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#Blockchain4EU

Blockchain for Industrial Transformations

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Blockchain4EU: Blockchain for Industrial Transformations
The project #Blockchain4EU is a forward looking exploration of existing, emerging and potential applications based on Blockchain and other DLTs for industrial / non-financial sectors. It combined Science and Technology Studies with a transdisciplinary policy lab toolbox filled with frameworks from Foresight and Horizon Scanning, Behavioural Insights, or Participatory, Critical and Speculative Design. Amid unfolding and uncertain developments of the Blockchain space, our research signals a number of crucial opportunities and challenges around a technology that could record, secure and transfer any digitised transaction or process, and thus potentially affect large parts of current industrial landscapes. This report offers key insights for its implementation and uptake by industry, businesses and SMEs, together with science for policy strategic recommendations.

#Blockchain4EU

Blockchain for Industrial Transformations

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Table of Contents

List of Boxes and Figures

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Notwithstanding the many contributors to the project #Blockchain4EU: Blockchain for Industrial Transformations, all final responsibility remains solely with the authors.

Executive Summary

Blockchain and other Distributed Ledger Technologies (DLTs) are immutable, encrypted and timestamped databases in which data is recorded, validated and replicated across a decentralised network of nodes. In an increasingly interconnected world a vast array of opportunities could emerge through the deployment of such technologies that could enable parties who are geographically distant, or have no particular trust in each other, to record, verify and share digital or digitised assets on a peer-to-peer basis with fewer to no intermediaries.

#Blockchain4EU: Blockchain for Industrial Transformations is a forward looking exploration of existing, emerging and potential applications based on Blockchain and other DLTs for industrial / non-financial sectors. This is a research project coordinated within the European Commission by the EU Policy Lab / Foresight, Behavioural Insights and Design for Policy Unit (I.2) of the Joint Research Centre (DG JRC), on request of the Innovation Policy and Investment for Growth Unit (F.1) of the Directorate-General for Internal Market, Industry, Entrepreneurship & SMEs (DG GROW).

The project combined Science and Technology Studies with a transdisciplinary policy lab toolbox filled with insights from Foresight and Horizon Scanning, Behavioural Insights, or Participatory, Critical and Speculative Design. We developed an innovative experimental approach that allowed first to select and refine the sectors, topics and dimensions to be explored, and second to generate ideas on how Blockchain and other DLTs could exist in the near future and ultimately test new narratives and plausible scenarios around it. This entailed a mix of desk and qualitative research with a series of interviews, surveys, and ethnographic explorations, together with co-creation workshops. These workshops resulted in the collaborative envisioning, design and creation of five prototypes aimed at physically showcasing how Blockchain could be applied in five specific sectors: energy, transports and logistics, creative industries, advanced manufacturing and health.

Amid unfolding and uncertain developments of the Blockchain space, our research signals a number of crucial opportunities and challenges around a technology that could record, secure and transfer any digitised transaction or process, and thus potentially affect large parts of current industrial landscapes. **Key insights for its implementation and uptake by industry, businesses and SMEs** are here summarised:

- Blockchain is still an early-stage and experimental technology. One of the crucial choices concerns the permissionless (public), permissioned (private) and hybrid continuum, and related disputes over scalability, energy consumption, security, privacy and protection of personal and sensitive data.
- Whatever the technical solutions to be developed in upcoming years, interoperable protocols should be promoted so that different Blockchain products and services don't end up closed, unable to communicate with each other. Yet, it is crucial to improve current multi-stakeholder governance processes for the development of open standards.
- Blockchain systems in many cases will be complementary or integrated with legacy IT systems. Another trend concerns the possible intersection of Blockchain with other key digital technologies in the industrial context, such as IoT, artificial intelligence, robotics, or additive manufacturing.
- Blockchain may enable efficiency gains and lowering of costs, and introduce new ways of extracting and delivering value in business and industry. They may also introduce new decentralised, collaborative, or peer-to-peer economic models, and even usher in 'token' or 'crypto' economies.
- Potential scenarios of Blockchain as a 'trust machine' don't mean the total dissipation of intermediaries and / or absence of governance. Instead the discussion should focus on the concrete conditions for decentralised, horizontal and open forms of coordination between individuals, groups and companies, which may require a rethinking of traditional, vertical and hierarchical models.

- Who processes, stores and owns data, how and for what purposes, are crucial questions. Close attention should be paid for instance to the quality of the data being entered, processed and stored on a blockchain, or possible incompatibilities of decentralised and cryptographic protocols in regard to privacy and personal data. Yet, Blockchain could offer alternative mechanisms to implement data protection by design or privacy by design, and / or data portability.
- Organisations shouldn't develop Blockchain solutions looking for problems, but instead find existing or foreseeable problems in their business and then look for possible Blockchain solutions. An in-depth analysis of opportunities and risks based on each company's business and regulatory context should be followed by an assessment of Blockchain technical feasibility, and ideally come up with a use case or prototype under an exploratory mode.

Nine **science for policy strategic recommendations** stem from #Blockchain4EU:

- **Supporting Experimentation and Piloting with Simplified Requirements.** The Blockchain space requires multiplication of high-risk prototypes, Proofs-of-Concepts (PoCs) and pilots in diverse areas and/or sectors. This needs simplified grant or procurement procedures, coupled with real-time monitoring and evaluation.
- **Building Upon Other Digitisation Initiatives and Programmes.** It is crucial to avoid duplications or overlaps while supporting the potential integration of Blockchain with other key industrial technologies. Existing or new innovation spaces, hubs or centres could be used to run Blockchain experimentation.
- **Stimulating Knowledge Sharing and Collaborations Between Projects.** Priority should be given to free and open source models for developing research, platforms and protocols. Incentivizing sharing of results and exchange of best practices will be essential to scale up projects and maximize their impact across sectors.
- **Fostering Interoperability and Open Standards With Wider Engagement.** Open standards should continue to be fostered following a multi-stakeholder, collaborative and consensus driven process. Dangers of platform or vendor lock-ins should be minimised by inclusive processes to facilitate participation of smaller or newer players.
- **Promoting Adequate Skills and Training Also Beyond Core Blockchain Spaces.** Incentives to recruitment and/or development of programs should create Blockchain expertise across a diversity of areas. Actions for upskilling or digital skills training with special attention to SMEs should be further pursued.
- **Cultivating Wider Exchanges Between Policy and Blockchain Stakeholders.** Policymakers should engage directly with Blockchain companies to understand the opportunities and challenges ahead. This could be facilitated in environments such as innovation hubs and regulatory sandboxes.
- **Funding Blockchain Interdisciplinary and Problem-Driven Research.** Funding should be geared not just to technological research, but also to policy, economic, social, legal and environmental analysis. Start with specific challenges to be addressed and not with internal issues of the technology itself.
- **Designing Stable Regulatory Frameworks for Better Policy Preparedness.** Regulatory certainty around key issues is needed to unlock opportunities for experimentation. Concerns about over-regulation shouldn't translate into missed opportunities to shape and guide Blockchain development.
- **Championing Blockchain in Public and Governmental Sectors.** Blockchain could be explored by public sector organisations to tackle specific challenges in their own activities. It could not only increase demand but also legitimize and stimulate experimentation across private and commercially driven worlds.

1. #Blockchain4EU: A Forward Looking Exercise

1.1. Setting the Scene

Technologies are not neutral. Even within the best scenarios where they are deeply connected with material and conceptual aspects of transparency, openness, adaptability, accessibility, reusability, interoperability, and so forth, they are still bound, influenced, and frequently attached to the policy, economic, social, technical, legal or environmental dimensions of the contexts in which they are created, designed, produced, distributed, used and even disposed of. This shouldn't mean in any way that specific regulatory or funding processes, for instance, are not able to insure some technologies don't become predominant, or that their impacts are mainly unpredictable or impossible to tackle. But when thinking about technologies, challenges and opportunities, actors involved or excluded, and more, accepting, or at least considering, this key notion is important if we wish to act upon them with the most encompassing overview[1].

Also, even if we just looked into the technological dimension in search of a deeper understanding of specific technologies, what we should get first and foremost, is that no technology ever exists just by itself. Their invention or production is often part of larger occurrence patterns shaped by wider trends touching not only several other technologies, but other dimensions, such as the social or economic[2]. In the particular context of Blockchain and other Distributed Ledger Technologies (DLTs), even if in the public eye it commonly seems they came out of nowhere as the most unique thought, we may observe for instance how other decentralised network structures strongly paved their way. From post-war cybernetic theories or practical outputs, evolving into the distributed computing paradigms and protocols of past century's last quarter, such as Ethernets or the WWW, to applications made possible via these same paradigms and outputs, as GNU/Linux or other FLOSS/H systems, Torrent files, or P2P and Wiki based platforms, distributed or decentralised technologies have been around for a while. And they often have a reach beyond the mere technological circles or uses, with other dimensions usually absorbing a few of their ideas, from the pervasive social and economic peaks of the 'network society' in 1990s[3], to newer forms of 'delegative political organisations' in mid 2010s[4].

As a technology as many others before, Blockchain is to be viewed through a wide scope, which should also critically interpret claims over its present revolutionary and disruptive character. We have come a long way, and in an incredibly short period of time, from the first views on Bitcoin, or in general the crypto space, often associated with money laundering, tax evasion, fraud or other criminal activities. Debates now orbit around soaring and volatile valuations of anything crypto, ICOs (Initial Coin Offerings), trading bubbles, cryptocurrency hedge funds, and a growing media coverage capturing the attention and curiosity of a general audience. Anecdotal yet revealing cases of such 'crypto mania' include for instance companies adding Blockchain in their name just to raise their public profile and value[5].

The hype around Blockchain[6] was certainly influenced or shaped by the spike of interest from financial institutions for the past 2-3 years, which

[1] Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago, IL: University of Chicago Press, 1986).Don Ihde, *Technology and the Lifeworld: From Garden to Earth* (Bloomington, IN: Indiana University Press, 1990).Albert Borgmann, *Technology and the Character of Contemporary Life: A Philosophical Enquiry* (Chicago, IL: University of Chicago Press, 1987).Andrew Feenberg, *Questioning Technology* (New York, NY: Routledge, 1999). Wiebe E. Bijker, Thomas P. Hughes and Trevor J. Pinch, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press, 1987).

[2] André Leroi-Gourhan, *Le Geste et La Parole: Technique et Langage, Tome 1* (Paris: Albin Michel, 1964). Bernard Stiegler, *La Technique et Le Temps 1. La Faute d'Epiméthée* (Paris: Galilée, 1994). Gilbert Simondon, *Du Monde D'existence Des Objets Techniques* (Paris: Editions Aubier, 1958).

[3] Manuel Castells, *The Rise of the Network Society* (Oxford: Blackwel Publishers, 1996). William Mitchell, *City of Bits: Space, Place, and the Infobahn* (Cambridge, MA: MIT Press, 1995).

[4] Jan Behrens and others, *The Principles of LiquidFeedback* (Berlin: Interaktive Demokratie e.V., 2014).

[5] Sarah Buhr, 'Long Island Iced Tea Shares Went Gangbusters after Changing Its Name to Long Blockchain', *TechCrunch*, 21 December 2017 <https://techcrunch.com/2017/12/21/long-island-iced-tea-shares-went-gangbusters-after-changing-its-name-to-long-blockchain/>.

[6] Gartner, *Hype Cycle for Blockchain Technologies, 2017*, 2017 <https://www.gartner.com/doc/3775165/hype-cycle-blockchain-technologies->.

translated in a series of trials and pilots aimed at cross-border payments and settlements, securities trading, capital lending, or digital identity management, among many other use cases. Projections over its impact also quickly populated a closely watched space, ranging from estimations that DLTs could reduce banks' infrastructure costs by $15-$20 billion per year by 2022[7], deliver $5-10 billion of savings for the reinsurance industry[8], or store 10% of global gross domestic products (GDP) by 2027[9].

But at the same time that more well-known Blockchain applications in the financial sector were developing and even maturing, its broader potential for other sectors increasingly came to the foreground[10]. A variety of players, from industry and academia, to governments and supranational organisations, is reflecting on how Blockchain could transform significant parts of industry, economy and society in the future[11]. In this sense it is one of the technologies expected to have a profound impact over the next 10-15 years[12]. Blockchain could also be ultimately connected to new production trends or the 'fourth industrial revolution', which include a vast set of other emerging technologies such as Internet of Things, artificial intelligence, robotics, new materials or additive manufacturing[13].

Although it might be difficult to see the concrete directions for development, there are, however, signs of compelling possibilities in Blockchain. Blockchain is part of the broader family of DLTs, simply defined as immutable, encrypted and timestamped databases in which data is recorded, validated and replicated across a decentralised network of nodes or participants. In an increasingly interconnected world, a vast array of opportunities could emerge through the deployment of such technologies that could enable parties who are geographically distant, or have no particular confidence in each other, to exchange any kind of digital assets, such as money, contracts, land titles, medical records, services or goods, on a peer-to-peer basis with fewer to non-existent central intermediaries.

Due to its particular combination of technical features, Blockchain based systems are seen to bring on a series of benefits, such as lowering operational costs, enhancing safety and efficiency of transactions, proving ownership, origin or authenticity of records, goods and content, executing contracts automatically, or avoiding fraud and counterfeiting. Across industries, businesses and companies, the ways they create value and conduct transactions is expected to be improved by faster, cheaper and more reliable mechanisms enabled by Blockchain. Possible scenarios are also marked by deep changes in economic and governance models towards decentralised exchanges of value, or even more inclusive, transparent and accountable digital economies[14].

Yet, from the beginning of the current research project we were always cautious about embarking

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7 Santander, *The Fintech 2.0 Paper: Rebooting Financial Services*, 2015 <http://santanderinnoventures.com/wp-content/uploads/2015/06/The-Fintech-2-0-Paper.pdf>.

8 PwC, *Blockchain: The 5 Billion Opportunity for Reinsurers* <http://www.pwc.com/gx/en/industries/financial-services/publications/blockchain-the-5-billion-opportunity-for-reinsurers.html>.

9 WEF (World Economic Forum), *Deep Shift Technology Tipping Points and Societal Impact*, 2015 <http://www3.weforum.org/docs/WEF_GAC15_Technological_Tipping_Points_report_2015.pdf>.

10 The Economist, 'The Trust Machine: The Promise of the Blockchain', 31 October 2014 <https://www.economist.com/news/leaders/21677198-technology-behind-bitcoin-could-transform-how-economy-works-trust-machine>. Robert Rosenkranz, 'Bitcoin's Value Isn't Currency, It's Technology', *Forbes*, 7 July 2015 <https://www.forbes.com/sites/robertrosenkranz/2015/07/07/bitcoins-value-isnt-currency-its-technology/#179a405c1f11>.

11 Uk Government Chief Scientific Adviser, 'Distributed Ledger Technology : Beyond Block Chain', 2016 <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf>. Jason Davidson, Sinclair and De Filippi, Primavera and Potts, 'Disrupting Governance: The New Institutional Economics of Distributed Ledger Technology', *Ssrn*, 2016, 1–27 <http://ssrn.com/abstract=2811995>.

12 OECD, *OECD Science, Technology and Innovation Outlook 2016* (Paris: OECD Publishing, 2016) <http://dx.doi.org/10.1787/sti_in_outlook-2016-6-en>.

13 Klaus Schwab, *The Fourth Industrial Revolution* (Geneva: World Economic Forum). OECD, *The Next Production Revolution: Implications for Governments and Business* (Paris: OECD Publishing, 2017) <http://dx.doi.org/10.1787/9789264271036-en>.

14 Dan Tapscott and Alex Tapscott, *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World* (New York: Penguin, 2016). William Mougayar, *The Business Blockchain: Promise, Practice and Application of the next Internet Technology* (New Jersey: Wiley, 2016). Michael J. Casey and Paul Vigna, *The Truth Machine: The Blockchain and the Future of Everything* (New York: St. Martin's Press, 2018).

on magnified promises and expectations around Blockchain, and now at its end, knowing more than we did before, we still are. Amid unfolding developments and uncertain futures, our project was designed to follow an exploratory mode and be framed as a wide-ranging overview of possible applications of Blockchain and other DLTs for industrial / non-financial sectors. As we recognised throughout the whole project crucial opportunities around a technology that could record, secure and transfer any digitised transaction or process, at the same time, we never overlooked the concrete challenges for its development and uptake.

From the beginning, this project overarching understanding was mainly directed at informing which actions could be necessary to prepare for potential transformations to existing or future European sociotechnical landscapes, considering how Blockchain could change how organisations operate at industrial and market levels. In this regard, the project's policy context is connected to a number of European Commission's strategies and initiatives fostering digital innovation across all industrial sectors and supporting Small and Medium-Sized Enterprises (SMEs) to fully benefit from new technologies[15]. In the specific domain of Blockchain and other DLTs, this engagement already resulted for instance in a H2020 Coordination and Support Action on 'Blockchain and Distributed Ledger Technologies for SMEs'[16] as part of the 'Innovation in Small and Medium-Sized Enterprises' programme.

But several options on how to approach emerging realities of Blockchain and other DLTs are also being explored within the European Commission. For instance, the EU Blockchain Observatory and Forum was launched in February 2018 and aims to monitor trends, developments and use cases for the next two years[17]. In December 2017, the Commission launched the European Innovation Council (EIC) Horizon Prize for Blockchains for Social Good, looking for scalable, efficient and high-impact decentralised solutions to social innovation challenges leveraging on DLTs[18]. And within the series of activities developed in the past year the Commission is also participating in International Organization for Standardization (ISO) and International Telecommunication Union (ITU) standardisation activities[19]. In addition, considering the wide financial sector, In November 2016 the Commission in collaboration with the European Parliament set up a Task Force on Fintech with a dedicated group on DLTs, and published in March 2018 the Financial Technology (FinTech) Action Plan[20]. And in this same sector, we also find the European Financial Transparency Gateway (EFTG) as a pilot project using DLTs to facilitate access to information about all listed companies on EU securities regulated markets[21].

1.2. Project Description

In this context, #Blockchain4EU: Blockchain for Industrial Transformations emerges as a project in March 2017 to be a forward looking exploration of existing, emerging and potential applications based on Blockchain and other Distributed Ledger Technologies for industrial / non-financial sectors.

This is a research project coordinated within the European Commission by the EU Policy Lab / Foresight, Behavioural Insights and Design for Policy Unit (I.2) of the Joint Research Centre (DG JRC), on request of the Innovation Policy and Investment for Growth Unit (F.1) of the Directorate-General for Internal Market, Industry, Entrepreneurship & SMEs (DG GROW).

DG JRC is the European Commission's in-house science and knowledge service, with a mandate to provide EU policies with independent, evidence based scientific and technical support throughout

[15] European Commission, *Digitising European Industry - Reaping the Full Benefits of a Digital Single Market* (European Commission, 2016) <https://ec.europa.eu/digital-single-market/en/news/communication-digitising-european-industry-reaping-full-benefits-digital-single-market>. European Commission, *Investing in a Smart, Innovative and Sustainable Industry*, 2017 <http://ec.europa.eu/docsroom/documents/25384>.

[16] <https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/innosup-03-2018.html>

[17] <https://www.eublockchainforum.eu/>

[18] <https://ec.europa.eu/research/eic/index.cfm?pg=prizes_blockchains>

[19] <https://ec.europa.eu/digital-single-market/en/news/blockchain-and-distributed-ledger-technology-policy-and-standardisation-workshop>

[20] European Commission, *FinTech Action Plan: For a More Competitive and Innovative European Financial Sector*, 2018 <https://ec.europa.eu/info/publications/180308-action-plan-fintech_en>.

[21] <http://europa.eu/rapid/press-release_MEMO-18-1406_en.htm>

the whole policy cycle. In particular, it aims to anticipate emerging issues that need to be addressed at EU level and understand its policy contexts; creates, manages and makes sense of knowledge; and develops innovative tools to make such knowledge available and useful for policy making. The EU Policy Lab / Foresight, Behavioural Insights and Design for Policy Unit encompasses both an innovative way of conducting research, and a collaborative and experimental space that makes use of a wide transdisciplinary toolbox to envision, connect and prototype solutions for better policies, with strong focus on citizen-centric frameworks and stakeholder engagement.

DG GROW is the European Commission's service responsible for creating an environment in which European firms can thrive; completing the Internal Market for goods and services; helping turn the EU into a smart, sustainable, and inclusive economy; fostering entrepreneurship and growth by reducing the administrative burden and facilitating access to funding for small and medium-sized enterprises (SMEs); generating policy on the protection and enforcement of industrial property rights, among several other activities. The main mission of its Innovation Policy and Investment for Growth Unit is to develop and support initiatives contributing to a stronger and high-performing EU industry by fostering both the supply and uptake of innovation.

This project is positioned on the intersection of Science and Technology Studies, Foresight and Horizon Scanning, and Design for Policy. Its main goals were to: a) map and analyse Blockchain and other DLT applications for industry across specific sectors; b) scan for and explore future scenarios of production, distribution and use; and c) identify and assess prospective funding and regulatory actions and other broader policy options.

The project's core outputs were aimed from the start at exploring and assessing sociotechnical challenges and opportunities for the development and uptake of Blockchain and other DLTs within EU industrial and business contexts, with focus on SMEs innovation and competitiveness. They will also help to shape options for regulatory, funding and other broader policy responses, and ultimately assist the European Commission and other EU public authorities to foresee and prepare for major positive or negative changes that may arise from potential widespread or accelerated adoptions in the short and medium term of Blockchain and other DLTs within industrial / non-financial sectors.

1.3. Roadmap and Methodology

The project's roadmap was divided into two stages. The first one ran from start to end of the project. The second one was mainly concentrated around three major moments. In both stages we were able to develop an innovative experimental approach that allowed us first to select and refine the sectors, topics and dimensions to be explored, and second to generate ideas on how Blockchain and other DLTs could exist in the near future and ultimately test new narratives and plausible scenarios around it. It combined empirical Science and Technology Studies with a transdisciplinary policy lab toolbox filled with theoretical and practical frameworks from Foresight and Horizon Scanning, Behavioural Insights, or Participatory, Critical and Speculative Design.

The first stage was based on desk research coupled with several qualitative explorations, with targeted engagement of technical experts and developers; social, economic and legal researchers; companies, entrepreneurs and business representatives; civil society organisations and think-tanks; and public administration actors, both at city, regional and national levels, and at supranational level, including other European Commission services and agencies, the European Parliament, United Nations, OEDC and the World Economic Forum.

We started this stage by carrying out secondary research, with literature reviews of general research on Blockchain and other DLTs and on current, emerging or potential applications for industry across specific sectors. This resulted in the mapping of around 270 key individual and collective stakeholders in the field. Afterwards, we proceeded into conducting multiple primary research activities, combining face to face and online open-ended interviews to 63 experts, two batches of semi-structured online surveys with 94 replies all together, and short duration multi-sited ethnographic explorations in selected Blockchain related companies, organisations and events. As mentioned above, this first stage was developed throughout the project's whole duration, with multiple feedback loops and iterations, including for example reconnecting with and interviewing again previously targeted stakeholders, or deploying overhauled versions of already existent surveys, which allowed us to maximize our outreach endeavours.

In the second stage, we moved into more practical and experimental grounds, based on collaborative research and stakeholder engagement activities. This stage's three key moments corresponded to three participatory workshops, A, B, and C. These workshops had distinct goals, structures and participants, but all three were still connected in a sequential way. Their outputs are deeply entrenched in the analysis and results of this report as it will be visible throughout several chapters and sub-chapters.

Workshop A took place on July 4 2017, with the aim of mapping multiple Blockchain present and future challenges and opportunities, especially considering their policy, economic, social, technological, legal and environmental dimensions. Based on a purposive sampling technique, 34 participants were selected from an extensive pool of stakeholders to act as a snapshot of the current Blockchain ecosystem in industrial and non-financial sectors. This group included technical experts, developers and scientists; social, economic, ethical and legal researchers; entrepreneurs and investors; business and labour representatives; and policy actors at local, national and EU levels. Our key outputs were the mapping and discussion of collective visions that could inform policy on present and future possibilities of Blockchain applications, as well as core factors that could support or hamper their development and uptake.

Workshop B occurred on November 15-16 2017 with emphasis on the material exploration of near future scenarios of creation, production, distribution and use of Blockchain and other DLT applications in previously selected sectors. We invited 25 participants, among which designers, technical and industry expert stakeholders, and social and economic researchers. We kick-started this workshop based on what had been amassed through our research, but most significantly, building upon core outputs of the first workshop. Attention was given to participatory, generative and speculative design methods to help us deliver the intended results. Key final output was the collaborative envisioning, design and creation of five prototypes that could physically represent and exemplify how Blockchain and other DLTs could be applied in a near future, considering five industrial sectors and use cases.

Workshop C happened on March 15 2018 centred on a broad spectrum discussion on policy strategies for digitisation of industry and businesses, with particular focus on technology adoption and SME innovation. Again based on a purposive sample, 23 participants were mainly drawn from a group of stakeholders at the forefront of EU digitisation and SME innovation, including industry, startups and SME representatives; European networks or initiatives; think tanks and business consultants in the field; and intergovernmental and international organisations. Our main output was a better understanding of how Blockchain and other DLTs fit into present and future digitisation landscapes, and how these technologies may potentially affect or impact different actors operating operating in more established industrial and non-financial sectors.

Additional information about each of the three workshops can be found in the EU Policy Lab blog. More details on methodologies and results are available on request for research and dissemination purposes, following the Joint Research Centre's EU Policy Lab open principles in terms of knowledge sharing and exchange of best practices.

In this same context, several communication activities were developed on a horizontal level throughout the whole project for dissemination and feedback on ongoing and final outcomes, such as participation in more than 20 events and scientific conferences. Furthermore, such activities were also based on communication via external channels, including institutional and personal social media accounts on Twitter, Facebook and Linkedin, with media coverage for the project's kick-off announcement in 10 digital media outlets, as well as through internal channels, such as the EU Policy Lab blog and other European Commission webpage, with lateral management of an informal community of practice with 107 members on the dedicated Connected platform of the European Commission. Additional outputs are now planned to complement the co-creation of prototypes that took place around Workshop B of the project's second stage, as well as outputs based on the final presentation event of the project on May 24 2018.

2. What are Blockchain and Other DLTs?

This chapter will put forward a brief account of what is Blockchain and other Distributed Ledger Technologies (DLTs) from a more technical point of view. Such introductory understanding of its main features will set groundwork for the subsequent understanding of the potential of Blockchain for industry which will come in the next chapters.

2.1. Key Features

Blockchain and other Distributed Ledger Technologies (DLTs) are technologies enabling parties who are geographically distant or have no particular confidence in each other to exchange any type of digital data on a peer-to-peer basis with fewer to non-existent third parties or intermediaries. Data could represent for instance money, insurance policies, contracts, land titles, medical records, birth and marriage certificates, buying and selling goods and services, or any other type of transaction or asset that can be translated in a digital form.

To be clear in the terminology, Blockchain is part of the broader family of Distributed Ledger Technologies (DLTs)[22]. DLTs are particular types of databases in which data is recorded, shared and synchronised across a distributed network of computers or participants. Blockchain technologies are a particular type of DLT that employs cryptographic techniques to record and synchronize data in 'chains of blocks'. The difference is about the way data is distributed, verified and registered by participants in the network. In short, all types of Blockchain are DLTs but not all DLTs are Blockchains. For the sake of simplicity we will mostly use the term 'Blockchain' or 'Blockchains' but we will make the distinction regarding DLTs when necessary.

Blockchain is a chronological database (ledger) operating in a distributed network of multiple nodes or computers that keeps track of data transactions[23]. It's called a 'Blockchain' because of the particular way transactions are recorded and verified. Information about a certain number of transactions is organized and encrypted into 'blocks'. Each new block is validated when the nodes or computers reach a consensus across the network. There are different cryptographic ways to reach a consensus, the most known being Proof-of-Work, that is, when a node or a computer ('miner') solves a complex mathematical puzzle, and the other nodes verify it.

The whole process ensures that each block is created in a way that irrefutably links it to the previous one and to the next one, thus forming a 'chain of blocks' or 'blockchain'. This unique record that forms the Blockchain is shared by each node or computer in the network and is constantly updated and synchronized.

As a database or ledger, a blockchain creates and verifies records of all transactions ever executed across a network. Its processes of validation and constant update makes it extremely difficult for unauthorised changes or tampering to happen without no one noticing it or being recorded. Plus transactions are open for inspection and validation anytime for anyone or for authorised parties. Public-private keys or cryptographic signatures ensure access is protected and secured. In principle it is also more resilient to outages or cyberattacks since it has no single point of failure. The existence of multiple and distributed nodes makes it very difficult to target the majority simultaneously, or to break down completely the whole network.

Blockchain should not be considered a new technology, but rather a unique combination of other existing technologies[24] such as peer-to-peer networks, cryptographic techniques, consensus protocols, and distributed data storage. This

[22] World Bank, *Distributed Ledger Technology (DLT) and Blockchain, FinTech Note no1*, 2017 <http://documents.worldbank.org/curated/en/177911513714062215/Distributed-Ledger-Technology-DLT-and-blockchain>.

[23] Aaron Wright and Primavera De Filippi, 'Decentralized Blockchain Technology and the Rise of Lex Cryptographia', *SSRN Electronic Journal*, 2015 <http://dx.doi.org/10.2139/ssrn.2580664>.

[24] Arvind Narayanan and Jeremy Clark, 'Bitcoin's Academic Pedigree', *Communications of the ACM*, 60.12 (2017), 36–45 <http://dx.doi.org/10.1145/3132259>.

combination was first developed in Bitcoin, the decentralised cryptocurrency originally introduced by Satoshi Nakamoto in 2008[25]. Curiously his, her or their identity as a developer or group of developers is still unknown and involved in continuous speculation[26].

Blockchain are still often associated in the public eye to Bitcoin and to concerns about money laundering, tax evasion, fraud or other criminal activities. Beyond the controversies around the potential uses of Bitcoin and other cryptocurrencies, what has recently come to the foreground is the potential of Blockchain as the underlying technology based on a set of key features or properties[27]:

Decentralisation. A distributed network is run by many different participants who don't necessarily know each other, and there is no central authority to approve transactions. So it requires setting up from the beginning a consensus mechanism defined as a set of rules that everyone follows to verify, validate and add transactions to the blockchain. The most known consensus mechanism is Proof-of-Work, which relies on the computational or processing power of the nodes or computers (called 'miners') to solve as quickly as possible a complex mathematical puzzle. Other consensus mechanisms are under development such as Proof-of-Stake in which nodes have different voting rights depending on the amount of resources ('stake') they possess[28].

Replication. Nodes or participants have a copy of the ledger or the Blockchain. If copies are lost, disappear or compromised, multiple other copies which are fully updated and validated exist in the network. This feature makes the Blockchain resistant to disruptions, failures or interferences, that is, in situations where nodes get disconnected by some reason, hardware breaks down, power goes down temporarily, or other unexpected problems happen. Unlike centralised systems, there is no single point of failure.

Transparency. The ledger or Blockchain is accessible to all participants or to a predefined set of participants. For instance, while in certain blockchains access to the records can be restricted to certain participants, in other types of blockchains everyone with an Internet connection to the network has the same rights to access and/or to update the ledger according to the consensus mechanism in place. So in the end transactions are transparent and visible, which may increase auditability and trust in the network.

Timestamping. All transactions on the Blockchain are time-stamped, that is, data such as details about a payment, a contract, transfer of ownership, etc., is linked publicly and immutably to a certain date and time. It means that no one should be able to modify what has been recorded and timestamped. Keeping track and verifying information in a secure way is one of the key advantages of the Blockchain. It makes it particularly useful for different parties to check when and who made a specific transaction, or to certify that data existed at a given instance in time.

Immutability. The way that each transaction is cryptographically recorded on the Blockchain and then validated through consensus makes it nearly impossible or very difficult (you would need to have a majority of 'votes' for instance) to make changes to the ledger without detection. In this sense, records are irreversible and tamper-proof. These features of non-repudiation, non-forgeability and immutability guarantee that there is a unique and historical version of the records which is agreed and shared between all participants.

Digital Signatures. Like other internet technologies, Blockchain relies on public-private key cryptography to ensure the authenticity and

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[25] Satoshi Nakamoto, ‘Bitcoin: A Peer-to-Peer Electronic Cash System’, 2008 <https://bitcoin.org/bitcoin.pdf>.
[26] See for instance news over the past years http://www.newsweek.com/2014/03/14/face-behind-bitcoin-247957.html; https://www.nytimes.com/2015/05/17/business/decoding-the-enigma-of-satoshi-nakamoto-and-the-birth-of-bitcoin.html; https://gizmodo.com/this-australian-says-he-and-his-dead-friend-invented-bi-1746958692
[27] Paolo Tasca and Thayabaran Thanabalasingham, ‘Ontology of Blockchain Technologies. Principles of Identification and Classification’, *SSRN Electronic Journal*, 2017, 1–58 <http://dx.doi.org/10.2139/ssrn.2977811>. Uk Government Chief Scientific Adviser. Igor Nai Fovino and others, *On Virtual and Crypto Currencies: A General Overview from the Technological Aspects to the Economic Implications* (Luxembourg, 2015).
[28] https://github.com/ethereum/wiki/wiki/Proof-of-Stake-FAQ

integrity of data exchanges or transactions. Participants have a distinct identity based on a combination of public and private keys: public keys are widely shared with the others in the network, while private keys are kept secret. For instance, messages or transactions encrypted with a private key can only be opened by recipients with the corresponding public key (shared by the sender). Or if a message is encrypted with a public key it can only be decrypted by a specified recipient using his or her private key. You can thus ensure messages or transactions are authentic, that is, they originated from the rightful person, and can't be accessed or modified by others.

Automation and Smart Contracts. Transactions can be automatically executed through the software running on the Blockchain without the need for human coordination or intervention. The way that transactions are verified and added on the Blockchain guarantees that conflicts or inaccuracies are reconciled, and in the end there is only one valid transaction (no double entries). Blockchain can also be the underlying layer for 'smart contracts'[29] which are basically computer programs that carry out the terms of any agreement between parties. These agreements can be recorded and validated into a Blockchain which can then execute and enforce automatically the contracted usually under 'if-then' instructions: 'if' something happens (for instance if you rent and pay for a car and short term insurance), 'then' certain transactions or actions are done (the car door unlocks and the payment is transferred).

2.2. Key Challenges

The set of features or properties presented above can be considered as the key elements for any Blockchain. It should be clear, however, there isn't just 'a Blockchain' but many different Blockchains (plural) with different functionalities and architectures. Such choices in design usually depend on the specific purposes in mind which entail trade-offs with corresponding advantages and limitations.

Moreover, Blockchains are still early-stage technologies with many unresolved issues still under development or wide discussion in the space. It's crucial to take into account such challenges and uncertainties when considering the deployment of Blockchain technologies to industrial applications as it will be addressed in the next chapter. A set of key issues stand out in the current Blockchain space:

Permissionless and Permissioned. One of the most disputed) choices of design or categorisation concerns the permissionless (public) and permissioned (private) continuum of Blockchain technologies[30]. Permissionless blockchains, like Bitcoin[31], Ethereum[32] or Litecoin, are distributed ledgers where anyone can participate without asking prior authorisation to central authorities or intermediaries. It's just enough to download the code or software available online and start running it in a computer. All participants can send transactions across the network, access the records, and validate transactions through a consensus mechanism, usually by contributing with computational power ('Proof-of-Work'). Through this particular type of consensus mechanism in return participants (or 'miners') are rewarded or payed with the native cryptocurrencies or 'coins'.

Permissioned blockchains, like Ripple, Chain, Hyperledger, are distributed ledgers in which a

[29] Nick Szabo, *The Idea of Smart Contracts*, 1997 <http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/idea.html>.; Vitalik Buterin, *A Next-Generation Smart Contract and Decentralized Application Platform*, 2015 <https://github.com/ethereum/wiki/wiki/White-Paper>.

[30] Gareth W Peters and Efstathios Panayi, 'Understanding Modern Banking Ledgers Through Blockchain Technologies: Future of Transaction Processing and Smart Contracts on the Internet of Money', in *Banking Beyond Banks and Money*, ed. by Paolo Tasca and others (Heidelberg: Springer, 2016), pp. 239–78 <http://dx.doi.org/10.1007/978-3-319-42448-4>.

[31] For an easy-to-follow but comprehensive introduction to Bitcoin, see Andreas Antonopoulos, *Mastering Bitcoin: Programming the Open Blockchain 2nd Edition* (Sebastopol: O'Reilly Media, 2017).; For a technical explanation (and with its own Coursera course) of Bitcoin and cryptocurrencies requiring a basic understanding of computer science, see Arvind Narayanan, Joseph Bonneau, and others, *Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction* (Princeton, NJ: Princeton University Press, 2016).

[32] *Ethereum Homestead Documentation* <http://www.ethdocs.org/en/latest/>. Henning Diedrich, *Ethereum: Blockchains, Digital Assets, Smart Contracts, Decentralized Autonomous Organizations* (Sidney: Wildfire Publishing, 2016).

company, a consortium, or a central administrator preselects or gives access to identified participants. So the rights to modify, read and access the Blockchain is restricted to some participants. Consensus across the network or the maintenance of the Blockchain is guaranteed by this private and trusted parties or intermediaries, under a defined set of rules. This configuration eliminates the need for native currencies and associated 'Proof-of-Work' mechanism to run and protect the ledger. Permissioned blockchains can be private, like MONAX or Multichain, to be used mostly inside an organisation with or without public access, or consortium blockchains, like R3 or Corda, where the consensus process is done by a pre-selected set of parties.

There is no agreement among technologists over the exact features that distinguish permissionless from permissioned blockchains. At this point in their ongoing technical development it should be seen more as a spectrum, where you can also find for instance hybrid blockchains combining different aspects of both[33]. In some cases, organisations or companies can build on top of Blockchain platforms like Ethereum, and then develop specific applications for permissioned networks.

Scalability and Performance. The discussions over permissionless and permissioned blockchains briefly explained above, have crucial implications for overall deployment. Permissionless or public blockchains at the moment can only handle a limited number of transactions because all participants or nodes verify and transmit the transactions across a distributed network. For instance, Bitcoin transactions are validated approximately every 10 minutes with around 300,000 transactions per day. In comparison Visa's electronic payments processing network processes an average of 150 million transactions per day.

But options to scale up such type of blockchains are not easy to implement. Due to the original design of its architecture, there is an inbuilt limit in public blockchains regarding the number of transactions and the amount of data to be included in any given 'block'. Also as the number of transactions grows requirements for participants in terms of computational power and storage also increases, taking into account an ever growing transaction history.

Fierce controversies over possible solutions stir up the space from time to time, especially in Bitcoin circles for instance on increasing block size (in Bitcoin only 1MB of data can be included in any given block) or introducing new protocols based on sidechains or off-chains[34]. Others are developing alternative mechanisms like 'sharding' and 'Proof-of-Stake' still within public blockchains[35] to limit the need for each node to validate the transactions and/or store a complete copy of the ledger. This type of restrictions is also at the core of permissioned or private blockchains, and it is in fact one of its major selling points to better handle the issue of scalability. As explained above, they only require a limited and predefined number of participants to run the network, so transactions are processed faster and the necessary computing power can be easier increased in specific nodes.

Energy Consumption. Concerns over the energy necessary to run public blockchains, especially the ones using 'Proof-of-Work', are widespread in media and specialised circles[36]. This concern was at least partially fuelled by the boost in Bitcoin prices in the past two years which spurred a more intensive use of the network and as such, of the 'mining' process needed to run it. As more and more participants join in and 'race' to validate transactions through 'mining', this competition lowers the possible reward to be gained, which in turn increases the need for more powerful computational techniques including application-specific integrated circuits (ASIC), cloud mining

[33] George Danezis and Sarah Meiklejohn, 'Centrally Banked Cryptocurrencies', *arXiv*, 2015, 1–16 <http://dx.doi.org/10.14722/ndss.2016.23187>.

[34] Laura Shin, 'Will This Battle For The Soul Of Bitcoin Destroy It?', *Forbes*, 23 October 2017 <https://www.forbes.com/sites/laurashin/2017/10/23/will-this-battle-for-the-soul-of-bitcoin-destroy-it/#66179ef33d3c>.

[35] Epicenter, 'Vlad Zamfir: Bringing Ethereum Towards Proof-Of-Stake With Casper', 22 April 2017 <https://www.youtube.com/watch?v=9nQPcNY32JQ>. Vlad Zamfir, 'Introducing Casper "the Friendly Ghost"', *Ethereum Blog*, 2015 <https://blog.ethereum.org/2015/08/01/introducing-casper-friendly-ghost/> [accessed 29 March 2018].

[36] Nathaniel Popper, 'There Is Nothing Virtual About Bitcoin's Energy Appetite', *The New York Times*, 21 January 2018 <https://www.nytimes.com/2018/01/21/technology/bitcoin-mining-energy-consumption.html?mtrref=undefined>.

and mining pools (basically groups of miners who bring together their resources to improve their odds of solving the mathematical puzzle and collect the reward).

There is no consensus over Bitcoin's estimated annual electricity consumption, varying between 18 and 58.43 terawatt hours/year[37]. If we consider the latter estimate, it would mean each Bitcoin transaction requires the same amount of energy used to power around 30 U.S. households for one day. Some say this is the trade-off for a decentralised, secure and censorship resistant network such as Bitcoin and its potential positive benefits in the economy[38]. Others say advances in technology will make mining operations more efficient in the long run, more renewable energy sources are being explored, or the overall consumption of Bitcoin is but a fraction of the total world energy consumption[39]. Still research indicates that 58% of Bitcoin mining pools are based in China[40] due to cheap labour, land and electricity. This is worrying for a number of reasons: electricity in China is mostly coal powered, and poor working and health conditions in mining pools have been reported[41].

Centralisation. Issues around 'mining' are also related to other concerns over high concentration or dependency in industrial-scale mining activities or mining pools[42]. In fact researchers have argued that both Bitcoin and Ethereum mining suffer from centralisation, taking into account that the top four miners in Bitcoin and the top three miners in Ethereum control more than 50% of the hash rate[43]. This may jeopardize the security of such networks by allowing for potential collusions or attacks from a group of miners controlling a majority of computational resources ('51% attack').

An alternative would be to adopt other consensus mechanisms or types of blockchains like permissioned ones which don't require mining processes. But concerns over centralisation and security hazards may also arise. Permissioned blockchains require a core group of parties to give access to others and in practical terms to run the network. It can be argued that it ends being a centralised or semi-centralised model in which a number of participants retain significant control that can lead to arbitrary decisions and high costs as it currently happens today in other systems.

This issue of centralisation in the Blockchain space touches core ongoing discussions about the prospects for decentralised governance and promise of disintermediation. Still the existence of intermediaries is visible nowadays for instance in the Bitcoin ecosystem[44] where you find currency exchanges which trade cryptocurrencies for traditional currencies and vice-versa, or digital wallet services which manage or store cryptocurrencies accounts, recorded transactions and even private keys in some cases. Such intermediaries can be centralised points to gather users and clients in the space and represent for instance enticing targets for attacks[45], or to introduce changes in services not fully agreed or attentive to users' needs or views.

Security. All technologies are breakable or hackable or can suffer from a number of vulnerabilities. Security is in fact a complex concept composed of many diverse factors that can be internal and/or external to any technical architecture. No one has yet managed to break the encryption and decentralised architecture of

[37] https://digiconomist.net/bitcoin-energy-consumption
[38] Marc Bevand, 'Bitcoin Mining Is Not Wasteful', 25 January 2016 <http://blog.zorinaq.com/bitcoin-mining-is-not-wasteful/>.
[39] Elaine Ou, 'No, Bitcoin Won't Boil the Oceans', *Bloomberg*, 7 December 2017 <https://www.bloomberg.com/view/articles/2017-12-07/bitcoin-is-greener-than-its-critics-think>.
[40] Garrick Hileman and Michel Rauchs, '2017 Global Cryptocurrency Benchmarking Study', *SSRN Electronic Journal*, 2017 <http://dx.doi.org/10.2139/ssrn.2965436>.
[41] Zheping Huang and Joon Ian Wong, 'The Lives of Bitcoin Miners Digging for Digital Gold in Inner Mongolia', *Quartz*, 17 August 2017 <https://qz.com/1054805/what-its-like-working-at-a-sprawling-bitcoin-mine-in-inner-mongolia/>.
[42] Fabio Caccioli, Giacomo Livan and Tomaso Aste, 'Scalability and Egalitarianism in Peer-to-Peer Networks', in *Banking Beyond Banks and Money*, ed. by Paolo Tasca and others (Heidelberg: Springer, 2016), pp. 197–211 <http://dx.doi.org/10.1007/978-3-319-42448-4>.
[43] Adem Efe Gencer and others, 'Decentralization in Bitcoin and Ethereum Networks', *arXiv Preprint arXiv:1801.03998*, 2018 <https://arxiv.org/abs/1801.03998>.
[44] Rainer Böhme and others, 'Bitcoin: Economics, Technology, and Governance', *Journal of Economic Perspectives*, 29.2 (2015), 213–38 <http://dx.doi.org/10.1257/jep.29.2.213>.
[45] Jen Wieczner, 'Hacking Coinbase: The Great Bitcoin Bank Robbery', *Fortune*, 22 August 2017 <http://fortune.com/2017/08/22/bitcoin-coinbase-hack/>.

public blockchains, although some say this might happen with quantum computing (but maybe not in the foreseeable future)[46]. Moreover, there is no single central authority or intermediary that could be hacked and compromise the whole network. But takeovers, manipulations and collusions of public blockchains are theoretically possible, for instance through a potential 51% attack when a majority of users has control of the hashing or computing power.

On the other hand, although they provide advantages in terms of scalability and energy consumption, private or permissioned blockchains are potentially more vulnerable to attacks, censure, collusion or other dishonest interventions. One of the major trade-offs of a smaller number of core participants is precisely the higher likelihood of side agreements or schemes to change the rules or revert transactions.

Another major source of security vulnerability lies on the challenges around key management, one of the main tenets of a cryptographic based system such as Blockchain[47]. The responsibility and burden for participants to manage their public and private keys can be as simple and serious as losing a phone or a backup of the credentials. This can easily end up in desperate situations from garbage diving, hypnotism to mental breakdowns in face of lost fortunes[48]. For these reasons but also for simplicity of use, many people rely on third parties in the Blockchain space such as mining companies or digital wallet services especially the ones that keep the account's private keys, which in the end reintroduces operational security risks if these companies are hacked[49].

Privacy. The way Blockchain ensures transactions are visible to all and indisputably authenticated by unique keys or credentials can be a matter of concern when it comes to protection of personal, sensitive or confidential data. It is currently one of most disputed issues in the Blockchain space, a still unsolved trade-off between transparency and privacy. It is also one of the main distinctions for companies or organisations when choosing between public and private blockchains.

Transparency and immutability of data on the Blockchain might be a problem when certain information is not meant to be publicly available, or needs to be altered later due to errors, inaccuracies or other problems in data entry. For this reason many companies are more inclined towards permissioned blockchains in which distinct layers of access to data can be configured to allow only access to specific participants and/or specific points in time. It allows for different disclosures of data, from completely public records to all participants, restricted access to information between two or more parties, up to private information only visible to one participant.

But when it comes to privacy, contrary to initial and still recurrent fears or misconceptions, public or permissionless blockchains are not anonymous but rather pseudoanonymous[50]. Taking the example of Bitcoin, on one hand transactions are not tied to real identities (anyone can transfer Bitcoin to others through private keys with no personal information) and are randomly transmitted over the peer-to-peer network. But on the other hand transactions can still be de-anonymised through a number of different techniques[51]. Research has showed for instance it is possible in over 60% of cases to link an individual's personally identifiable information to

[46] Amy Castor, 'Why Quantum Computing's Threat To Bitcoin And Blockchain Is A Long Way Off', *Forbes*, 25 August 2017 <https://www.forbes.com/sites/amycastor/2017/08/25/why-quantum-computings-threat-to-bitcoin-and-blockchain-is-a-long-way-off/#56ea01322882>.

[47] ENISA, *Distributed Ledger Technology & Cybersecurity: Improving Information Security in the Financial Sector*, 2016 <https://www.enisa.europa.eu/publications/blockchain-security>.

[48] Mark Frauenfelder, ''I Forgot My Pin: An Epic Tale of Losing $30,000 in Bitcoin', *Wired*, 29 October 2017 <https://www.wired.com/story/i-forgot-my-pin-an-epic-tale-of-losing-dollar30000-in-bitcoin/>. Nicole Kobie, 'This Man's Lost Bitcoin Are Now Worth $75m – and under 200,000 Tonnes of Garbage', *Wired*, 1 December 2017 <http://www.wired.co.uk/article/bitcoin-lost-newport-landfill>.

[49] Jeff John Roberts, 'How Bitcoin Is Stolen: 5 Common Threats', *Fortune*, 8 December 2017 <http://fortune.com/2017/12/08/bitcoin-theft/>.

[50] Aaron van Wirdum, 'Is Bitcoin Anonymous? A Complete Beginner's Guide', *Bitcoin Magazine*, 18 November 2015 <https://bitcoinmagazine.com/articles/is-bitcoin-anonymous-a-complete-beginner-s-guide-1447875283/>.

[51] Adam Ludwin, 'How Anonymous Is Bitcoin?', *CoinCenter*, 20 January 2015 <https://coincenter.org/entry/how-anonymous-is-bitcoin>.

Bitcoin addresses used for ordinary purchases in major online merchants[52].

Still ongoing experiments and research are trying to tackle such privacy concerns by using cryptographic protocols such as zero-knowledge proofs. For instance, JPMorgan Chase recently worked with Zcash to add zero-knowledge functionality to Quorum, its own private Ethereum based distributed ledger[53].

Mutability. Another major issue of disagreement revolves around if Blockchain is indeed 'immutable'. As seen before, it's still a technology vulnerable to threats and attacks which may hypothetically allow individuals or groups to change the records or revert transactions. Still such a systemic attack hasn't occurred yet in any known Blockchain system. Instead the main issue here concerns another key Blockchain feature according to which participants can vote or choose to make changes or alter the record. In fact this is a key design in a decentralised network based on cryptographic techniques such as Blockchain in which decisions and relationships between participants are governed by consensus mechanisms. In a strict sense, this means that immutability should not be understood as 'unchangeable', but rather hard to change[54].

Changing the record of transactions or simply a Blockchain via consensus has happened before. One of the most controversial cases was 'The DAO hack'[55]. Known simply as 'The DAO' (Distributed Autonomous Organization), it was designed as an experimental type of collective or firm (or decentralised investment fund) where rules and decisions were codified and executed autonomously through smart contracts running on Ethereum. After its launch on April 30th 2016, it raised $150 million worth of Ether (native cryptocurrency of Ethereum) from roughly 11000 investors, considered at the time the biggest crowdfunding in history. However, on June 17 The DAO was hacked by someone who discovered a bug in the code and stole over $50 million. This spurred a fierce debate between those who advocated for the reversal of the illicit transaction, and those adamant that the attacker simply exploited a technical loophole. In the end the consensus was to reserve the theft by restoring the original balance of The DAO through a splitting or 'forking' of Ethereum.

Most importantly this case generated a wide discussion over what immutability, openness and trust means in Blockchain systems[56]. It laid bare the centrality of governance as in reality Blockchain relies on a set of agents (developers, miners, users and other participants) that have specific roles and can intervene in specific moments when it's necessary to fix problems, upgrade the system or reverse unintended consequences.

[52] Steven Goldfeder and others, 'When the Cookie Meets the Blockchain: Privacy Risks of Web Payments Via Cryptocurrencies', 2017, 1–19 <http://arxiv.org/abs/1708.04748>.

[53] Matthew Leising, '"Mind-Boggling" Math Could Make Blockchain Work for Wall Street', *Bloomberg*, 5 October 2017 <https://www.bloomberg.com/news/articles/2017-10-05/-mind-boggling-math-could-make-blockchain-work-for-wall-street>.

[54] Angela Walch, 'The Path of the Blockchain Lexicon (and the Law)', *36 Review of Banking & Financial Law 713*, 2017 <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2940335>.

[5555] For a more detailed history of 'The DAO hack', see Joon Ian Wong and Ian Kar, 'Everything You Need to Know about the Ethereum "hard Fork"', *Quartz*, 18 July 2016 <https://qz.com/730004/everything-you-need-to-know-about-the-ethereum-hard-fork/>. David Siegel, 'Understanding The DAO Attack', *CoinDesk*, 25 June 2016 <https://www.coindesk.com/understanding-dao-hack-journalists/>.

[56] Primavera De Filippi, 'A $50M Hack Tests the Values of Communities Run by Code', *Motherboard*, 11 July 2016 <https://motherboard.vice.com/en_us/article/qkjz4x/thedao>. Tjaden Hess, River Keefer and Emin Gün Sirer, 'Ethereum Is Inherently Secure Against Censorship', 5 July 2016 <http://hackingdistributed.com/2016/07/05/eth-is-more-resilient-to-censorship/>. Christoph Jentzsch, 'The History of the DAO and Lessons Learned', 24 August 2016 <https://blog.slock.it/the-history-of-the-dao-and-lessons-learned-d06740f8cfa5>.

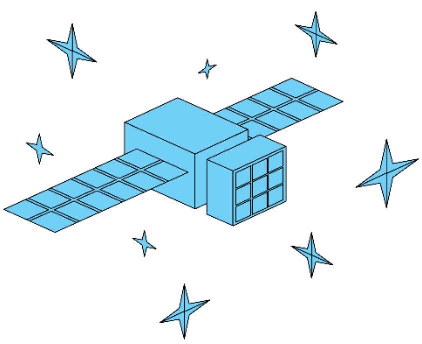
3. Blockchain Possibilities in Nine Industrial Sectors

Multiple actors beyond the financial sector are now observing that Blockchain and other DLTs could enable major transformations of products, processes and business models across their operational spaces. Promises of transparent, secure or decentralised ways to manage nearly all kinds of data and digital assets are being taken into consideration in an extended range of applications where it became key to move from siloed systems to shared infrastructures.

To explore this sociotechnical landscape we chose nine sectors where Blockchain based applications are reaching interesting early stage development, or where existing problems present themselves as potentially primed to be tackled by Blockchain features as explored in the previous chapter.

In each sector we signal an already existent application and the organisations behind it, in order to provide a better connection between abstract and empirical levels in such a complex field. There is no predefined order for these sectors, and the criteria for categorisation mainly corresponds to a simplified synthesis of other sectorial lists or catalogues currently in use by the European Commission when dealing with entrepreneurship, digitisation and wider industrial policies in the internal single market[57].

3.1. Space and Aeronautics



Blockchain and other DLTs could have a number of applications to key activities in aeronautics and space, such as use and protection of sensitive data, encrypted communications, verification of quality and security standards, distributed information processing, or overall network management and security.

Blockchain architectures make it very hard or nearly impossible to change data without detection. In this sense, records of transactions or data flows are irreversible and tamper-proof. This feature of immutability can be used to verify the integrity of highly sensitive data in critical systems, satellites, nuclear command and control systems, or weapon systems. For instance, Blockchain based systems could monitor if someone accessed a particular piece of data and if was modified, hacked, stolen or misused for other purposes[58]. It could potentially strengthen cyber defence infrastructures through quicker detections of data breaches and vulnerabilities.

box01 = **Use Case on Space Environments**

In NASA recent reflections on Distributed Spacecraft Missions (DSM) for Earth Science, Blockchain systems could support operational coordination and dynamic tasking between existing satellite, airborne and ground sensors. Here the purpose would be to develop an interoperable environment to host shared copies of particular datasets across multiple teams, grant access permissions, or publish data to user specified locations. All this in a distributed system that could make space based sensor networks more efficient, faster and less exposed to corruption or disruptive uses[59]. A decentralised architecture such as Blockchain could be also

[57] See for instance < https://www.clustercollaboration.eu/> and <https://ec.europa.eu/growth/sectors_en>

[58] Galois, 'Galois and Guardtime Federal Awarded $1.8M DARPA Contract to Formally Verify Blockchain based Integrity Monitoring System', 13 September 2016 <https://galois.com/news/galois-guardtime-formal-verification/>.

[59] Dan Mandl, 'Bitcoin, Blockchains and Efficient Distributed Spacecraft Mission Control', in *NASA Goddard IS&T Colloquium Lecture Series*, 2017 <https://sensorweb.nasa.gov/Bitcoin Blockchains and Distributed Satellite Management Control 9-15-17v12.pdf>.

integrated with other software networking architectures, deep learning techniques and fuzzy logic. This next generation decentralised computing infrastructure could combine Blockchain and AI to allow satellites to make decisions quickly and independently at a distance in a resilient, efficient and safe way[60].

The decentralised feature of Blockchain, that is, to operate across a network of nodes or computers, could be embedded in space hardware and software. Such systems could connect different technologies and devices with each other, such as sensors, satellites, artificial intelligence systems, or other points of processing and control.

Another potential application is to leverage satellite communications to improve the performance of Blockchain systems for instance in Machine-to-Machine (M2M) / Internet of Things (IoT) scenarios. In these cases, nodes could send transactions and receive validated blocks via satellite. The advantage is that satellites could broadcast at high speed allowing nodes to be synchronised quicker and also reach nodes not necessarily connected to usual networks[61].

For instance, the European Space Agency (ESA) is conducting the project 'Blockchain for Space Activities'[62] within their Big Data related initiatives. The overall aim is develop and prototype a set of Blockchain technologies to enable secured and traceable exploitation of data from space related activities, leveraging for instance on growing availability of large sets of data from missions such as the Sentinels, Euclid, or Galileo. The goal is to enable both end-users and data providers, in particular from private sector, to access data remotely in a secure and traceable way. Smart contracts could be set up among farmers who explore land that can be monitored from space, and a bank or insurer could lend money through micro-credit to the farmers depending on the status and outcomes of crops. New types of digital marketplaces could be created for many other assets with an economic value (infrastructures, buildings, forests, water sources, etc.) that are monitored from space. Such assets could be transacted between other actors such as fishers, builders, resource managers, development agencies, cooperatives, banks, urban and rural planners.

Still within aeronautics companies but with cross-sectoral applicability, Blockchain technologies could be used for as a transparent and immutable database to monitor the entire supply chain together with suppliers and manufacturers[63]. That is, such systems could help track the location, use, quality and compliance of products and parts in a distributed manufacturing model. Files for certain parts for an airplane could be sent and 3D-printed at a nearby or local factory. All files can encode the adequate quality and security standards and a smart contract could verify the terms of the transaction or operation.

Other wider applications in the aerospace industry could use Blockchain for simplification and increased efficiency of administrative and operational processes. It includes for instance streamlining procurement with the added value of faster and accurate payments, audit trails, and real time access and updates, or information and documentation management that could individualise data access and track changes to data, or even voting processes through Blockchain systems that could ensure immutability and security of the whole process and across parties often geographically distant[64] [65].

[60] Jin Wei, *RNCP : A Resilient Networking and Computing Paradigm for NASA Space Exploration*, 2017 <https://www.nasa.gov/directorates/spacetech/strg/ecf17/RNCP>.

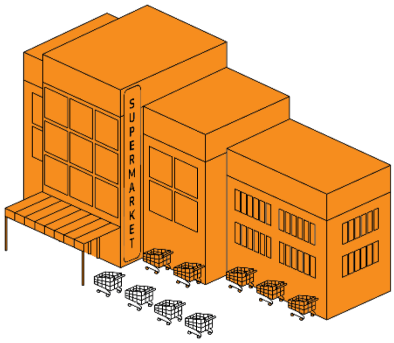
[61] See for instance the second call for the European Space Agency (ESA) MakerSpace for the SatCom IoT space, in particular Challenge 7 "Develop a demonstrator test bed for a Blockchain implementation over satellite using open-source tools", <http://www.dcualpha.ie/2017/10/981/>

[62] European Space Agency, 'GSTP Element 1 "Develop" Compendium of Potential Activities 2017', 2017 <http://emits.sso.esa.int/emits-doc/ESTEC/News/GSTPE1-DevelopCompendium2017.pdf>.

[63] Airbus, *Blockchain: The Trust Protocol*, 2017 <http://www.airbus.com/newsroom/news/en/2017/03/Blockchain.html>.

[64] For more information on ESA activities, see <https://www.esa.int/About_Us/Digital_Agenda/Beyond_Bitcoin_Leveraging_the_Blockchain_for_Space_4.0> Torben David, *Distributed Ledger Technology: Leveraging Blockchain for ESA 'S Success*, 2017 <http://esamultimedia.esa.int/docs/corporate/Distributed_Ledger_Technology_Leveraging_Blockchain_for_ESA_s_Success_Final_Annex.pdf>.

3.2. Food Processing and Distribution



Blockchain and other DLTs have the potential to improve a number of processes in the food processing, manufacturing and distribution, such as ascertaining origin or provenance, public health and safety compliance, organic certification, or overall transactions along a vast supply chain of producers, distributors, retailers, suppliers and consumers.

Blockchain allows for any type of asset and associated transaction to be recorded, certified and tracked between parties, no matter their physical distance. Its features of timestamping, immutability and digital signatures guarantees that a product was processed or distributed by a specific actor at a specific date and time, with little to no chance for anyone to change that record. For food distributors and retailers, Blockchain based systems can provide an accurate and updated record of products along its production, shipment and sale, helping for instance in case of outbreaks to determine more quickly and precisely the points of contamination[66]. It could also enhance efficiency for real-time management of food stocks and delivery, and help for instance to identify where and why food is thrown out or expired and thus potentially reduce food waste.

Traceability and quality control for how products are grown, stored, inspected and transported, that is, from the farm to the fork, could enhance accountability for all involved including suppliers, regulators and consumers. In a Blockchain system, everyone has access to and a copy of the same updated record (features of replication and transparency), so relevant parties can verify or inspect it at any time or at specific moments.

It confers a certain level of trust about transactions between distant and often unknown parties in global food chains. Most data is still stored on paper or in centralised databases that are costly, unreliable, and prone to inaccuracies, hacking, unintentional errors or frauds along a complex network of actors. It also offers an irrevocable, authenticated and time-stamped history of products for keeping track not only of food safety but also ethical standards. Proof of origin and compliance with environmental rules, organic labelling, fair trade or other type of characteristics could help consumers to make informed decisions, and steer companies towards more sustainable business models[67].

box02 = **Use Case on Food and Drinks**

London based startup Provenance is working with over 200 retailers and producers in the food and drinks sector to use Blockchain technology to help demonstrate the provenance of their physical products[68]. *The overall goal is to improve transparency and secure traceability for any materials, ingredients and products. In a pilot with The Co-op, the world's largest consumer co-operative, they were able to track fresh produce from origin to supermarket, using real-time data gathered throughout the entire supply chain to prove its journey and credentials. In another pilot, Blockchain technology, mobile phones and smart tags, were used to track yellowfin and skipjack tuna fish in Indonesia from catch to consumer, or*

[65] Giulio Prisco, 'NASA, ESA Considering Innovative Applications of Blockchain Technology', *Bitcoin Magazine*, 20 February 2018 <https://bitcoinmagazine.com/articles/nasa-esa-considering-innovative-applications-blockchain-technology/>.

[66] Roger Aitken, 'IBM & Walmart Launching Blockchain Food Safety Alliance In China With Fortune 500's JD.com', *Forbes*, 14 December 2017 <https://www.forbes.com/sites/rogeraitken/2017/12/14/ibm-walmart-launching-blockchain-food-safety-alliance-in-china-with-fortune-500s-jd-com/#162edeb77d9c>.

[67] Jutta Steiner, 'Blockchain Can Bring Transparency to Supply Chains', 19 June 2015 <https://www.businessoffashion.com/community/voices/discussions/does-made-in-matter/op-ed-blockchain-can-bring-transparency-to-supply-chains>.

[68] Provenance, 'Blockchain: The Solution for Transparency in Product Supply Chains', 21 November 2015 <https://www.provenance.org/whitepaper>.

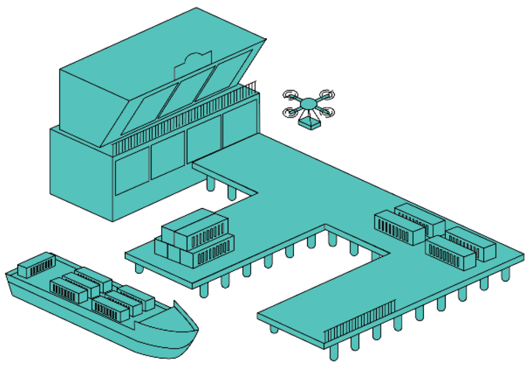
from origin to point of sale (POS). This monitoring enables proof of compliance to standards and social sustainability claims for instance by the fishermen, authenticate these certificates along the chain and put in place an open and transparent system for food and other physical goods.

Safeguarding the accuracy of food certificates and preventing risks of fraud and adulteration, could be supported by Blockchain based systems. A trusted registration of products' attributes and transactions, together with easy transfer of import and export certificates, could be the basis for more open ecosystems of producers, growers, traders, logistics companies, product standard organisations or certification scheme owners, data/information standard organisations, ICT services and solution providers, certification organisations, supervisory authorities such as accreditation authorities and food safety authorities, financial service providers such as banks and investors, and consumers[69]. It could be particularly useful for smaller farmers and cooperatives if it could facilitate digital certification, direct information flows and marketing to consumers, or even automate a number of transactions and procedures using smart contracts with other stakeholders such as distributors and retailers.

Such food certification is at the core of the production and sale of goods for instance with protected designations of origin (PDO), such as those awarded to regional products. It is expected that more companies could experiment with the integration of Blockchain technologies with mobile phones, smart tags and other IoT devices to scan QR codes in their products' labels and access information in a blockchain about their origin, production process, quality, expiry dates, lot numbers, and so on.

Blockchain could also be used to authenticate and trace the origin of high-value, rare and luxury goods in the food industry, such as wine. Fraud and counterfeit products are a costly burden for many companies dealing with lost revenue and compromises in their reputation. Authenticity and provenance of a particular bottle of wine for instance could exist in a blockchain through a registry of its unique 'thumbprint' composed of high-resolution photographs, ownership and storage records and even a certification for the physical bottle[70]. This digital representation of a bottle is further complemented by inputs from certified wine producers, licensed vendors and other authenticators. Different stakeholders such as retailers, warehouses, auctions houses, buyers and consumers can verify the provenance and the corresponding value of the wine (and bottle) in question.

3.3. Transports and Logistics



Applications of Blockchain and other DLTs for transports and logistics sectors range from overall supply chain and fleet management, asset transfer and movements, security of data exchanges, processing of import/export customs documentation, and automatic execution of contract terms between parties, up to proof of origin and conformity to safety rules, and tracking of sensitive materials or products[71].

Any kind of physical asset, supply and merchandise, together with movements or transfers between involved parties, can be cryptographically registered and tracked through a Blockchain system. Through its inherent features, Blockchain could offer near real-time data

[69] Lan Ge and others, *Findings from the Pilot Study Blockchain for Agriculture and Food* (Wageningen Economic Research, 2017) <www.wur.eu/economic-research>.

[70] See <https://www.winefraud.com/chai-wine-vault/>

[71] Phillip Boucher, Susana Nascimento and Mihalis Kritikos, 'How Blockchain Technology Could Change Our Lives', *European Parliamentary Research Service*, 2017, 24 <http://dx.doi.org/10.2861/926645>.

integrity for transports and logistics sectors that mostly rely on a global and distributed supply chains of distant and untrusting actors including manufacturers, shipping lines, freight forwarders, port and terminal operators, and customs authorities. All of them constantly need to exchange information for instance about the origin of goods, tariff codes, classification data, import/export certificates, manifests and loading lists, customs values, or status updates[72]. Transparent, secure and paperless flows of data could greatly reduce time and costs associated with current intermediaries, frauds, losses or duplications, and in the end assure overall conformity and delivery of goods.

Nowadays documentation to process and verify any cross-border shipping is done manually most of times and operational information is often transmitted over the phone, email or fax. Such processes are prone to errors, manipulations and delayed communication. If inserted in a blockchain for instance documents such as traditional bill of lading about a shipment of any good could be securely submitted, validated and approved across port authorities, security departments, customs, terminal operators and all other parties involved[73].

If Blockchain is coupled with other technologies such as artificial intelligence and data analytics, verification tools could automatically process documents for authenticity and compliance. Or if coupled with facial recognition technology, Blockchain could enable terminal and asset operators to log through digital credentials and monitor goods or equipment. It could help to speed up required cargo control and clearance in ports, terminals and warehouses.

Or if coupled with IoT devices, Blockchain could allow for instance for monitoring data about containers in ships, planes, trucks or other transports, regarding for instance the characteristics of the load, location, shipping conditions such as humidity and temperature, or specific instructions. Such encrypted and crucial data could be made accessible to only authorised parties along the supply chain based on smart contracts. Cargo management could also be optimised for instance by tokenizing cargo reservations, that is, to link a cryptocurrency token to a transaction, with the goal of incentivising suppliers to prevent unfilled shipments or overbooking by carriers[74].

box03 = **Use Case on Shipping Containers**

The SmartLog[75] project is a Proof of Concept (PoC) currently developing a Blockchain solution for operational data transfer traffic in logistics industry. Funded through the Interreg Central Baltic program, it is led by Kouvola Innovation Oy with partners Region Örebro County from Sweden, Latvia's Transport and Telecommunication Institute, Valga County Development Agency from Estonia, Sensei LCC from Estonia, Tallinn University of Technology, and IBM. The goal is to reduce end-to-end cargo transit times along two TEN-T core network corridors in the Baltics, namely the ScanMed and the North Sea – Baltic. IoT devices are attached to shipping containers to keep track of actual movements and added to a Blockchain system, in this case based on Hyperledger. This secure and unique record is shared between all participating companies along the supply chain, with the goal of improving operational flows, resource management and route optimization planning. In the future, data could flow seamlessly between the companies' operational information management systems using Blockchain systems, within a transparent and encrypted multi-party transaction ecosystem.

Data silos and fragmented software systems, such as Transport, Warehousing and Customs Management Systems, and Enterprise Resource Planning Systems used by most businesses, prevent in practice an efficient sharing of information between a decentralised chain of

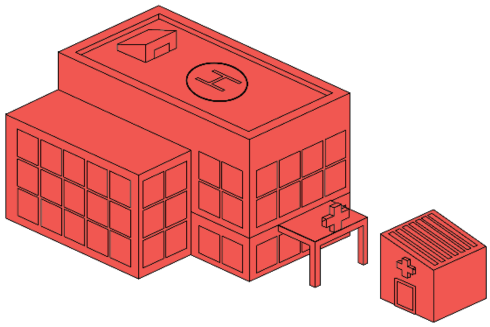
[72] Wolfgang Lehmacher, 'Why Blockchain Should Be Global Trade's next Port of Call', *World Economic Forum*, 23 May 2017 <https://www.weforum.org/agenda/2017/05/blockchain-ports-global-trades/>.
[73] Ian Allison, 'Ship Operator Maersk Testing Blockchain Tech to Replace Bill of Lading', *Newsweek* (21, 2016) <http://www.newsweek.com/ship-operator-maersk-testing-blockchain-tech-replace-bill-lading-512506>.
[74] Sara L M Golden and Allison Price, *Sustainable Supply Chains: Better Global Outcomes with Blockchain*, 2018 <https://newamerica.org/documents/2067/BTA_Supply_Chain_Report_r2.pdf>.
[75] See <https://smartlog.kinno.fi/>

shippers, freight forwarders, carriers, warehouses, customs authorities, government authorities, global terminal operators, road transport companies and many others. In principle there is an added value to develop open digital platforms for streamlining and standardising information flows, all potentially interconnected with global quality tracking systems to coordinate international quality assurance operations, and maintain records of standards compliance for geographically distributed actors[76].

Another application of Blockchain and other DLTS in the transports and logistics sectors concerns inventory and supply chain finance, especially in countries where SMEs are the main players operating warehouses, delivering containers with trucks, barges or trains, and/or providing customs clearance services[77]. For instance in a post shipment scenario, a consignment note for a delivered cargo could be made available on a Blockchain system, triggering the payment of the invoice based on a smart contract. Or for in-transit financing scenarios, information about the inventory at a Logistics Service Provider could be readily accessible to financing parties, which could then provide credit more quickly to SMEs or increase the percentage of the financed inventory. It could potentially stimulate more agile business models between financial institutions, logistics providers, shippers and receivers, all working in the same ecosystem.

As cross-sectoral applications, Blockchain could be used to track assets coming from other industries by providing an updated, encrypted and irrevocable record about a product's lifecycle, including provenance, raw materials, producer and supplier information, manufacturing details, distribution routes, or certificates. Counterfeit and/or illicit materials, products, or dangerous substances have a huge cost for regulators, industry and producers at a global scale, and represent a challenge when it comes to overall protection of global supply chains and enforcement of health and safety regulations. Blockchain systems could potentially provide resilient and shared registries of such assets under common protocols to be used by customs authorities, rights holders and logistics operators for more effective decision-making and faster actions against potential infringements[78].

3.4. Health and Biopharmaceuticals



Applications of Blockchain and other DLTS in the health and biopharmaceuticals are being explored regarding for instance electronic medical records, identity management, data authentication and sharing, interoperable systems between healthcare providers and other stakeholders, pre-authorisation payment infrastructure, claims management, clinical trial, counterfeit drug prevention and detection, among many others[79].

Blockchain relies on public-private keys to ensure the authenticity and integrity of data exchanges between different parties, all recorded in an irrevocable and time-stamped record or ledger. Patients, doctors, hospitals and other healthcare providers could store electronic health records in Blockchain based decentralised management systems, in which they are able to encrypt personal and/or sensitive information and grant access to records only to authorised parties via appropriate credentials[80]. The capacity to record

[76] <https://www.maersk.com/press/press-release-archive/maersk-and-ibm-to-form-joint-venture>

[77] Aljosja Beije and Janjoost Jullens, *A Lead via Blockchain Technology: Position Paper on a Digital Port of Rotterdam*, 2016 <http://www.blocklab.nl/media/uploads/2017/09/A-lead-via-Blockchain-Technology.pdf?x54716>.

[78] See <https://euipo.europa.eu/ohimportal/en/web/observatory/blockathon/challenges/customs-authority> and <https://euipo.europa.eu/knowledge/course/view.php?id=3038>

[79] Sean Hogan and others, *Healthcare Rallies for Blockchains: Keeping Patients at the Center*, 2016 <https://public.dhe.ibm.com/common/ssi/ecm/gb/en/gbe03790usen/GBE03790USEN.PDFN.PDF>.

[80] Ariel Ekblaw and others, *A Case Study for Blockchain in Healthcare: ' MedRec ' Prototype for Electronic Health Records and Medical Research Data, IEEE Technology and Society Magazine*, 2016 <http://dx.doi.org/10.1109/OBD.2016.11>. RJ Krawiec and others, 'Blockchain : Opportunities for Health Care', *NIST Workshop on Blockchain & Healthcare*, 2016, 1–12

and authenticate medical data and customise its use for other parties could leverage the informational and economic value of such data. It could stimulate new business models for privacy-preserving solutions, personalised medicine, data sharing for drug, treatment and public health research purposes, or even selling, buying and re-marketing for any number of stakeholders.

Data confidentiality and security is a major concern in this sector, so any Blockchain solutions need to put in place strong privacy mechanisms and in compliance with data protection regulation. For instance, from the viewpoint of the patient their data could be pseudonymised or anonymised through robust de-identification and encryption technologies. Patients could implement dynamic consents through smart contracts, that is, define data access rights stating for example the type of data to be given, intended uses, authorised third parties, conditions for revocation or storage limits. In these conditions they could more easily share their records and ask for second opinions to different doctors, find other patients with similar condition, or provide their information for research purposes to biomedical centres and universities[81].

box04 = **Use Case on Clinical Trials**

Blockchain could have an impact on accountability and transparency in clinical trials reporting and management processes[82]. Data and metadata that needs to be circulated in a clinical trial between multiple stakeholders (sponsors, researchers, patient groups, regulatory agencies, registries, statisticians, drug suppliers, patients, data manager, trial monitors, etc.), could be timestamped and cryptographically stored on a blockchain. Researchers could greatly benefit from sharing anonymised raw data, datasets or statistical analysis plans in clinical trials through distributed and secure channels. Smart contracts (as computer programs or agreements between different parties that are executed automatically according to the terms specified) could also be used for clinical trial phase control. Patients could give specific consents for data analysis for instance under the condition that the database is not shared with third parties and/or used for commercial purposes.

Overall Blockchain could introduce changes on how data is used and managed within the health sector. Nowadays health data is still fragmented, siloed and opaque or under the control of a few dominant stakeholders. Blockchain could provide permanent records to be verified and accessed with a greater level of speed, security and openness for everyone involved or with the adequate authorisation.

Other applications interlinked with other sectors such transports and logistics, Blockchain systems could be used to record and track biopharmaceutical products along their supply chains[83]. Drugs and other products could be tagged with IoT devices, authenticated and recorded in a blockchain, which could prevent and/or allow for quicker detection of counterfeits, thefts or misplacements along a complex multiparty network of producers, manufacturers, regulatory agencies, suppliers, distributors and others. It could help to keep track of required environmental conditions for transport of pharmaceuticals and other healthcare products, such as temperature and time. Overall Blockchain based systems could support companies to prove compliance with mandatory quality controls, speed up logistics, minimize errors and costs, and overall improve transparency of the whole supply chain.

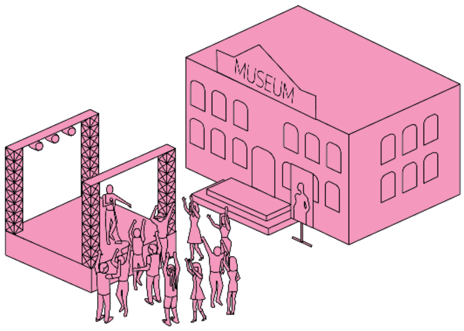
<https://www2.deloitte.com/content/dam/Deloitte/us/Documents/public-sector/us-blockchain-opportunities-for-health-care.pdf>.

[81] See <http://www.myhealthmydata.eu> Rocco Panetta and Lorenzo Cristofaro, 'A Closer Look at the EU-Funded My Health My Data Project', *Digital Health Legal*, 2016, 10–11 <http://www.myhealthmydata.eu/wp-content/uploads/2017/11/DHL-November-2017-p10-11.pdf>.

[82] Mehdi Benchoufi and Philippe Ravaud, 'Blockchain Technology for Improving Clinical Research Quality', *Trials*, 18.1 (2017), 1–5 <http://dx.doi.org/10.1186/s13063-017-2035-z>.

[83] Modum.io, *White Paper - Data Integrity for Supply Chain Operations, Powered by Blockchain Technology*, 2017 <https://modum.io/whitepaper/>.

3.5. Creative Industries



Within the sector of creative industries taken in a broad sense to encompass digital knowledge and information, Blockchain and other DLTs could be applied for intellectual property and content management for any type of digital work (books, music, art, games, photos, texts, etc.), for instance for ownership and sub-licensing rights, payments and financial transactions, metadata on creation and consumption of content, or authentication systems for information value and reliability.

As a database or ledger, a blockchain can store an encrypted, transparent and irrevocable record of all data exchanges in a multiparty ecosystem. From here emerges the possibility of creating a shared database to register ownership rights, licensing terms and royalty rules, globally accessible and potentially validated by all parties depending on the type of consensus mechanisms in place. An immutable and tamper-proof register of all sales, licences, loans, donations and other transfers of original works would help authors or artists to track when and who is using their work and specify royalty fees. Consumers or buyers could also more easily verify the real owner of the content, the type of version, the set of rights attached to it, and agree to the terms set by the rights holders.

Organisations and entities involved in the music and media business, like record labels, publishers, performing rights societies, streaming services, managers, artists and startups, could greatly benefit from such a record to counter lost or misdirected rights revenues. Blockchain could be the technological basis of such a concerted effort[84], despite previous unsuccessful attempts to build single online copyright and information portals for musical works[85].

box05 = Use Case on Music Licences

Ujo Music[86] is a music software services company developing an Ethereum based platform that allows musicians to automatically license and sell their work using smart contracts and associated cryptocurrencies. A piece of music is inserted and published publicly in the ledger as belonging to the artist, also including licensing terms to allow consumers or buyers to compensate the artist according to the terms set out in smart contracts. As a first demonstrator, for instance they worked with Imogen Heap in 2016 to release the track 'Tiny Human' through a direct fan-to-artist payment scheme. In the future it could be possible for artists and consumers to have portable digital identities running on a blockchain but interoperable with streaming services like Soundcloud, YouTube and other online music services. By digitising and authenticating rights and metadata and making them accessible, such open ecosystems could reduce the barriers of entry for new artists, simplify licensing and rights management, facilitate immediate payments to owners and creators, and enable new applications, products and services with minimal friction and more balanced distribution or sharing of the work[87].

The wide deployment of Blockchain systems in creative industries could help prevent infringements or unauthorised uses, and overall enable more efficient, cost-effective and potentially fairer ways to compensate the owners and creators through pay-per-usage, micropayments or automatic payment distributions. Smart contracts could potentially manage the whole process for instance registering that a particular composition is owned

[84] See for example <http://open-music.org/blog/2016/6/6/why-us-why-now>
[85] See for instance previous case of Global Repertoire Database (GRD), Klementina Milosic, 'GRD's Failure', *Music Business Journal*, 2015 <http://www.thembj.org/2015/08/grds-failure/>.
[86] <https://ujomusic.com/>
[87] See <https://blog.ujomusic.com/welcome-back-1addcc06bcc6>

by specific parties such as writers, publishers or artists, registering the use or streaming of this composition, and then automatically executing how the revenue is divided by the owner or owners of the copyright, and eventually distributing seamlessly the payments. However, smart contract technology is not at a mature stage where it can enable this type of agreements and automatic transactions across a multiparty network[88].

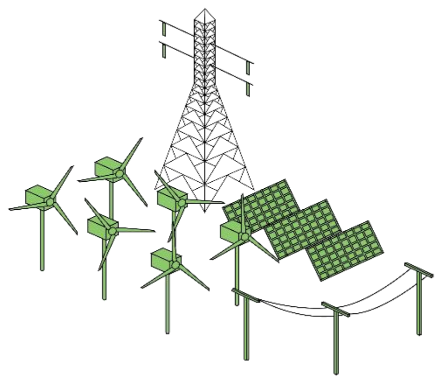
Another Blockchain application in this sector could be the curation and management of metadata regarding any type of digital work. A distributed and verified database could host valuable information that today is mostly opaque except for distributors, publishers and/or record labels, including how many times a song or a book was played, watched or read online, where or by which means it was bought, and even by whom. Additional information potentially interesting from the viewpoint of both creators and consumers could be stored, such as instruments used in the production of a song, the place where it was composed, involved musicians, direct comments and/or feedback, and so on[89].

The general expectation around the use of Blockchain is that it could support alternative business models for digital works according to conditions set by their rights owners (either for free under certain conditions, or at a price), and ultimately change the dynamics between creators, authors, users and distributors. It would imply defining and experimenting with new incentives to connect such a different set of stakeholders through greater transparency and sharing of data.

It can be argued that open and trusted access to data could create knowledge feedback loops between diverse stakeholders and foster ground-breaking data-driven applications running not only on Blockchain, but deploying AI, machine learning, data analytics and so on[90]. Yet, concerns remain for instance about excessive commoditisation of digital works in a future where all content is catalogued, tracked and monetised.

In the long run, multi-stakeholder inclusive innovation ecosystems could be running on a blockchain with no central authority, with multiple providers depending on the function needed, and with full interoperability between different services[91]. It would be a modular approach for an open and transparent meta-system running with individual systems, not only adapted to the specific problems they are designed to solve, but also fully interoperable with each other by using open standards and accessible data running on Blockchain systems, and in compliance with independent certification and/or regulatory frameworks within a multi-stakeholder model.

3.6. Energy



Blockchain and other DLTs could be applied in the energy sector when it comes for instance smart grid and microgrid management, peer-to-peer energy trading, micro transactions or payments, carbon trading, energy production and consumption monitoring, renewable energy procurement, or electric vehicle charging.

Leveraging on its feature of decentralisation, Blockchain could offer alternatives to long-standing inefficiencies, vulnerabilities and losses of centralised solutions, mostly relying on mass production energy infrastructure. Blockchain allows for multiple parties to coordinate among

[88] George Howard, 'Salzburg Hack: A 12 Hour Sprint to Build a Blockchain Music Product', *Open Music*, 10 April 2018 <http://open-music.org/blog/2018/4/5/salzburg-hack-a-12-hour-sprint-to-build-a-blockchain-music-product>.
[89] Yessi Bello Perez, 'Imogen Heap: Decentralising the Music Industry with Blockchain', 14 May 2016 <http://myceliaformusic.org/2016/05/14/imogen-heap-decentralising-the-music-industry-with-blockchain/>.
[90] Andrew Dubber, 'Blockchain AI and beyond', 15 December 2017 <http://musictechfest.net/blockchain-ai-and-beyond/>.
[91] Petter Ericson and others, *# MTFLabs: Blockchain*, 2016 <http://musictechfest.net/wp-content/uploads/2016/08/Blockchain-Whitepaper.pdf>.

themselves and execute transactions in an open and transparent way, still with differences depending on the chosen type of public or private architectures. Many are seeing it as a data coordination and management infrastructure that could boost the emergence of a decentralised energy transaction and supply system[92].

One possible application concerns the use of smart contracts to manage automatically supply and demand flows in near real-time and towards an optimal use of available energy[93]. When such smart contracts are embedded in other technologies such as smart meters, smart devices and/or sensors, peer-to-peer trading scenarios could be foreseen. Appliances, batteries, power plants, or any point in the grid could sell and buy energy constantly and automatically toward a balancing of the market. Several companies are testing out Blockchain based trading platforms for power, natural gas and others that could connect large producers and factories, retailers and eventually households[94].

box06 = **Use Case on Energy Platforms**

Co-founded by Rocky Mountain Institute and Grid Singularity and with a network of nearly 50 affiliates, Energy Web Foundation (EWF)[95] is developing an open-source and scalable Blockchain platform as a digital infrastructure designed for the energy sector's regulatory, operational, and market specificities. EWF affiliates can build proprietary applications on top of the EWF's open-source Blockchain as a foundational base layer, under a framework licence agreement between EWF and Parity Technologies. In its current configuration, their platform is based on a decentralised proof-of-authority (PoA) consensus mechanism with permissioned industry validators and a combination of on- and off-chain governance. Affiliates are testing it in use cases such as transactive energy, microgrids, community solar, renewable energy procurement and trading, electric vehicle charging, and demand response[96]. EWF is also developing several open-source solutions such as 'EW Origin' which records information such as location, time, source type, and CO2 emissions and automatically tracks the ownership of renewably generated electricity.

Deployment of Blockchain systems could be potentially valuable for integration of renewable energy sources, taking into account their volatile and intermittent generation or current inability of market prices to reflect the irregular flows of local energy. As a decentralised coordination infrastructure, Blockchain could support microgrid energy markets in which individual customers could trade locally produced renewable energy (using solar systems, wind turbines or other small-scale systems) directly with others in their communities with (near) real-time pricing[97].

Such a peer-to-peer and local energy system could strengthen the feasibility of transforming consumers into 'prosumers'. By bringing production and consumption points closer, it could potentially reduce energy losses in the grid as it happens currently with long-distance transmission. The overall system could not only be more sustainable due to a more efficient use of local resources, but also more resilient (no single point of failure) to potential shortages[98].

[92] Felix Hasse and others, *Blockchain – an Opportunity for Energy Producers and Consumers?*, *PwC Global Power & Utilities*, 2016 <https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf>.

[93] Dan Brandon and others, 'Industrial Blockchain Platforms : An Exercise in Use Case Development in the Energy Industry', *International Journal of the Academic Business World*, 2420.3 (2016) <http://dx.doi.org/10.1017/CBO9781107415324.004>. Taneli Hukkinen and others, 'A Blockchain Application in Energy', *ETLA Reports*, 71.71 (2017) <https://www.etla.fi/en/publications/a-blockchain-application-in-energy/>.

[94] Jesper Starn, 'Blockchain a Savior for Stretched Computers at Energy Trader', *Bloomberg*, 6 February 2018 <https://www.bloomberg.com/news/articles/2018-02-06/blockchain-a-savior-for-stretched-computers-at-energy-trader>.

[95] <http://www.energyweb.org>

[96] See https://energyweb.org/2018/04/17/energy-web-foundation-unveils-major-blockchain-milestones-at-event-horizon/

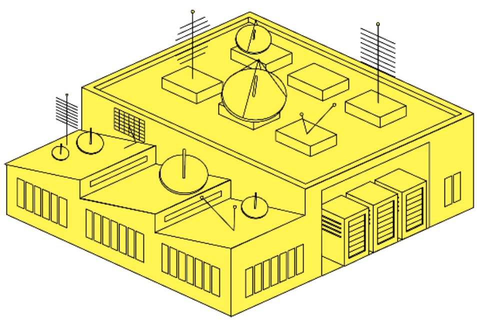
[97] Esther Mengelkamp and others, 'Designing Microgrid Energy Markets. A Case Study: The Brooklyn Microgrid', *Applied Energy*, 2017 <http://dx.doi.org/10.1016/j.apenergy.2017.06.054>.

[98] Rieul Techer, 'DAISEE — Our Compass for the New World (More Complex than Ever) That Is Coming', 9 December 2016 <https://medium.com/daisee/daisee-our-compass-for-the-new-world-more-complex-than-ever-that-is-coming-9925997cf332>.

Other applications of Blockchain in the energy sector concern for instance secure storage of ownership records of energy flows and business activities, including carbon emission allowances, renewable energy certificates, and status of assets like smart meters, networks or generation facilities. Secure and near real-time monitoring of energy consumption could also allow for more efficient metering and billing, even coupled with micropayments via cryptocurrencies.

Shared records and tracking could lower costs and enhance transparency of all activities among diverse stakeholders, and eventually facilitate access to energy markets for smaller and medium players. Overall, secure access to information on a shared ledger about the origin, allocation and use of energy could be considered valuable in a new energy system paradigm. Knowing more precisely who's producing and consuming what type of energy, at what times and through which means, could be used for new local market and business approaches in the sector.

3.7. Information Technologies



Blockchain and other DLTs could offer a number of applications in the information technologies sector, including for instance encrypted and peer-to-peer telecommunications, mesh networking, decentralised file systems and cloud storage, and other web services and applications.

Blockchain's feature of digital keys could support authentication in current telecommunications such as audio and video calling. Within encrypted Voice over Internet Protocols (VoIP), it could replace the need for service providers or phone carriers to authenticate callers and in the end bring forward open, reliable and secure networks of communication no matter the users' locations[99].

Features of decentralisation and digital keys offered by Blockchain could also be leveraged in mesh networks, which are local decentralised system of nodes or wireless connection points (antennas, bridges, switches, or other devices) connecting directly and cooperating with each other to efficiently route data. In a mesh network, participants share resources (internet connection, battery power, cell phone) to run the network. For example a limited number of participants downloads files and then disperses to the others participants who don't need to be actually connected to the internet. In a Blockchain architecture, participants can be incentivised to run the mesh network by getting rewards in tokens or cryptocurrencies. Also the identity of each participant could be securely managed in a Blockchain system, allowing for selective sharing of resources and data[100].

Another application of Blockchain in the IT sector concerns its potential integration with decentralised file storage which means sharing files across a peer-to-peer network. Such integration is usually built on BitTorrent protocols currently used for online sharing of large digital files (mostly video and audio). Instead of storing and/or accessing files through central servers, decentralised storage protocols connect multiple users to dispersed copies of files which are stored in other users' computers or devices. Other Blockchain's complementary integrations with other decentralised technologies concern peer-to-peer and distributed file systems. For example other techniques for timestamping, encrypting and sharing files could help to solve Blockchain's limited capacity to host large sets of data. In such cases the files could be stored in a distributed network and only its 'digital fingerprints' or cryptographic representations need to be inserted in a Blockchain ledger[101].

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[99] See for instance <https://encryptotel.com/>

[100] Robbie Abed, 'RightMesh Is Looking to Connect the World via Blockchain', *Huffington Post*, 18 December 2017 <https://www.huffingtonpost.com/entry/rightmesh-is-looking-to-connect-the-world-via-blockchain_us_5a38918ee4b0cebf48e9f6dd>.

[101] Juan Benet, 'IPFS White Paper: Content Addressed, Versioned, P2P File System (Draft 3)', 2014 <http://arxiv.org/abs/1407.3561>.

box07 = **Use Case on Cloud Storage**

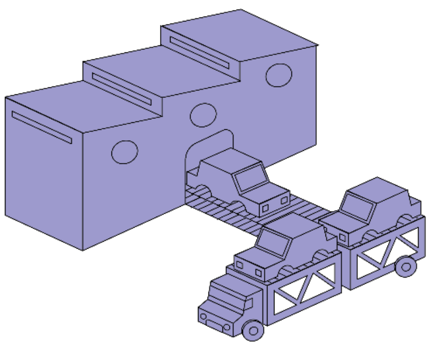
Storj[102] offers a decentralised and end-to-end encrypted cloud storage platform that uses Blockchain's ledger, public/private keys, and cryptographic hash functions for security purposes. A user can encrypt a file using its keys and then the file is divided in smaller pieces called 'shards'. These pieces are sent to a decentralised network of individual computers which only store a piece of the original file. To recall it, the original user uses its private key to locate it and all the others send back the pieces to rebuild the file. The network is run by nodes or 'farmers' which rent out their extra hard drive space in return for Storj tokens. It's similar to cryptocurrency mining as it occurs in Proof-of-Work consensus mechanism in Bitcoin or Ethereum, in which individual computers are verifying transactions by solving mathematical puzzles. Storj has a community of around 20.000 users (uploaders) and 19.000 farmers (storage providers).

Decentralised architectures such as Blockchain and others are increasingly considered as alternatives to centralised platforms and associated problems of user privacy, data control and vulnerability to security breaches. Most of current applications and services store user data in central servers and/or use third parties to manage keys and certificate based authentication, which then become privileged targets for attacks.

Blockchain could be applied in decentralised web applications[103] for domain names, identity and storage, in which users control where their data is kept (in their own computers or specific cloud servers) and how it's accessed. For example, all data generated by the users could be stored locally in their computers or devices, and then encrypted for backup copies in cloud storage systems if needed[104]. Users would only share a restricted profile or part of the data relevant to the requested access for applications and services, especially if the latter were also built on top of decentralised platforms. Access to the data could also be revoked at any time, thus allowing for full data portability between services. In such cases, a Blockchain system would allow individuals to have a universal identity system based on digital keys generated on their own devices.

Other cross-sectoral applications of Blockchain in the IT sector include for instance launching satellite-enabled Blockchain systems. These systems would be independent of satellite networks now mostly controlled by governments, contractors, and major commercial players. Such open source and decentralised systems could be used to run Blockchain applications in space at a lower cost, which could help its industrial adoption and widespread experimentation[105]. They could also be used to run distributed networks for cryptocurrencies, making them fully accessible anywhere and anytime, even in places with poor or expensive Internet connectivity[106].

3.8. Advanced Manufacturing



[102] <https://storj.io/index.html>
[103] Laura Shin, 'Blockstack Unveils A Browser For The Decentralized Web', *Forbes*, 23 May 2017 <https://www.forbes.com/sites/laurashin/2017/05/23/blockstack-unveils-a-browser-for-the-decentralized-web/#3272b60871cd>.
[104] Muneeb Ali and others, 'Blockstack Technical Whitepaper Blockstack: A New Internet for Decentralized Applications', 2017 <https://icotokn.com/wp-content/uploads/2017/11/blockstack-whitepaper.pdf%0Ahttps://blockstack.org/whitepaper.pdf>.
[105] Qtum, 'Qtum Launches Satellite for Blockchain Advantages with SpaceChain Foundation Collaboration', *2018*, February <https://www.prnewswire.com/news-releases/qtum-launches-satellite-for-blockchain-advantages-with-spacechain-foundation-collaboration-300594163.html>.
[106] See for instance <https://blockstream.com/satellite/blockstream-satellite/> and <https://www.prnewswire.com/news-releases/vector-and-nexus-team-up-to-bring-cryptocurrency-to-space-300573678.html>

Blockchain and other DLTs offer a set of potential applications for advanced manufacturing, such as asset sharing, distributed value and supply chains, automation management of production processes in agile and smart factories, tracking of digital representations of any product, life cycle management, certification and authentication, among others.

Blockchain could support the use of digital data in manufacturing processes in close integration with other digital technologies such as Internet of Things (IoT), artificial intelligence, robotics, or additive or subtractive manufacturing. As an encrypted and immutable digital record, a blockchain could register the set of characteristics associated to a product, such as physical qualities, design specifications, used materials, ownership, place of manufacture, maintenance history, certifications or warranties. If the products are monitored via IoT devices or sensors along the whole process, Blockchain could also register information on location, availability, or status.

This record would support in fact the digital representation of any physical or digital product, that is, in a certain sense a 'digital twin' or digital product memory encompassing all relevant data to be accessed and used through the whole chain[107]. Any changes to the product made by involved parties would be added, timestamped and tracked on a blockchain. This updated record would be available to everyone no matter their location with the proper or necessary identity credentials.

Blockchain's decentralised feature could also be useful in production scenarios using additive manufacturing or 3D printing. Digital files could be easily transmitted across a number of parties and geographical sites, from the original designers to the production floors of a factory. Its encryption mechanisms would also guarantee authentication of such files. Overall Blockchain could serve as the backbone and security layer for digital data flows for the design, modelling, production, validation, use and monitoring of 3D manufactured parts[108].

Digital supply chain solutions for 3D printing are being tested within the trends of Industry 4.0[109]. Blockchain could support more lean manufacturing processes based on point-of-use and time-of-need supply chains, that is, on availability of parts when and where they are needed. A company could purchase a digital file and use a blockchain to transfer the file and also to verify the 3D printing vendor and 3D printing machines which are closer to the final place of production or assembly. Transactions including orders and payments between companies are automatically executed and completed through smart contracts which also maintain logs of authorised uses of an asset[110].

In the future, smart contracts could eventually locate the most appropriate production facilities and negotiate the terms autonomously based on availability, price, quality, delivery or location. Such processes are expected not only to save inventory, import and logistic costs, but also lead to a decrease of ecological footprints and ultimately boost self-sufficient local economies.

box08 = **Use Case on 3D Printing**

The Genesis of Things project[111] is developing an open secure platform to decentralise industrial manufacturing, with the goals of reducing inventory costs and lead times, increasing production efficiency and improving product life cycle management. The proposed model would allow for companies to scan and/or access 3D designs of spare parts for example, securely their

107 Carsten Stocker, 'Implementing First Industry 4.0 Use Cases with DAG Tangle — Machine Tagging for Digital Twins', *Medium*, 24 January 2017 <https://medium.com/@cstoecker/implementing-first-industry-4-0-use-cases-with-iota-dag-tangle-machine-tagging-for-digital-twins-baf1943c499d>.

108 Stuart Strouton, Mark Vitale and Jason Killmeyer, *3D Opportunity for Blockchain: Additive Manufacturing Links the Digital Thread*, 2016 <https://www2.deloitte.com/content/dam/insights/us/articles/3255_3D-opportunity_blockchain/DUP_3D-opportunity_blockchain.pdf>.

109 See <http://www.moog.com/news/corporate-press-releases/2018/STAerospaceCollaborate3DPrinting.html> and <https://www.automationworld.com/blockchain-coming-manufacturing>

110 Vincent Dieterich and others, *Application of Blockchain Technology in the Manufacturing Industry*, Frankfurt School Blockchain Center, 2017 <http://explore-ip.com/2017_Blockchain-Technology-in-Manufacturing.pdf>.

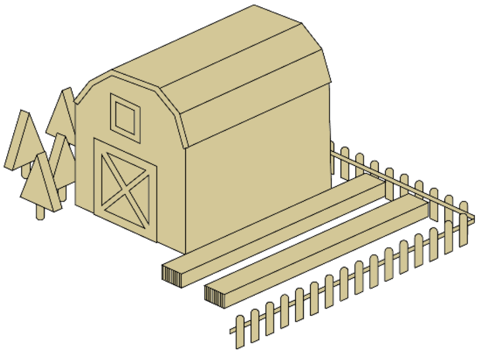
111 <http://www.genesisofthings.com/>

transfer and produce them on demand in 3D printers at locations close to their operation and maintenance centres. Smart contracts could eventually be used to select, track and automate any type of transaction, including permissions of access, logistics procedures, associated rights and execution of payments. In a proof-of-concept or demonstrator for a Blockchain based shared 3D printing factory, some of the involved companies (Cognizant, innogy and EOS GmbH Electro Optical Systems) tested end-to-end encryption of 3D print files to produce titanium cufflinks with a unique ID and digital product memory (from their creation to their transmission and fabrication at a 3D printer).

Within scenarios of additive and subtractive manufacturing, Blockchain serves as a tamper-proof record of ownership of digital files, and in the end could help to prevent unauthorised uses, thefts and infringements. It could improve processes of intellectual property management such as patents, trademarks or design rights, along a long distributed network of creators, providers, sellers, manufacturers and distributors. Blockchain could also store the digital identity of each manufactured part via embedded serials and identifiers, and thus provide proof of compliance with mandatory warranties, licences and standards in their production, installation and maintenance.

In more future-oriented scenarios, Blockchain could usher profound changes in manufacturing processes towards decentralised and autonomous smart production[112]. For instance, such technologies could create more trusted and flexible relationships between manufacturers, suppliers and customers in a context of open and digitalised ecosystems, particularly for niche players such as micro-factories or small service providers. It would be mostly a data-driven ecosystem as the basis for potential new business models, which could be able to leverage on available real-time data about source raw materials, best manufacturers, characteristics and location of products, and/or quality controls and assurances.

3.9. Natural Resources



Blockchain and other DLTs could have potential applications within activities of extraction and collection of natural resources such as farming, fishing or mining, for example when it comes to data monitoring of crops and extraction processes, management of contractual obligations, trading of commodities, land and property registry, resource tracking, and sustainability measurement and management.

A Blockchain system could offer a shared and immutable record for data collected in real-time with IoT sensors and handheld devices for instance by farmers. Information about the status of the crop like salt and sugar content, pH levels, location and level growth, could help farmers to better plan when to harvest and share this information with buyers and distributors. Data sharing with multiple parties could help improve management of stocks, transportation and delivery, that is, reduce costs, shortages, surplus and overall inefficiencies along the whole chain[113].

By allowing encrypted but shared access to the record in a more open or restricted way (depending on the architecture), a blockchain could help involved parties to keep track of all transactions and contractual obligations. Smart contracts could be used to implement and execute operations automatically among buyers, suppliers and other stakeholders, by setting up conditions

[112] Burkhard Blechschmidt and Carsten Stöcker, *How Blockchain Can Slash the Manufacturing 'Trust Tax'*, *Cognizant*, 2016 <https://www.cognizant.com/whitepapers/how-blockchain-can-slash-the-manufacturing-trust-tax-codex2279.pdf>.

[113] Peter Newman, 'This Startup Is Pairing the Blockchain with Farming', *Business Insider UK*, 10 November 2017 <http://uk.businessinsider.com/ripe-blockchain-farming-startup-2017-11?r=US&IR=T>.

such as selling and buying prices, insurances, profit distribution, compliance with necessary certifications, and so on. It could potentially minimise fraud and introduce more transparency and accountability between often distant parties.

Access to a shared record of data and possible execution of operations via smart contracts could also be used for actual trading of agricultural commodities[114]. Delays related to manual checks and paper documentation could be greatly reduced if up-to-date digital data was fully available, including contracts, letters of credit, or certifications.

In other cases, Blockchain could even allow for alternative ownership, governance and distribution models, particularly for community-supported agriculture or small producers. Proof and transfer of ownership or co-ownership could be supported by an encrypted and unique registry. Tokens representing shares of harvested crops could be distributed, bought or sold among participants, or even represent votes for decision-making and operational processes within organisations or companies. Such models could improve overall resource management by smaller and local producers and in the end support self-sufficient local economies.

box09 = **Use Case on Land Registry**

Startups in Kenya and Ghana are developing Blockchain based digital records for land ownership and transfer, which could translate into more transparency for all parties, including farmers, governments, banks, brokers, buyers and sellers[115]. The main idea is to create a secure and tamper proof record to tackle persistent problems of duplicated or forged documents, corruption, bribes and disputes over land or property. One of the most immediate benefits would be the formal acknowledgement of land titles informally owned by communities or through oral agreements between subsistence farmers and land-owners. Registering land titles or business licences on a blockchain could also enable individuals and families to request loans and mortgages to banks, and overall to conduct transactions without the direct presence of lawyers, notaries or government officials. Challenges may arise from the reluctance of governments and state agencies to support the development and open access of Blockchain based registries, to recognise its legitimacy or to use them to complement state records. Also any registration effort would imply on the ground verification with associated high costs and potential disputes. For instance surveyors would need to interview farmers, neighbours and chiefs in specific communities to come to shared agreements when no previous written registry of land rights is available.

As previously seen in other sectors, Blockchain architectures are also increasingly being deployed for ascertaining origin or provenance of food, products and materials within global supply chains. Such architectures could be used for tracking and certification of mineral supply for batteries in cell phones, computers and electric cars, in order to prevent further use of minerals extracted in conflict zones where profits are fuelled to war efforts ('conflict minerals'), or from companies using child labour or with known record of human rights violations. Minerals produced by certified miners or companies would be embedded with a digital tag containing information about their characteristics, date and time, and then encrypted on a Blockchain based immutable record. At every stage, from the miner to the trader, smelter and buyer, the transactions would be recorded and authenticated by involved or relevant parties[116].

Resource tracking and certification via a blockchain could be at the core of emerging

[114] Andy Hoffman and Ruben Munsterman, 'Dreyfus Teams With Banks for First Agriculture Blockchain Trade', *Bloomberg*, 22 January 2018 <https://www.bloomberg.com/news/articles/2018-01-22/dreyfus-teams-with-banks-for-first-agriculture-blockchain-trade>.

[115] Kevin Mwanza and Henry Wilkins, 'African Startups Bet on Blockchain to Tackle Land Fraud', *Reuters*, 16 February 2018 <https://www.reuters.com/article/us-africa-landrights-blockchain/african-startups-bet-on-blockchain-to-tackle-land-fraud-idUSKCN1G00YK>.

[116] Barbara Lewis, 'Blockchain to Track Congo's Cobalt from Mine to Mobile', *Reuters*, 2 February 2018 <https://www.reuters.com/article/us-mining-blockchain-cobalt/blockchain-to-track-congos-cobalt-from-mine-to-mobile-idUSKBN1FM0Y2>.

solutions aligned with sustainable development goals or circular economy models[117]. From carbon emissions and material recycling, to monitoring and authentication of natural resources, a tamper proof record of product data could help regulatory councils, governments and certification bodies to perform sustainability measurement and management processes. For instance verifying timber or forest products in a value chain could be improved by using a more reliable and immutable digital traceability system[118]. Still, this system would need to put in place adequate procedures for entering and verifying data inputs from different stakeholders, which could imply certification schemes or guidelines defined within a distributed network of validators.

[117] Benedikt Christian Eikmanns, *Blockchain : Proposition of a New and Sustainable Macroeconomic System*, 2018 <http://www.explore-ip.com/2018_Blockchain-and-Sustainability.pdf>.

[118] Boris Dudder and Omri Ross, 'Timber Tracking: Reducing Complexity of Due Diligence by Using Blockchain Technology (Position Paper)', *SSRN*, 2017 <https://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID3015219_code1324274.pdf?abstractid=3015219&mirid=1>.

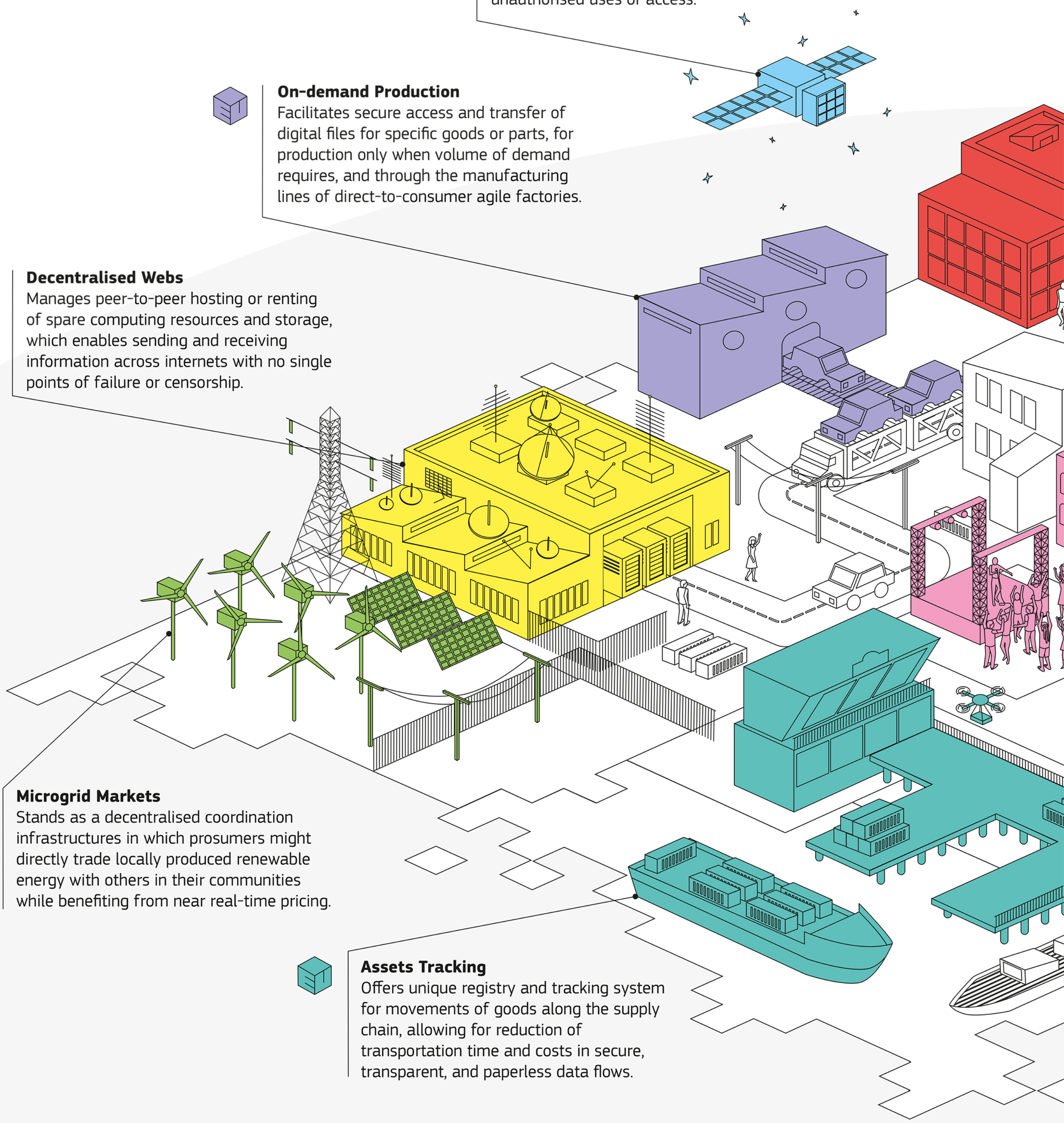
#Blockchain4EU

Blockchain for Industrial Transformations

Infrastructure Security
Enables the integrity and immutability of highly sensitive or classified data in critical systems, aiming to quickly detect breaches or vulnerabilities, or preventing unauthorised uses or access.

On-demand Production
Facilitates secure access and transfer of digital files for specific goods or parts, for production only when volume of demand requires, and through the manufacturing lines of direct-to-consumer agile factories.

Decentralised Webs
Manages peer-to-peer hosting or renting of spare computing resources and storage, which enables sending and receiving information across internets with no single points of failure or censorship.



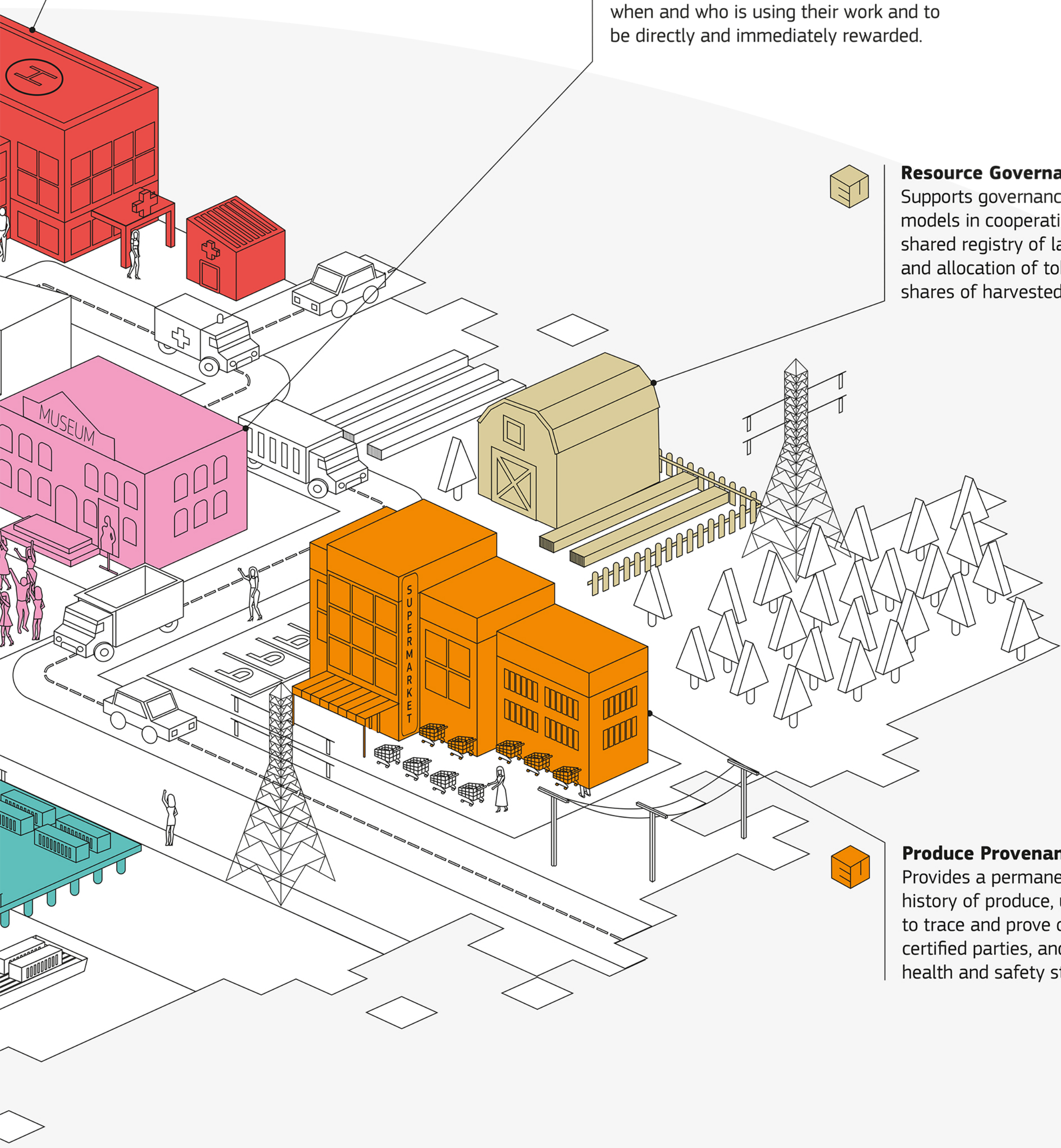
Microgrid Markets
Stands as a decentralised coordination infrastructures in which prosumers might directly trade locally produced renewable energy with others in their communities while benefiting from near real-time pricing.

Assets Tracking
Offers unique registry and tracking system for movements of goods along the supply chain, allowing for reduction of transportation time and costs in secure, transparent, and paperless data flows.

Blockchain and other Distributed Ledger Technologies enable parties who are distant or have no particular trust in each other, to record, verify and share digital or digitised assets on a peer-to-peer basis with few to no intermediaries.

Data Permissions
Allows for data from patients, researchers, regulators or other parties to be timestamped and cryptographically stored, under consent or access agreements automatically enforced through smart contracts.

Content Management
Stores and authenticates ownership rights and licensing terms for digital content, allowing for authors or artists to know when and who is using their work and to be directly and immediately rewarded.



Resource Governance
Supports governance and distribution models in cooperative farms based on a shared registry of land property rights and allocation of tokens representing shares of harvested crops.

Produce Provenance
Provides a permanent and authenticated history of produce, using real-time data to trace and prove origin, characteristics, certified parties, and compliance with health and safety standards.

4. Prototyping for Policy

4.1 #Blockchain4EU in a Policy Lab context

Policy Labs are a new generation of material and conceptual spaces devoted to opening up public policies to inter and transdisciplinary innovation, and connect them with experimental, participatory, and stakeholder-centric frameworks. Their ways of operating are often oriented towards setting up extended partnerships with a wide diversity of actors and expand the pool of 'usual suspects' called into play, thus standing as unique connectors between public, private and hybrid sectors. Existing in and around governments and other public bodies, at local and regional, national, or supranational levels, Labs seek to disrupt the most traditional ways of providing robust evidence based advice for policy, and consequentially change policy making itself[119].

Developed within the EU Policy Lab of the Joint Research Centre, the #Blockchain4EU project was initiated with the same mindset. Beyond conventional desk research, and qualitative analysis that combined open-ended interviews, semi-structured surveys, and short duration multi-sited ethnographic explorations, we also strived for more innovative pathways to create and deliver key outputs for policy advice. Mixing Science and Technology Studies, with a toolbox filled with theoretical and practical insights from other fields, as Foresight and Horizon Scanning, Behavioural Insights, or Participatory and Critical Design, from day one we were deeply invested in pushing the frontiers of what's common practice in policy when looking into new technologies.

The main route through which we pursued this was based on the engagement of an extensive and diverse array of stakeholders in the Blockchain space, and the posterior collaborative envisioning, design and creation of objects, systems or services, hereafter referred as prototypes. And this was based on the aggregation of several methodological frameworks throughout more than six months, from concept to physical artefact.

[119] Lucy Kimbell and Jocelyn Bailey, 'Prototyping and the New Spirit of Policy-Making', *CoDesign*, 13.3 (2017), 214–26. Christian Bason, *Leading Public Sector Innovation: Co-Creating for a Better Society* (Bristol: Policy Press, 2010). UNDP, *Growing Government Innovation Labs: An Insider's Guide*, 2017 <http://www.eurasia.undp.org/content/rbec/en/home/librarypage/growing-government-innovation-labs--an-insider-s-guide.html>. Robert Madelin and David Ringrose, *Opportunity Now: Europe's Mission to Innovate*, 2016 <https://ec.europa.eu/epsc/publications/strategic-notes/opportunity-now-europe's-mission-innovate_en>.

4.2. Between Stakeholder Engagement and Co-creation

After embarking on exploratory research based on the mix between desk and qualitative research mentioned above, we devised a series of three co-creation workshops that could help us to better steer methodologically this endeavour. This allowed us to bring into the mix not only key individual and collective stakeholders in the Blockchain space on our first and second workshops, but also, on our third workshop, stakeholders who not being directly involved with Blockchain and other DLTs, might be affected its potential developments in the near future, and even become interested in entering the space by acquiring or developing their own solutions.

The first workshop took place on July 2017[120], aimed at mapping multiple existent and foreseeable Blockchain spaces on present and future challenges and opportunities, and especially considering the policy, economic, social, technological, legal and environmental dimensions of such challenges and opportunities. Based on a purposive sampling technique, participants were selected from an extensive pool of stakeholders to act as a snapshot of the current Blockchain ecosystem in industrial and non-financial sectors. The group included technical experts, developers and scientists, social, economic, ethical and legal researchers, entrepreneurs and investors, business and labour representatives, and policy actors at local, national and EU levels, highly interested or already engaged with Blockchain and other DLT applications. Our key outputs were the mapping and discussion of collective visions that could inform policy on present and future possibilities of

[120] <https://blogs.ec.europa.eu/eupolicylab/first-workshop-of-blockchain4eu-blockchain-for-industrial-transformations/>

blockchain applications, as well as on core factors that could support or hamper their development and uptake.

And in March 2018[121] we had our third and final workshop centred on a broad spectrum discussion on policy strategies for digitisation of industry and businesses, with particular focus on technology adoption and SME innovation. Again based on a purposive sample, participants were mainly drawn from a group of stakeholders at the forefront of EU digitization and SME innovation, including industry, startups and SME representatives, European networks or initiatives, think tanks and business consultants in the field, and intergovernmental and international organisations. Our key goals now were to gain a better understanding of how Blockchain and other DLTs could fit in present and future digitisation landscapes on the ground, and how these technologies might affect or impact different actors operating in more established industrial and non-financial sectors.

But the centre of our process was the second workshop, which took place on November 2017 throughout two days at FabLab Brussels of Erasmusschogeschool, and where emphasis was fully placed on the material exploration of near future scenarios of creation, production, distribution and use of Blockchain and other DLT applications in previously selected sectors. We kick-started this workshop based on what had been amassed so far through research, but most crucially, building upon core outputs of the first workshop. As in the entire project, we also combined Science and Technology Studies with other fields, but full attention was given here to participatory, generative and speculative design methods to help us deliver the intended results[122].

Our major purpose was to co-create prototypes that could physically represent and exemplify in tangible and interactive ways how blockchains and other DLTs could exist in near future scenarios, considering five of the nine sectors we had previously selected. And we invited not only lead designers to work with us on each prototype, before, during and after the workshop, but also technical and industry stakeholders, along with social and economic researchers, to stimulate discussions in more encompassing and interdisciplinary ways.

The main challenge was to build artefacts that could simultaneously serve two main goals. First, to inform or agitate current views on Blockchain, not only of policy makers at EU, national and local levels, but also of traditional industrial and business stakeholders. And second, to help frame Blockchain applications according to the EU Industrial Policy Strategy[123], with special focus on SMEs and their innovation and competitiveness, but also to the shaping of options for better funding, regulatory, and other broader policy responses, in the remit of the European Commission service behind the request for the #Blockchain4EU research project, DG GROW, the Directorate-General for Internal Market, Industry, Entrepreneurship & SMEs.

4.3. From Making to Policy Making

Our prototyping developments were never assumed as mere secondary streams throughout the project, but as core research components that would increase the range of our forward looking research while providing better ways to communicate about Blockchain. Their existence ran both in parallel and perpendicular to all of our other activities, becoming a critical space to expand our understanding of blockchain and its potential, through distinct moments of co-creation massively attached to wide stakeholder engagement efforts.

When the term prototyping is used within policy contexts, it usually means the piloting and testing of services before implementation or scaling up stages. This might happen at multiple phases of a

[121] <https://blogs.ec.europa.eu/eupolicylab/third-workshop-of-blockchain4eu-blockchain-for-industrial-transformations/>

[122] E.B.-N. Sanders and P.J. Stappers, *Convivial Toolbox: Generative Tools for the Front End of Design* (Amsterdam: BIS Publishers, 2012). Christian Bason, *Design for Policy* (New York, NY: Routledge, 2016). Susana Nascimento and Alexandre Pólvora, 'Social Sciences in the Transdisciplinary Making of Sustainable Artifacts', *Social Science Information*, 55.1 (2016), 28–42. Susana Nascimento and others, 'Sustainable Technologies and Transdisciplinary Futures: From Collaborative Design to Digital Fabrication', *Science as Culture*, 25.4 (2016), 520–37.

[123] See < https://ec.europa.eu/commission/news/new-industrial-policy-strategy-2017-sep-18_en>

research project or experimental intervention embedded in one or more public or hybrid sectors. It often involves creations going from quick and cheap wireframing websites or low-fidelity mock-ups, to fully fledged services nearly ready for deployment. And actors such as regular citizens, public officers, technical experts, service providers or third party stakeholders are usually called in to trial such prototypes through role playing, user journeys, contextual mappings, and other adequate methodologies, towards fine tuning and possible iterations, and a search for the best possible evidence on how to move plausible proofs-of-concept into working solutions[124].

But there are also other uses for prototyping in policy, even if sometimes less used or tested in government or public sector organisations, such as the creation of fictional artefacts meant to trigger forward looking discussions into the possibilities of yet to be fully fledged realities. Connected with more traditional foresight approaches, critical, speculative and fiction design frameworks came to the forefront in this project. These frameworks offer us ways through which we do not predict futures, as if creating maps for tomorrow, but build instead compasses for the years to come. They help us open up discussions that act as catalysts for better informed decisions on the preferred directions to build what's next[125]. And the material outputs produced within them become learning devices attached to imaginative leaps, rather than monolithic representations of tomorrow which are never adequate for the essential questioning of potential policy realities to come[126].

Primary audiences for the prototypes are policy makers and political agents at EU, national and local levels, already engaged, potentially interested in dealing with, or working in sectors that may be impacted by Blockchain and other DLTs. Main secondary audience are SMEs or large enterprises already developing or purchasing Blockchain and other DLT applications, potentially interested in doing so, or operating in sectors that may be impacted by its deployment. Other secondary audiences include industry, business and labour organisations, public and private research and innovation bodies and specialized or general media outlets.

4.4. Blockchain and Design Fictions

One of the questions we were often asked was: why the effort of developing fictional artefacts and systems in the Blockchain space, and just not proceed to analyse and showcase what is already out there? Multiple answers are possible here. We looked indeed into several of these existent applications and the companies behind them throughout the whole project, detailing some in previous chapters, and engaging as many as possible in stakeholder engagement initiatives as the prototypes co-creation. And given this is a research for policy project based on independent evidence within a particular institutional context, it would always be sensitive to pick flagship players or applications considering the nascent and uncertainty of both technological and market fields. Nevertheless, the main and ultimate explanation is that in producing prototypes for policy we have different goals than technical or commercial driven ventures, and we need this differentiation.

Prototypes can be a more understandable and compelling way to explain how something might work[127]. In prototyping and creating design fictions on top of Blockchain, we address different issues and ask different questions from those who have their resources placed on functionality and intricate proofs of concept, stake or others. For instance, we were always concerned about the creation of prototypes that would not merely address essential distributed ledger features, as immutability, time-stamping, decentralisation or automation, but were also capable of reflecting within their conceptual and material choices a comprehensive overview on relevant policy,

[124] Emma Blomkamp, 'The Promise of Co-Design for Public Policy', *Australian Journal of Public Administration*, 2018 <https://doi.org/10.1111/1467-8500.12310>. Cynthia Selin and others, 'Experiments in Engagement: Designing Public Engagement with Science and Technology for Capacity Building', *Public Understanding of Science*, 26.6 (2017), 634–49 <http://dx.doi.org/10.1177/0963662515620970>.
[125] Anthony Dunne and Fionna Raby, *Speculative Everything: Design, Fiction and Social Dreaming* (Massachusetts: The MIT Press, 2013). p6 + p44
[126] Lucy Kimbell, *Applying Design Approaches to Policy Making: Discovering Policy Lab* (Brighton: University of Brighton, 2015).
[127] Vasant Chari, 'On Prototyping and Putting Something out There...', *UK Policy Lab Blog*, July <2017>.

economic, social, technological, legal and environmental questions surrounding Blockchain. What is more, all five prototypes had to tackle not the need to use this particular technology, but problems in each industrial sector where Blockchain and other DLTs could be tested and applied in search for solutions.

On a higher level, each prototype had to be able to illustrate what could be a potential application in its respective use case, preferably taking into account future adoption or upscaling scenarios, and showcasing properties inherent to what most people would consider a blockchain based application. But on a lower level, our main interest was that each prototype could represent an accessible entry point for the subject at hand, Blockchain and other DLTs in industrial and non-financial sectors. Their existence was always meant to allow non experts to understand what they do, how do they work, how are they going to address, solve or pose specific problems, in what kind of scenario would they exist, who would be the actors involved, etc.

4.5. Collaborative Productions

The second workshop was in fact the central point of co-creation for the prototypes. Starting with the nine sectors we had previously selected to be central in our overall forward-looking research, we then narrowed them down to five where the prototypes would fit. We started our formulation with a mix between ample sectors, such as energy, use cases such as supply chains, and even general blockchain functions, such as data authentication and certification. But we ended up framing the final prototypes in the larger energy, transports and logistics, creative industries, advanced manufacturing and health sectors. We considered these sectors to be not only more adequate for the development of speculative prototypes for policy, but also sectors where the maturity or visibility of already existing applications would make it simpler to connect our design fictions with real life scenarios considering the heterogeneous audiences who could later interact with them.

Each sector was assigned to five interdisciplinary groups composed by five participants. As mentioned above, all these groups included designers, technical and industry expert stakeholders, and social and economic researchers. Moreover, policy makers from different European Commission services briefly joined each group in the first workshop morning to provide input on policy files potentially relevant to their sector. There were always two designers responsible to co-lead the process during the workshop in each of the groups. These designers worked previously with the EU Policy Lab in the preparation of the workshop, and were also invited to remotely finalize the prototypes in the following months, in connection with other members of their group.

We strived for all participants to have an equal say in their group's prototype development during and after the workshop. As such we asked everyone to contribute to all material and conceptual prototyping activities, aiming at a collective vision of what a final prototype will be, deciding on its specifications and functions, and insuring the prototype was built by reflecting ongoing and foreseeable debates on Blockchain and other DLTs.

We started by offering multiple ideas on potential use cases, applications and topics for the conceptual and material developments of each group, as well as defining a few boundaries on feasibility given all groups had to produce a first materially tangible and interactive version of their prototype at the end of the workshop. But we left it open to their criteria where to take the prototype and what kind of Blockchain properties and functions it should demonstrate or simulate. The only major request we had was for each group to always address policy, economic, social, technological, legal and environmental questions in the conceptualization and design of their prototype, and embed them as much as possible in its materialization processes.

The set of questions and topics inside each dimension was drawn from our desk research, our qualitative explorations, and the first stakeholder workshop. It was then given to all groups at the start of the workshop. Groups could choose to define and address new questions and topics inside each dimension or reformulate those provided, but they all had to consider at least four dimensions within their prototype development.

All prototypes had to have a first version at the end of the workshop, and a final version to be finalized after the workshop by the lead designers of each group with inputs from other participants. No version needed to be fully functional or demonstrate real Blockchain or other DLT functions, however, provided they were able to simulate their operations in alternative ways and be easily identifiable with the technology in question.

First prototypes versions were mainly low fidelity three dimensional mock-ups with a limited number of core components and functionalities already mapped. They were mainly the result of interdisciplinary collaborative process inside each group, and reflected the diversity of inputs made possible by the combination of design, technical, industrial and social and economic knowledge brought to the table by all group members.

Final versions, however, were requested to have materially tangible and interactive existences, that is, three dimensional forms able to illustrate main functions, while being equally responsive to external inputs. There were no predefined limitations regarding materials, volumetric or operational procedures. These versions just had to be built with a solid internal structure, resistant external materials, based on low power requirements to function over significant periods of time, be simple to carry and assemble and disassemble when required, easy to operate by lay people, and accessible to the largest possible number of users and audiences.

All prototypes and respective design and coding elements will be made available by the EU Policy Lab of the Joint Research Centre to the general public, under EU Public Licence (EUPL)[128], and where not applicable under a Creative Commons Attribution-Share Alike 4.0 International (CC BY-SA 4.0)[129]. Some of the prototypes include, however, elements already covered under previous licensing schemes, and their availability will reflect this, namely with mentions to licences such as Jelurida[130] and Apache 2.0[131]. In case of use, remix or adaptation of any prototype, fully or partially, previous licensing should be respected and mentioned. Direct attribution must be granted as following: European Commission, Joint Research Centre, lead designers, other contributors.

4.6. Meet the Prototypes!

The five prototypes that will be presented in the following pages are not an end in any possible way. They are the beginning of a conversation that we hope can be extensive, complex, multifaceted and challenging.

In the following pages are information teasers for physical objects, with a hint of the questions we hope all of them will be able to provoke. Each group created and provide additional information and outputs about their prototypes, which are available in the EU Policy Lab blog, along with other #Blockchain4EU research and communication materials.

We foresee these prototypes as a step forward considering present and future discussions about Blockchain and other DLTs. But the best way to understand what they are, what challenges and opportunities they might pose in their respective sectors, and above all what type of discussions they can trigger at policy, economic, social, technical, legal or environmental levels, is still, and always will be to interact with them. Having the physical prototypes in front, being able to push buttons, play with the apps, get hold of what each group produced as background information, or even get in touch with those who helped us co-create such artefacts in order to learn more about their processes, is the most adequate way to make the best of what was built.

Beyond their public presentation in the #Blockchain4EU final event, the five prototypes will be used later for research purposes in the scope of future activities developed by the Joint Research Centre, not only in the field of distributed ledger technologies or other decentralised networks, but also in policy innovation domains considering new

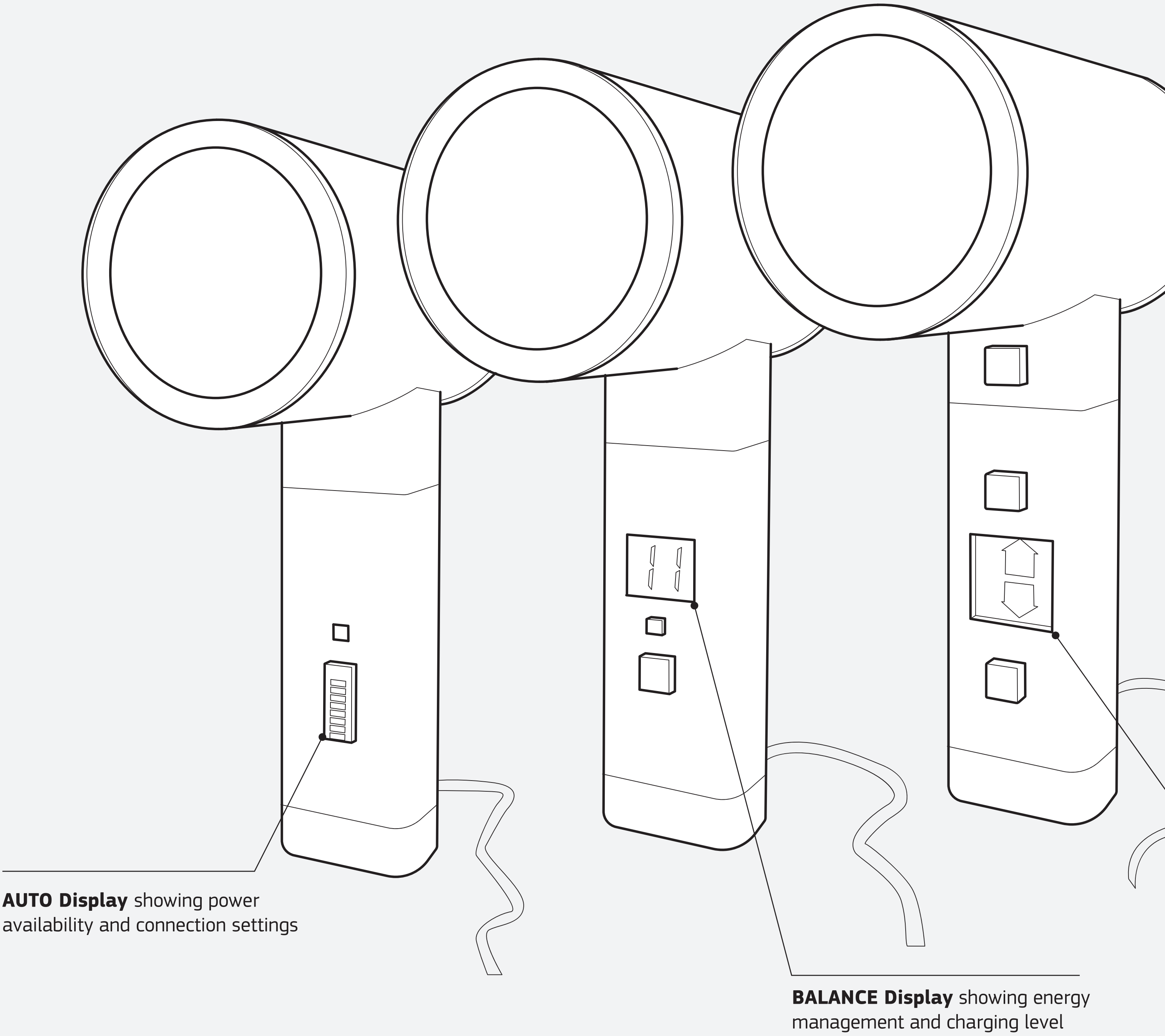
[128] <https://joinup.ec.europa.eu/collection/eupl>
[129] <https://creativecommons.org/licenses/by-sa/4.0/>
[130] <https://www.jelurida.com/>
[131] < https://www.apache.org/licenses/LICENSE-2.0>

methodological approaches and transdisciplinary toolboxes, from Science and Technology Studies, to Foresight and Horizon Scanning, Behavioural Insights and Design for Policy. But most crucially, the prototypes will be used by DG GROW, other European Commission DGs, and other EU institutions to trigger and stimulate debates in several other instances considering Blockchain and other DLTs within EU policy, industrial and business contexts. We wish to invite everyone in advance to join us in such an endeavour.

For now, meet **Gigbliss** in the energy sector, **Bloodchain** in transports and logistics, **Gossip Chain** in creative industries sector, **Vantage Point** in advanced manufacturing, and **Care AI** in health.

Gigbliss

Gigbliss is an IoT suite that offers three models of the same hairdryer, AUTO, BALANCE and PLUS, linked to three distinct economic models of energy consumption, management and trading.



#Energy #IoT #Consumption #EnergyTrading #Autor

AUTO Model _

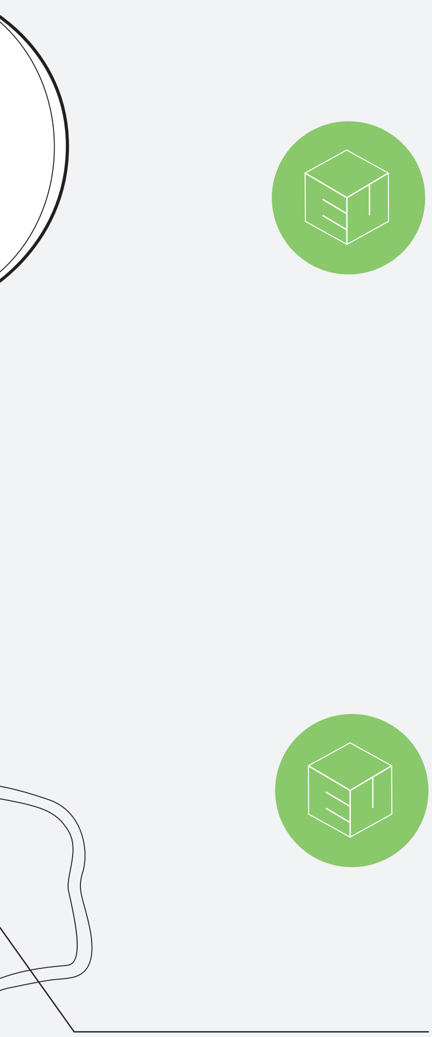
is offered for free but works only automatically at off-peak times. /

/ It is linked to a smart contract that enables users to dry their hair without energy costs until their allocated time period ends.

BALANCE Model _

lets consumers use it when energy prices are marked low. /

/ A smart contract manages it and minimises energy costs by automating the trade of stored energy when the hairdryer is not being used.



PLUS Display showing market trading credits and energy storage

PLUS Model _

allows usage on low energy costs at all times, automatically finding the best energy deals. /

/ It also monetises itself by letting users choose when to buy or sell energy, or negotiating directly with the grid.

Gigbliss

The point of departure for Gigbliss was the energy sector. The group behind this prototype was composed by Chris Speed (University of Edinburgh) and Larissa Pschetz (University of Edinburgh) as lead designers, Marco Sachy (Dyne.org), Michael Rüther (Spherity GmbH) and Juri Mattila (ETLA / Research Institute of the Finnish Economy) as expert stakeholders, and Rory Gianni (University of Edinburgh), Katherine Snow (Povo design) and Linda Ma (Povo design) in support to the prototype production.

fig.03 = Gigbliss BALANCE simulated heating system

The work started with the notion of smart domestic appliances attached to different levels of control offered to consumers based upon the cost of 'instant access' energy.

The initial assumptions for a prototype were that traditional domestic products tend toward an on demand model of energy in which the consumer has complete control of when they what energy for an appliance to work. Using blockchain technology to support smart energy balancing contracts, the group then progressed on top of three categories that challenged this status quo and could gradually move domestic appliances from human control to machine control on the sociotechnical intersection of DLTs with IoT.

Beyond what was deemed as an H2m model (Human to machine, with main control by the human agent) in which traditional appliances usually have a button or interface that allows the consumer to turn it on and use it at will, new models were discussed to develop IoT products linked to blockchain systems, such as h2M (human to Machine, with main control by the machine agent), m2M (machine to Machine, with main control by the second machine agent) and M2M (Machine to Machine, with distributed control between both machine agents).

In the first model, h2M, buttons on devices could work to signal that a consumer would like to initiate the operation of a device. However the device would delay being turned on until it found the best energy price by trading on the open energy market according to the balancing of energy demand. This would cause a delay in the user getting their device to function, but it would guarantee lower energy costs through the execution of smart contract linked to the product's operations.

In the second model, m2M, there would be no buttons and instead products would operate once a day at a time when they were able to get the best possible price for energy. This would require consumers to remain highly alert to the sound of m2H hairdryers turning on to have the possibility of using them, or prepare appliances such as washing machines in advance, filling them with clothes and detergent to function when the price becomes adequate.

The third, M2M, would imply funding the appliance energy costs through tokenisation schemes, an entirely autonomous suite of renewable energy products would 'take jobs' in an emerging 'gig energy market' to sell energy back to those who pay for it the most. In this case beyond energy consuming products, we could even have solar panels that bid for energy jobs, pay off their *sponsors, and invest in replicating themselves with automated demands for the production of new solar panels to complement demand.*

After several iterations on these three initial concepts, the final output of this group was a suite of three similar hairdryers, Gigbliss, which loosely follows the three models enunciated before. These hairdryers mainly differ amongst themselves due to three different user models of energy consumption and management executed through smart contracts linked to blockchain based energy trading and management platforms.

The first hairdryer is Gigbliss AUTO, presented under the slogan "More for everyone". This specific product could be available for free through local Councils, community services and charities. To maximise investment from all actors, it would turn on at off-peak times, allowing users to use it at no cost until the time period ends, with energy only supplied at pre-defined times. A "timely bargain because every minute counts", as the group states. The operation of Gibliss AUTO would imply a smart contract set by a fictional Gigbliss&Co to allocate the sponsor's budget to supply energy to the max number of households possible, that is. supplying in off-peak times. Moreover, councils or charities could sponsor energy supply for deprived communities in this context, allocating Gigbliss tokens to sponsor energy supply for a large number of households, with Gigbliss Coins transferred back to the sponsor and Gigbliss Tokens potentially transferred to trading platforms.

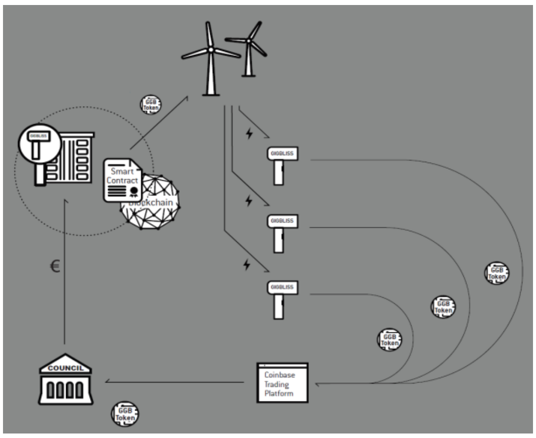


fig.04 = Detail of Gigliss AUTO operational system

The second hairdryer is Gigbliss BALANCE, presented under the motto "Balance is all you need". When inactive this appliance would trade energy through a smart contract devised on top of a blockchain, allowing costs and energy prices to be drastically minimised to users. Available at mid price ranges, and allowing users to dry their hair when energy prices are low, Gigbliss BALANCE could become a convenient and economic option for everyone. Furthermore, to lower costs even more this appliance could also be based on a sustainable business model that allow consumers to host the hairdryer and return it to the Gigbliss factory when they no longer need it. Similar to the previous model, Gigbliss Coins and Tokens could be also object of transfer and trading, now considering a scenario where a Gigbliss & Co cryptocurrency wallet is put into place.

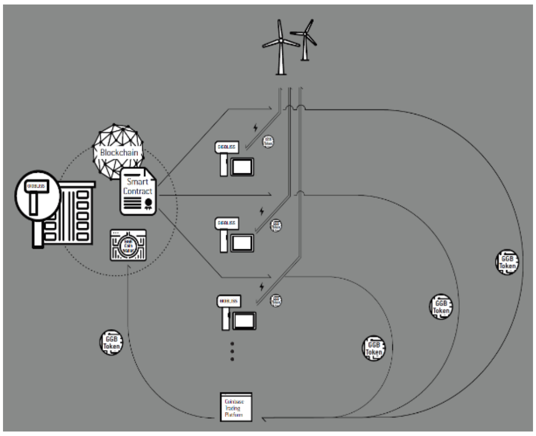


fig.05 = Detail of Gigliss BALANCE operational system

The third and last hairdryer of the suite is Gigbliss PLUS, attached to the catchphrase "Because you are worth it". This is a hairdryer that would earn money for users, trading for instance with a wide net of microgrid energy providers fully integrated into blockchain systems. By combining a patent-pending energy storage technology with the ability to track energy prices, this hairdryer would let owners buy energy when prices are low and sell when they are high, or yet provide an IoT-driven system that could simply analyse the market, find and execute the best deals for these owners. The main idea of Gigbluss PLUS is that it puts the user in control compared with the other models. It would still benefit, however, from automated *procedures where in built smart contracts regulate transactions between it and energy suppliers. Coins and Tokens would be exchanged with Energy units now based on standards such as ERC20, assuming that owners synchronise their devices with their own cryptocurrency wallet as soon as they acquire the hairdryer.*

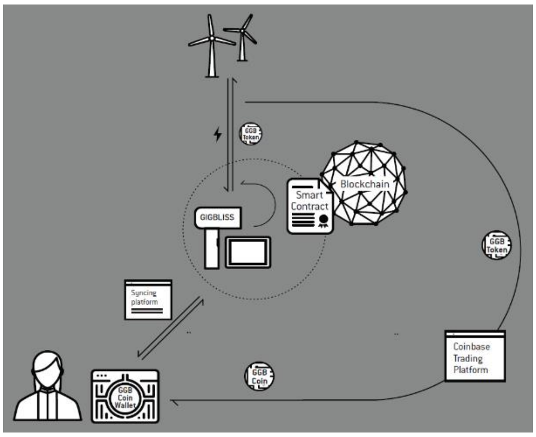


fig.06 = Detail of Gigliss PLUS operational system

The Gigbliss product suite attempts to question upfront what kind of changes take place when blockchain based systems starts mediating energy transactions between consumers and the grid.

The starting point this group had for such interrogations is that nowadays energy provisions in Europe are mostly based on large power plants, which generate energy, transmitting it to national grids and then to cities, companies and households. National grids are well established, regulated, and centralised. A few emerging trends, however, suggest different energy futures. Distributed energy generation, for example would allow smaller companies and even households to produce and sell energy in a free market economy.

The key idea is that with blockchain infrastructures, energy can be produced in small scales and traded more flexibly and in wider scales. This could enhance for instance green energy production, increasing competition and the creation of new ways of consuming and adding value to energy, according to peak times and access to energy storage, for instance. Gigbliss envisions a future where domestic devices will be able to store and/or adapt energy usage to fluctuations in prices and demand, thus contributing to a discussion on the potential relations between blockchains and energy systems.

Within the Gigbliss scenario, blockchains would have the ability to guarantee data immutability based on cryptography and distribution / synchronisation of records across multiple locations. They can host immutable algorithms, or so called smart contracts, which can securely perform transactions according to pre-defined conditions. This way, blockchains would be used to manage transactions across small energy providers and consumers in a secure and transparent way, allowing new energy production, distribution and consumption models to emerge.

Several other questions still emerge through this prototype in the Energy sector. Within the domain of control and governance of energy for instance, this suite of hairdryers raises the issue about consumer objects and appliances having the ability to balance energy cost/demand at the point of use in a distributed network, rather than centrally, and what would it truly entail at regulatory level, for instance. And while doing so, these hairdryers equally challenge existing models of material ownership, which have remained largely the same up until recently. Predicated upon smart contracts that allow objects to trade and broker energy deals, the prototypes ask questions about the legal contracts that surround increasingly autonomous products.

fig.07 = Gigliss PLUS automatically trading energy

Moreover, the group states it’s possible to observe and question across these three products how *different economies for the purchase and consumption of energy are explored according to the control that we take away from humans, and give to products such as ordinary IoT appliances. This prototype suggests that to tackle behavioural 'energonomics', that is personal energy habits, designing levels of autonomy into objects may force consumers to change their habits in order to get the best use of energy, thus increasing the mediating role of objects and moving them closer to deterministic behavioural patterns. And this would even become more visible if we question environmental benefits of taking control away from consumers and placing it in the authorship of algorithms that will seek lower environmental impacts of the use of energy.*

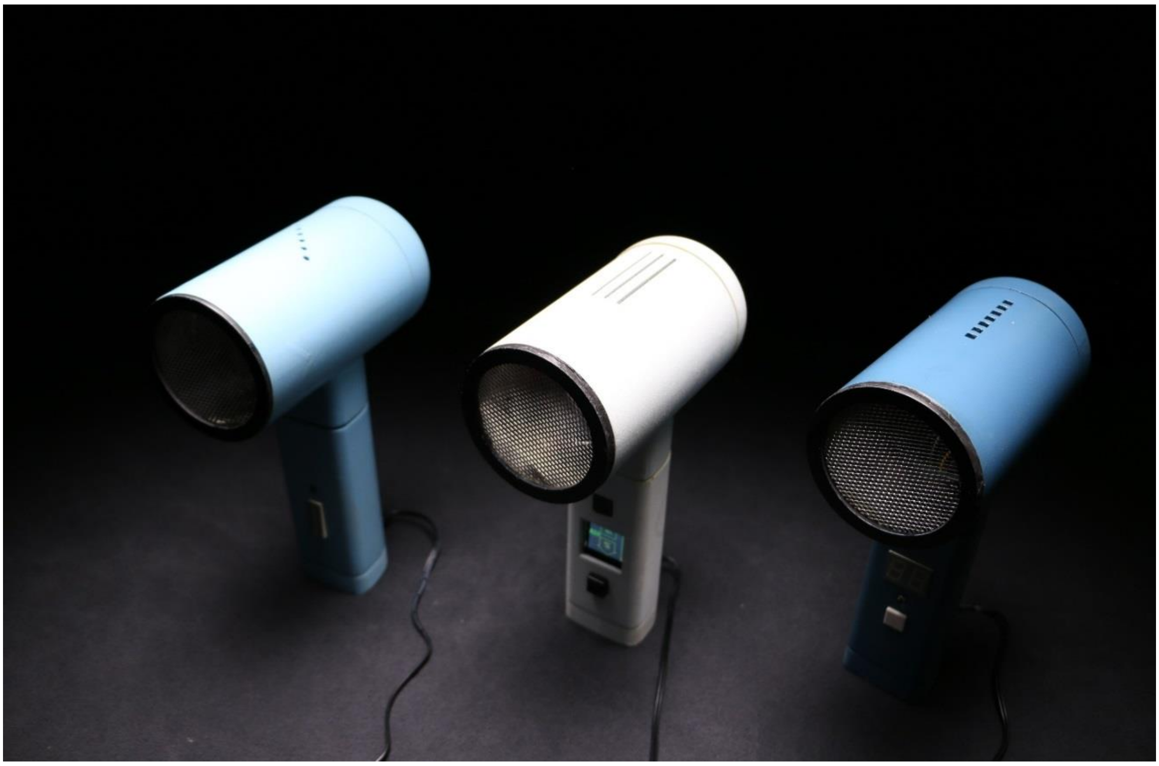
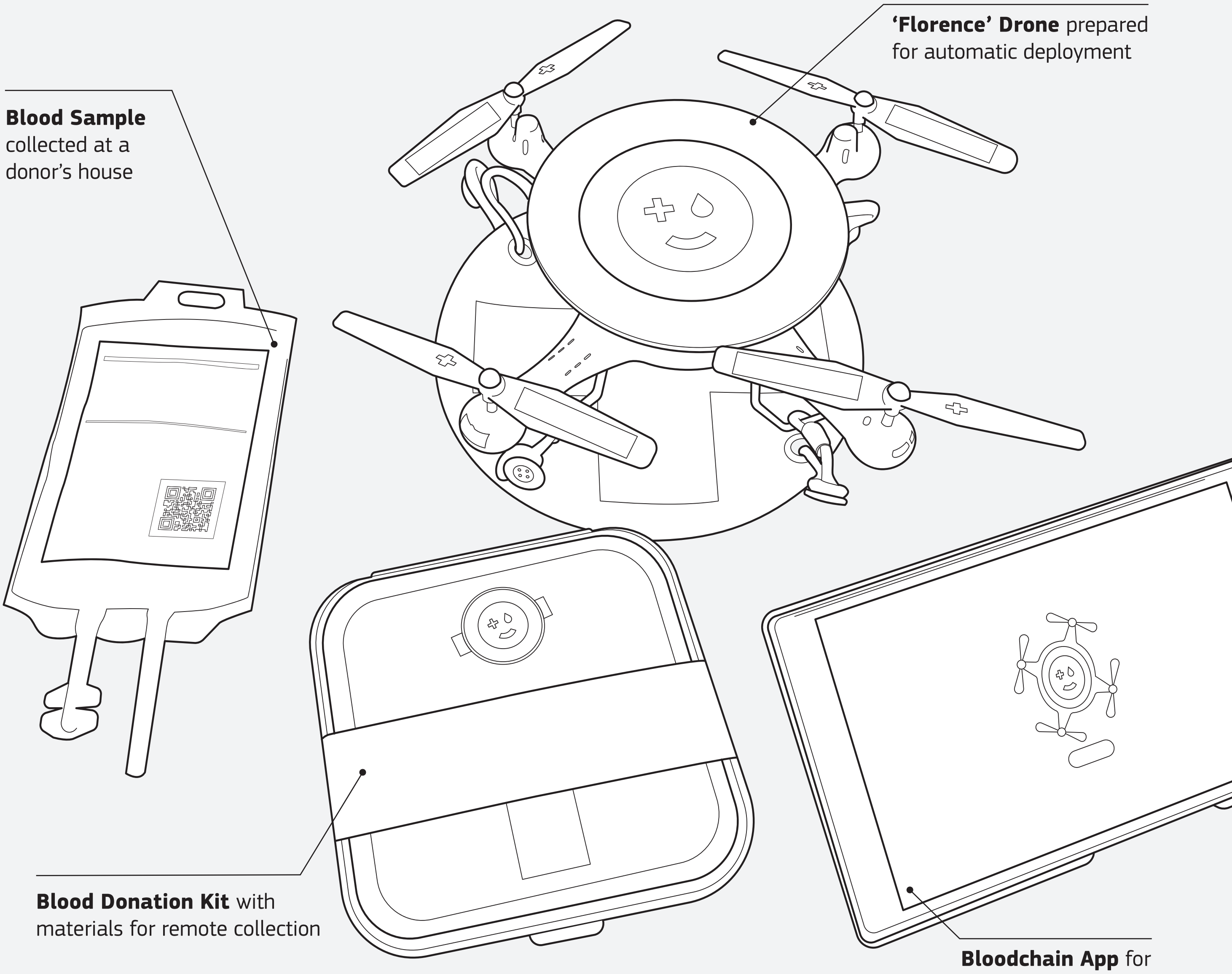


fig.08 = Gigbliss Suite with AUTO, BALANCE and PLUS prototype models

Bloodchain

Bloodchain is an assets management system designed to deal with multiple points of supply and demand for the collection and transport of blood and other sensitive biological materials.



#Transports&Logistics #SupplyChains #FleetManagemer

Back and Front End Systems _

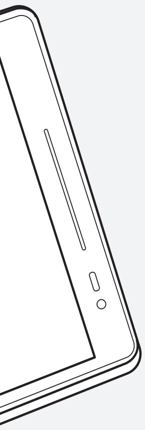
allow people to securely sign-up as donors and register blood type with an encrypted key. /

/ This is connected to a distributed blood bank managing supply and demand in real-time.

Hospital Nodes _

get access to donor information and receive notifications if desired blood type and other key data sets are added. /

/ Matching of request and offer depends on compatibility criteria and interests' alignment.



Autonomous Fleet Management _

dispatches drones to people's homes with materials for remote blood collection. /

/ These fly back to hospitals for checks and use, with guarantees of encrypted privacy for donors.

nt #Tracking #Collection #Encryption #MedicalSpecimen

Bloodchain

Bloodchain belongs to the transports and logistics sector. The members of the group that co-created this prototype were Cat Drew (Uscreates) and Robbie Bates (Uscreates) as lead designers, and Travin Keith (Agavon & Member Representative Hyperledger), Mika Lammi (Kouvola Innovation) and Marcella Atzori (University College of London) as expert stakeholders.

fig.10 = 'Permissioned Blockchain' Jargon Buster card

The group started their prototype development by reflecting not only about contexts where supply chains were in need of strengthening, but also contexts where such strengthening would help to tackle already existent social issues. As such, blood donation and all the logistics involved in it were chosen as their use case.

This pick was based on the shortage of voluntary donations in a country such as the UK, and above all, on one of the apparent underlying motives for this shortage. Blood collection tends to still happen sporadically, when someone has the motivation and time to go out of their way to visit a blood donation centre, often only located in hospitals, or at best, in mobile donation units. According to the group, an integrated supply and demand management system enabled by blockchain technology could help to address this in two ways.

Firstly, it would allow people to securely register their blood types into a distributed blood bank which could manage supply and demand in real-time. Call-outs across the system would be made when particular blood types were in need. The use of a permissioned, multi-chain structure, such as Hyperledger Iroha, could maintain people's privacy until after they had consented to a particular donation, and otherwise keep their blood type separate and unlinked from their personal ID. Moreover, applications of AI running on the top of data would be able to foresee the future demand of blood, for instance in hospitals, and prevent in time the exhaustion of blood stock.

Secondly, this would allow the deployment of an autonomous fleet of drones to be sent out to people's homes to remotely collect the blood and return it to the hospital for checking and onward use. The blockchain would allow optimisation of drone workflows, making sure they are in the right place at the right time, and verification of their journeys to and from donors' homes. This would reduce infrastructure costs, create savings in public expenditure, and reduce $CO2$ emissions.

Another potential use case, Organchain, was also developed within the same scenario to showcase a similar backend demonstration of how the technology might actually work in practice for the transport of organs. Information about this other use case is available online and it will not be detailed here as this groups' primary focus was put on the Bloodchain system.

Bloodchain includes both digital and non-digital artefacts. Across five stages, which are Sign-up, Blood Collection, Piggy-backing, Logistics, and Fleet management, this prototype is meant to simulate how it would work in a real life scenario, thus encouraging people to think about the implications of a blockchain-enabled system for the transport of highly sensitive materials.

Within the first stage, the Sign-up, we find in the prototype a paper based set of cards simulates the various stages of a user signing up to the Bloodchain system. The process has been designed to include the technical details of how blockchain would be an integral part of this sign-up process for potential donors, with the prototype focusing on showcasing the front-end experience of becoming a donor and donating blood.

The second stage, Blood Collection, has a drone delivery system at the centre, Florence, which is designed to assist and take blood at home, once the donor completed the sign-up process. The drone includes a soft and 'friendly' aesthetic to encourage people to donate. It also includes a mock-up package to simulate some of the medical utensils that would come with the drone to allow people to take their own blood at home.

fig.11 = Home blood donation kit and blood sample

In the third stage, Piggy-backing on Existing Transport, the prototype takes its concept a step further. A plane ticket and sticker set bring to life the idea of 'donating at the gate'. The underlying discussion is whether beyond its own transportation means, Bloodchain could also piggy-back onto existing transport such as commercial flights, to more efficiently meet demand for blood donation. As an example, if a major accident happened in Madrid, for instance, people travelling there would be encouraged to donate whilst waiting for their flight. That same blood would be registered on the Bloodchain system and later transported in the same flight.

fig.12 = Boarding pass with Bloodchain donation stickers

The stage number four, related to Logistics, contains the main interactive piece of the Bloodchain prototype. This comprises both a back and a front end, that is, a functional blockchain system and an app that allows interaction with that system. These elements will not be fully detailed here, and additional extensive information about them is available online. But accessed via a tablet this gives a basic demonstration of how people could sign-up and use not only Bloodchain but also Organchain.

This includes first a Donor Registration Step, where users submit personal and medical information to the system with an encrypted key, and where participating hospitals running nodes are able to see these properties being set and can set up an internal notification system should the desired blood type and other key data be added to the system. In second place, it comprises the matching of the hospital request and donor offer based not only on compatibility criteria but also on both actors' interests. And in third, it contains the drone blood collection and return, with each drone pre-fitted with their own account on the Logistics chain, the hospital having approval permissions on the transfer request, and the donor access to notifications guaranteeing save arrival of their blood.

The blockchain systems used for this prototype architecture are Hyperledger Iroha, which primarily handles the identity management of each patient, as well as Ardor, which primarily handles the logistics around the transfer of blood and organs. Part of the need for having two blockchain *systems for this architecture is to further protect the privacy of each patient, as well as to allow the logistics chain to remain unaffected if ever the identity chain needs to have information completely removed.*

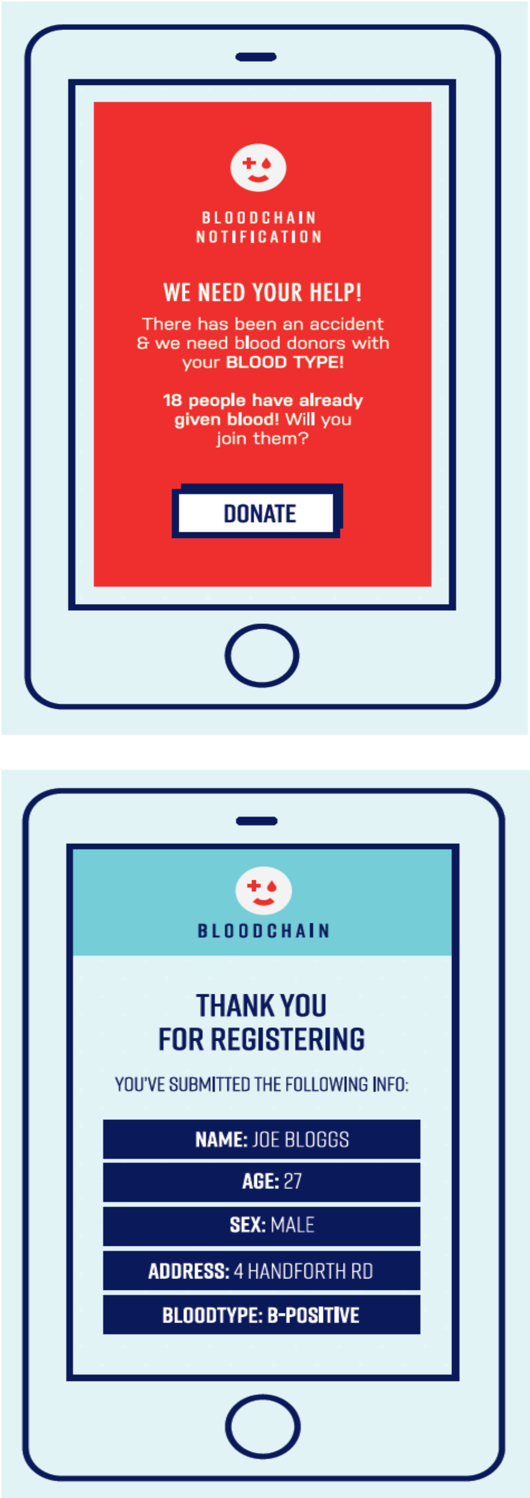


fig.13 Bloodchain mobile app in beta development

Finally, in the last stage of the prototype, number five, the Bloodchain Drone Fleet Management. Here, a specific artefact aims to showcase and describe how the blood donations and drone are managed and monitored using chips and QR codes. That artefact is a mock-up blood bag with mock-up donated blood, which includes a code that the donor must scan via the Bloodchain app to register their donation and validate the legitimacy of their donation.

Through Bloodchain multiple questions and provocations are meant to be explored and discussed, being the most immediate one, perhaps, how would people react to it. People don't often like their blood being taken even by the most reassuring nurses. How would they engage with a scenario where giving blood might happen via an autonomous drone? Bloodchain has been designed to increase privacy and trust into the system through the use of blockchain technology, and it was also designed to provide a reassuring and convenient experience for blood donors. But following this same road, the group poses questions such as what kind of responses should be also prepared, from policy to behavioural dimensions, so that systems as Bloodchain could be adopted in the near future?

In this scenario, blockchain technologies could enable privacy for donors to the bloodbank, and security of transport, thus addressing issues such as system integrity. However, people could also want to know this technology is full-proof. Digital systems carrying highly sensitive material cannot be allowed to fail as it would compromise their life-saving activity. The nodes which run the network and validate transactions need to guarantee business and service continuity, disaster recovery, financial stability and preservation of data.

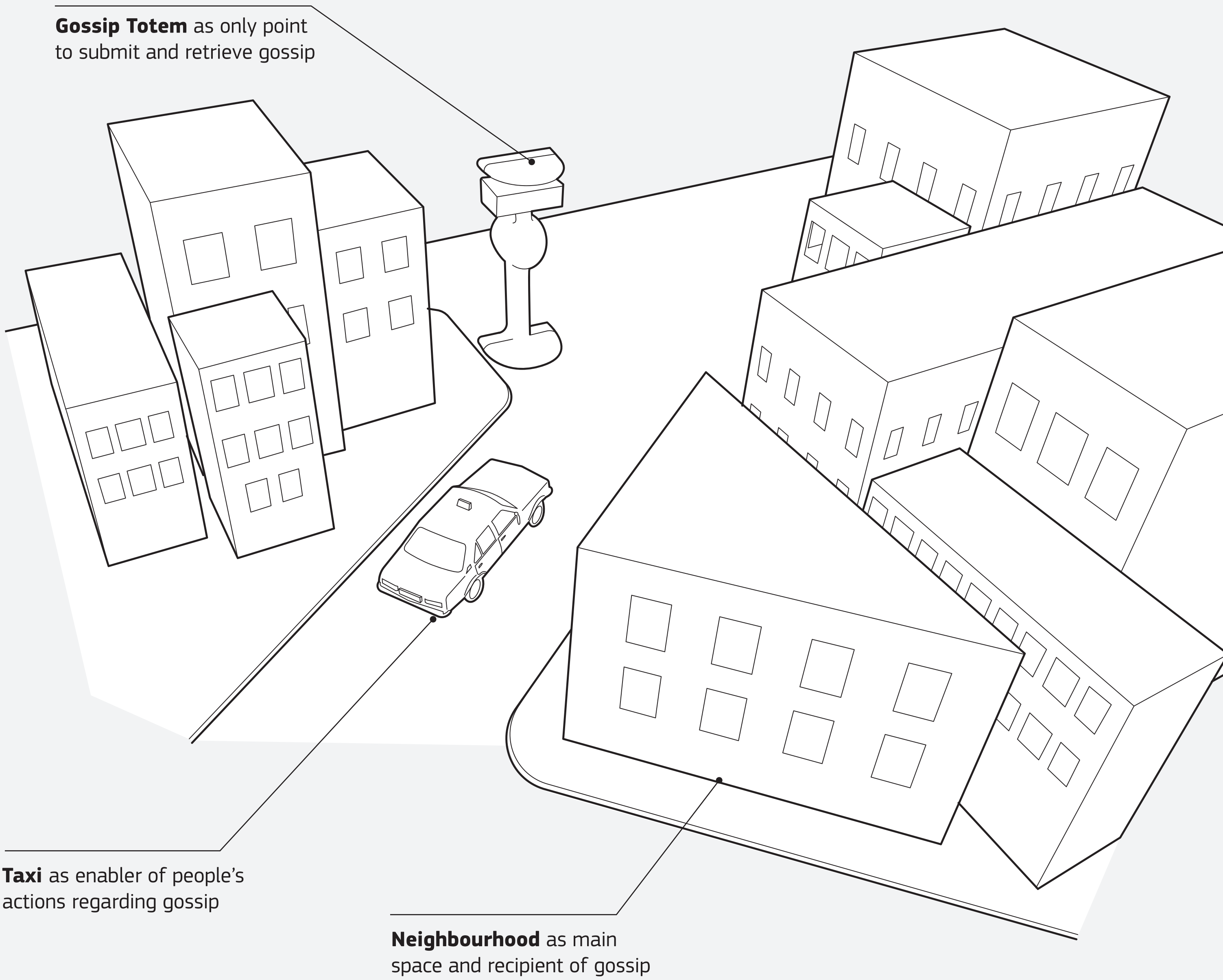
Bloodchain aims to put the emphasis on a balance that would need to be struck between making blood donation easy, attractive and socially rewarded, and the potential monetisation / tokenisation of the service. Regulation would be needed not only to ensure standards for blood between different EU countries, but also how donors might be incentivised to provide blood.

As transport and logistics companies think about how to extend into other areas, these issues become more acute. In this case, what would blockchain for organ donation look really like? Where would it be more likely that blood or organs will be transported not just by drones, but by a distributed network of multiple transport carriers? Do all of those have to be big suppliers and contracts? How can we all take advantage of the transport that is taking place anyway and for other purposes, to ensure efficiency? And will this all be obsolete with the creation of synthetic blood and organs? Or will we much better be able to match up demand with supply, with the better commissioning and manufacturing of this material on demand?

fig.14 = Bloodchain stages and elements on the prototype's system map

Gossip Chain

Gossip Chain allows anyone to submit rumours to a localised Blockchain and then combines people's reputations and prediction markets to assess and register the information value and reliability.



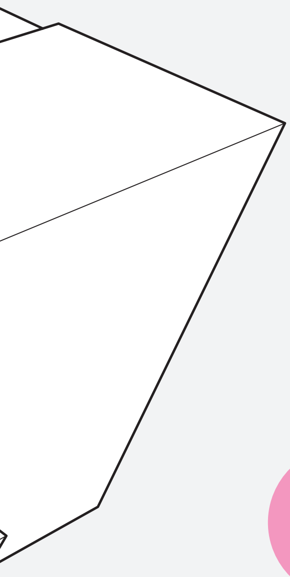
#IntellectualProperty #Information #Validation #Pred

New Rumours _

can only be submitted and retrieved at a Gossip Totem physically localized in the neighbourhood . /
/ A Gossip Wallet then allows everyone to participate and receive rewards through prediction markets.

Information Reliability _

is assessed based on the reputation of the person that submits the content. /
/ This in turn depends on market demand for their gossip, and other people vouching for them and the content itself.



Verifying Gossip _

guarantees financial rewards through a smart contract attached to the Gossip Wallet. /
/ But financial sanctions also exists if enough evidence is added to contradict the information originally provided.

dictionMarkets #Reputation #Reliability #DigitalGoods

Gossip Chain

Gossip Chain is positioned within the creative industries sector. The group that lead its co-creation had Enrique Encinas (M-ITI / Madeira Interactive Technologies Institute) and James Auger (M-ITI / Madeira Interactive Technologies Institute) as lead designers, and Jaya Klara Brekke (Durham University), Juan Blanco (Consensys Systems) and Carlotta de Ninni (Mycelia) as expert stakeholders.

fig.16 = 'On the Block' Scenario where Gossip Chain exists

The group explored this sector by pinpointing a particular historical context where the circulation of information was being challenged by traditional institutions and social actors on the ground, and where alternative solutions where devised for information spreading at bottom-up level. This context was the Tahir Square's protests on January 2011, and the inspiration behind the prototype was not only the difficulty to disseminate information without unconditioned access to internet or other major telecommunication infrastructures, but especially how to insure information was not halted at specific points of the chain, due to suspicions or divergent views that would evolve into arguments and discussion rather than diffusion.

The solution found at the time was to take advantage of taxi drivers' 'gift of gab' and position in a physical social network. Activists on the ground realised that if they could direct conversations towards the gathering at Tahir, taxi drivers would spread the word and the protest would be a success. But instead of direct conversations that were mainly resulting into arguments and discussions, the strategy was to exploit the use of gossip. Thus, they allowed taxi drivers to overhear cell phone conversations where details of the protests would be disclosed, so that they could eavesdrop believing to have overheard a secret and subsequently spread the information.

Blockchains create new possibilities for governing and registering content in new and more open ways, allowing for trusted management, shared data and knowledge layers across industries. In Gossip Chain, however, the more informal aspects of these questions are explored, tracing what might happen if the more volatile and unpredictable nature of rumours and gossip become tokenised, formalised and immutable on the blockchain.

The Gossip Chain prototype is placed within a larger scenario named On the Block, an imaginary city where informal knowledge becomes intellectual property through the blockchain. This scenario simulates a neighbourhood where a taxi becomes not only a vehicle for transportation but also a vessel for the capture of informal exchanges of rumours. It expands the case of gossip as common knowledge that circulates and is registered but whose meaning mutates with the ear that hears it and the mouth that voices it.

In this On the Block scenario, a different path of light arises depending on the route the taxi follows. Mimicking the path a rumour follows when it spreads. Gossip happen within the taxi and can be only heard from certain perspectives. The taxi is moved by human hands towards the Taxi Stop marked by the GossipTotem, triggering magnetic switches when it travels, and creating a unique light path depending on its route. Finally, *once the vehicle arrives at a specific taxi stop the gossip is registered on the blockchain and made broadly accessible and marketable, through the existence of a Gossip Totem. One of the buildings in the scenario has a directional speaker that broadcasts gossip in a very specific direction. As such, it is only from one corner of the model that one can hear the voices whispering and try to guess its meaning. With this effect, the prototype encourages people to discover the source of the gossip, to move around the model and possibly invite commentary on how gossip is generated and heard from certain perspectives.*

fig.17 = Taxi as enabler of people's interactions with rumours

Gossip Chain can be therefore described as a reputation and market-backed ledger of rumours, using uses scores and prediction markets to assess the value and reliability of a given piece of gossip. Gossip about a specific place can only be submitted to the chain at the gossip totem for the neighbourhood. Reliability is assessed based on the reputation of the person submitting the gossip. There are two ways that contributors gain reputation. First, through market demand for their gossip. And second, through checkers who vouch for a piece of gossip by adding their signatures. Evidence for and against the piece of gossip is incentivised by a prediction market. Those signing the piece of gossip will gain financial rewards for verifying the information but on the other hand will be financially punished if evidence is added that contradicts this information.

Gossip Chain was not developed as a single use case, however, as the group decided to develop two other secondary use cases that operate on similar grounds to Gossip Chain. These are Civic Chain and Maker Chain. The first suggests a model based on hashing tables where verification of local knowledge is done deliberately rather than via the market and contributes to a common resource of local histories and knowledge. While the second allows for a community of makers to determine differential access based on fine-grained commons and commercial contractual arrangements.. These secondary use cases will not be detailed here. But they are fully are accessible online as further possibilities to explore the Blockchain dynamics allowed by the validation and verification mechanisms already in place for the Gossip Chain use case.

Blockchains are used within this whole scenario for identity validation, tokenisation of gossip and reputation, prediction markets based on tokens. Bootstrapping a public blockchain platform based on systems such as Ethereum network, Gossip Chain is created through a smart contract responsible for all the Gossip system functionality. The Gossip application acts then as the interface between the public blockchain, Decentralised Storage Systems, such as IPFS, where gossip details in digital format are recorded, Search and Indexing databases, such as IPDB, and Decentralised Identity Systems such as uPort or Circles.

fig.18 = Taxi Stop where the Gossip Totem is localised

The core elements that would allow Gossip Chain to function are the Gossip Totem, a neighbourhood physically localized artefact where Gossip about a local place is submitted and retrieved, and the Gossip Wallet which allows a person to submit new Gossip, retrieve Gossip *information and participate and receive rewards in the Gossip prediction markets.*

There is a custom local application for validators responsible for gossip classification that allows people to challenge gossip but also to automate classification using artificial intelligence. This would be done considering that to automate the process of classification of Gossip entries and details, validators may also use artificial intelligence components to simplify the classification process. On top, gossip would also be verified through price mechanisms in a prediction market, such as Gnosis or Augur, where people can bet on what gossip is truthful or not.

A possible explanation of how Gossip Chain would work can be explored using a storyline with Alice and Bob.

Alice has many friends in the catering industry and has recently heard that Bob, the owner of an otherwise very popular competitor restaurant does not have the correct immigration papers. She submits this gossip on the GossipChain. The restaurant is popular, so plenty of people want to hear what her gossip is and pay for access to it, and Alice quickly starts to make money from submitting this gossip. Five of Alice's friends sign her piece of gossip, giving her a good reputation that further increases the value of her gossip. In the meantime, Bob the restaurant owner is getting worried that immigration will check the GossipChain and cause problems at his restaurant. He submits a challenge to her gossip, and because his restaurant is so popular gains plenty of signatures in his favour. The more people sign his challenge against Alice's gossip, the more Alice's reputation as well as that of her co-signatories goes down, potentially affecting their future ability to earn from submitting gossip. Alice was counting on licencing her accumulated gossip about the catering industry to a high profile food magazine but the value of her gossip is dropping due to the signatures gathered against her claim. A secondary prediction market taking bets on the outcome is primarily backing Alice's claim, driving more people to go to the neighbourhood GossipTotem to submit signatures supporting Alice. The neighbourhood rallies in support for Bob, holding pickets and picnics by the GossipTotem to prevent anyone from supporting Alice with more signatures. Alice watches, as her future ability to earn from her GossipChain reputation is determined through the competition between the prediction market and Bob's popularity in the neighbourhood and ability to gather support and signatures.

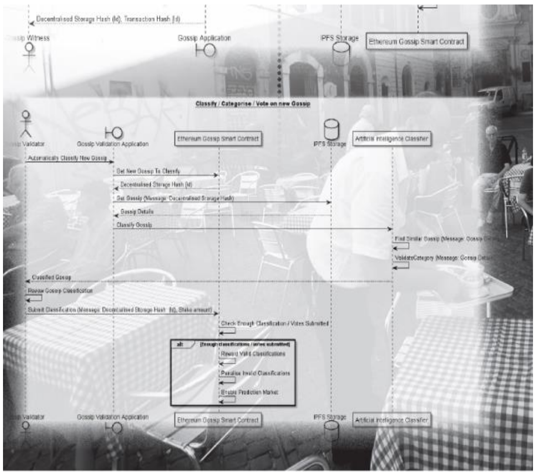


fig.19 Detail of Gossip Chain's operational scheme

Within such a context, Gossip Chain aims to question how knowledge is created and spread in the first place, and what happens when it is turned into intellectual property for instance. Taking advantage of the authority a data-entry has once it is added to the blockchain, Gossip Chain in the On the Block scenario plays with the interactions between the informal and untrusted and the highly formalised and trustworthy.

fig.20 = Detail of the larger On the Block scenario

Gossip Chain questions how information can be institutionalised into more structured forms such *as intellectual property, and who it is produced by and for whom. It raises questions on the existence of intellectual property that adds intrigue to information, intellectual property that is produced and consumed locally, or that finds its value in the scarce and colloquial rather than the ubiquitous and global. And in the end it poses bigger questions on the plausibility or desirability of future market places and commercial applications based on such a system.*

These questions are referenced by appealing to the ability of blockchain technologies to re-introduce scarcity into the otherwise fluid space and endless copies of digital assets in a continuously changing creative industries sector. Instead of reproducing and reinforcing the same relations of property rights in the digital space, the group questions what are the new and fine-grained ways that blockchain facilitates the curation of conditions of access and a contribution to digital goods? How might blockchain not simply enforce but radically transform what intellectual property is in the cultural sector? And what could be the real new possibilities that arise for cultural agents from the application of blockchain in contexts such as those explored in the On the Block scenario?

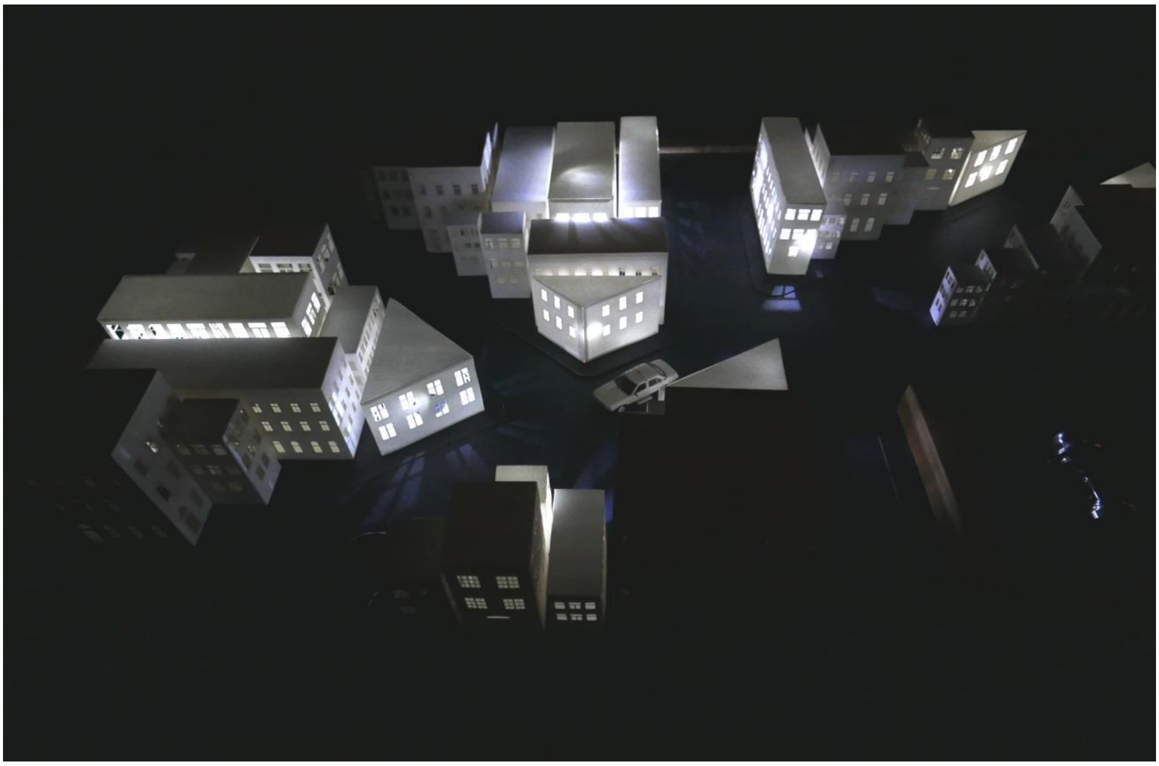
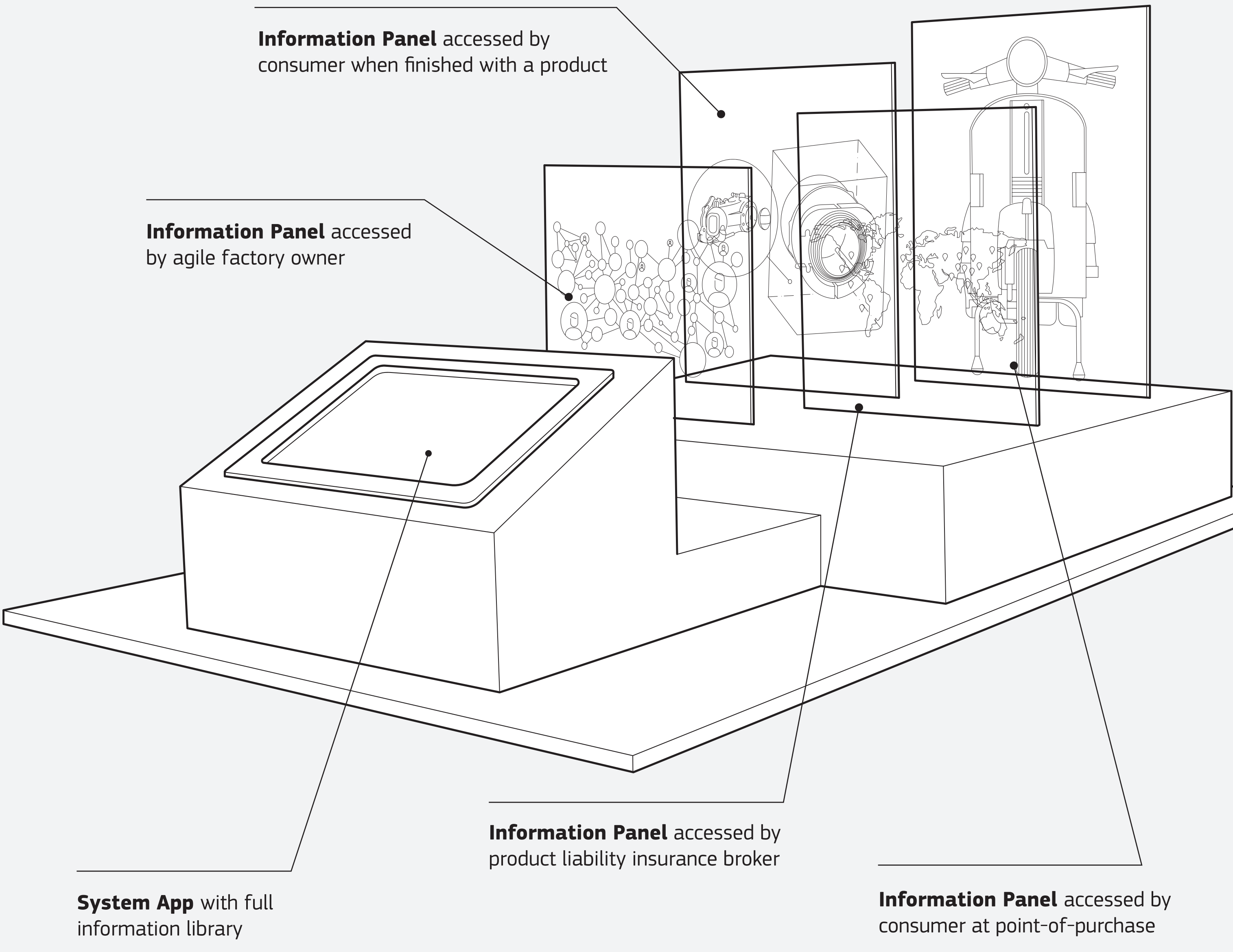


fig.21 = Full Panorama of the prototype with Gossip Chain in motion

Vantage Point

Vantage Point is a platform tackling data sharing, interoperability and integrity in manufacturing systems by storing products' digital twins and providing distinct information on them based on specific actors' needs .



#AdvancedManufacturing #MaterialsLibrary #DigitalTwi

Digital Twins _

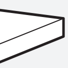
of consumer products are created with their full history from cradle to cradle. /

/ These twins are then stored on blockchains to ensure authenticity, validity and interoperability of the contained information .

Tracking and Tracing _

of materials and processes is made possible at every point of the supply chain. /

/ Information integrity is guaranteed through combined, immutable, real-time data through a decentralised database.



Multiple Actors _

in the same chain get access to distinct information sets. /

/ These sets are adapted to their needs, based on the use of private key cryptography linked to distinct agent profiles and permissions.

ns #SupplyChains #InformationIntegrity #AgileFactories

Vantage Point

Vantage Point was developed inside the advanced manufacturing sector. The group behind it is constituted by Liz Corbin (Institute of Making, University College of London) and James Tooze (Royal College of Art) as lead designers, Burkhard Blechschmidt (Cognizant Technology Solutions), Pierre-Alexis Ciavaldini (Particl Foundation), and Wessel Reijers (Dublin City University) as expert stakeholders, and Romain Meunier (Institute of Making, University College of London) in support to the prototype production.

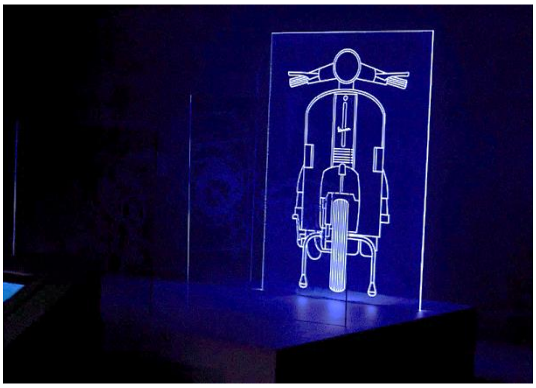


fig.23 = Visualisation panel with second-hand scooter.

The main challenge chosen by this group was the opaqueness of manufacturing chains. Their underlying assumption was that much of the information within these chains is currently kept within silos, fragmented and disconnected across what are often multi-actor, multi-sited systems. This often comes as result of a lack of authentication and verification of information shared between different stakeholders, all managing their own information silos throughout the manufacturing process. And it implies not only a lack of transparency between agents, but also lack of trust that leads to ineffective decision-making by individual actors as decisions become based upon speculation rather than real-time, immutable data.

Vantage Point attempts to go against the troubles that manufacturers often have to exchange production information with other manufacturers, as they don't have guarantees that information can be trusted or that intellectual property contained in information transfers is respected. Moreover, the prototype also aims to insert itself where product designers commonly have little clarity of exactly where, by whom, and at what costs product will be manufactured, as they rarely have a clear line of communication with other actors across the supply chain. And last but not least, Vantage Point even looks for a place in the consumer space, where actors usually have also no idea where their products truly come from, or if they are made and distributed in responsible and sustainable ways, for example.

This prototype aims to address such problems by creating a digital twin for each and every consumer product from cradle to cradle, which is then stored on a distributed ledger such as a blockchain system, in order to ensure the authenticity, validity and interoperability of the information it consists of.

By using blockchains as focal management point of a highly intricate materials library, Vantage Point would allow products in a manufacturing process to be tracked and traced at every point throughout its various use stages and life-cycles, thus granting it a complete historical record. But most significantly, it would enable new ways to visualize and sort out complex information from multiple perspectives, as it could grant each stakeholder access to a particular 'vantage point' adapted to their needs through the use of private key cryptography linked to distinct agent permissions.

The Vantage Point is materialized through this prototype in an app that has a companion system of simulated holographic projections to help users better visualize the information they require. This *was designed to allow actors such as manufacturers to easily retrieve and visualize information about material properties, certification bodies to get data about compliance with standards, and consumers about companies and materials involved in the process, all captured in the "digital twin" residing on a blockchain and accessible through the app.*

Following the prototype development, to understand it with a finer grain we may look at how the group pictured several actors interacting with Vantage Point, and what would they get out of it considering a particular product. For instance, we may pick the example of a second hand scooter and envision how a manager of a small scale agile factory, Carol would use the platform and what she could say about it.

In her automotive factory orders have been in steady decline over the last five years, which has resulted in a great deal of latent capacity on the production floor. Rather than reducing shifts or staff size, Carol started using Vantage Point to make use of their latent capacity by producing component parts for a brand of motor scooters. Carol used to be very cautious about taking on additional production jobs. This frequently meant long-winded and unreliable streams of communication between various actors across the supply chain. And it often made such opportunities too complicated and risky to take on regardless of their obvious benefits to our bottom line. Thanks to Vantage Point, Carol now has access to a reliable information source that easily and efficiently connects me to the product's wider multi-actor, multi-sited supply chain. Vantage Point acts as a one-stop-shop for accessing vital information across the whole chain in real-time - from the technical specifications of components, to peer-reviewed reputations of other manufacturers in the chain; from the material specifications of the components, to any delays occurring at other points of the production process. Because the majority of this information is registered in real-time on an immutable ledger, Carol can be certain of its integrity. The transparency and integrity of Vantage Point has allowed Carol to flexible in their production decisions working securely and efficiently within multi-actor supply chains.

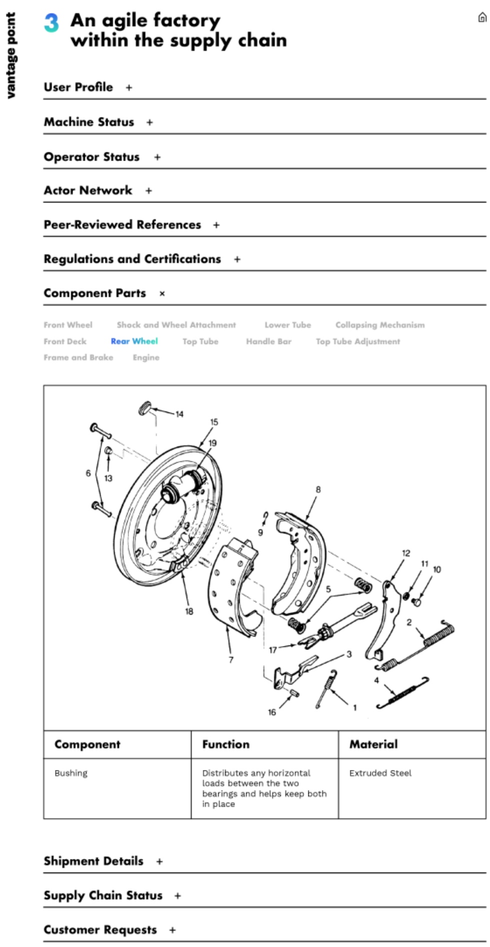


fig.24 = App information as accessed by factory owner

From another viewpoint, we could now picture how David, a product liability insurance broker, could make use of the same system, and what would he obtain, considering the same second hand scooter.

As an insurance broker, assessing the liability of products that are a result of multi-actor, multi-sited supply chains has always proven difficult for David. The challenge has been in developing warranties that can embrace the flexibility and fast-paced nature of real-time distributed design, production and assembly. Blockchain technologies like Vantage Point are an ideal solution to claims handling for retail products that are manufactured across a decentralised supply chain. Through Vantage Point David can ensure objective insurance policy criteria are encoded into the smart contracts that surround the production of a *product. By using smart contracts in this way David can automate peer-to-peer and sensor monitored assessments from trusted authoritative sources in order to determine whether the claims conditions are being satisfied. Current Claims Vantage Point creates an environment of trust between insurer, customer, manufacturer and regulator and ensures that claims are assessed in a timely, transparent, and evidence based manner. In this way, it enables David to collaborate across multi-actor, multi-sited supply chains while still creating legal accountability.*

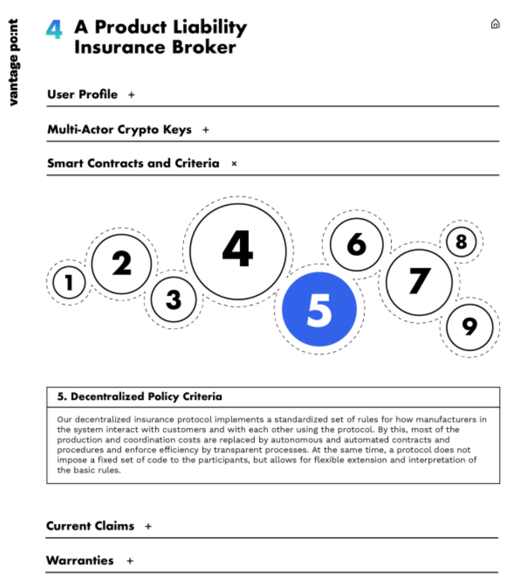


fig.25 = App information as accessed by insurance broker

And last, but not least, we can look at how Frank, owner at the end of its relationship with the second hand scooter, would interact with Vantage Point.

After ten years of use, Frank's motor scooter is nearing the end of its life. He feels that is often impossible to understand the various disposal, re-sale, re-use and recycle options that are available to the owner of a product at the end of its life. Some options can be gathered from various references like user manuals, local recycling centres, and regional resale networks. Yet, almost always these references are difficult to cross-compare and noticeably incapable of speaking to the specificities of your particular product. He now sees that his scooter and its history have been tracked and traced throughout its life by Vantage Point. By accessing the scooter's history through Vantage Point Frank is able to make a more informed decision about what re-sell and recycle options are available for him. He is then able to more clearly see what component parts of the scooter fit within various local recycling infrastructure, and estimate the scooter's depreciated value should he decide to resell it online. And because Vantage Point provides detailed technical and material information about the scooter, Frank is also capable of exploring what new uses for the scooter's component parts are possible. Thanks to Vantage Point he can make much clearer and responsible decisions for how best his scooter can be reused and recycled.

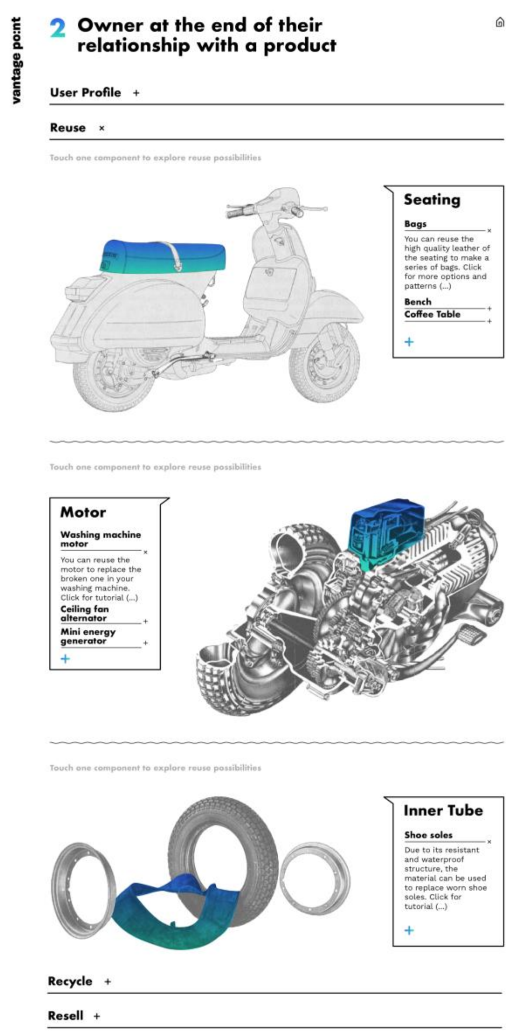


fig.26 = App information as accessed by consumer

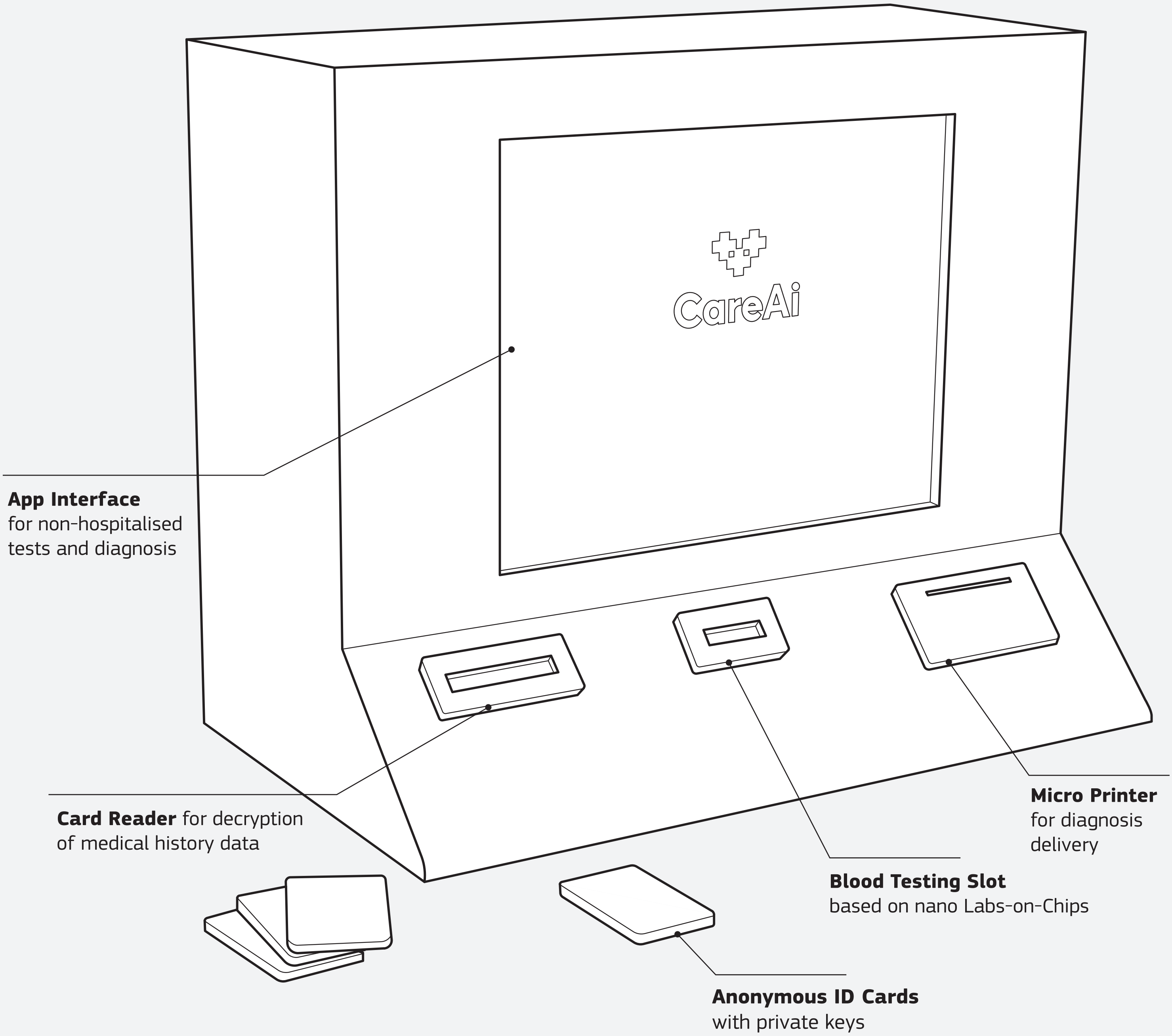
This is the value proposition of this prototype as a blockchain based database. It would create a desired effect of information scarcity, meaning that a "digital twin" of a product would always refer exactly that particular product and information integrity, and meaning the information a consumer retrieves about the origin of the materials in a product is the single one available to everyone, and exactly the same as the information recorded at the moment when the materials were extracted for instance. But it would also allow for different stakeholders to retrieve the information they need at all times and be certain that such information would be about that exact product or part of the manufacturing process they're looking for, and, above all, that the integrity of the information would be guaranteed.

Vantage Point could reduce the barriers to data exchange with strong focus on data protection, making it not only easier to lower barriers of entry into manufacturing markets, thus fostering competition and innovation, but also to respect intellectual property by tracking and tracing IP rights. Moreover, it would also function as a crucial enabler of the circular economy, by supporting the ethical production, consumption and disposal of consumer products, offering not only value for each party engaged in manufacturing chains, but also for societal structures as a whole.

fig.27 = Vantage Point prototype with information app and visualisation panels

Care AI

Care AI is a service providing access to basic healthcare in exchange of anonymised personal health data, which is later connected through smart contracts to a data marketplace for third party public and private entities.



#Health #IdentityManagement #Authentication #An

Automated Networks _

of CareAI Points provide non-hospitalised test and diagnosis for people without access to traditional healthcare. /

/ Labs-on-Chips are distributed for free and include materials for blood sampling and testing.

Anonymous Identity Cards _

allow users to donate personal health data in exchange for healthcare. /

/ A private key serves to decrypt the card holder's medical history and upload new collected data onto a smart contract.

Public Bodies or Businesses _

can pay to access information for research, planning, or other purposes. /

/ This subsidises medical treatments while also paying pruducers, owners and maintainers of Care AI Points.

onymisation #ArtificialIntelligence #InvisiblePopulations

Care AI

The sector to which Care AI belongs to is the health sector. The group behind it includes Gui Seiz (FabLab Barcelona, IAAC / Institute for Advanced Architecture of Catalonia) and Jordi Planas (Vimod Studio) as lead designers, Maciej Hirsz (Parity), Ivo Lõhmus (Guardtime), Annalisa Pelizza (University of Twente) as expert stakeholders, and Lucas Peña (Ideas for Change) in support to the prototype production.

fig.29 Detail of slot for ID cards

The main concern behind the development of Care AI was the existence of invisible populations that are unregistered in traditional healthcare systems. Sometimes these are travellers or professionals temporally working in other countries, but most remarkably they are deprived social groups such as migrant refugees or people in situation of homelessness. These populations experience constraints in accessing health care due to legal, social or economic limitations, and usually find themselves in the absence of answers for this situation.

CareAI is a platform conceived to allow such invisible populations to get not only access to basic healthcare but also information about other means by which they can obtain support to proceed further into curing their illnesses and ensuring a sustained good quality of life. What is more, is that if for some of these groups the crucial point is the need to access healthcare without compromising their identity, Care AI is designed to allow it.

This prototype was developed as such by having its starting point in questions of identity management and data authentication and certification, and its conceptualization orbited around data anonymization, or at least data pseudonymization. According to the development assumptions of the group behind Care AI, as sensitive health data would not be directly linked to personal identities, but to elements such as anonymous card and registries, compliance with data privacy regulations would more easily achievable, even if requiring further legal analysis considering new data security policies and regulatory frameworks such as GDPR.

While personal identification does not follow established legal and jurisdictional definitions in this scenario, an alternative understanding of "identity" based on health data is proposed. As a result, the proposed solution allows the inclusion of people usually left out of healthcare for diverse reasons, not creating, however, further exclusion.

The Care AI system operates as a network of micro-entrepreneurial owned, automated CareAI Points. Each CareAI Point provides non-hospitalized test and diagnosis to people without access to traditional health care. The CareAI Point interacts with a CareAI Smart Contract running on any smart-contract-enabled blockchain, such as those possible through the Ethereum network.

Within the scenario proposed by Care AI, we find Erin, an undocumented migrant in need of medical assistance for an illness he has have contracted recently. Due to her irregular migratory situation, Erin is afraid to visit a doctor within the national healthcare system, and cannot afford any of the private care services offered at her location.

Through the implementation of Care AI as a service targeted to individuals with his profile, Labs-on-Chips (LOCs) are distributed for free in homeless shelters, pharmacies and other places and grant access to any Care AI Point. Erin acquires a LOC in one of these places and finds out that it includes a fingerstick for venous blood collection and further analysis. She reads the instructions provided, pricks her finger and deposit a small sample of blood onto the chip. After this, Erin proceeds to enter the chip into one of the Care AI Points, establishing the connection between her blood sample and her personal identity with an anonymous card.

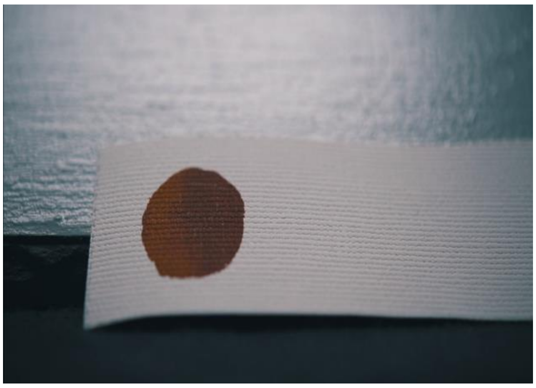


fig.30 = Simulated fingerstick with blood for analysis

A recurring user would be able to scan their card at any CareAI Point, while a new user would invited to generate a new private key and get a new card printed out during the first interaction with the system. However, the personal identity card used in Care AI could have several categories of personal data and even be one that users already possess to use other services, providing that it at least has means of interaction and authentication adequate for data anonymization. In the prototype this card is simulated through a generic QR code card, but in a real life scenario it would also include a private key and used as simple means of authentication to the system, decrypting the medical history of the card holder and uploading new encrypted records for the card holder onto the CareAI Smart Contract.

Erin's blood sample is anonymous and analysed at one of the CareAI Points by a HealthBot Artificial Intelligence assistant. The machine asks for consent for this anonymous data to be shared for medical research and upon approval prints out a receipt with a potential diagnosis and suggestions for further action. This action may depend on the degree of confidence of the analysis conducted, but it may go from recommendations for self-care, to prescriptions at participating pharmacies and escalation to medical attention at NGO doctors. If the process goes accordingly to previewed, Erin would then be asked if she would like to add the results to her anonymous logbook for later reference, and if so, another card with a bespoke QR code would be issued, which then Erin could use later on to create a medical issue with each data exchange with a Care AI point..

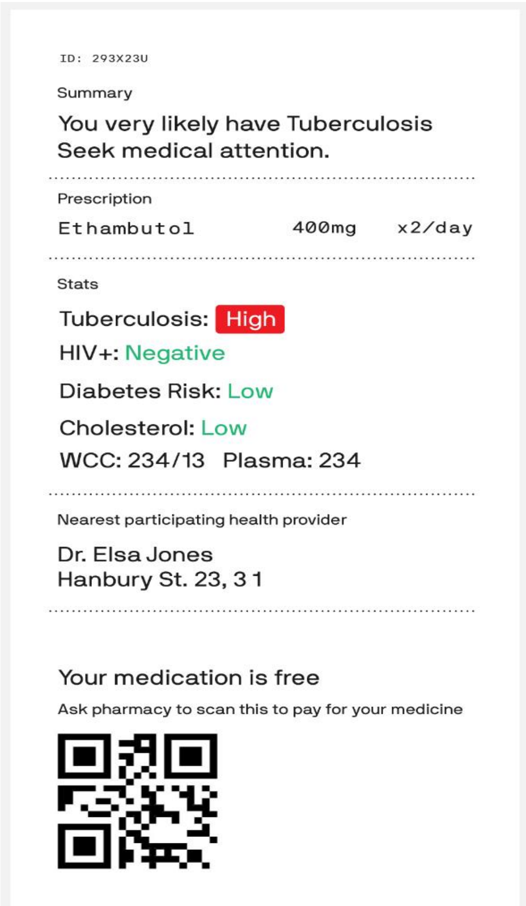


fig.31 = Mock-up of Care AI diagnostic receipt

The underlying idea behind the Care AI system is that in exchange for the analysis, suggestions for further actions or additional information, the person also donates its anonymized health data.

And in all this process, Care AI strives to promote the creation of anonymized medical history for future diagnosis and future potential integration into traditional healthcare systems. However, as the amount and type of information the user decides to provide and donate to the Care AI system can vary greatly, in this scenario such variations would also imply different gains for the user in a sort of credit system, whether in terms of the information received, whether in terms of possibilities of access to healthcare.

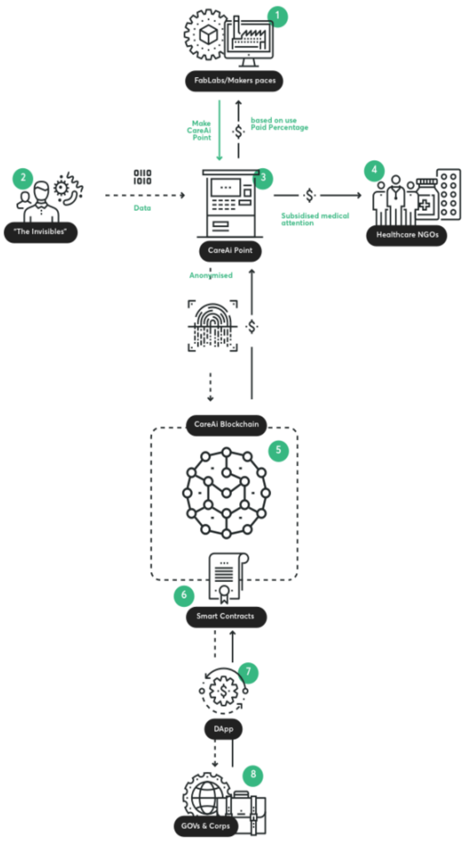


fig.32 = Care AI stakeholder system diagram

Public authorities could be the first actor managing this information and allowing the system to self-finance itself through the creation of distributed apps (Ðapps). These would allow not only public health and research bodies to access the anonymised data through the smart contracts inscribed in the blockckain, but also third parties with market goals to make use of the same information if granted access. Payments would serve to subsidise the medical treatment while also paying the creators, owners and maintainers of Care Ai Points. While diagnostics work is delegated to an AI, this is not expected to entail a loss of medical jobs, as the target would not access healthcare without CareAI and NGOs would be involved in case of escalation.

Access to medical insights could help to better plan public funding and policies such as in the forecast and potential management of seasonal outbreaks. But the potential of the data collected and exchanged through Care AI could even go beyond health, allowing authorities to become aware of other ongoing issues within these invisible communities, thus building information on socio-economic dimensions or demographic shifts, and gain plan accordingly to it in an integrated fashion.

Other actors could come also into play in the same scenario, such as Startups and other SMEs. Having heard of the CareAI project, they can download Care AI Point blueprints, fabricate their own or even iterate new models, and being bound to the main smart contract protocols they will be only dependant on public authorizations to deploy the Care AI Points into the public space. These companies will receive remuneration for data accessed, and would be as such incentivised to keep their machines working. In addition, to foster the growth of the network a research spin-off that provide LOCs or works with Care AI points, can run Initial Coin Offerings (ICO) to fund the research and development of the CareAI Point Open Hardware and Software specification, the smart contract code and the data specification.

Questions may emerge, however, with such new business and innovation models. These third party actors can exploit low entrance barriers in producing LOCs and replicating Care AI Points for instance, and flood the market in ways that are counterproductive considering the main social goals of Care AI. Or yet, big and established biotech companies can take advantage of their forefront market position and become the major supply of LOCs to all micro-companies deploying CareAI Points, thus promoting monopolist practices.
In this case a central body could issue a payment to the CareAI Smart Contract, which would then

allow it to decrypt a number of records collected by different CareAI Points, in a first-in first-out manner. This could help to redistribute the payment not only to managers or maintainers of different CareAI Points but also to different providers of supplementary technologies such as LOCs. Moreover, it could also help not only to cover costs and provide economic incentives for a bigger number of players, but also the creation and inputing of soft regulatory measures into the market.

Beyond its main social function, the Care AI prototype aims to showcase how to stimulate entrepreneurship through open hardware and distributed manufacturing, creating a blockchain based marketplace in which the local CareAI Point providers, parties interested in purchasing the anonymous medical history records and healthcare authorities can cooperate in a trust-free fashion. But looming questions remain in the end. Does all this respect or even consider ethical implications of a personal-data-for-healthcare exchange? And will any of the players involved in the production and exploitation of Care AI Points ever think about the kind of problems they might be causing for the creation of more inclusive healthcare systems?

fig.33 = Care AI Point with ID cards, fingersticks, and diagnostic receipt being printed

5. Key Insights for Industrial Transformations

Based on what we seen so far, Blockchain and other DLTs have potential to affect large parts of current industrial landscapes. At the same time the wide range of possibilities place us in an exploratory mode looking on how the implementation and uptake of these technologies could reshape or create innovative products, services, processes or models. Drawing from our extensive research in the project #Blockchain4EU this chapter will present our assessment of main insights for industrial transformations that revolve around or engage with Blockchain and other DLTs. A number of benefits and challenges that are already visible or may arise in the near future will be identified across a set of policy, economic, social, technological, legal and environmental dimensions.

5.1. Dynamics of Blockchain Space

Blockchain is an early-stage and experimental technology, which still needs time and space to work out many of its uncertainties over its present developments and future directions. Yet, any technological uptake concerns not only technical successes and failures, but also surrounding business and economic models, supporting ecosystems, social conditions, legal frameworks and policy decisions that will shape possible paths forward for the Blockchain space.

In terms of its technical properties, a number of unsolved issues or still under development will most likely subsist in the near future (for more detailed account see chapter 3). There isn't just 'a Blockchain' but many different Blockchains with diverse architectures depending on the purposes in mind. One of the most crucial choices in design concerns the permissionless (public), permissioned (private) and hybrid continuum, and related disputes over scalability, energy consumption, security, privacy and protection of personal and sensitive data.

In terms of scalability and performance, **permissionless or public blockchains currently face limits in terms of amount of data to be included in any given 'block' and the number and speed of transactions**, which need to be validated and disseminated across the whole network. Possible solutions such as increasing block size or introducing new consensus mechanisms or protocols based on sidechains or off-chains, are still being tested. **So far hybrid or permissioned blockchains are more effective in scaling up** as transactions can be processed only by a limited and predefined number of participants or nodes.

Similar concerns apply to **high energy consumption necessary to run permissionless or public blockchains, in particular due to the 'Proof-of-Work'** underlying mining process. Some say eventual advances will make mining operations more efficient, or other consensus mechanisms like 'Proof-of-Stake' will eliminate the need for intensive competition between participants to validate transactions.

When it comes to security, unlike centralised systems, **there is no single point of failure in permissionless or public blockchains which makes them extremely resilient** to takeovers, manipulations or collisions. Yet, **security vulnerabilities might arise in the future through the use of quantum computing, or in the present through the theft, hack or compromise of private and public keys**. Also **permissioned or private blockchains are potentially more vulnerable** due for instance to higher likelihood of attacks targeted at a core group of participants or collusions among individuals or groups of participants.

When it comes to privacy and protection of personal or sensitive data, **transparency and immutability in permissionless blockchains make it a very hard problem to keep certain data out of the chain, or to alter it later** due to errors or inaccuracies. Moreover, **Blockchain cryptographic protocols offer pseudonymisation, not complete anonymisation**, which could still lead to re-identification of specific data subjects in indirect and remote cases. A number of ongoing research is developing additional cryptographic protocols such as zero knowledge proofs to tackle these problems. **Hybrid or permissioned blockchains currently offer more flexibility to configure different levels of access to data**, which allows for limiting the availability of personal, sensitive or private information in a case by case logic.

Whatever the possible technical solutions to be developed in upcoming years, **interoperable protocols should be promoted so that different Blockchain products and services don't end up closed, unable to communicate with each other**. Interoperability could be achieved through standardisation at supranational level, following current efforts from standardisation organisations working on Blockchain and DLTs[132]. On one hand, some argue that such standardisation will be essential to harmonize its applications, de-niche the technology and enable cross-industry adoption. On the other hand, others argue that premature adoption might validate still untested technologies and/or privilege solutions from influential companies and lock out new players.

Challenges of ongoing standardisation activities concern not only the fragmented and nascent body of conceptual and practical knowledge on Blockchain, but also the lack of integration of certain Blockchain communities which tend to be more disconnected from these activities or overshadowed by larger technological or commercial members[133]. Dangers of platform or vendor lock-ins should be minimised by inclusive processes that would allow in practice newer or smaller players to participate in a meaningful way, taking into account their possible limitations of time, capital and human resources.

It is crucial to improve current multistakeholder governance processes for the development of standards, in order to fulfil in practice the guiding principles of openness, transparency and consensus[134]. Furthermore, the development of open standards also done independently within the Blockchain space should be carefully considered. Take the example of the wide implementation of ERC-20[135] in ICOs (Initial Coin Offerings) as the technical standard for Ethereum based tokens or smart contracts, or the recent efforts to build common frameworks for an open source and shared ledger of rights owners in the music and media business[136]. The vitality of these and other efforts point towards the **importance of grassroots and open source research in the Blockchain space**[137], also taking the example of other decentralised technologies and communities[138].

The development of open standards in the Blockchain space should also be linked to other standardisation processes in specific industrial ?_ non-financial sectors or in relevant products, services and systems[139]. **Blockchain systems in many cases will be complementary or integrated with legacy IT systems** currently used by industries, businesses and SMEs. Instead of a swift and complete replacement of existing

[132] See for instance International Standards Organisation (ISO) Technical Committee 307 on Blockchain and Distributed Ledger Technologies <https://www.iso.org/committee/6266604.html>; International Telecommunications Union (ITU) Focus Group on Application of Distributed Ledger Technology (FG DLT) <https://www.itu.int/en/ITU-T/focusgroups/dlt/Pages/default.aspx>; European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) Focus Group on Blockchain and Distributed Ledger Technologies (DLT) <https://www.cencenelec.eu/news/articles/Pages/AR-2017-012.aspx>

[133] Adrianne Jeffries, '"Blockchain" Is Meaningless', *The Verge*, 7 March 2018 <https://www.theverge.com/2018/3/7/17091766/blockchain-bitcoin-ethereum-cryptocurrency-meaning>.

[134] Urs Gasser, Ryan Budish and Sarah Myers West, 'Multistakeholder as Governance Groups: Observations from Case Studies', *SSRN Electronic Journal*, 7641 (2015) <http://dx.doi.org/10.2139/ssrn.2549270>.

[135] See <https://theethereum.wiki/w/index.php/ERC20_Token_Standard>

[136] Andy Edwards, 'Who Will Build the Music Industry's Global Rights Database?', *Music Business Worldwide*, 15 February 2016 <https://www.musicbusinessworldwide.com/who-will-build-the-music-industrys-global-rights-database/>.

[137] Juho Lindman, 'Open Source Software Research and Blockchain', in *Opportunities and Risks of Blockchain Technologies – A Research Agenda*, ed. by Roman Beck and others (Dagstuhl Reports, 2017), VII, 99–142 <http://dx.doi.org/10.4230/DagRep.7.3.99>.

[138] Klint Finley, 'Tim Berners-Lee, Inventor of the Web, Plots a Radical Overhaul of His Creation', *Wired*, 4 April 2017 <https://www.wired.com/2017/04/tim-berners-lee-inventor-web-plots-radical-overhaul-creation/>.

[139] See for instance Joint Initiative on Standardisation: responding to a changing marketplace < http://ec.europa.eu/growth/content/joint-initiative-standardisation-responding-changing-marketplace-0_en>

enterprise systems, most likely scenarios will revolve around the interfaces between those systems and a blockchain as a shared and encrypted record of transactions. In many cases, a blockchain will perform specific functions for example for data registry or automatic processing in coordination with other systems which will perform other functions that a blockchain is simply not designed or useful for.

Nonetheless, another trend concerns the possible **intersection of Blockchain with other key digital technologies in the industrial / non-financial context, such as Internet of Things (IoT), data analytics, cloud computing, artificial intelligence, robotics, or additive manufacturing**. Consider for instance ongoing applications for food processing and distribution, in which a blockchain records information about a product's origin, production process, quality or expiry dates, which is scanned through a combination of smart tags, IoT sensors and mobile phones. Future scenarios could even foresee Blockchain as the basis of a decentralised data infrastructure towards a convergence ecosystem. In such scenarios, data is seamlessly collected by IoT devices, then authenticated, validated and encrypted on a shared ledger, and finally automatically processed through a combination of smart contracts, decentralised computation and machine learning[140].

In terms of its supporting ecosystems, the **Blockchain space is increasingly populated by multistakeholder and cross-sectoral engagement**. Interest from established companies and industries, technology vendors, academia, venture capital firms, startups, among others, are translated into a number of private consortia like R3 (mostly financial), Hyperledger and Enterprise Ethereum Alliance (broader in scope), among others smaller or sector-specific. For many organisations, consortia could offer an accessible and low-risk entry to better understand Blockchain technology, to collaborate with other companies in similar issues, and eventually to implement Blockchain based systems and develop their own pilots[141]. Collaboration between consortia members is a positive sign for the Blockchain space, although robust governance mechanisms are needed to incentivize open sharing and exchange of results often between competitors.

The development of the Blockchain space could also be connected to broader capacity building and knowledge sharing activities. In this sense, it would be beneficial **to build on existing European programmes for digitising industry and SMEs, in order to bridge current gaps between on one hand the Blockchain space, and on the other hand companies potentially interested in developing it** but still only partially engaged or not engaged at all. Funding mechanisms like SME Instrument, ongoing startup and entrepreneur networks, or supporting initiatives like digital innovation hubs, competence centres, and incubators/accelerators could be further connected to experimentation and piloting on Blockchain.

For instance, in innovation hubs and spaces in general companies could learn more about the maturity of the technology, associated costs, compatibility with legacy systems, potential new business models under decentralised, collaborative or peer-to-peer logic, early impact assessment, and also very importantly to experiment through pilots in possible collaboration with other companies. This would be particularly useful for SMEs which struggle to develop their assessments over benefits and challenges of digital technologies[142].

[140] Outlier, *The Convergence Ecosystem: Convergence 2.0 Building the Decentralised Future*, 2018 <https://outlierventures.io/wp-content/uploads/2018/03/OV_TCESR_001_SCREEN_med.pdf>.

[141] Peter Gratzke, David Schatsky and Eric Piscini, 'Banding Together for Blockchain: Does It Make Sense for Your Company to Join a Consortium?', *Deloitte*, 16 August 2017 <https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/emergence-of-blockchain-consortia.html>.

[142] European Commission, *Roundtable on Digitising European Industry Working Group 1 Digital Innovation Hubs: Mainstreaming Digital Innovation Across All Sectors Final Version*, 2017 <https://ec.europa.eu/futurium/en/system/files/ged/dei_working_group1_report_dec2016_v1.2.pdf>. Sami Koskela, Mika Ruokonen and Juho Kinnunen, *Digital Innovation Hubs Review: Turning Large Corporations towards Agility*, 2017 <http://futurice.com/files/sites/377/futurice_digitalinnovationhub_review.pdf>.

Regulatory sandboxes are other capacity-building and experimentation environments, currently being developed in a number of countries such as UK[143], Australia[144], Hong-Kong, Switzerland, Singapore, Canada, Indonesia, Malaysia, Taiwan, Thailand, Japan, among others. So far they have been mostly targeted at Fintech with the participation of a few DLTs companies, but could be expected to cover more Blockchain applications in non-financial and industrial sectors.

Sandboxes stand out due to the particular ways large firms, startups, entrepreneurs, SMEs, and policy makers could work with each other to test Blockchain based products, services and business models[145]. They could provide companies access to robust regulatory and supervisory guidance which could be adapted to their particular needs, while also assessing commercial viability and building potential collaborations with other companies.

By engaging directly with the companies, policy makers could also expand their in-depth knowledge not only of the technology but also associated economic and social conditions. It could potentially improve the quality and speed of policy responses, and provide more regulatory certainties for companies. Such inner insights might also prove crucial to put forward **regulatory approaches that could greatly influence the Blockchain space in the near future**. Several options are possible, for instance dynamic co-regulation that gathers together a diversity of stakeholders including Blockchain companies, industry and SMEs representatives, think tanks, academia and research centres, and/or the redrawing of regulatory boundaries informed by fitness checks or reviews taking into account particularities of Blockchain technology[146].

5.2. New Business and Economic Models

Blockchain based systems are developed according to a peer-to-peer logic in which people and organisations can exchange goods, services and information without the need of central authorities to verify identity, validate transactions or enforce commitments, or at least by removing the need of many intermediaries as it happens today. At a first level, it may enable **gains in efficiency and lowering of costs** for companies and organisations, by allowing for faster transactions disseminated and synchronised digitally across a number of different but fewer parties.

At a second level, such technologies could potentially introduce major changes on today's mainstream ways of **extracting and delivering value in business and industry**. One of the crucial points in digitalisation strategies not exclusive to Blockchain but common to other digital technologies is precisely the creation of new services to new clients and markets.

As timestamped, shared and immutable databases operating in a distributed network, Blockchain and other DLTs could be a **backbone for new digital transactions between economic agents**, such as producers, manufacturers, distributors, consumers, and so on. For instance, keeping track of data about a car's use and lifecycle, such as mileage, mobility patterns, or maintenance checks, could be used to offer new services like pay-per-use, short-term insurances or other liability schemes, energy packages, among others. Or having a unique and reconciled registry of intellectual property rights for any type of products, goods and digital content (design files, music, art, etc.) could enable new licences and distribution networks, establish agreements in a more global scale, or simplify

[143] FCA / Financial Conduct Authority, *Regulatory Sandbox Lessons Learned Report*, 2017 <https://www.fca.org.uk/publications/research/regulatory-sandbox-lessons-learned-report>.

[144] Australian Securities and Investments Commission, *Retaining ASIC ' S Fintech Licensing Exemption*, 2017 <http://download.asic.gov.au/media/4570456/cp297-published-12-december-2017.pdf>.

[145] Chamber of Digital Commerce, *Global Regulatory Sandbox Review: An Overview on the Impact, Challenges , and Benefits of Regulatory FinTech Sandboxes*, 2017 <https://digitalchamber.org/wp-content/uploads/2017/11/Regulatory-Sandbox-Review_Nov-21-2017_2.pdf>.

[146] Julie Maupin, 'Mapping the Global Legal Landscape of Blockchain Technologies', *SSRN*, 2017, 1–15 <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2930077>. Michèle Finck, 'Blockchain Regulation', *German Law Journal*, 2018 <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3014641>.

authentication and tracking of rightful use and ownership.

Most companies and organisations are looking into Blockchain from what we can call a conventional perspective on what it could bring to their business or its added value compared to their existing technologies, systems or models. And this is in fact a practical course of action when dealing with early-stage technologies such as Blockchain and other DLTs, which may offer alternative solutions but might not be targeted or adapted at tackling immediate and specific problems for organisations.

Here what's missing is a strategic and mid to long-term analysis of potential wider transformations if such technologies are taken to a next level, that is, if Blockchain's features of decentralisation, replication, transparency, timestamping, immutability, public-private key cryptography and automation are fully maximised. Such technologies may introduce **new processes and mechanisms for economic organisation which could be more 'decentralised', 'distributed, 'collaborative', or 'peer-to-peer'.** So far most companies operate through centralised infrastructures either run by them or other companies for data processing, storage and verification. This situation ends up creating data silos with associated high costs of reconciliation, mismatch or incompatibility when organisations need to exchange information with each other[147].

Data-driven economies, however, may further push businesses and companies to rethink their centralised logic based on closed boundaries and move towards opening up their internal assets and integrate them into open ecosystems with external partners, customers and other players[148]. The new logic here would be around collaboration, transparency and sharing through secure channels. Such elements could be at the same time enabled and further developed precisely by leveraging on inherent features of Blockchain and other DLTs.

On one hand, such technologies could be expected to be cost effective and competitive compared with traditional centralised systems[149]. The costs of adoption and deployment of Blockchain and DLTs could potentially fall if they follow other trends regarding costs of processing (Moore's law), storing (Kryder's law), and shipping (Nielsen's law) digital information. On the other hand, efficiency and productivity gains derive not solely from faster and cheaper end-to-end completion of tasks or processes. Instead the main change comes from the re-organisation of production of value which could eliminate the need for third parties and most of their costly and slow activities. Such activities could then be replaced and potentially performed more efficiently and securely by distributed consensus networks such as Blockchain.

Still it would require a **shift in traditional business mindsets** that could acknowledge or try out emerging models more reliant than ever in constant availability and exchange of digital data. We have already witnessed for instance the disruptive effects of such models in a number of sectors, under the wide umbrellas of 'platform economy', 'sharing or collaborative economy'[150], 'peer economy' or other digital data driven endeavours. Again Blockchain and other DLTs could boost the development of new innovation models and sources of growth across the economy, sometimes at the expense of

[147] Jerry Cuomo, Shanker Ramamurthy and James Wallis, *Fast Forward: Rethinking Enterprises, Ecosystems and Economies with Blockchains*, *IBM Institute for Business Value*, 2016 <http://dx.doi.org/10.1177/0306422013500187>.

[148] Cognizant, *Blockchain in Europe : Closing the Strategy Gap*, 2018 <https://www.cognizant.com/whitepapers/blockchain-in-europe-closing-the-strategy-gap-codex3320.pdf>.

[149] Sinclair Davidson, Primavera De Filippi and Jason Potts, 'Economics of Blockchain', *Social Science Research Network*, 1–23 <http://ssrn.com/abstract=2744751>.

[150] Funda Celikel Esser and others, *The European Collaborative Economy: A Research Agenda for Policy Support* (Luxembourg: Publications Office of the European Union Studies, 2016) <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC103256/20161114_jrc collaborative economy_jointreport_formatted_onlineversion.pdf>; Anne-Katrin Bock and others, *The Future of the EU Collaborative Economy: Using Scenarios to Explore Future Implications for Employment* (Luxembourg: Publications Office of the European Union Studies, 2016) <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102766/jrc102766 collaborative economy foresight final.pdf>; Cristiano Codagnone, Fabienne Abadie and Federico Biagi, *The Passions and the Interests: Unpacking the Sharing Economy* (Luxembourg: Publications Office of the European Union Studies, 2016) <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/passions-and-interests-unpacking-sharing-economy>.

established businesses. Registering, sharing and synchronising data through a Blockchain across a distributed network can indeed disintermediate many of these tasks so far executed by central authorities or third parties. In certain scenarios many traditional or incumbent companies or organisations could see a decline of usual markets, competition models and revenue streams, or ultimately the dilution of their main product, service or business model.

But the deployment of such technologies could also allow for the creation of more diverse sources of creation of value, revenue distribution and overall **re-balancing of asymmetric relationships between economic actors**. Disintermediation could also mean spurring more dynamic models in which many different actors, individual or collective, can create, sell, buy or get compensated for their digital assets, by making use of accessible, secure and authenticated Blockchain based databases keeping track of every transaction.

It could foster **new forms of micro entrepreneurship**, in which creating a business around specific functions, skills, ideas and knowledge is easier, faster and cheaper. This could prove potentially valuable in **social innovation or social economy initiatives** by enabling the development of businesses for local or niche markets. Or it could also lower barriers of entry for small businesses for instance by lowering costs through automation of most transactions with their producers, suppliers or distributors through smart contracts, or by allowing for attracting new and more clients through micropayments, or by accessing alternative ways of crowdfunding such as Initial Coin Offerings (more on this topic below).

Moving from centralised to decentralised forms of economic organisation should not be taken as a given or inevitable. There are a number of challenges that don't stem only from the resistance, reluctance or inertia of organisations mostly relying on centralised structures and modes of operation.

Considering Blockchain as an early stage technology, the novelty and uncertainty around its very basic features raises a number of questions over broader consequences. For example, the **proliferation of parallel or unregulated economies in the future**, with little connections with mainstream economies, could be more significant than current pockets of criminal activity, frauds or scams. Blockchain properties could enable the spread of transnational, non-territorial and permissionless innovation for entrepreneurs and business operations that circumvents any regulatory or political supervision, for instance in the form of 'crypto-anarchies' or 'cryptosecession'[151] potentially defined as political-economic ruptures.

But probably one of the most potentially ground-breaking developments orbits around the notion of **'tokens' within present and future scenarios of 'cryptoeconomies'**. In simple terms, 'cryptoeconomy'[152] is a emergent field of study which is rethinking terms such as 'currency', 'coins' or more generally, 'tokens' or 'digital assets'[153].

So far most discussions are focused on the issuing of cryptocurrencies as the main operating and incentive mechanism for networks such as Bitcoin, Litecoin, Ripple, EOS, IOTA, Monero and many others, estimated at more than 1500[154]. This is in fact a first definition of anything 'cryptoeconomic'[155]. It refers to decentralised cryptographic protocols used in public blockchains (such as the Proof-of-Work) as the technical basis for the economic incentives for participants to continue to run the network (for instance getting payed or rewarded with more cryptocurrencies).

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151 Trent J Macdonald, Darcy W E Allen and Jason Potts, 'Blockchains and the Boundaries of Self-Organized Economies: Predictions for the Future of Banking', in *Banking Beyond Banks and Money*, ed. by Paolo Tasca and others (Heidelberg: Springer, 2016), pp. 279–96 <http://dx.doi.org/10.1007/978-3-319-42448-4>.

152 Marc Pilkington, 'Blockchain Technology: Principles and Applications', in *Research Handbook on Digital Transformations*, ed. by F. Xavier Olleros and Majlinda Zhegu (Camberley: Edward Elgar, 2015) <http://papers.ssrn.com/abstract=2662660>.

153 Melanie Swan, *Blockchain: Blueprint for a New Economy* (Sebastopol CA: O'Reilly Media, 2015).

154 For list of all active cryptocurrencies, see https://coinmarketcap.com/all/views/all/

155 Vitalik Buterin, 'Visions Part I: The Value of Blockchain Technology', 2015 <https://blog.ethereum.org/2015/04/13/visions-part-1-the-value-of-blockchain-technology/>.

The explosion of Initial Coin Offerings (ICOs) in 2017 put a spotlight on the creation and sale of 'coins' and 'cryptocurrencies' by many entrepreneurs, startups and companies. It can be considered as an alternative source of funding akin to crowdfunding, so far with considerable success for raising money (reported $8.84 billion dollars raised as of February 2018[156]). Here the advantages and disadvantages of ICOs[157] are still very much wrapped up in regulatory uncertainty, suspicions of fraud and scams, or actual value in bootstrapping a network or a company through rewarding or incentivising the contribution of different players.

What's more important here is to go beyond a pure 'financial' connotation. A 'currency' or more generally a 'token' in a Blockchain system can be simply understood as a multipurpose unit of value used in particular business models or economic systems[158].

For instance, in different Blockchain systems a token can give special access of a product (for instance cloud storage), represent voting rights within a group or community, and/or compensate participants for their time, work, reviews or other contributions, everything within the network or company. In this sense, it can be a mechanism for organising and coordinating behaviour, interactions or relationships between participants or users, that is, distributed economies within groups or communities under shared goals.

In a 'crypto' or 'Blockchain economy', it's conceivable that a person, group or organisation could create their own tokens (or currencies) based on protocols that govern the development, production, distribution and use of goods and services, maybe even unconstrained by geographic and political frontiers[159]. The world of tomorrow might well be one of digital assets that leverage on the possibilities of digital scarcity powered by Blockchain[160], that is, the ability to create economic value by registering an asset, prove its ownership or authenticity, and trade it on a distributed marketplace.

5.3. Trust and Decentralised Governance

Blockchain is often heralded as a 'trustless' technology or as a 'trust machine'. Such terms, however, have caused misunderstandings over how this technology could reframe what 'trust' means among individuals, groups, institutions or organisations. Generally speaking, Blockchain's particular combination of peer-to-peer networks, cryptographic techniques, consensus protocols and distributed data storage could allow for exchange of digital data with fewer to non-existent central authorities or intermediaries.

Traditionally third parties like financial institutions, governments, regulatory bodies or other commercial services verify or authenticate most of current transactions. They act as intermediaries that warrant for example that product suppliers or distributors are who they claim to be and keep their end of the contract (delivery and agreed budget), and if necessary, provide compensation or legal appeal in case of mistakes, disputes or unlawful activities. Companies rely on such organisations to provide 'trusted' mechanisms to conduct their businesses on a daily basis, with associated costs covering the execution of those services, unforeseen mishaps, or enforcement of transactions or agreements.

In Blockchain architectures third party verification could be replaced by consensus mechanisms that verify the authenticity of transactions across a distributed network[161].

[156] See CoinDesk ICO Tracker <https://www.coindesk.com/ico-tracker/>
[157] Christian Catalini and Joshua S Gans, 'Initial Coin Offerings and the Value of Crypto Tokens', 2018 <http://dx.doi.org/10.3386/w24418>.
[158] William Mougayar, 'Tokenomics — A Business Guide to Token Usage, Utility and Value', *Medium*, 10 June 2017 <https://medium.com/@wmougayar/tokenomics-a-business-guide-to-token-usage-utility-and-value-b19242053416>.
[159] Vlad Zamfir, 'What Is Cryptoeconomics?', *Presentation at CryptEconomicon 2015. Crypto Technology Conference, Mountain View CA, 26-29 January*, 2015 <https://www.youtube.com/watch?v=9lw3s7iGUXQ>.
[160] Consider for instance CryptoKitties (<https://www.cryptokitties.co/>) as one of the first (and playful) examples of a digital good turned rapidly into a scarce and valuable commodity. See Joseph Hincks, 'Introducing "CryptoKitties," the New Digital Pets Taking Ethereum by Storm', *Fortune*, 4 December 2017 <http://fortune.com/2017/12/04/blockchain-cryptokitties-ethereum/>.
[161] Davidson, Sinclair and De Filippi, Primavera and Potts.

This technology could offer a number of advantages for instance in terms of efficiency, security, availability and data integrity in comparison with current procedural, organisational and technological infrastructures run by central bodies or a few third parties providers[162].

Prospects of disintermediation is particularly appealing in industrial sectors such as transports and logistics, which rely on global supply chains of distant and untrusting players including manufacturers, shipping lines, freight forwarders, port and terminal operators, and customs authorities. Access to a transparent and secure record could reduce time and costs associated with inaccurate and inconsistent data between all parties, and ultimately help to prevent frauds, losses or duplications.

It is in this particular sense that **'trust' could be reassigned or displaced from intermediaries to code or software deployment on a Blockchain**. Due to its particular features, a **Blockchain is an encrypted, shared and tamper proof ledger which is designed to stand as a 'trusted' data source for all stakeholders**. From one side of the spectrum closer to cyber-libertarian aspirations, it could be argued that trust, or rather lack of trust in people and organisations mainly seen as fallible and corruptible, could be ultimately replaced in favour of trust in technical architectures that could execute autonomously and neutrally all transactions. Such views, however, conflict with a more comprehensive understanding of the specific workings of Blockchain as a technology and its interplay with economic, cultural, social, political and institutional dimensions[163].

A first assumption is that users or companies need to 'trust' the exactness of Blockchain's technical features based on decentralisation, replication, transparency, timestamping, immutability, digital keys and smart contracts. However, among other issues previously mentioned in the report, for example high concentration or dependency on mining pools for Blockchain platforms running Proof-of-Work mechanisms may endanger its decentralised nature and allow for potential collusions or attacks.

When it comes to smart contracts for instance, ongoing discussions raise potential problems around their 'trustless' character. So far major lacunas between legal language and technical language of smart contracts require (or potentially will always require) the presence or intervention of lawyers and other legal experts with both an overall and precise knowledge of relevant legal frameworks[164]. Furthermore, a part of current smart contracts were found not to be 'trustless' in the sense they require trust in other third parties that could change unilaterally the program that enforces the agreement, putting in question the feature of immutability[165]. Another potential threat to 'trust' concerns the possibility to change the status of a Blockchain by majority and 'fork' or split it. Such 'forks' are usually very contentious decisions within public blockchains such as Bitcoin and Ethereum, precisely because they call into question 'trust' in a record that is designed to be immutable.

But more interestingly, all these issues bring to light that Blockchain systems ultimately rely on the consensus or interactions among a set of stakeholders involved in its design and deployment, that is, developers/coders, miners, validators or other participants (depending if it is a public or private Blockchain), all with a role to play or decision-making power.

Blockchain's technical features can't establish by themselves all the intricate terms through which different parties trust

[162] Bill Briggs, Tech Trends 2016, Deloitte University Press, 2016.

[163] See for instance ongoing research <https://blockchain-society.science/>. Ruth Catlow and others, Artists Re:Thinking The Blockchain (Liverpool: Liverpool University Press, 2018).

[164] Firas Al Khalil and others, *Trust in Smart Contracts Is a Process, as Well, Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2017 <http://dx.doi.org/10.1007/978-3-319-70278-0_32>.

[165] Michael Fröwis and Rainer Böhme, 'In Code We Trust?', in *ESORICS 2017, DPM 2017, CBT 2017: Data Privacy Management, Cryptocurrencies and Blockchain Technology*, 2017, pp. 357–72 <http://dx.doi.org/10.1007/978-3-319-67816-0_20>.

and engage with each other[166]. This happens because all technical systems are designed, deployed and used by individuals, groups, companies and other organisations, that is, they don't exist in a vacuum protected from a myriad of other factors.

Potential scenarios of Blockchain as a 'trust machine' don't mean the total dissipation of intermediaries and/or absence of governance. Although often fraught with cumbersome, costly and corrupt processes, third-parties, government, or other central bodies still play a vital role for instance in defining equal conditions for participation in society and economy, deciding on responsibility and liability, enforcing rules and settling disputes, or providing guarantees and protection under the law.

Instead the discussion should focus on the concrete conditions for **decentralised, horizontal and open forms of coordination between individuals, groups and companies**, which may require in most instances a rethinking of traditional, vertical and hierarchical models. Governance mechanisms capable of organising individual and collective interactions will always be essential to the running of any Blockchain, no matter its position closer to public or private architectures[167].

Public and/or permissionless blockchains may sometimes be misconstrued as purely disorganised, chaotic and ineffective given the open and informal character of its communities. Still, it can't be denied that free, libre and open source software (or FLOSS) communities[168], similar in many aspects to those at the core of public blockchains, have developed and continue to enable high quality (and some might say through more lean, secure and productive processes) products and operating systems already running a considerable part of current servers, desktops and smartphones. It can be argued that for instance **Bitcoin and Ethereum communities, working mostly through voluntary, grassroots and open processes, have created the more successful Blockchain architectures to date**.

Also self-organisation in such distributed networks turns out to be more complex. In fact **discussions over the importance of governance within public blockchains communities are ongoing, and a number of proposals or protocols are under development**[169]. Taking the example of current debates around 'on-chain' or 'off-chain' governance, there is a lively exchange of arguments over how to at the same time preserve and improve the delicate balance between often conflicting roles of involved stakeholders like token or coin holders, miners and users[170]. Some are more in favour of formalised and automatic execution of rules embedded in the protocol itself, which might help to reach consensus more quickly and avoid constant deadlocks or forks. Others are more wary of potential power imbalances arising from such 'on-chain' mechanisms, and point towards more contextual and tacit governance processes[171]. Such 'off-chain' mechanisms relate in a certain way with how governance and leadership in open source communities has been shown to emerge from a fluid combination of personal motivations, meritocratic pursuit of technical proficiency, shared values of accountability, transparency and openness, organisation-building behaviours, and overall collective practices over time (e.g. online discussions, meetings, conferences, etc.)[172].

[166] Florian Hawlitschek, Benedikt Notheisen and Timm Teubner, 'The Limits of Trust-Free Systems: A Literature Review on Blockchain Technology and Trust in the Sharing Economy', *Electronic Commerce Research and Applications*, 29 (2018), 50–63 <http://dx.doi.org/10.1016/j.elerap.2018.03.005>.

[167] Don Tapscott and Alex Tapscott, *Realizing the Potential of Blockchain: A Multistakeholder Approach to the Stewardship of Blockchain and Cryptocurrencies*, *Whitepaper*, 2017 <https://www.weforum.org/whitepapers/realizing-the-potential-of-blockchain>.

[168] Georg von Krogh and Eric von Hippel, 'The Promise of Research on Open Source Software', *Management Science*, 52.7 (2007), 1–13 <http://dx.doi.org/10.1287/mnsc.1060.0611ec>.

[169] See for instance <http://backfeed.cc/>

[170] Rachel Rose O'Leary, 'Polkadot's Plan for Governing a Blockchain of Blockchains', *Coindesk*, 22 March 2018 <https://www.coindesk.com/polkadots-radical-plan-governing-blockchain-blockchains/>.

[171] Vlad Zamfir, 'Against on-Chain Governance', *Medium*, 1 December 2017 <https://medium.com/@Vlad_Zamfir/against-on-chain-governance-a4ceacd040ca>.

[172] Siobhán O Mahony and Fabrizio Ferraro, 'The Emergence of Governance in an Open Source Community', *The Academy of Management Journal*, 50.5 (2007), 1079–1106. Gabriella Coleman, *Coding Freedom: The Ethics and Aesthetics of Hacking* (New Jersey: Princeton University Press, 2012).

Despite such noteworthy debates, public blockchain communities still need to grapple with underlying conditions and realities. It is a distributed system based on consensus through cryptoeconomic incentives, that is, based on the alignment of rational agents following their own best individual interest, which may raise concerns over an illusion of egalitarianism based on a majority rule.

Human and social coordination, however, is much more complex in reality, and power dynamics play a central role through informal and sometimes invisible alignments of interest between individuals or groups, or in the Blockchain space, the influence of core developers or members of the community in steering debates or major decisions. Use of any technology also needs to be considered in relation to inclusion and diversity when it comes to gender, age, ethnicity, geographical origin, education, and other social and cultural capital imbalances. Claims for egalitarian and meritocratic levelling of the playing field rarely match a levelling of opportunities to access[173].

In private and/or permissioned blockchains, **governance is usually implemented through more formal mechanisms and approaches, at least partly due to its very design**. In such architectures, participation is restricted to trusted nodes and/or members which clear and explicit permission to access specific features or data. **At the protocol level, rules about who does what and when (users, validators, regulators, ...) are defined and each participant performs its assigned role**. In this sense, private blockchains carry out a distinctive mode of decentralised governance between individuals, groups and companies by allowing them to interact more openly with each other but under specific boundaries.

Many companies and businesses are more inclined to deploy private blockchains precisely because it allows in their view for more stable, closed and verifiable governance and its associated mechanisms for identity management, data rectification and attribution of responsibility. It may disentangle for instance a number of concerns when using this technology, namely conformity with current regulatory frameworks for daily business operations such as protection of personal data, validation of electronic signatures or digital certificates, or management of electronic document storage and archiving[174].

Private **consortia such as Hyperledger may also offer a perceived balance between open source collaborative efforts between its members and the assurance of a formal governance framework**, including a core team, governance board, a technical committee, an advisory board with an agreed set of responsibilities, procedures for decision-making and codes of conduct. It can be argued if this type of decentralised governance follows too closely conventional centralised systems, and it may miss in the end one of the major advantages of more open decentralised governance, that is, the full transparency and resulting enhanced trust between all participants.

Whatever might be the exact configurations of governance in different Blockchain architectures, more public, closed or hybrid, there are increasing signs of organisational change and new market dynamics brought by decentralised forms of socioeconomic coordination[175]. Though it is still unclear its potential wide impact, more open and horizontal Blockchain-enabled governance might shift power dynamics between stakeholders in many sectors[176]. At a nearer future, the boundaries might revolve around new types of economic and social institutions executing Blockchain rule-systems like smart contracts towards polycentric and common pool resources governance.

[173] Susana Nascimento and Alexandre Polvora, 'Opening Up Technologies to the Social: Between Interdisciplinarity and Citizen Participation', *Design Issues*, 29.4 (2013), 31–40. Susana Nascimento and Alexandre Pólvora, 'Maker Cultures and the Prospects for Technological Action', *Science and Engineering Ethics*, 2016, 1–20 <http://dx.doi.org/10.1007/s11948-016-9796-8>.

[174] Marcella Atzori, 'Blockchain Governance and the Role of Trust Service Providers: The TrustedChain Network', *SSRN Electronic Journal*, 2017 <http://dx.doi.org/10.2139/ssrn.2972837>.

[175] Paolo Tasca and others, Banking Beyond Banks and Money (Heidelberg: Springer, 2016).

[176] Aaron Wright and Primavera De Filippi, 'Decentralized Blockchain Technology and the Rise of Lex Cryptographia', 2015, 58.

For instance at a first level companies and businesses might start adopting Blockchain systems to support more flat and collaborative interactions and increase transparency and accountability. Others might develop more distributed, peer-to-peer or commons models where inputs and outputs are shared, freely or conditionally, while decision-making is still made inside the organisation. And others might even experiment with decentralised autonomous organisations, or DAOs, that could own, exchange, or trade resources and interact autonomously with other humans, devices, organisations or other DAOs, in a sort of algorithmic decision-making[177].

5.4. Emerging Regimes for Data Management

Managing digital data has become a central part of most businesses and industries and it will most probably intensify in the foreseeable future. **Who processes, stores and owns data, how and for what purposes, are or will become crucial questions for any organisation**. The conditions for enabling a data economy[178] is at the core of recent and ongoing European regulatory initiatives within the Digital Single Market strategy, namely the draft Regulation on a framework for the free flow of non-personal data in the EU[179], the EU General Data Protection Regulation (GDPR)[180], and the Regulation on electronic identification and trust services for electronic transactions in the internal market (eIDAS)[181], among others[182]. From here derives the potential of Blockchain and other DLTs as emerging decentralised data architectures that could support the execution of a number of principles under certain conditions.

Blockchain and other DLTs operate through a distributed network of multiple nodes or participants. Its feature of replication means each node has an updated and authenticated copy of the ledger or record. Unlike centralised systems, there is no single point of failure. So even in multiple nodes are disconnected or break down, data will continue to be available throughout the distributed network. **This decentralised architecture could fulfil the goals of data storage, processing and availability of data across Member States and between providers and different IT environments**, as defined in the draft Regulation on free flow of non-personal data. Moreover, data remains available for regulatory control from public authorities, or if necessary, under specific conditions of access for authorised participants in private and/or permissioned blockchains.

When it comes to cybersecurity requirements that apply to any industries and businesses storing and processing data, **Blockchain and other DLTs could offer resilient and secure architectures**. Its feature of immutability makes it very hard or nearly impossible to change data without detection, and that's mainly why Blockchain is being tested to verify for instance the integrity of highly sensitive data in critical systems, satellites, nuclear command and control systems, or weapon systems. Blockchain's potential to enhance data integrity, however, is not free of potential corruptions or problems. Sources of vulnerability remain for instance on potential takeovers, manipulations or collusions in

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[177] William Mougayar, 'An Operational Framework for Decentralized Autonomous Organizations', 2015 <http://startupmanagement.org/2015/02/04/an-operational-framework-for-decentralized-autonomous-organizations/>; Vitalik Buterin, 'DAOs, DACs, DAs and More: An Incomplete Terminology Guide', *Ethereum Blog*, 2014 <https://blog.ethereum.org/2014/05/06/daos-dacs-das-and-more-an-incomplete-terminology-guide/>.

[178] European Commission, *Communication from the Commission to the European Parliament, the Council, Economic and Social Committee and the Committee of the Regions: Building a European Data Economy, COM(2017) 9 Final*, 2017 <https://ec.europa.eu/digital-single-market/en/news/communication-building-european-data-economy>.

[179] European Commission, *Proposal for a Regulation of the European Parliament and of the Council on a Framework for the Free Flow of Non-Personal Data in the European Union, COM(2017) 495*, 2017 <https://ec.europa.eu/digital-single-market/en/news/proposal-regulation-european-parliament-and-council-framework-free-flow-non-personal-data>.

[180] 'Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC' <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0679>.

[181] 'Regulation (EU) No 910/2014 of the European Parliament and of the Council of 23 July 2014 on Electronic Identification and Trust Services for Electronic Transactions in the Internal Market and Repealing Directive 1999/93/EC' <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.257.01.0073.01.ENG>.

[182] See for instance upcoming revision of the legal framework on ePrivacy: European Commission, *Proposal for a Regulation on Privacy and Electronic Communications*, 2017 <https://ec.europa.eu/digital-single-market/en/news/proposal-regulation-privacy-and-electronic-communications>.

public blockchains (51% attack), censures or interventions by small groups in private blockchains, or in the compromise, theft or loss of public and private keys.

Overall, data integrity is also connected to the accuracy, consistency or validity of data throughout its whole life cycle[183]. For instance, **organisations need to pay close attention to the quality of the data being entered, processed and stored on a Blockchain**, that is, if data is incorrect, invalid or complete. This technology is only records, verifies and encrypts the data as it is introduced and by consensus of involved participants or nodes, with no guarantees or fact checking about its veracity.

Stability and continuity of Blockchain technical architectures might also be a problem. For instance, public and/or permissionless blockchains depend on the distributed effort of developers and miners which can simply stop working in a particular Blockchain for whatever reason and/or move to another system ('fork'). If this happens, the records from the previous system may no longer be preserved, updated or maintained and create confusion throughout the network about the legitimate and new version of the record. The same issue could happen in private and/or permissioned blockchains when changes are introduced and decided by a restricted number of core participants.

Overall **organisations need to invest their resources to establish trusted digital repositories** and guarantee additional technical, policy and institutional capacity for **proper archival storage, data management, access, and overall preservation of records**[184].

Blockchain and other DLTs could offer alternative mechanisms to implement principles of data protection by design or privacy by design, and the right of data portability as underlined in current European data policy, particularly in GDPR. By design, a Blockchain only records a cryptographic hash (or 'digital fingerprint') of the transaction, date and time, plus the public keys of the involved parties. Personal data, like names, addresses, telephones, location, etc., is not publicly accessible so it precludes direct identification[185]. At its minimum such mechanisms offer pseudonymisation and not full anonymisation, so in most cases they would need additional layers of encryption and/or obfuscation in order to conceal details about the transactions (solutions under development are discussed in the following sub-chapter)[186]. If properly designed depending on the needs of organisations, Blockchain systems could potentially enable decentralised and privacy-friendly solutions.

In a Blockchain system people, any type of encrypted data (identity documents, health records, transactions between IoT devices, payments, transfer of ownership, etc.) can be recorded, validated and transmitted according to specific rules for access. That is, it's possible to give authorisation to information only to specific or trusted parties, or to revoke access in specific times. It could enable **faster and more secure data management processes for both individuals and organisations, and overall a greater control over the disclosure and selective sharing of data**.

For instance, Blockchain could be at the basis of distributed identity and authentication systems potentially in line with the eIDAS Regulation which foresees the use of electronic identification (eID) and electronic Trust Services (eTS), namely

[183] Victoria Louise Lemieux, 'In Blockchain We Trust? Blockchain Technology for Identity Management and Privacy Protection', in *CeDEM17: Proceedings of the International Conference for E-Democracy and Open Government*, ed. by Peter Parycek and Noella Edelman, 2017, pp. 57–62 <http://www.donau-uni.ac.at/imperia/md/content/department/gpa/zeg/bilder/cedem/cedem17/cedem17_proceedings_donau_universit__t_edition.pdf>.

[184] Victoria Louise Lemieux, 'Trusting Records: Is Blockchain Technology the Answer?', *Records Management Journal*, 26.2 (2016), 110–39 <http://dx.doi.org/10.1108/RMJ-12-2015-0042>.

[185] Deloitte, 'Blockchain from a Perspective of Data Protection Law: A Brief Introduction to Data Protection Ramifications' <https://www2.deloitte.com/dl/en/pages/legal/articles/blockchain-datenschutzrecht.html>.

[186] Primavera De Filippi, 'The Interplay Between Decentralization and Privacy: The Case of Blockchain Technologies', *Journal of Peer Production*, 2016 <http://peerproduction.net/issues/issue-9-alternative-internets/peer-reviewed-papers/the-interplay-between-decentralization-and-privacy-the-case-of-blockchain-technologies/>.

electronic signatures, electronic seals, time stamp, electronic delivery service and website authentication, to enable secure and cross-border electronic interactions between businesses, citizens and public authorities. Blockchain could also further the application of data portability as stipulated in GDPR by allowing for selective, seamless and secure flows of data between IT environments run by individuals, companies, or service providers.

Decentralised solutions for these purposes are still currently under development, and subject to critique[187]. But there are several ongoing projects and initiatives working for example on **new regimes of citizen-controlled and self-sovereign digital identity**[188] **based on distributed, open and modular architectures** for managing online identity and data in real-time and confidential ways. Such regimes could also enhance GDPR's objectives of strengthening citizen's fundamental rights over their personal data and simplify the rules for companies in order to achieve a level playing field.

Paradoxically the same decentralised and cryptographic protocols used in Blockchain to potentially enhance data protection could also compromise the rights of privacy and personal data, as discussed in more detail in the next sub-chapter. To be noted though that uncertainties and risks around data management are not exclusive to Blockchain but are in fact very much present in ongoing discussions over the use of artificial intelligence, big data or in general data analytics for large-scale and automated processing, classification and access to personal data[189].

5.5. Dealing with Privacy and Transparency

One of the most pressing issues for data in Blockchain concerns possible incompatibilities of its decentralised and cryptographic protocols in regard to privacy and personal data, namely in the framework of GDPR which becomes enforceable from 25 May 2018[190]. There are a number of issues that still remain uncertain or unresolved for the time being, which may further complicate how organisations and businesses can make decisions on their data policies and strategies.

As GDPR only applies to personal data, one key element is to determine which type of data stored on a Blockchain qualifies as personal data. On public blockchains for instance, **transactions are encrypted and linked to a set of public and private keys** owned by specific participants. So the Blockchain doesn't record specific elements of participants' identities, and instead just the public keys of the sender and recipient, the date and time (timestamping), and the cryptographic hash (or 'digital fingerprint') of the transaction content (payment, transfer of ownership, medical records, a piece of art, etc.).

However, this cryptographic protocol doesn't guarantee complete anonymisation, in the sense that records of transactions could be still be traced back to individuals. Instead, **encryption is considered a pseudonymisation technique** under the EU data protection regime[191]. Following this high standard for anonymisation, encrypted data on a Blockchain will most probably be considered as personal data for the purposes of GDPR.

In addition, while they don't allow for direct identification, **public keys can be still be connected with additional information that will allow to pinpoint an individual or**

[187] Arvind Narayanan, Vincent Toubiana, and others, 'A Critical Look at Decentralized Personal Data Architectures', 2012 <http://arxiv.org/abs/1202.4503>.

[188] John Thornhill, 'Reclaiming Europe's Digital Sovereignty, Podcast with Francesca Bria', *Financial Times*, 25 October 2017 <https://www.ft.com/content/f096bcf6-87d5-4023-a9b5-73ae847076b2>.; Tom Symons and others, 'Me, My Data and I: The Future of the Personal Data Economy', 2017, 88 <https://decodeproject.eu/publications/me-my-data-and-ithe-future-personal-data-economy>.

[189] Tal Z Zarsky, 'Incompatible: The GDPR in the Age of Big Data', *Iowa Law Review*, 102.2 (2017), 651–707 <http://dx.doi.org/10.3366/ajicl.2011.0005>.

[190] Winston Maxwell and John Salmon, *A Guide to Blockchain and Data Protection*, 2017; Michèle Fink, 'Blockchains and Data Protection in the European Union', *Max Planck Institute for Innovation and Competition Research Paper No. 18-01*, 18.1 (2017), 1–30 <http://dx.doi.org/10.2139/ssrn.3080322>.

[191] 'Article 29 Working Party, Opinion 05/2014 on Anonymisation Techniques, 0829/14/EN WP216', 10 April 2014 <http://ec.europa.eu/justice/article-29/documentation/opinion-recommendation/files/2014/wp216_en.pdf>.

company, for instance when a public key is re-used and then certain IP addresses are recognised, when keys are stolen or hacked, or when identity is requested by central authorities in the context of Know-Your-Customer (KYC) and AML (Anti-Money Laundering) regulation). In these terms, public keys are pseudononymous data and will be presumably considered as personal data under GDPR. A strong signal to this argument also comes from the case *Patrick Breyer v Bundesrepublik Deutschland* on 19 October 2016, which classified dynamic IP addresses as personal data. Dynamic IP addresses, that is, addresses assigned to computers when connected to a network, could be considered personal data even if additional data able to identify an individual is only in possession of a third party (such as an internet service provider).

Other features of Blockchain and other DLTs also pose potential problems, such as decentralisation, transparency, replication and immutability. In a broad definition forgoing for a moment the differences between different architectures, a Blockchain is a chronological database in which data is permanently recorded and shared across a distributed network of nodes or computers.

In these decentralised systems, **nodes or participants can be 'data controllers'** according to the GDPR lexicon when they upload data into the Blockchain, **or 'data processors' because they verify transactions and keep a full copy of the Blockchain**. It may be hard to determine not only the responsibilities for each node or participant, but also to enforce compliance throughout a network of multiple data controllers and processors across the world. To determine the location and identity of decentralised nodes for jurisdiction purposes and then compel them to comply won't be easy or straightforward tasks. In a potentially global and cross-border environment run through Blockchain systems, the applicability of data regulation might need to be analysed depending on the transaction in question. This uncertainty does not offer, however, a clear background for companies and businesses to operate and may constitute additional risks.

Probably of the one discussed issues concerns **potential conflicts between Blockchain feature of immutability and the GDPR right to data erasure**, most known as 'the right to be forgotten'. By design particularly in public and permissionless Blockchains, the records of transactions or in general data are very hard to change or delete. Depending on the consensus mechanism in place, a majority of the nodes or participants need to agree and then implement the changes across the whole network. The potential need to identify and contact all the necessary nodes with a request to delete or even rectify data (right to amendment) might not be feasible in reality. Also any changes in a supposedly 'immutable' database may erode the trust of participants in the Blockchain itself and lend it to suspicions of tamper-proofing and interference.

There might be some flexibility in what constitutes 'erasure'. It ultimately will depend on the interpretation by data protection authorities in regard to what is technically (im)possible in Blockchain. In some instances irreversible encryption used in Blockchain, deleting a private key, or restricted access mechanisms that make it no longer possible to view data might still be considered as erasure, despite the fact it won't be not absolute deletion.

Nonetheless, a number of technical proposals are being developed with the explicit purpose of solving such pressing issues. One possible solution is to **store confidential, sensitive or personal data 'off-chain'** or in other databases. This data is linked to the Blockchain only through a hash reference or pointer, keeping access to the original data in the other database restricted to authorised parties. So in this case the Blockchain is more of an access-control manager[192] that provides proof regarding the authenticity of the data and overall preserves the privacy of transaction details[193]. An example would be Blockchain systems managing patient medical

[192] Guy Zyskind, Oz Nathan and Alex Sandy Pentland, 'Decentralizing Privacy: Using Blockchain to Protect Personal Data', *Proceedings - 2015 IEEE Security and Privacy Workshops, SPW 2015*, 2015, 180–84 <http://dx.doi.org/10.1109/SPW.2015.27>.
[193] See for example https://www.cambridge-blockchain.com/single-post/2016/08/09/Event-1

records but the records themselves would be stored in hospital or other third parties' databases.

To be compliant with GDPR, most companies will most probably decide to move personally identifiable data off the Blockchain and store in traditional databases. However, setting up and maintaining such databases or IT infrastructure can be expensive, especially for smaller companies and startups, also taking into account overall high standards for data security[194]. Also such 'off-chain' solutions may hide potential corruptions or errors in the diverse records maintained by companies or other parties outside of the Blockchain, and in the end compromise the original added value of a tamper-proof system with a single and shared record.

Another problem is that moving public keys 'off-chain' is not a viable option because they are in fact an inextricable part of the validation process at least for public blockchains. So far there are no clear or mature GDPR-compliant solutions, but practitioners and experts are working on obfuscation techniques such as additional signatures by multiple users using their private keys and stealth addresses (one-time public keys)[195]. Present cryptographic research is also looking into other techniques such as zero knowledge proofs. It allows the validation of a transaction between parties without the need to reveal information such as the addresses of the parties involved or the amounts. Such cryptographic tools are being tested as a complement to public and permissionless blockchains, and potentially guarantee at the same time the use of personal (and private) data on a Blockchain and the mathematical proof that a transaction is authentic[196]. Other potential solutions for anonymisation are being tested such as Multi-Party Computation (MPC) in which data and tasks are distributed through multiple parties in a way that you can't single out specific details so it's still encrypted throughout the network[197].

Another option being explored by a number of companies is to use **private and/or permissioned blockchains.** In these cases **access to data can be restricted to authorised parties, which allows for limiting the availability of personal, sensitive or private information to a case by case need**. It means necessarily that specific participants or nodes get to decide the terms of access to data and even revise and change parts of the records, making them in reality intermediaries, third parties or arbitrators. One hand it may solve the issue of data privacy and facilitate identification of responsibility and compliance. But on the other hand such options may undermine data integrity and thus jeopardize one of the main benefits of decentralised protocols such as in public blockchains.

If parts of the data is kept 'off-chain' and is susceptible to be changed or altered by a core group as it happens in private blockchains, a number of questions may arise in terms of proper governance arrangements. Companies or businesses opting or developing such private and/or permissioned blockchains need to put in place **proper guidelines and mechanisms for data ownership, access, encryption and security, and storage which are agreed and acknowledged with all participants**. Still suspicions, attacks or threats can be more widespread in Blockchains architectures which are not completely transparent and available to all.

Such **governance arrangements will be probably the main basis to determine the applicability and compliance of Blockchain systems when it comes to data protection regulation**. In private blockchains responsibility may fall on the core group of organisations running it, while in public blockchains the situation is more unclear[198]. As described above, many

[194] Olga Kharif, 'Is Your Blockchain Business Doomed?', *Bloomberg*, 22 March 2018 <https://www.bloomberg.com/news/articles/2018-03-22/is-your-blockchain-business-doomed>.
[195] See for instance Monero protocol < https://getmonero.org/>
[196] See for instance Zcash <https://z.cash/technology/zksnarks.html>
[197] Andy Greenberg, 'MIT's Bitcoin-Inspired "Enigma" Lets Computers Mine Encrypted Data', *Wired*, 30 June 2015 <https://www.wired.com/2015/06/mits-bitcoin-inspired-enigma-lets-computers-mine-encrypted-data/>.
[198] David Meyer, 'Blockchain Technology Is on a Collision Course with EU Privacy Law', *International Association of*

technical solutions are being developed but are not mature enough to guarantee full anonymity for instance. More research is needed on how to conciliate Blockchain features concretely with the principles set out by regulation such as GDPR. This interconnection is not easy also considering the gaps and discrepancies between technical and legal terms.

In general **organisations should perform through risk assessments to their data frameworks,** taking into account that at least some data verified and stored on a Blockchain could be considered personal data. Of course this assessment can be further complicated by the customisable and open-ended character of most available Blockchain solutions. Such uncertainties may discourage many companies to deploy Blockchain systems and in the end create limitations on its potential applications. At the same time, companies shouldn't close off innovative decentralised systems for data processing and managing such as Blockchain and other DLTs can offer. It can be argued that current regulations were mostly designed for centralised cloud services model in which a limited number of providers are responsible for processing and collecting personal data[199]. Still the possibilities around decentralised systems might change this landscape and even stimulate new regimes for data management in general as the previous sub-chapter explored in more detail.

5.6. Strategies and Guidelines for Uptake

Blockchain and other DLTs are captivating the attention of a growing number of companies, think tanks, consultancies, governments and other institutions. Enthusiastic statements over their radical and disruptive character, considered by some in no less degree than the wide transformations enabled by the internet, have poured on almost daily to business and media arenas. This frenzy is regularly met with critical assessments and backlashes, all within an extremely accelerated and often chaotic space. The **present Blockchain space is faced with inflated expectations and hype over its opportunities and risks, which leaves most industry, businesses and SMEs baffled and unsure about its expected importance and the demand to deploy it**.

Efforts from industry, businesses and SMEs to engage with this space shouldn't be primarily targeted or start from Blockchain's technical features[200]. That is, **organisations shouldn't develop Blockchain solutions looking for problems, but instead find existing or foreseeable problems in their business and then look for possible Blockchain solutions** that could help at least partly. Failing to do so might compromise the success of any Blockchain experimentation or deployment, which may lead to lost investments, high costs and overall missed opportunities to benefit from overarching impact. It calls for an initial and through analysis of specific problems for instance in each company's operating and IT models and external marketplaces, which leads to identifying concrete opportunities to be explored[201].

At the same time, a **first assessment of specific problems to solve should be informed by an accurate understanding of what Blockchain and other DLTs could be used (and not used) for**, that is, if these technologies are the best or most appropriate solutions to the identified problems[202]. For this purpose it would be useful to consult or engage with external experts or practitioners knowledgeable and familiar with Blockchain and other DLTs which could support this initial assessment.

For instance, organisations should at least have a first estimation **if it would be more cost-**

Privacy Professionals (IAPP), 27 February 2018 <https://iapp.org/news/a/blockchain-technology-is-on-a-collision-course-with-eu-privacy-law/>.

[199] Greg McMullen, 'Blockchain Law Report Card 2017', *Medium*, 7 January 2018 <https://medium.com/@gmcmullen/blockchain-law-report-card-2017-43b04a7e1139>.

[200] Cognizant.

[201] See for instance <https://www.pwc.com/us/en/industries/financial-services/fintech/blockchain.html>

[202] World Economic Forum, *Blockchain Beyond the Hype A Practical Framework for Business Leaders*, 2018 <http://www3.weforum.org/docs/48423_Whether_Blockchain_WP.pdf>. Roger Maull and others, 'Distributed Ledger Technology: Applications and Implications', *Strategic Change*, 26.5 (2017), 481–89 <http://dx.doi.org/10.1002/jsc.2148>.

effective to eliminate or reduce the number of intermediaries in favour of more direct collaborations with other companies. They should also consider **if the translation of physical assets into digital representations is feasible and/or advantageous**. This would be the case for example in the manufacturing sector when information of a physical product could be digitalised, and then tracked throughout the supply chain as it is designed, built and distributed by different stakeholders.

Furthermore, companies should assess **if there is a need for a permanent and tamper proof record that is accepted and accessible by multiple parties**, which ultimately results in constant data sharing and updates across the network. Also to be considered is the type of data to be recorded on a Blockchain, that is, **if personal, sensitive or non-transactional data is an important part of the company's activities**, which might bring in the end extra difficulties or costs to protect that data when deploying a Blockchain. Another factor for the assessment would be **if authentication of transactions and management of contractual obligations across distant and often untrusted parties could be improved** via a Blockchain solution.

As an early-stage technology with a limited set of successful pilots and available results, **Blockchain and other DLTs often entail potential risks and barriers** to be taken into account by industry, businesses and SMEs interested in its deployment. **Present uncertainties over the legal status or formal acceptance of several Blockchain solutions, such as the creation of tokens or coins, transactions performed via smart contracts, or management of personal data, make any assessment of regulatory ramifications very challenging**.

Despite prospects over replacing third parties verification by Blockchain mechanisms, in reality most companies will need to comply with a number of existing rules and standards, that is, to operate in a particular regulatory framework. This compliance usually has high costs linked to services provided by third parties such as banks, clearing houses, payments networks, governments, certification bodies, etc. In this sense, they provide a stable environment for businesses and companies when authenticating identities and transactions, providing guarantees and possible compensations, or providing mechanisms for arbitration and conflict resolution. Each organisation needs to assess to the best of their capacity, preferably under legal specialised counsel, the potential trade-offs between regulatory uncertainty and high compliance costs in their current ecosystem.

A **common concern or barrier for industry, businesses and SMEs aiming to deploy any digital technology relates to upskilling their workforce and overall potential impact on current jobs**. Successful deployment and customisation of Blockchain solutions in most organisations might require not only recruitment of proficient Blockchain developers and architects (now in high demand), but also suitable investments in digital skills training for many of their staff. Moreover, these technologies could be expected to change the job landscape across sectors[203] by revamping for instance tasks of registry and authentication (e.g. notaries), processing and auditing of transactions (e. g. customs personnel, bank clerks, accountants), trading, risk assessment and design of prediction models (e.g. financial analysts), monitoring and execution of contracts (e.g. lawyers), to name a few.

It is far too soon to estimate potential job losses or displacements resulting from the deployment of Blockchain's encrypted and automated mechanisms. Such potential changes echo in many cases, however, **ongoing research looking into the future of work and the impact of automation, artificial intelligence and machine learning**. Despite its high prominence in the political and economic agenda, **there is no consensus over the future impact of digital technologies on jobs.**

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[203] See <https://www.sbs.ox.ac.uk/school/news/school-launches-blockchain-strategy-programme>

Estimates greatly vary depending on categorisations, methodology, and/or geographical reach. A McKinsey report projects losses of 400 million to 800 million jobs worldwide by 2030[204] and up to one third in the United States and Germany and nearly half in Japan. Other research estimates up to 47% of US jobs at high risk of automation in the next few decades[205]. And a recent OECD report indicates that 14% of jobs in 32 countries are highly automatable with a probability of automation of over 70%, and overall close to one in two jobs are likely to be significantly affected by automation, depending on the performed tasks.[206]. In this context, organisations might face significant challenges in providing workers' retraining and social protection as a result of restructured jobs or downsizings.

An in-depth analysis of opportunities and risks based on each company's business and regulatory context should be followed by an assessment of Blockchain technical feasibility. It entails a **functional and technical scoping of possible architectures** according to specific opportunities and risks previously identified[207]. Design choices for a Blockchain solution include its basic requirements regarding **governance and consensus mechanisms based on the type of public (and/or permissionless), private (and/or permissioned) or hybrid architecture**. Organisations would need to define who has permission to record or access the ledger, or validate transactions, that is, to clearly define the roles of each participant. Security and encryption requirements, for instance regarding management of digital keys (if they are hold by participants separately or managed by third parties) should also be carefully delineated.

A clear outline of **what, how and when data is shared and kept (on-chain for open access, or off-chain for restricted or local storage) across the network is essential**, also taking into account current regulatory frameworks for privacy and personal data, namely GDPR. Organisations should also consider their **requirements in terms of speed and number of transactions to be processed**, that is, the issue of scalability which for public blockchains at the present time is under considerable limits, although several solutions are under development.

After an assessment of available options and comparison of different architectures, organisations would ideally come up with their own **use case or prototype, under an exploratory mode with constant feedback loops** to monitor and evaluate their preliminary and final results. Building a customised Blockchain solution from scratch might require considerable investment in resources and IT capacity, also facing potential incompatibility with legacy IT systems which may need to be readjusted or completely revamped.

Another option would be to acquire platform and enterprise integrated solutions or 'Blockchain as a Service' (Baas), now being offered by a number of companies such as Microsoft, SAP, Oracle, Hewlett-Packard, Amazon and IBM. Consortia such as Hyperledger[208] (gathering organisations in finance, banking, IoT, supply chain, manufacturing and technology, including IBM) or Ethereum Enterprise Alliance[209] (joining enterprises, startups, academics, and technology vendors) are also developing among its members enterprise grade and open source DLTs across industries.

In sum, an overall assessment of opportunities and risks can be a burdensome and challenging exercise at the same time for most industries, businesses and SMEs. This is further complicated because there is no robust and/or freely available cost-benefit analysis or business impact of

[204] James Manyika and others, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, *McKinsey Global Institute*, 2017 <https://www.mckinsey.com/featured-insights/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages>.
[205] Carl Benedikt Frey and others, *The Future of Employment: How Susceptible Are Jobs to Computerisation?*, 2013 <http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf> [accessed 26 July 2016].
[206] Ljubica Nedelkoska, Glenda Quintini and Glenda Quintini, *Automation, Skill Use and Training, OECD Social, Employment and Migration Working Papers,* (Paris, 2018) <http://dx.doi.org/10.1787/2e2f4eea-en>.
[207] KPMG, Blockchain Consensus: Immutable Agreement for the Internet of Value, 2016.
[208] <https://www.hyperledger.org/members/join>
[209] <https://entethalliance.org/>

ongoing Blockchain pilots or initiatives[210], or the perception that large returns will take time and much depend on how the whole ecosystem develops to provide robust results[211]. Facing such uncertainties, at present organisations should try to the best of their ability to answer questions such as which Blockchain features or use cases are most relevant for their markets, branches or corporate divisions[212], how Blockchain could successfully be introduced to generate business value[213], or ultimately how their business models would need to be changed or redesigned.

[210] Marten Risius and Kai Spohrer, 'A Blockchain Research Framework: What We (Don't) Know, Where We Go from Here, and How We Will Get There', *Business and Information Systems Engineering*, 59.6 (2017), 385–409 <http://dx.doi.org/10.1007/s12599-017-0506-0>.
[211] Gartner, *Blockchain-Based Transformation: A Gartner Trend Insight Report*, 2018 <https://www.gartner.com/doc/3869696/blockchainbased-transformation-gartner-trend-insight>.
[212] Florian Glaser, 'Pervasive Decentralisation of Digital Infrastructures: A Framework for Blockchain Enabled System and Use Case Analysis', *HICSS 2017 Proceedings*, 2017, 1543–52 <http://dx.doi.org/10.1145/1235>.
[213] Roman Beck and Christoph Müller-Bloch, 'Blockchain as Radical Innovation: A Framework for Engaging with Distributed Ledgers as Incumbent Organization', 2017, 5390–99 <http://dx.doi.org/10.24251/HICSS.2017.653>.

6. Science for Policy Strategic Recommendations

Supporting Experimentation and Piloting with Simplified Requirements. A fast-paced, uncertain but at the same time promising space such as Blockchain requires more open explorations, for instance through the multiplication of high-risk prototypes, Proofs-of-Concepts (PoCs) and pilots in diverse areas and/or sectors. This would need, however, simplified mechanisms with higher level of funding and shorter time from calls for proposals to grant agreements, such as in SME Instrument. The purpose is to attract the best players currently put off by burdensome procedures, and to lower the barrier of entry for SMEs and entrepreneurs with limited administrative and financial capacity. Yet, real-time monitoring and evaluation with adequate follow-up should be in place to learn from setbacks, extract lessons and improve next rounds.

Building Upon Other Digitisation Initiatives and Programmes. The Blockchain space should be incentivized to connect with ongoing strategies for digitising industry, considering larger companies or SMEs. This is crucial to avoid duplications or overlaps in a crowded context already faced with problems of visibility and access especially for smaller players. Such choice could also help with policy integration and potential convergence of Blockchain with key industrial technologies, such as Internet of Things (IoT), artificial intelligence, robotics, 3D printing, or advanced materials and manufacturing. If done right, Blockchain companies could leverage on existing and new incubators / accelerators, innovation spaces and labs, digital innovation hubs, or competence centres. In this setting, not only larger industry and business players but also SMEs would be able to run experiments with this particular technology, helping to advance new economic and organisational models in integrated ways and from the ground-up.

Stimulating Knowledge Sharing and Collaborations Between Projects. Facilitating constructive and inclusive dialogues between Blockchain projects should help the space to achieve maturity and clear it of deceptive and / or volatile ventures. Priority should be given to free and open source models for developing research, platforms and protocols within a mix of public, private or hybrid consortia, alliances and programs. Technical developments should be embedded in robust and transparent governance frameworks, agreed across communities and involved stakeholders, including clear identification of responsibilities and decision-making procedures. Incentivizing sharing of results and exchange of best practices in decentralised ways for all players will be essential to scale up projects and maximize their impact across common sectorial and market boundaries.

Fostering Interoperability and Open Standards With Wider Engagement. Definition of interoperable protocols should be promoted at supranational level, so that Blockchain architectures don't end up siloed and unable to communicate with each other, as they grow in number and diversity. Lessons can be drawn from free and open source worlds where fragmentation often hampers adoption and investment return. Open standards should continue to be fostered by existing bodies and organisations as a main approach following multistakeholder, collaborative and consensus driven processes. Yet, a balance between, on one hand, the benefits of standards for cross-industry adoption and, on the other hand, concerns over premature adoption possibly validating untested technologies and / or solutions from influential members, should be further addressed. Dangers of platform or vendor lock-ins as barriers for innovation should be minimised by inclusive processes that would allow in practice smaller or newer players to fully participate in the development of open standards or other interoperability mechanisms.

Promoting Adequate Skills and Training Also Beyond Core Blockchain Spaces. Incentives to recruitment and / or development of programs to mobilise the best talent in the Blockchain space could be designed or built on top of existing European, national and local initiatives. Yet, taking into account the novelty of the space and skills shortage, these efforts should also create Blockchain expertise across a diversity of areas, from software engineering and development, cryptography and business strategy, to behavioural economy, law, design, and political and social science. There is no consensus over the future impact of digital technologies on jobs, let alone Blockchain's specific impact. It could be expected, however, to revamp a number of tasks and jobs across sectors. Adequate actions for upskilling or digital skills training, with attention to SMEs, should be further pursued, also building on present strategies for digital education.

Cultivating Wider Exchanges Between Policy and Blockchain Stakeholders. Capacity building and knowledge sharing between policy makers, regulators and supervisors, on one side, and Blockchain companies, startups and entrepreneurs, on the other side, should be fostered throughout the whole policy cycle. Aiming to surpass the crowded profusion of white papers, and to go beyond inflated expectations or vested interests, policymakers should engage directly with Blockchain companies with ongoing applications in order to understand the opportunities and challenges ahead. Environments such as innovation hubs and regulatory sandboxes should be welcomed if they are able to provide robust regulatory and supervisory guidance to companies, while also improving policymakers' knowledge and potential responses to innovative technologies, products and models. But requirements in current sandboxes such as consumer protection measures, or IT and cyber risk management, should also include comprehensive economic and social impact assessments. In this context, access to data by public bodies and/or independent researchers is essential to review progress, acknowledge pitfalls, and allow for anticipatory analysis.

Funding Blockchain Interdisciplinary and Problem-Driven Research. In order to strengthen the advance of Blockchain ecosystems in Europe, funding should be geared not merely to technological research, but also towards different areas of knowledge that could contribute to better tackle its current limitations while also revealing its potential opportunities. Regarding early stage and experimental technologies there is no question that basic protocols and platforms need to be further developed and optimised. But funding should target, however, specific challenges to be addressed, that is, start with external problems that need to be addressed and not with internal issues of the technology itself. In this sense, policy, economic, social, legal and environmental analysis of Blockchain's conditions and impacts would go hand-in-hand with any technology push.

Designing Stable Regulatory Frameworks for Better Policy Preparedness. Regulatory certainty around key issues in the Blockchain space should unlock opportunities for industries, businesses and SMEs to pursue experimentation within reliable environments. Concerns about over-regulation and its potential negative effects on innovation shouldn't translate into plain 'wait-and-see' approaches that miss the opportunity to shape and guide the development of this technology. Legal status of Blockchain features or applications such as tokens or smart contracts, together with compatibility in relation to EU regulatory frameworks such as privacy and data protection, should be the subject of in-depth yet swift scrutiny. This scrutiny shouldn't dismiss, however, possible need for reframing or reviewing present regulation, which despite its technology and business-neutral intention may end up in practice restricting the development of Blockchain as an emerging technologies with fundamentally new properties.

Championing Blockchain in Public and Governmental Sectors. Supranational, national, regional and local public sector organisations should further explore the potential for Blockchain-based applications to tackle specific challenges in their own activities. Blockchain could prove useful to improve efficiency and transparency of public services and how they are created and run for and with citizens and businesses, in cases such as identity management, business registration, property transfers, protection of personal and sensitive data, or taxation. Blockchain could also be used within trends or 'regulatory technology', that is, solutions for regulatory compliance in monitoring and reporting of public funds, environmental, safety and health standards, risk assessment, among others. What is more, multiplication of pilots and other projects in public and governmental sector could increase demand and steer the development of the Blockchain space towards specific problems, while also helping to legitimize and stimulate experimentation with Blockchain and other DLT based applications across private and commercially driven worlds.

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Annex

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