



European
Commission

BLOCKCHAIN NOW AND TOMORROW

ASSESSING MULTIDIMENSIONAL IMPACTS OF DISTRIBUTED LEDGER TECHNOLOGIES

EXECUTIVE SUMMARY



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We have come a long way, in a short period of time, from the first views on Bitcoin and cryptocurrencies to a growing hype and media coverage capturing public attention, and now a profusion of funding and experimentation with blockchain or, in a broader sense, distributed ledger technologies.

Blockchain can enable parties with no particular trust in each other to exchange digital data on a peer-to-peer basis with fewer or no third parties or intermediaries. Data could correspond, for instance, to money, insurance policies, contracts, land titles, medical and educational records, birth and marriage certificates, buying and selling goods and services, or any transaction or asset that can be translated into a digital form. The potential of blockchain to engender wide-ranging changes in the economy, industry and society – both now and tomorrow – is currently being explored across sectors and by a variety of organisations.

The report *Blockchain Now and Tomorrow* brings together research from different units and disciplinary fields of the Joint Research Centre (JRC), the European Commission's science and knowledge service. It provides multidimensional insights into the state of blockchain technology by identifying ongoing and upcoming transformations in a range of sectors and setting out an anticipatory approach for further exploration. Moving beyond the hype and debunking some of its controversies, we aim to offer both an in-depth and practical understanding of blockchain and its possible applications.

How blockchain works

Blockchain is a tamper-resistant and time-stamped database (ledger) operating through a distributed network of multiple nodes or users. It is, however, a particular type of database. Transactions between users do not require intermediaries or trusted third parties. Instead, **trust is based on the rules that everyone follows to verify, validate and add transactions to the blockchain** – a 'consensus mechanism' (*Figure 1*).

Blockchain is based on a particular combination of key features: decentralisation, tamper-resistant, transparency, security and smart contracts.

The lack of a central entity controlling the system creates strong resilience against single point-of-failure flaws. Since it is extremely difficult to change or delete the record of transactions, in this sense the **records on a blockchain are tamper-resistant**. In public or open blockchains **all transactions are transparent and visible**. **All transactions are time-stamped** – that is, data such as details about a payment, a contract, transfer of ownership, etc. are linked publicly to a certain date and time. And **smart contracts enable the terms of agreement between parties to be executed and enforced without the need for human coordination or intervention**.

However, **a number of challenges remain unresolved**, such as the **limited scalability and performance** of public blockchains, mainly related to the low volume of transactions,

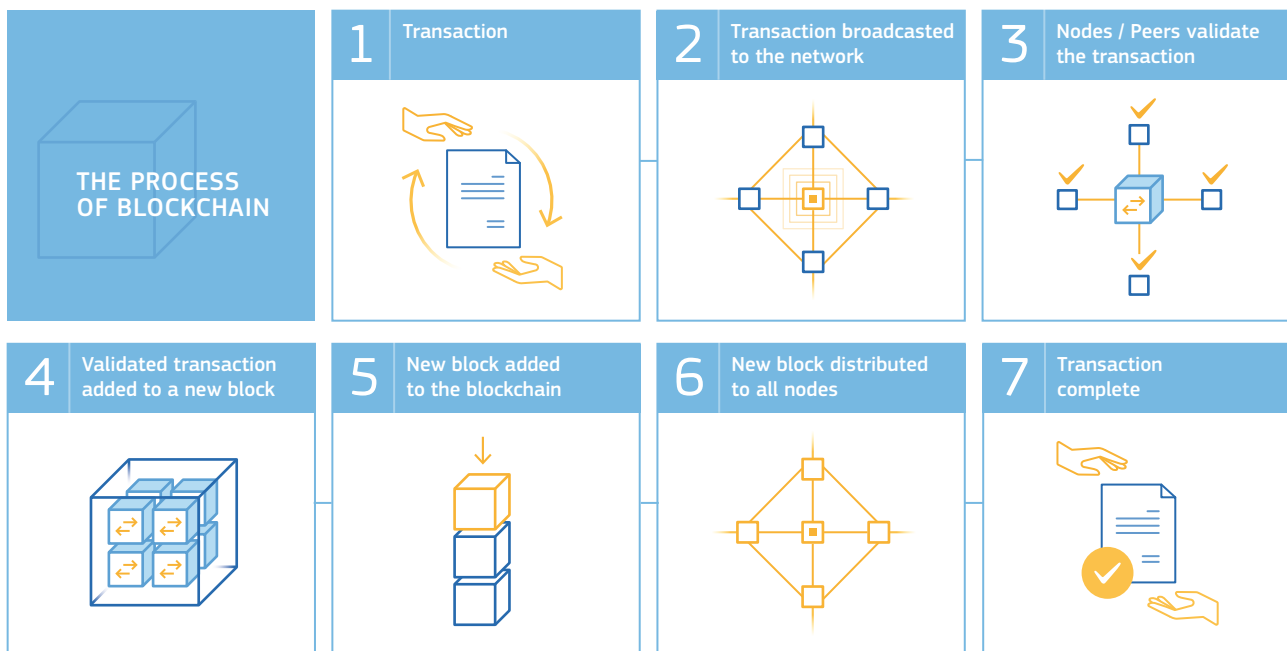


Figure 1: How a blockchain works

or the **high energy consumption** when deploying current PoW consensus mechanisms. Other threats can arise from **potential collusion** from a majority of participants which could overrun the network (51 % attacks), or from the high dependency of running the network on a limited number of participants. A major source of security vulnerability also lies in the **added responsibility for key management**, which can be as simple and serious as losing a phone or a back-up of the credentials.

Another key issue that needs further research is **how to safeguard personal, sensitive or confidential data**. Transparent data on a blockchain might be a problem when specific data sets are not meant to be publicly available, or need to be changed due to errors, inaccuracies or other problems in the original data entry. Potential conflicts between specific blockchain architectures and the EU's GDPR warrant a wider debate.

Scanning blockchain ecosystems

To a certain degree, the hype around blockchain technology has been influenced or shaped by

a spike in interest from financial institutions since 2014. However, while more well-known applications in the financial sector were under development, **blockchain's broader potential for other sectors increasingly came to the fore**. At the moment, a number of initiatives and pilots are ongoing which means much of blockchain's potential has yet to be fully tested. For instance, recent analyses of its actual economic impact have sent mixed signals.

Nevertheless, blockchain is now **one of the technologies which is anticipated to have a profound impact over the next 10-15 years**, backed in the short term by upward forecasts for investment. This is visible, for instance, on how **the attention of investors worldwide has shifted to blockchain companies since 2009**.

The rise of blockchain is witnessed by both the **sharp growth in blockchain start-ups and the volume of their funding**. Massive funding started in 2014 with EUR 450 million and rapidly increased to EUR 3.9 billion in 2017 and over EUR 7.4 billion in 2018.

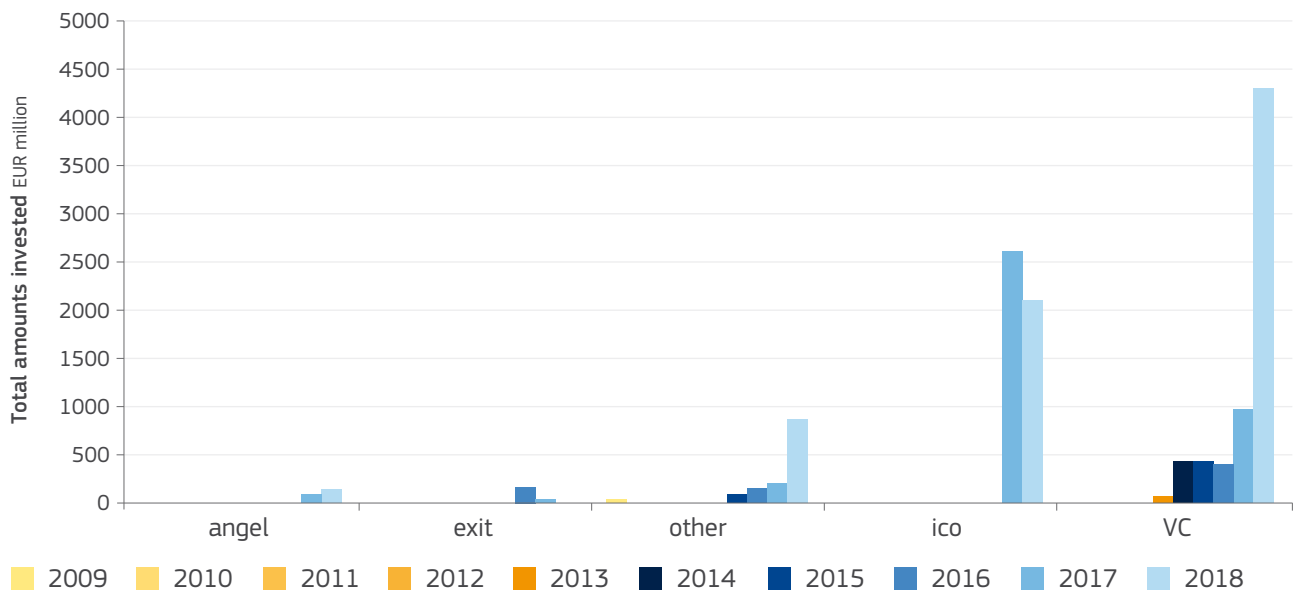


Figure 2: Total amounts (EUR million) invested in blockchain start-ups across different funding instruments (2009-2018)

Note: The category labelled 'other' includes equity-based funding, private and public grants and accelerator funds. The 'exit' category contains acquisitions and initial public offerings.

Source: Venture Sources - Dow Jones

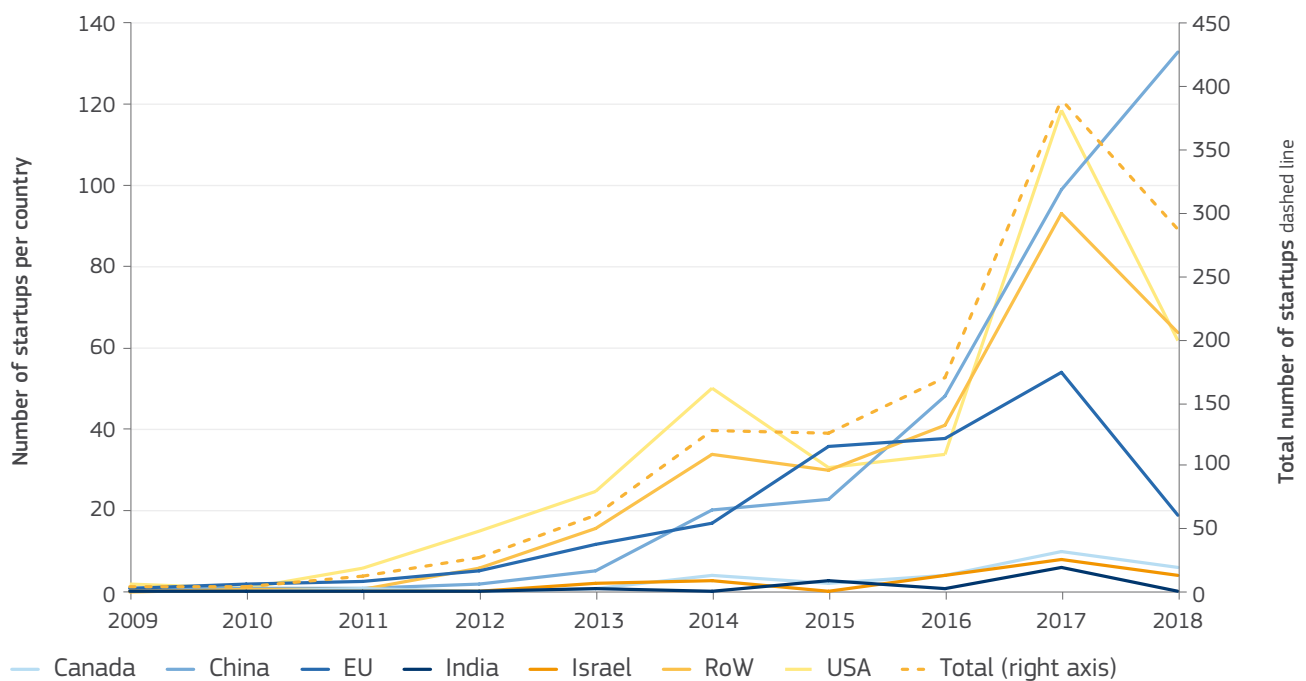


Figure 3: Trends in total blockchain start-ups across the main world players

Source: Venture Sources - Dow Jones

In 2017, the amount of invested capital grew at an unprecedented scale due to the explosion of ICOs and venture capital investments which continued at a high level in 2018 (Figure 2).

There is strong competition from the USA and China, as they now appear to lead in terms of blockchain start-ups (Figure 3). The UK has a key role in Europe both in terms of numbers

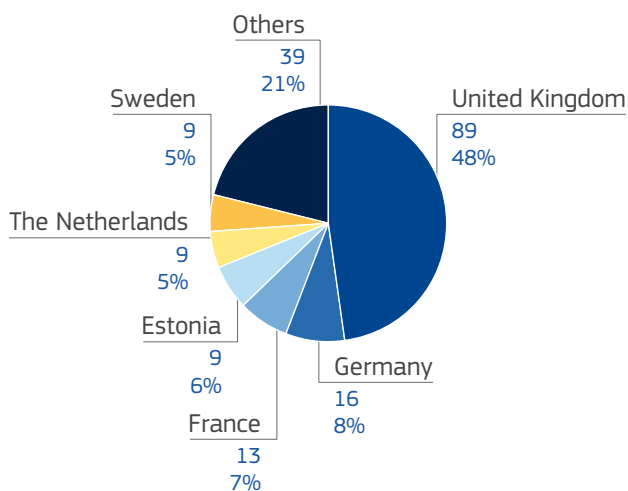


Figure 4: Numbers and shares of blockchain start-ups established between 2009–2018 across: EU Member States

Source: Venture Sources - Dow Jones

of blockchain start-ups (hosting almost half of them, [Figure 4](#)), and in funding (attracting about 70 % of EU investments, [Figure 5](#)). A broader look at international players shows **Switzerland and Singapore displaying particular dynamism followed by Japan and South Korea.**

Blockchain in the EU policy context

The growth and increasing attention to blockchain technology has not gone unnoticed at EU policy level. The main focus was initially placed on the **emergence of crypto-assets and virtual currencies such as Bitcoin**. In November 2016, the EC, in collaboration with the EP, set up a horizontal **task force on FinTech with a dedicated group on DLTs**, which was followed by a public consultation in the following year and the FinTech Action Plan in 2018.

Blockchain, as one of the breakthrough technologies with a huge potential impact for other sectors, has also been publicly recognised by European institutions, with evidence-based research projects such as #Blockchain4EU: Blockchain for Industrial Transformations. This project was carried by the JRC in support of DG GROW as a forward-looking socio-technical

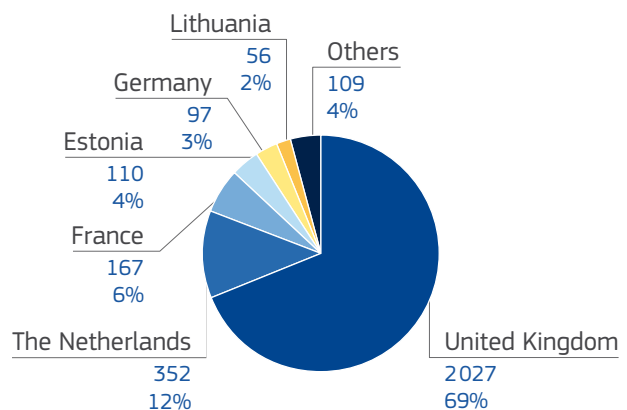


Figure 5: Shares and amounts (EUR million) received via all funding mechanisms by blockchain start-ups between 2009–2018 across: the EU Member States

Source: Venture Sources - Dow Jones

exploration of existing, emerging and potential applications based on blockchain and other DLTs for industrial sectors (Nascimento, Pólvara and Sousa Lourenço, 2018).

Several strategies oriented towards blockchain's cross-cutting effects are now being explored across the EC. Amid its recent efforts, **the EU Blockchain Observatory and Forum, the EBP and the Anti-Counterfeiting Blockchain Forum** stand out as key initiatives in close cooperation with stakeholders from industry, start-ups, governments, international organisations and civil society.

A range of **calls, research programmes and funding for third parties** is also at the core of EC support for experimentation and innovation. It includes, for instance, a call in 2018 on 'Blockchain and Distributed Ledger Technologies for SMEs', an EIC Horizon Prize for 'Blockchains for Social Good', and the Pilot Project '#DLT4Good: Co-creating a European Ecosystem of DLTs for Social and Public Good'. The latter is being developed by the JRC in collaboration with DG CNECT and the support of the EP. It is centred on research and experimentation for

the development and scale-up of DLT solutions suited to specific challenges of public and third-sector organisations at local, regional, national or supranational levels.

A number of EC services are conducting, starting or reflecting on **exploratory activities using blockchain as possible ways to improve and support the execution of core EC processes and policies**. Such internal explorations or pilots are targeted, for example, at the accessibility of regulated information; real-time reporting; management of identities; notarisation services; and monitoring the movement of goods.

The EP is also actively engaged in past and ongoing discussions about the cross-sectorial potential of blockchain, following its first **Resolution on virtual currencies** that spurred the setting up of the FinTech task force. Since then, the European Parliamentary Research Service has published reports and other materials on the topic. In addition, **two Resolutions** – ‘**Distributed Ledger Technologies and Blockchains: Building Trust with Disintermediation**’, and ‘**Blockchain: A Forward-Looking Trade Policy**’ – were discussed and approved in 2018.

Transforming financial systems

As of February 2019, there are more than 2000 cryptocurrencies (Bitcoin being the most well-known). **Unlike the so-called fiat currency, the value of most cryptocurrencies is not supported by the status of legal tender**. Instead, it is determined by the trust each person has that the underlying technology (blockchain) will not allow double spending, will not be debased, but will be accepted as a means of payment by other economic actors.

The **absence of a monetary authority and of a lender of last resort, however, exposes most cryptocurrencies to high volatility in the face of speculative activities**. It also makes them potentially harder to recover

“ The EC is supporting multi-stakeholder initiatives that gather industry, start-ups, governments, international organisations and civil society. ”

from crises, and exposes them to a long-term deflationary dynamic.

Blockchain activity in finance has remained very strong, with the development of new product classes hybridising cryptocurrencies and DLT-supported fund-raising: **ICOs**. These offerings are becoming significant **fund-raising venues for businesses and start-ups** in particular, as an alternative to formal financing systems.

However, **ICOs currently carry important risks**. Such risks arise from the uncertainty of the applicable regulatory framework for ICOs and crypto-asset markets, the lack of financial consumer-protection safeguards, and limitations in the structuring of ICOs and operational risks related to DLTs.

Traditional financial intermediaries have shown great interest in this technology. **Blockchain and DLTs are promising to lower the costs associated with the entire life cycle of a financial instrument** (issuance, trading, settlement, etc.) while simplifying the process of issuing and significantly reducing the clearing and settlement time. Other **successful implementations include a substantial reduction in payment systems' transaction costs.**

For instance, effective benefits in cross-border payments are related to real-time reporting and the update of positions, liquidity management, the complete traceability of transactions, and simplified reconciliation across accounts.

However, in most cases, the technology is either not sufficiently well developed to be broadly adopted or is still limited to small subsets of participants. Beside **performance and scalability**, other technical challenges remain regarding **integration with legacy infrastructures** or **standardisation and interoperability** between different systems. For example, regulatory challenges (Blandin et al., 2019) include the **validity and enforceability of smart contracts**; the nature and financial **classification of tokens**; **consumer and investor protection**; enforcement of anti-money laundering requirements; and the overall **compliance with securities law.**

Transforming industry, trade and markets

Blockchain technology is expected to bring a series of benefits to a number of industrial sectors, firms and businesses already experimenting with the technology, or which may soon see their sector or activities impacted by its existence.

For instance, **blockchain-based systems could facilitate interactions in global and distributed supply chains between untrusting actors**, including producers, retailers, distributors, transporters, suppliers and consumers.

Traceability and quality control covering how products are grown, stored, inspected and transported – i.e. from the farm to fork, could enhance accountability for all those involved. **Proof of origin and compliance with environmental rules, organic labelling, fair trade** and other characteristics could help consumers to make informed decisions and steer companies towards more sustainable business models.

In additive and subtractive manufacturing, a blockchain could also serve as a **tamper-resistant record of digital file ownership**, and help to **prevent unauthorised use, theft and infringements (Box 1)**. In the creative industries, it also has the potential to implement

BOX 1. Foresight and prototyping for policy

The JRC recently developed the project '#Blockchain4EU: Blockchain for Industrial Transformations' whereby five speculative prototypes were co-created with stakeholders in the field (Nascimento, Pólvara and Sousa Lourenço, 2018). These fictional learning artefacts were designed to represent in tangible and interactive ways how blockchain and other DLTs may exist in the near future in five industrial

sectors. The prototypes are meant to stimulate a foresight culture in policy by inspiring anticipatory thinking on opportunities and challenges of a particular emerging technology. They also aim to engage and inform other parties, such as industry or SMEs, already involved with, potentially interested in, or working in areas that may be impacted by blockchain and other DLTs in the short or medium-term.

fairer ways of compensating owners and creators through pay-per-usage, micropayments or automatic payment distributions.

In energy communities and peer-to-peer energy trading and pilots, **smart contracts are automatically managing supply-and-demand flows** towards the optimal use of available energy (*Box 2: Gigbliss*). Microgrid energy markets could be supported whereby individual customers

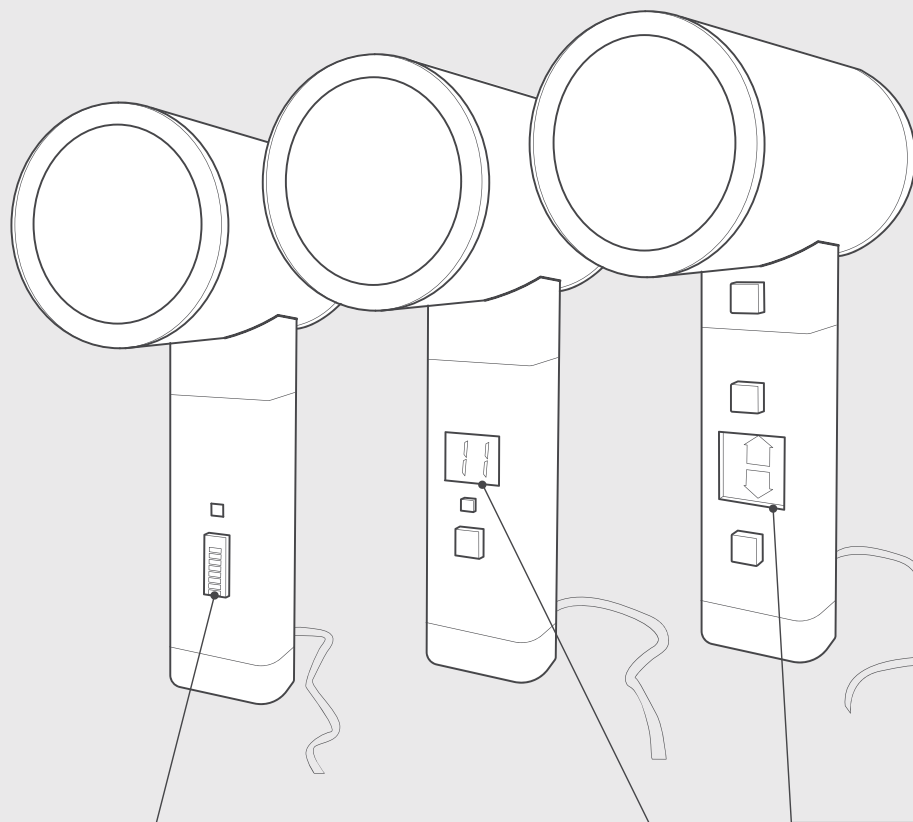
trade locally produced renewable energy directly with others in their communities with (near) real-time pricing.

However, a number of key challenges lie ahead. Blockchain could support the use of digital data across sectors in **close combination with other digital technologies**, such as IoT, AI, robotics, or additive and subtractive manufacturing. But it is still uncertain how that

BOX 2. Gigbliss

What if your hairdryer could save you money by trading energy with power grids or even other hairdryers? Gigbliss is an IoT suite that offers three models of the same hairdryer, AUTO, BALANCE and PLUS. These appliances allow for and represent distinct economic models of automated energy consumption, management and trading.

#Energy #IoT #Consumption
#Trading #SmartStorage
#SmartContract #SmartGrids



AUTO Display showing power availability and connection settings

BALANCE Display showing energy management and charging level

PLUS Display showing market trading credits and energy storage

To learn more about Gigbliss and the other prototypes go to: blogs.ec.europa.eu/eupolicylab/blockchain4eu

convergence can actually happen, taking into account the **cost of integration or migration**, for example. **Interoperability between different systems**, blockchain or non-blockchain, is also key.

It is also foreseen that ways of creating value and conducting transactions will be improved by faster, cheaper and more reliable mechanisms enabled by blockchain across industries

and businesses. However, the **feasibility of new business models** and the **set of necessary incentives needed for players** to operate in open and decentralised ecosystems needs to be further tested.

Furthermore, regulatory constraints include issues of **applicable laws and jurisdictions for decentralised networks; reliable rules and definitions for smart contracts; and data protection and privacy safeguards.**

Transforming government and the public sector

The benefits of blockchain technology for the public sector are the ability to provide **tailored services for specific citizens, greater trust in governments and improved automation, transparency and auditability.** Significant incremental benefits can be achieved in some areas by using blockchain technology for the provision of public services. This can range from **more security (enhancement of data integrity, tamper-resistant and consistency between organisations), to efficiency gains (lower operational costs, reduced processing time, less paper and human-labour-intensive processes).**

For instance, a **government-issued identity on a blockchain** can generate time and cost savings for citizens, businesses and public administration in terms of setting up, managing and accessing identities for specific services. **Allocation of public benefits, such as pensions, grants, subsidies or other funds,** can benefit from a decentralised network supported by blockchain to manage transactions without relying on additional third parties or intermediaries. **In education,** blockchain can be used to register digital credentials, thereby enabling the immediate verification and validation of these credentials and, at the same time, **reducing bureaucratic procedures** for education institutions, employers, graduates and jobseekers

The co-creation of this prototype was coordinated by the EU Policy Lab of the Joint Research Centre, with the contributions of Chris Speed (University of Edinburgh), Larissa Pschetz (University of Edinburgh), Marco Sachy (Dyne.org), Michael R  ther (Spherity GmbH), Juri Mattila (ETLA / Research Institute of the Finnish Economy), Rory Gianni (University of Edinburgh), Katherine Snow (Povo design) and Linda Ma (Povo design)



In these and other cases, blockchain functionalities, such as **workflow automation and shared database** (as a single source of truth for all the different parties), can be leveraged to generate significant **efficiency gains in settling multi-party transactions and reducing uncertainties among agents**.

However, until now, and in many cases, **blockchain is neither transformative or even disruptive for the public sector**, as it is often portrayed. Blockchain systems neither provide for the disintermediation of organisations nor replace any existing public institution systems involved in the provision of services.

Blockchain still needs to be integrated with **legacy systems** in order to provide, for the most part, additional new functionalities offering greater assurances for citizens. This technology also still relies on **inputs from centralised or government-owned systems** as regards the provision of property details, for example, or to link to specific natural or legal persons. Moreover, there are doubts about how the external consistency of electronically submitted statements could be ensured, without and outside an arbiter.

The scale and complexity of current public services go beyond current technological blockchain developments. In particular, the **large volume of transactions to be processed with smart contracts** constitutes a major challenge.

“ Beside performance and scalability, other technical challenges remain on *integration with legacy infrastructures or standardisation and interoperability.*”

Ultimately, the adoption of blockchain technology also relies on the **ability to set up, scale up and maintain collaboration between many different stakeholders**.



Key Messages

There is space beyond cryptocurrencies and financial applications

It is the technology behind cryptocurrencies – blockchain – that has been capturing most of the attention. Beyond its financial applications, its potential has come to the foreground in many other sectors, such as trade and supply chains, manufacturing, energy, creative industries, healthcare, and government, public and third sectors.

A global ecosystem is on the rise from start-ups to capital investment

The rise of blockchain technology is witnessed by both the sharp growth in blockchain start-ups and by the volume of their funding. International players in the United States are taking the lead, followed by China and the European Union. Funding reached over EUR 7.4 billion in 2018 due to the explosion of ICOs and venture capital investments.

Blockchain does not follow a 'one-size-fits-all' model

The potential opportunities and challenges of deploying blockchain technology are strongly related to context, application or sectorial issues. That is why organisations should not develop solutions looking for problems, but instead should find existing or foreseeable problems in their operations or business, and then look for possible blockchain solutions.

Bottlenecks and complex challenges lie ahead

Blockchain technology is still at the embryonic stage and facing many challenges, such as performance and scalability, energy consumption, data privacy, integration with legacy infrastructures, or interoperability between different blockchains. Still based on a limited set of proven use cases, blockchain often entails additional risks and barriers for firms, businesses and organisations piloting it or interested in its deployment.

The concepts of trust and disintermediation are changing

Despite widespread misconceptions, blockchain does not imply the total elimination of intermediaries or third parties. Some intermediaries may disappear but new ones will appear and traditional ones, like governments, will continue to play a long-term role, not least to guarantee equal conditions for participation, check the quality and validity of data, decide on responsibility and liability, or settle disputes and enforce rules.

Regulatory frameworks and guidelines are catching up

Policymakers and regulators need to progress in assessing whether existing policies and laws are fit for purpose or if new frameworks will be required. Pressing discussions include, for instance, the legal classification of tokens and coins, validity of smart contracts, applicable jurisdictions, consumer and investor protection, enforcement of anti-money laundering requirements, and data protection and privacy safeguards.

Integration with digitisation initiatives and programmes is key

Blockchains will be complementary or will work together with other key digital technologies, such as artificial intelligence, internet of things, data analytics, cloud computing, robotics and additive manufacturing. The development of blockchain should be connected to existing digitisation initiatives and programmes to avoid overlaps and to maximise impact.

Piloting and experimentation spaces are needed

As an emerging technology, blockchain requires the multiplication of use cases to test its added value in specific applications and sectors. Further support and funding for frontier pilots and experimentation spaces must bring together a diversity of stakeholders from universities, research centres, industry, SMEs and start-ups.

Capacity building and knowledge sharing can be decisive

Environments such as regulatory sandboxes and other experimentation spaces can promote more direct exchanges between policymakers, regulators and supervisors, on the one hand, and blockchain companies, start-ups and entrepreneurs, on the other. Key benefits can include testing new solutions and business models and improving the quality and speed of policy guidance.

Blockchain calls for an interdisciplinary and comprehensive approach

Blockchain applications can have far-reaching implications at policy, economic, social, technical, legal or environmental level. Potential changes,

for example, in economic and business models, governance mechanisms or trust between parties, can only be grasped through a mix of different areas of knowledge, including computer science, economics, law, public finance, environmental sciences, and social and political sciences.

Monitoring should be combined with an anticipatory outlook

Policy dilemmas today involve a balance between adequate enforcement of existing regulations from day one, and the flexibility to accommodate an evolving technology with both foreseeable and unforeseeable benefits. This balance can be grounded in a foresight and trend monitoring approach to enable preparedness and adaptation to an increasingly rapid pace of change.



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