Blockchain could impact industry, governments and society in the future, and design innovative governance models that ensure that their benefits are maximised, and the associated risks kept under control.	https://www.weforum.org/communities/the-future-of-blockchain
Blockchain for good	Knowledge diffusion	Climate driven	Blockchain For Good is a think tank which brings together the greatest minds around the world to explore and debate the development of blockchain, for the greater good of humanity, society, economy and our environment.	https://www.blockchainforgood.com/
Blockchain for Social Impact	Knowledge diffusion	Climate driven	Blockchain for Social Impact Coalition (BSIC) incubates, develops, and implements confederated blockchain products and solutions that can address social and environmental challenges across the United Nation's Sustainable Development Goals. We aim to inspire, federate, and create bridges between NGOs, and government agencies, foundations, impact investors, philanthropists and technologists.	https://www.blockchainforsocialimpact.com/
Blockchain in energy forum	Knowledge diffusion	Climate driven	Join other innovators from utilities, start-ups, investors and policymakers for a day of networking, dynamic conversations, and learning what the future may hold for this technology.	https://www.greentechmedia.com/events/live/blockchain-in-energy-forum/speakers
Climate Chain Coalition	Knowledge diffusion	Climate driven	A multi-stakeholder group of 25 organisations working on distributed ledger technology (DLT, i.e. blockchain) held a meeting to agree to collaborate and establish an open global initiative called the Climate Chain Coalition (CCC) on 12.12.2017.	https://cop23.unfccc.int/news/un-supports-blockchain-technology-for-climate-action
Energy Web Foundation	Knowledge diffusion	Climate driven	The Energy Web Foundation is a global non-profit organisation focused on accelerating blockchain technology across the energy sector.	energyweb.org
EventHorizon	Knowledge diffusion	Climate driven	EventHorizon is the ONE exclusive annual event centered on energy blockchain solutions for a future based solely on renewable resources.	https://eventhorizon2018.com/
Hack4Climate	Knowledge diffusion	Climate driven	Hack4Climate aims to bring together Developers and Climate Experts in order to build innovative solutions to fight climate change. Held annually at COP.	https://hack4climate.org
Blockchain Austria	Knowledge diffusion	DLT driven	Blockchain association of Austria.	https://www.blockchain-austria.gv.at

Actor name	System function	Sub-group	Description / Pitch	URL
Blockchain Hub	Knowledge diffusion	DLT driven	Blockchain Hub advocates blockchain, smart contracts and the decentralised web to all stakeholders in society.	https://blockchainhub.net/
Blockchain Policy Initiative	Knowledge diffusion	DLT driven	Promoting sound policy foundations for a global cryptoeconomy.	https://blockchainpolicy.org
Bundesblock	Knowledge diffusion	DLT driven	Association for the promotion of blockchain technology in Germany.	http://bundesblock.de/bundesverband/
Consensys	Knowledge diffusion	DLT driven	ConsenSys is a global formation of technologists and entrepreneurs building the infrastructure, applications, and practices that enable a decentralised world. They offer labs, consulting, capital, and events. Additionally, they are co-developing the Ethereum blockchain.	https://new.consensys.net
Crypto Valley Association	Knowledge diffusion	DLT driven	We support and connect startups and established enterprises through policy recommendations, projects across verticals, initiating and enabling research, and organising conferences, hackathons, and other industry events.	https://cryptovalley.swiss/
ERCIM	Knowledge diffusion	DLT driven	ERCIM - the European Research Consortium for Informatics and Mathematics - aims to foster collaborative work within the European research community and to increase co-operation with European industry.	https://www.ercim.eu/contact
Frankfurt Blockchain Center	Knowledge diffusion	DLT driven	The Frankfurt School Blockchain Center is a think tank and research center which investigates implications of the blockchain technology for companies and their business models.	http://www.frankfurt-school.de/home/research/centres/blockchain.html
UNITE	Knowledge diffusion	DLT driven	UN ICT office with the goal to make the world a better place. Challenges on the Unite Idea Platform drive various ICT projects, including Blockchain based.	https://unite.un.org/
WEF - Future of Blockchain	Knowledge diffusion	DLT driven	This WEF council explores how the Blockchain could impact industry, governments and society in the future, and design innovative governance models that ensure that their benefits are maximised and the associated risks kept under control.	https://www.weforum.org/communities/the-future-of-blockchain
Ecosphere+	Resource mobilization	Climate driven	Supports Poseidon (carbon credits on blockchain) and other projects to save forests.	https://www.ecosphere.plus/

Actor name	System function	Sub-group	Description / Pitch	URL
Energy Blockchain Labs	Resource mobilization	Climate driven	Energy Blockchain Labs, which was founded in May 2016, aims to provide financial services to the environmental protection industry based on blockchain technology.	http://energy-blockchain.com/ENHome
Energy Unlocked	Resource mobilization	Climate driven	Unlocking innovation today will allow us to most effectively tackle the energy 'trilemma' of low cost, low carbon and resilient energy for all. No global organisation exists today to support this innovation. Energy Unlocked aims to fill that gap.	http://www.energyunlocked.org/
Fintech4Good	Resource mobilization	Climate driven	Global FinTech and Blockchain network, that works with start-ups, industrial leaders, NPOs, and investors to develop and implement solutions for a better world. The network focuses on incubation, acceleration and investment. The network comprises of several subgroups that appear to be loosely connected and following their own agenda.	https://www.fintech4good.co/
Generation Investment	Resource mobilization	Climate driven	Investment into long-term opportunities. Also, annual research reports.	https://www.generationim.com/
Grid.vc	Resource mobilization	Climate driven	We build and grow promising energy sector startups from the pilot phase onwards. We are happy to offer facilities for pilot projects, but we do not take an active part in operative R&D work. Our first investment is typically from between €100k and €500k. We can be the lead investor or co-invest with others.	https://grid.vc/
Hack4Climate	Resource mobilization	Climate driven	Hack4Climate aims to bring together Developers and Climate Experts in order to build innovative solutions to fight climate change. Held annually at COP.	https://hack4climate.org
Innogy Innovation Hub	Resource mobilization	Climate driven	Subsidiary of RWE. Focused on innovating the energy industry through key focus areas: machine economy, urban exponentials, smart & connected, disruptive digital and cybersecurity ventures. Innogy Innovation Hub supports many start-ups in the blockchain for Climate area (e.g. OMOS, MotionWerk).	https://innovationhub.innogy.com/

Actor name	System function	Sub-group	Description / Pitch	URL
Inven Capital	Resource mobilization	Climate driven	The investment strategy is focused on Smart Energy, where they look for innovative and fast growing European startups, with scalable business models proven by sales.	http://www.invencapital.cz/
KIC InnoEnergy	Resource mobilization	Climate driven	InnoEnergy is the innovation engine for sustainable energy across Europe supported by the European Institute of Innovation and Technology. Among others, it supports FlexiDao.	http://www.innoenergy.com/
KWHackaton	Resource mobilization	Climate driven	The energy industry's first blockchain hackathon, organised by Electron.	https://www.kwhack.com/
Next-Incubator	Resource mobilization	Climate driven	Der Next-Incubator ist das Open Innovation Lab der Energie Steiermark, eines der größten Dienstleistungsunternehmen Österreichs. 1.700 MitarbeiterInnen widmen ihre Erfahrung und Kompetenz einer fairen Partnerschaft mit den rund 600.000 KundInnen im In- und Ausland. Wir suchen innovative PartnerInnen, um gemeinsam Produkte und Services für das digitale Neugeschäft der Energie Steiermark zu entwickeln.	https://next-incubator.e-steiermark.com/
Porini Foundation	Resource mobilization	Climate driven	Porini's core mission is to encourage the use of innovative technology for the protection of endangered species and ecosystems worldwide and for the benefit of people living there and we want to support local communities as first line of defense to reduce the impact of wildlife crime.	https://porini.foundation/de/#focus
Set Ventures	Resource mobilization	Climate driven	At SET Ventures we help entrepreneurs build companies that impact the future of energy.	http://www.setventures.com/
Blockchain Capital, LLC	Resource mobilization	DLT driven	The pioneer and premier venture capital firm focused exclusively on the blockchain technology sector and crypto ecosystem.	http://blockchain.capital/
Consensys	Resource mobilization	DLT driven	ConsenSys is a global formation of technologists and entrepreneurs building the infrastructure, applications, and practices that enable a decentralised world. They offer labs, consulting, capital, and events. Additionally, they are co-developing the Ethereum blockchain.	https://new.consensys.net
Endesa Blockchain lab	Resource mobilization	DLT driven	Blockchain lab is the latest challenged launched by Endesa Energy Challenges in search of the leading experts in Blockchain to propose ideas and solutions for transforming the future of energy.	http://endesaenergychallenges.com/blockchain/

Actor name	System function	Sub-group	Description / Pitch	URL
Katapult Accelerator	Resource mobilization	DLT driven	3 months accelerator program built around exponential technologies: AI, Blockchain, VR, IoT.	http://katapultaccelerator.com/
Konfid.io	Resource mobilization	DLT driven	Accelerating the adoption of disruptive technologies to build a more decentralised future.	https://www.konfid.io/
Next Big Thing	Resource mobilization	DLT driven	Next Big Thing offers a complete framework for the acceleration of IoT ventures.	http://www.nextbigthing.ag/
Outlier Ventures	Resource mobilization	DLT driven	PRE-SEED & SEED AT WHERE BLOCKCHAIN CONVERGES WITH OTHER DEEP TECH in Services (fintech, etc), Health, Industry 4.0, Smart Cities.	https://outlierventures.io/
UNITE	Resource mobilization	DLT driven	UN ICT office with the goal to make the world a better place. Challenges on the Unite Idea Platform drive various ICT projects, including DLT based.	https://unite.un.org/
UNOPS	Resource mobilization	DLT driven	UNOPS provides UN partners with services. Services cover infrastructure, project management, procurement, financial management and human resources. Their partners call on them to supplement their own capacities, improve speed, reduce risks, boost cost-effectiveness and increase quality. Part of Blockchain for Humanity project.	https://www.unops.org/about
Blockchain Climate Institute	Advocacy support	Climate driven	Building a decentralised climate economy in the blockchain era. Blockchain Climate Institute (BCI) is a not-for-profit entity combining the functions of a think-and-do tank, an advocacy group, and a chamber of commerce.	https://www.blockchainclimateinstitute.org/
Blockchain for Climate	Advocacy support	Climate driven	Helping mint successful climate initiatives on the blockchain.	https://www.blockchainforclimate.org/
Blockchain for Social Impact	Advocacy support	Climate driven	Blockchain for Social Impact Coalition (BSIC) incubates, develops, and implements confederated blockchain products and solutions that can address social and environmental challenges across the United Nation's Sustainable Development Goals. We aim to inspire, federate, and create bridges between NGO's, and government agencies, foundations, impact investors, philanthropists and technologists.	https://www.blockchainforsocialimpact.com/

Actor name	System function	Sub-group	Description / Pitch	URL
Climate Chain Coalition	Advocacy support	Climate driven	A multi-stakeholder group of 25 organisations working on distributed ledger technology (DLT, i.e. blockchain) held a meeting to agree to collaborate and establish an open global initiative called the Climate Chain Coalition (CCC) on 12.12.2017.	https://cop23.unfccc.int/news/un-supports-blockchain-technology-for-climate-action
dena	Advocacy support	Climate driven	dena is the German competence center for energy efficiency, renewable energy and smart energy systems. They contribute to reaching Germany's environmental goals. Among others, they published a report about applications of blockchains in energy.	https://www.dena.de
Energy Web Foundation	Advocacy support	Climate driven	The Energy Web Foundation is a global non-profit organisation focused on accelerating blockchain technology across the energy sector	energyweb.org
Blockchain Policy Initiative	Advocacy support	DLT driven	Promoting sound policy foundations for a global cryptoeconomy.	https://blockchainpolicy.org
Bundesblock	Advocacy support	DLT driven	Association for the promotion of blockchain technology in Germany.	http://bundesblock.de/bundesverband/
WEF - Future of Blockchain	Advocacy support	DLT driven	This WEF council explores how the Blockchain could impact industry, governments and society in the future, and design innovative governance models that ensure that their benefits are maximised, and the associated risks kept under control.	https://www.weforum.org/communities/the-future-of-blockchain

7.3. List of energy DLT observers

These are actors who are observing the ecosystem or cooperate with some of the identified energy DLT actors as shown in the ecosystem landscape map (see chapter 4.2) and listed in detail in chapter 8.3.

ABB Switzerland	Energon holding	Lyons Group	Stedin
agiplan GmbH	Engie	M2G-Consult	Strategische Kreativiät
agl	ENTSO-E	Magnus Commodities	Studio Wolfpack
Alliander	Enyway	Mainzer Stadtwerke AG	SUPSI
American Standard Power	enyway	MeetInReykjavik	Swisspower
AML	ESCP Europe	Microsoft	Synergy
Andritz Hydro	ESMIG	Missing Link	Tal.Markt
Atkins	European Energy Exchange AG	Mitsubishi Corporation	TATA Consultancy Services
Austrian Ministry for Technology	EWE AG	Mitsui & Co. Global Strategic Studies Institute	Tepco
Austrian Ministry of Transport, Innovation and Technology	ewz	Modus Energy	Thermopolis Partners
Axpo	Exelon	Motor Entertainment GmbH	Thüga Aktiengesellschaft
BBOXX	Eximprod Grup	MVP Workshop	Tiko Energy Solutions
BKW Energie	Federal Ministry of Economic Affairs and Energy	Navigant Research	tiko Energy Solutions AG
Boralex Inc.	Fronius International	novenergia	TIWAG-Tiroler Wasserkraft AG
Bundesverband Erneuerbare Energie e.V.	G&R abogados	OMV	TOHO GAS CO., LTD
Centrica	German Renewable Energy Federation	Pacific Gas & Electric	Tokyo Electric Power Company
Chalmers University of Technology	German Solar Association	Pfalzwerke Aktiengesellschaft	TransAlta Energy Marketing
Chubu Electric Power	g-events	Powernext SA	Transclick, Inc
Dachgold e.U.	GIZ	PowerSolution Energieberatung GmbH	Trueken
Deutsche Bank AG	GIZ Gmbh	PSE Innowacje	TWL
deveritec GmbH	Goodcen	ptt group	Umeå Energi AB
duke energy	GRDF	RhönEnergie Fulda GmbH	UN ICT Office

ABB Switzerland	Energon holding	Lyons Group	Stedin
E.ON	GRIPS Energy AG	Salzburg AG	Uniper
Eandis	Gründungszentrum Start Up Tirol GmbH	Saras Ricerche e Tecnologie s.r.l.	Vandebron
Ecofys	ilwerke vkw	Sasha Waltz & Guests	Vattenfall
ECOHZ	inno2grid GmbH	SB Energy	VOEST Alpine
EDF	Iskandar Widjaja	Schneider Electric	Wipro
Electric Power Research Institute	Iskratel	SEAS-NVE	WSW
ELES d.o.o.	IWB - Industrielle Werke Basel	Sembcorp Industries Ltd	XU
Elia	Korean Power Exchange	Sempra Energy	Yuso
EnBW AG	Kucinich Consulting	Shell	Zentrum Digitalisierung. Bayern
eneco	kwp consulting group	Siemens	ZfK
Enedis	Lakestar	South Frontier Energy	ZMART
Enercity	Landsbankinn hf.	SP group	Zumtobel Lighting
energate gmbh	Lebanese Center for Energy Conservation	St.Galler Stadtwerke	
Energie Control Austria	Lexon	Standortagentur Tirol	
Energie Steiermark	Lichtermacher	Statoil	

8. About

EIT Climate-KIC (Knowledge and Innovation Community) is the EU's largest public-private partnership addressing climate change through innovation. Our community network comprises over 300 leading business, academia, public sector and NGO partners from across the whole of Europe, committed to creating a prosperous, inclusive, climate-resilient society founded on a circular, zero-carbon economy. EIT Climate-KIC is predominantly grant-funded by the European Institute for Innovation and Technology, a body of the European Union.

» www.climate-kic.org

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sus.lab's mission is to bring sustainability research into practice through collaborative project work with industry and other organisations.

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9. Imprint

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