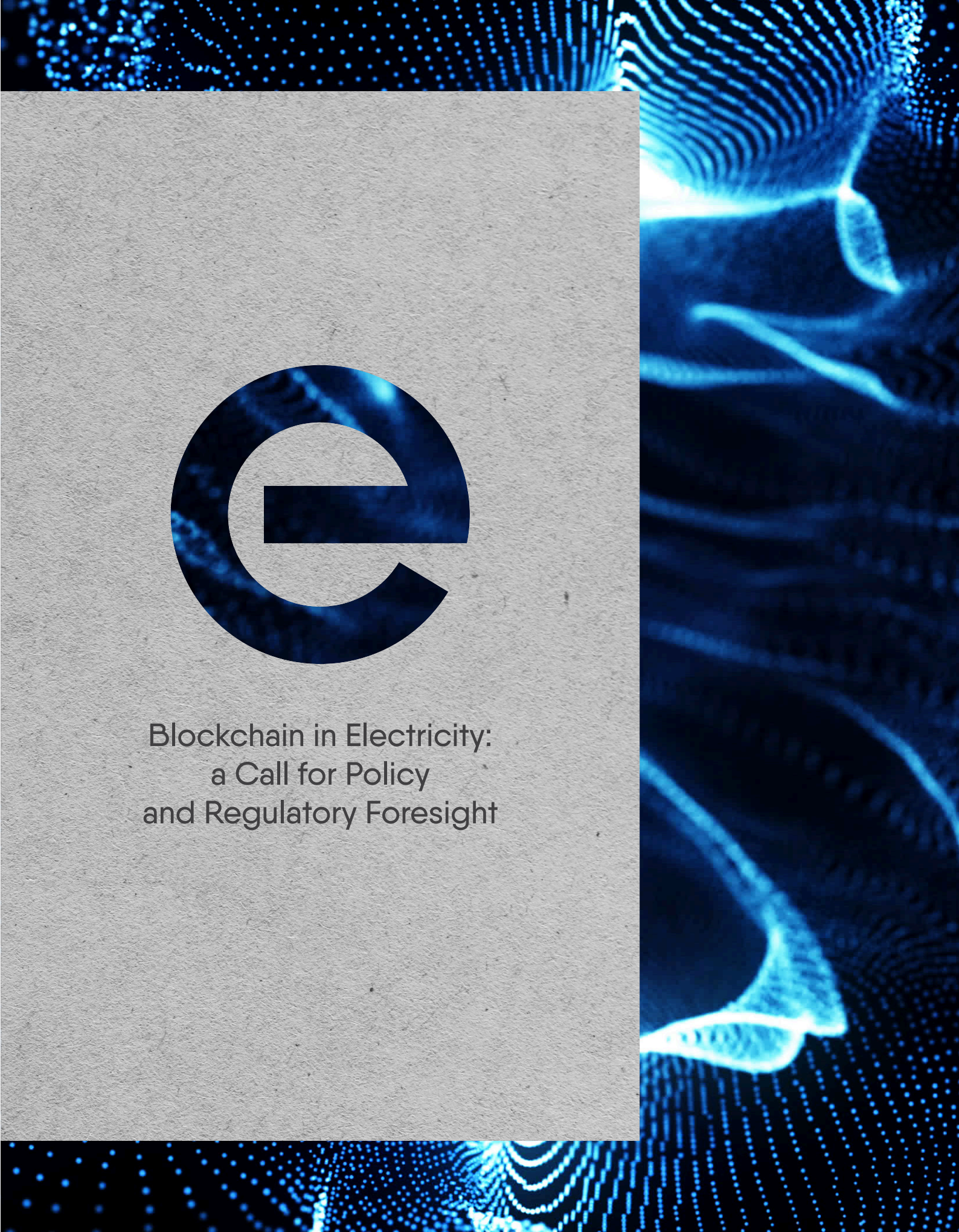

Blockchain in Electricity: a Call for Policy and Regulatory Foresight

DISCLAIMER

This report has been drafted by NERA Economic Consulting in close liaison with Zdenek Pekarek and members of Eurelectric's Blockchain discussion platform. It aims at taking stock of current developments with regard to the blockchain technology, as one of the various possible digital solutions in developing the future energy system. In so doing, the report aims at mapping out the challenges and opportunities linked to the use of this technology. Through this report, the Eurelectric Blockchain platform seeks to initiate further, long-term debates on the role of blockchain and other distributed ledger technologies in the future energy sector. The report provides a preliminary, fact-based, assessment of existing initiatives which allow the forward-looking energy consumers and utilities to better understand and navigate the potential offered by blockchain technology.

The report does not represent a formal Eurelectric position and should be treated as a White Paper, marking the direction and scope of future work on the topic.

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1. Introduction

The past year saw a marked increase in global recognition of blockchain technology and its potential applications. The number of projects using the Ethereum blockchain platform—designed to feature "smart contract" functionality—increased to well over 1,000.[1] Initial Coin Offerings (ICOs) have gained significant traction as an alternative to traditional venture capital funding: there were 210 ICOs in 2017 (compared to just 46 in 2016) that together generated more than €3 billion. In the first quarter of 2018, 166 ICOs generated €4.8 billion.[2]

In the electricity sector, there are over 120 organisations involved in blockchain-based applications and around 40 deployed projects globally. Between the second quarter of 2017 and the first quarter of 2018, a combination of venture capital and ICOs invested over €240 million in blockchain-based energy applications (with ICOs making up 75 percent of the total).[3] Blockchain technology has the potential to add value to the electricity sector but also poses risks and challenges to the sector.

As the blockchain ecosystem continues to grow, policymakers and regulators could play pivotal roles in unlocking its potential value and in safeguarding market participants and customers against its potential risks. With appropriate regulatory support, blockchain technology could drive significant value for electricity customers, distributed energy resource (DER) providers, wholesale market participants, and regulated electricity network operators—distribution system operators (DSOs) and transmission system operators (TSOs). On the other hand, left unregulated, blockchains could expose system operators' IT systems to unanticipated cybersecurity risks, and could develop in ways that undermine the efficiency of wholesale and retail electricity markets.

AS THE BLOCKCHAIN ECOSYSTEM CONTINUES TO GROW, POLICYMAKERS AND REGULATORS COULD PLAY PIVOTAL ROLES IN UNLOCKING ITS POTENTIAL VALUE AND IN SAFEGUARDING MARKET PARTICIPANTS AND CUSTOMERS AGAINST ITS POTENTIAL RISKS.

1 State of the ĐApps, https://www.stateofthedapps.com/ (last accessed April 24, 2018).
2 CoinSchedule, https://www.coinschedule.com/stats.html (last accessed April 24, 2018).
3 Metelitsa, C., "Blockchain for Energy 2018: Companies & Applications for Distributed Ledger Technologies on the Grid," GTM Research, March 2018.

This paper calls for European electricity policymakers and regulators to exercise foresight with respect to the development of blockchain technologies. Blockchains today represent immature technologies that are quickly evolving. Policy and regulatory support will be required to enable investors and entrepreneurs to continue to demonstrate blockchain applications in the power sector. Simultaneously, proactive consideration must be given to regulatory measures that minimise the potential risks and challenges. The paper is organised as follows. Section 2 briefly summarises the opportunities, limitations and risks associated with the development of blockchain technology in the electricity sector. Section 3 summarises European blockchain-related policy initiatives. Section 4 investigates regulation from the perspective of "customer journeys," stories of electricity sector participants in futures in which blockchain-enabled systems have come to replace certain electricity sector processes. Section 5 concludes with general recommendations for policymakers and regulators.

2. Blockchain in Electricity: Opportunities, Limitations, and Risks

Blockchain technology has the potential to be most immediately useful in sectors where there is no physical exchange, such as in the financial, banking, and insurance sectors.[4] In such sectors, blockchains can provide credible records of transactions without the need for verification of physical exchange. Of the sectors with physical exchange, however, the electricity sector is perhaps more susceptible than others to the integration of blockchain technology. Electricity travels at the speed of light and cannot be tracked between two points in an electricity network. Because of this, electricity markets are pooled—that is, electricity sales and purchases are cleared in aggregate on centralised trading platforms similar to stock exchanges and other financial market platforms.

Recent years have seen the emergence of blockchain-enabled projects that seek to enhance electricity sector markets and operations. Today, there are more than 120 organisations involved in such projects and about 40 deployed pilot projects.[5] These projects hope to find application in retail and wholesale electricity markets, peer-to-peer energy marketplaces, the provision of "flexibility" or balancing services, electric vehicle charging and coordination, network security, and markets for environmental attributes (such as renewable energy and carbon emission certificates). Table 1 summarises these potential applications, the opportunity they provide to the electricity sector, and project examples. These potential applications and projects are discussed in more detail in a companion paper, "Blockchain in Electricity: a Critical Review of Progress to Date."

Table 1: Opportunities for Blockchain in the Electricity Sector

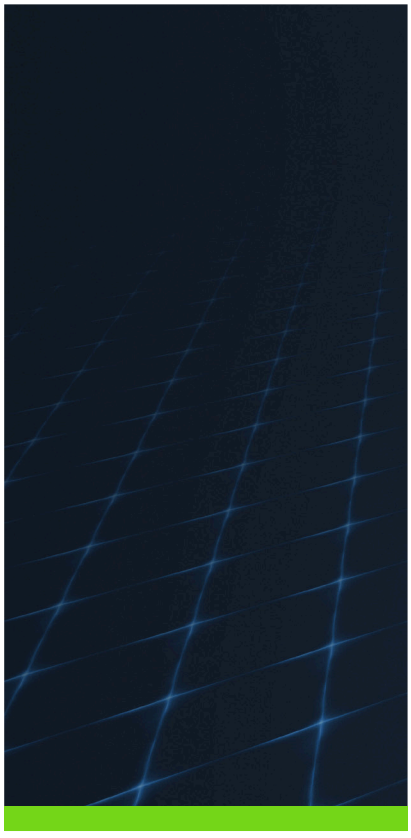
4 Indeed, those three industries comprise about half of all blockchain projects. See Hileman, G. and M. Rauchs, "Global Blockchain Benchmarking Study," Cambridge Centre for Alternative Finance, University of Cambridge Judge Business School, 2017.

5 Metelitsa, C. "Blockchain for Energy 2018: Companies & Applications for Distributed Ledger Technologies on the Grid," GTM Research, March 2018.

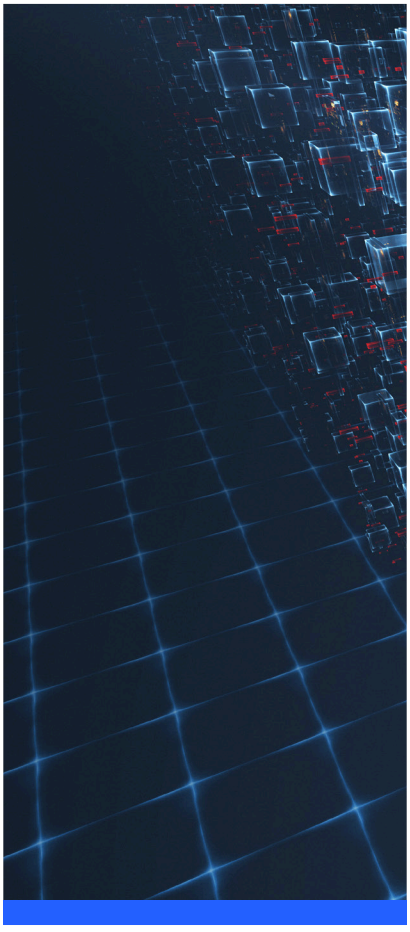
	OPPORTUNITY/ POTENTIAL BENEFIT	PROJECT EXAMPLES
Wholesale energy trading	– Reduce transaction costs in wholesale energy trading	– Enerchain (Ponton) – Interbit (BTL)
Retail electricity markets	– Reduce variable costs of retail payment processing and accounting – Greater transparency into billing – Fluid energy contract entry/exit – Greater customer choice of energy supply	– Drift – Grid+
Peer-to-peer marketplaces	– Relieve stress on transmission networks – Improve DER economics – Greater customer choice of energy supply	– Brooklyn Microgrid Project (LO3 Energy) – Jouliette (Alliander and Spectral) – Verbund and Salzburg AG
Flexibility services	– Improve TSO ability to balance supply and demand	– TenneT – Electron
Electric vehicle charging and coordination	– Improve DSO ability to coordinate electric vehicle load and discharge	– Share&Charge (MotionWerk) – eMotorWerks
Network management and security	– Improve DSO and TSO network management and security	– Keyless Signature Infrastructure (Guardtime)
Environmental attribute markets	– Improve efficiency and transparency of environmental attribute markets	– SolarCoin – Ideo CoLab

Blockchain is a new class of technologies with no scaled commercial projects in the electricity industry. As such, it remains burdened by technological limitations, risks, and challenges including high costs, unproven security, the lack of responsible parties, a lack of flexibility, and unresolved user-friendliness challenges. These limitations, risks, and challenges are summarised below.

- **Limited throughput:** A well known limitation of current public blockchains is their limited throughput, i.e. number of transactions processed per second. Limited throughput hinders the ability for blockchain applications to scale. High costs and slow speeds stem from energy-intensive consensus mechanisms and the maintenance of large distributed ledgers.



- **Unproven security:** Blockchains' security remain unproven until they have grown large enough to be attractive to cyber-attackers. Blockchains with bugs can last without evidence of attack if they are not valuable enough to entice them, and when attacks do occur the consequences can be large.



- **Lack of responsible party:** It is unclear who bears legal and technical responsibility for a blockchain when there are security breaches and other unforeseen events (such as an electricity price spike). Public blockchains are inherently decentralised and users are anonymous (or pseudonymous). Without central authorities or insurers, users are fully exposed to the risk of cyberattacks and other unforeseen events.

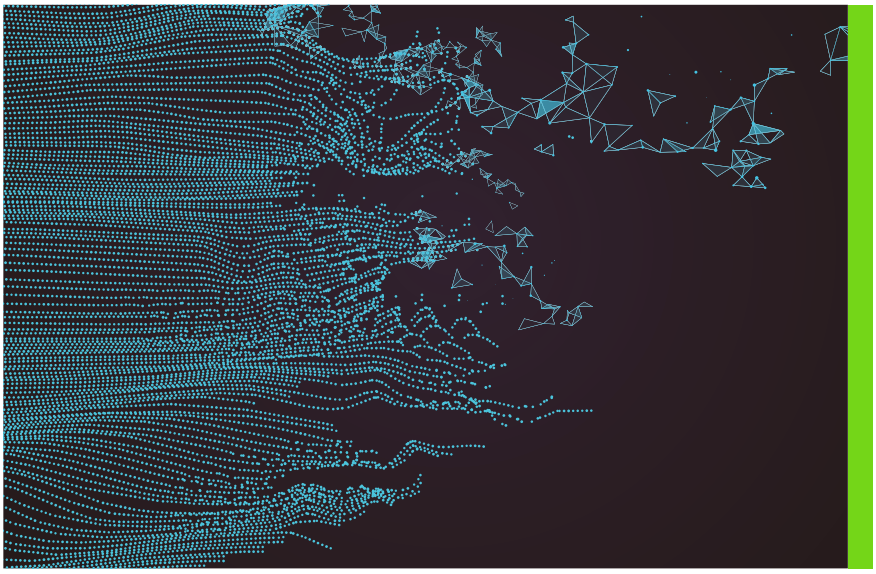
- **Lack of flexibility:** Once live, blockchains require significant stakeholder buy-in before large upgrades can be made. Without such buy-in, there are risks of disagreeing sub-communities "forking" their blockchains and becoming adversarial.

- **Unresolved user-friendliness challenges:** Users are required to safeguard their private key to participate in blockchains. If they lose their keys they likely also lose their digital assets. Moreover, maintaining user privacy requires that all data pertaining to that user is encrypted. Reliable, secure, and private accessibility can be challenging on a blockchain and is an active area of blockchain research.

These and other limitations, risks, and challenges are discussed in greater detail in a companion paper, "Blockchain in Electricity: a Critical Review of Progress to Date."

3. The European Blockchain Policy Landscape

European policymakers and regulators are engaged in several initiatives aimed at supporting blockchain technology development. These include efforts to standardise and build consensus around the development of blockchain technologies, the provision of funding for blockchain research and development, and efforts related to the financial technology sector that could improve crowd-funding opportunities for blockchain projects. National public-private initiatives are also underway, such as the Alastria initiative in Spain.



EUROPEAN POLICYMAKERS AND REGULATORS ARE ENGAGED IN SEVERAL INITIATIVES AIMED AT SUPPORTING BLOCKCHAIN TECHNOLOGY DEVELOPMENT. THESE INCLUDE EFFORTS TO STANDARDISE AND BUILD CONSENSUS AROUND THE DEVELOPMENT OF BLOCKCHAIN TECHNOLOGIES, THE PROVISION OF FUNDING FOR BLOCKCHAIN RESEARCH AND DEVELOPMENT, AND EFFORTS RELATED TO THE FINANCIAL TECHNOLOGY SECTOR THAT COULD IMPROVE CROWD-FUNDING OPPORTUNITIES FOR BLOCKCHAIN PROJECTS

3.1 Standardisation and consensus-building

As set out in its "Digital Single Market" policy strategy, the European Commission aims to develop a common approach to the development of blockchain for the EU.[6] On February 1, 2018, Commissioner Mariya Gabriel and Jakob von Weizsäcker (a Member of the European Parliament) launched the EU Blockchain Observatory and Forum.[7] The EU Observatory seeks to highlight key blockchain-related developments, promote European blockchain-related activity, and improve European engagement with stakeholders that are involved in blockchain-related activities. The company ConsenSys has been selected as partner to support the Observatory's outreach in Europe.

On April 10, 2018, 22 European countries signed a "Declaration on the establishment of a European Blockchain Partnership." The partnership is intended to encourage member states to exchange technical and regulatory experience with blockchain technologies and to prepare for the launch of EU-wide blockchain applications.[8]

Finally, the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) have created a new CEN-CENELEC Focus Group on Blockchain and Distributed Ledger Technologies.[9] The objectives of the Focus Group will be to identify potential specific European standardization needs and to support the current standardization activities being developed in ISO/TC 307: "Blockchain and DLT".[10]

6 European Commission, "Blockchain Technologies," https://ec.europa.eu/digital-single-market/en/blockchain-technologies (last accessed April 25, 2018).
7 European Commission, "European Commission launches the EU Blockchain Observatory and Forum," February 1, 2018.
8 European Commission, "European countries join Blockchain Partnership," April 10, 2018.
9 CEN/CENELEC, "CEN and CENELEC's new Focus Group on Blockchain and Distributed Ledger Technologies (DLT)," December 14, 2017.
10 International Organization for Standardization, "ISO/TC 307," https://www.iso.org/committee/6266604.html (last accessed April 25, 2018).

3.2 Research and development funding

Spanning seven years (2014-2020) and with a budget of €77 billion, Horizon 2020 is the largest EU research and innovation funding programme ever. Horizon 2020 provides funding to projects tackling research and innovation across many sectors, and there are several funding categories that blockchain-based projects can to apply to (some directly related to the electricity sector).[11] Funding categories that blockchain-based projects can apply to are listed in Table 2. More information about each opportunity can be found on the Horizon 2020 webpage[12] by searching for the "Call for Proposal" identifier listed in the third column of Table 2.

In addition to the funding categories listed in Table 2, the European Directorate-General for Communications Networks, Content and Technology (DG Connect) is launching a €5 million prize competition titled "Blockchains for Social Good." Prize money will be awarded to initiatives that attempt to develop solutions to social innovation challenges that leverage Distributed Ledger Technologies (DLTs).[13]

In total, the European Commission has provided €83 million in funding for blockchain-related projects and could commit up to an additional €340 million from 2018 to 2020.[14]

Table 2: Funding Opportunities for Blockchain Projects Through Horizon 2020

11 European Commission, "Topics of the Blockchain / DLTs Horizon 2020 Work Programme 2018-2020," http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=49017 (last accessed April 25, 2018).
12 European Commission, "H2020 Calls," https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/master_calls.html (last accessed April 25, 2018).
13 European Commission, "Blockchains for Social Good," https://ec.europa.eu/digital-single-market/en/news/blockchains-social-good (last accessed April 25, 2018).
14 European Commission, "Blockchain Technologies," https://ec.europa.eu/digital-single-market/en/blockchain-technologies (last accessed April 25, 2018).

FUNDING CATEGORY	HORIZON 2020 "CALL FOR PROPOSAL" TITLE	HORIZON 2020 "CALL FOR PROPOSAL" IDENTIFIER
Energy	TSO – DSO – Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation	LC-SC3-ES-5-2018-2020
	The role of consumers in changing the market through informed decision and collective actions	LC-SC3-EC-1-2018-2019-2020
Smart Mobility and Living	Interoperable and smart homes and grids	DT-ICT-10-2018-19
	Advanced technologies (Security/Cloud/IoT/BigData) for a hyper-connected society in the context of Smart City	EUJ-01-2018
Transport	InCo Flagship on Integrated multimodal, low-emission freight transport systems and logistics	MG-2-9-2019
Next generation Internet	Future Hyper-connected Sociality	ICT-28-2018
	Next Generation Internet - An Open Internet Initiative	ICT-24-2018-2019
	An empowering, inclusive Next Generation Internet	ICT-30-2019-2020
eGovernment	Transformative impact of disruptive technologies in public services	H2020-SC6-TRANSFORMATIONS-2018-2019-2020
eHealth	Digital health and care services	SC1-DTH-10-2019-2020
	Prototyping a European interoperable Electronic Health Record (EHR) exchange	SC1-DTH-08-2018
	Trusted Digital Solutions and Cybersecurity in health and care	H2020-SC1-FA-DTS-2018-2020
	Toolkit for assessing and reducing cyber risks in hospitals and care centres to protect privacy/data/infrastructures	SU-TDS-02-2018
	Raising awareness and developing training schemes on cybersecurity in hospitals	SU-TDS-03-2018
FinTech	Support to experimentation frameworks and regulatory compliance	ICT-35-2018
Other	Blockchain and distributed ledger technologies for SMEs	INNOSUP-03-2018
	Internet of Things	ICT-27-2018-2020

3.3 Crowd-funding opportunities

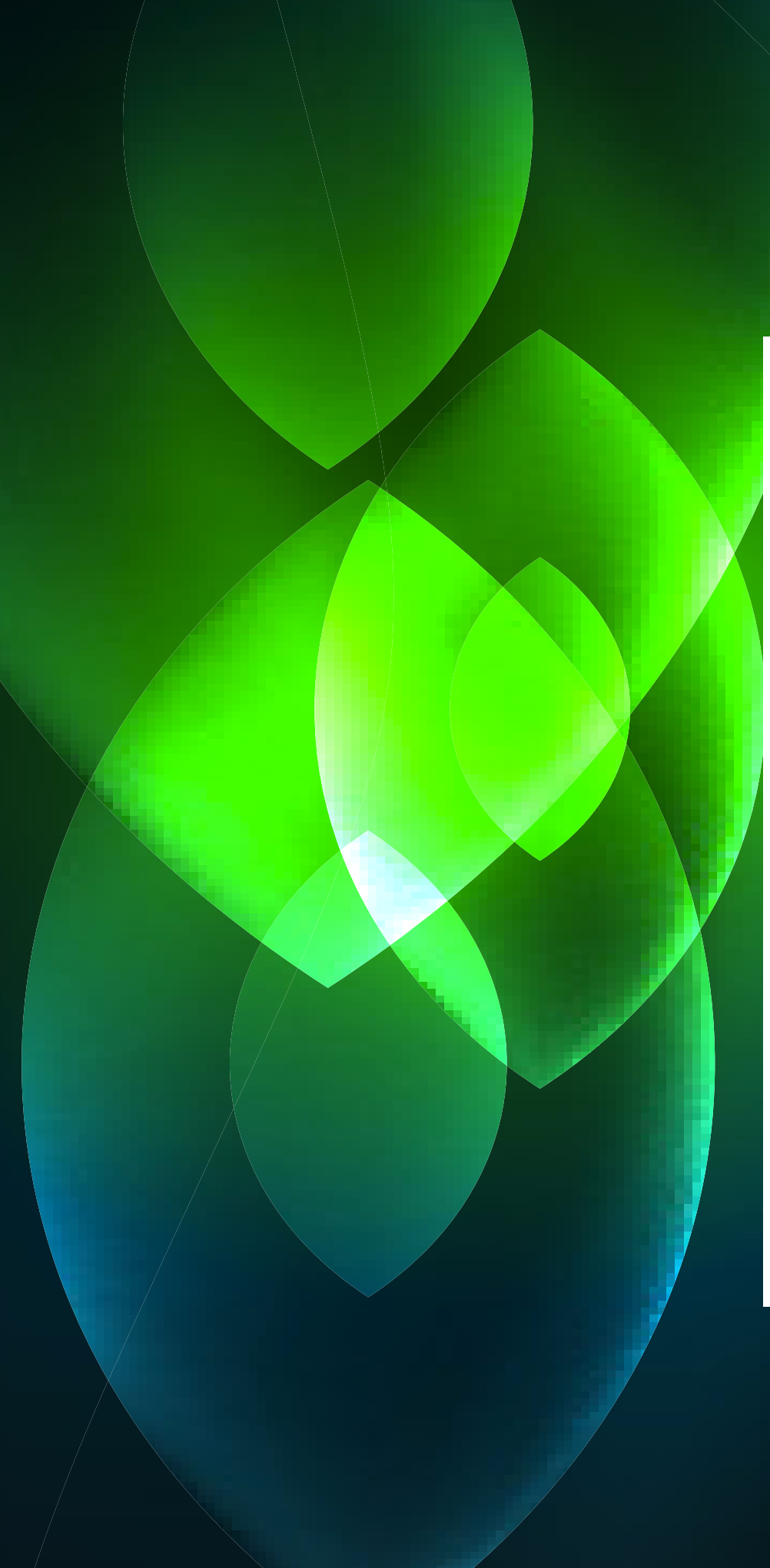
In March 2018, the European Commission set out a range of measures in the financial technology sector as part of its wider effort to wean the region's economy off its heavy reliance on bank funding. The European Commission's "FinTech Action Plan"[15] details several actions designed to support a more competitive and innovative financial market. The plan rests on three pillars: 1) to encourage innovative business models; 2) to support the uptake of new technologies, and 3) to increase security and integrity of the financial sector.

One of the proposed measures—the only one proposed as draft legislation—would introduce an optional, pan-EU regime whereby a crowdfunding platform that wants to operate across the EU could obtain a "passport" license from the European Securities and Markets Authority.[16] Crowdfunding allows start-ups to collect small sums of money from many individuals as an alternative to a bank loan, the main source of funding for small and medium sized companies. There are currently no EU-wide rules for crowdfunding; businesses and entrepreneurs must contend with a patchwork of national rules that can be costly. Under the proposed legislation, instead of having to comply with different regulatory regimes, platforms would need to comply with only one set of rules, both when operating in their home market and in other EU member states.

Blockchain-based startups, including those in the electricity sector, could benefit greatly from increased access to crowdfunding. This is particularly important for Initial Coin Offerings (ICOs), which are used as an alternative to traditional venture capital funding to raise money for blockchain-based projects. ICOs are blockchain-based, carried out via decentralised ledgers without financial intermediaries. They are conducted over the internet and are inherently "cross-border." Additionally, ICO initiators may not disclose their locations and in such cases are "stateless." In November 2017, the European Supervisory Markets Authority (ESMA) issued two statements[17] to inform investors of potential risks posed by certain ICOs and to remind firms involved in ICOs that these activities may fall under existing EU legislation, depending on their precise structure and characteristics. Authorities in the EU and across the world are evaluating ICOs and regulation that may be applicable to them.

BLOCKCHAIN-BASED STARTUPS, INCLUDING THOSE IN THE ELECTRICITY SECTOR, COULD BENEFIT GREATLY FROM INCREASED ACCESS TO CROWDFUNDING. THIS IS PARTICULARLY IMPORTANT FOR INITIAL COIN OFFERINGS (ICOS), WHICH ARE USED AS AN ALTERNATIVE TO TRADITIONAL VENTURE CAPITAL FUNDING TO RAISE MONEY FOR BLOCKCHAIN-BASED PROJECTS.

15 European Commission, "FinTech Action plan: For a more competitive and innovative European financial sector," March 8, 2018.
16 European Commission, "Proposal for a Regulation on European Crowdfunding Service Providers (ECSP) for business," https://ec.europa.eu/info/law/better-regulation/initiatives/com-2018-113_en (last accessed April 25, 2018).
17 European Securities and Markets Authority, "ESMA highlights ICO risks for investors and firms," November 13, 2017.

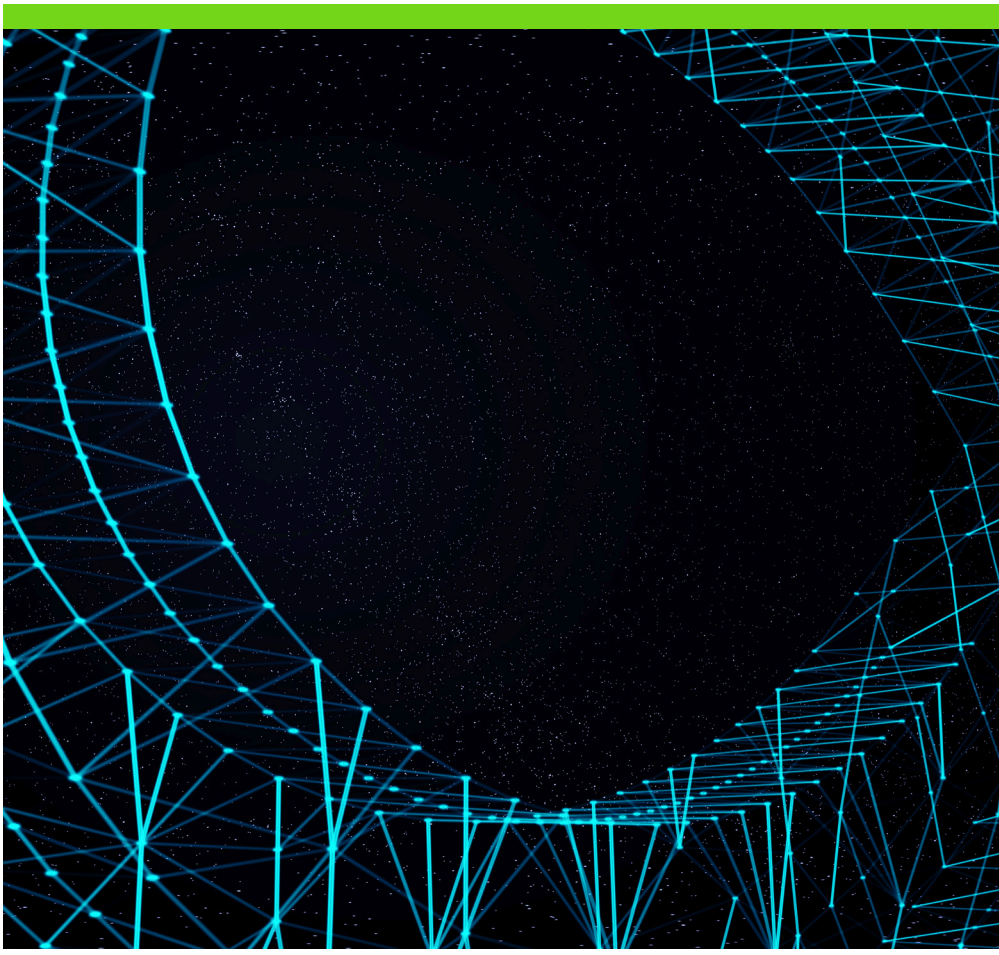


National Blockchain Initiatives: The Case of Alastria

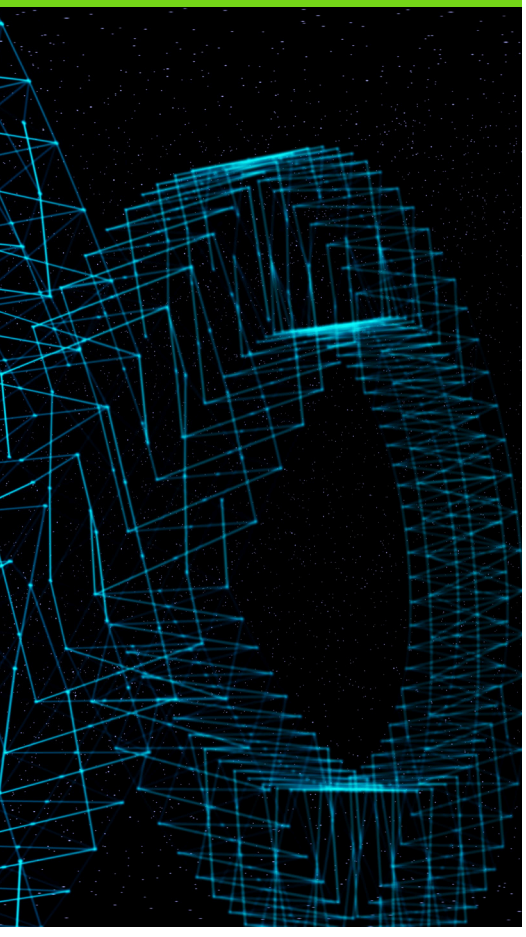
In addition to policy initiatives at the European level, some member states are involved in national blockchain-related initiatives. The Alastria network was announced in October 2017. It is a not-for-profit blockchain-based ecosystem comprising more than 150 Spanish firms and institutions including Endesa, BBVA, Banco Santander, Telefonica, University of Girona, University of Malaga, the University of Valencia, the Spanish Treasury, and others. The network will provide a standard methodology for information transfer across all consortium members by means of smart contracts, digital IDs, and data security protocols that are compliant with European regulations. The diversity of the consortium members (banks, universities, regulations, technology companies) will provide opportunities for developers to create apps that are interoperable across various sectors. One of Alastria's initial focuses will be on fostering a developer community that will use the platform to innovate.

4. Regulatory Insights from "Customer Journeys"

The following "customer journeys" are stories of electricity sector participants in scenarios in which currently tested blockchain-enabled systems have come to scale to production levels. In each scenario, an electricity sector participant is confronted with a decision or challenge that requires the use of blockchain technology and thus might raise regulatory questions. The stories illustrate the importance of regulation in enabling and steering large-scale blockchain applications.



4.1 “Here comes the sun”



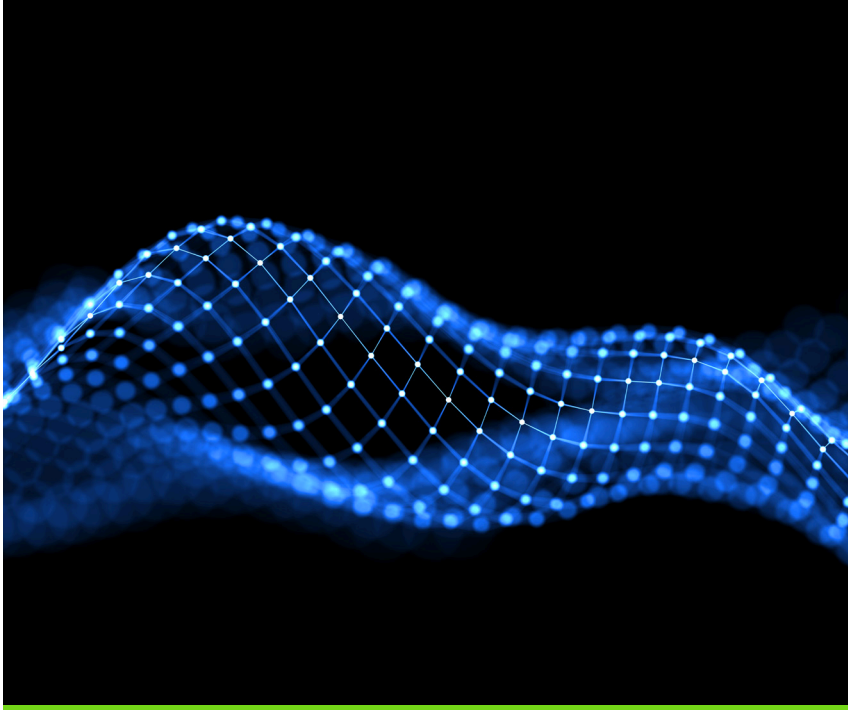
Tom enjoys helping his community, particularly now that he is retired. He has always been skillful with tools and his neighbours, younger by a generation, often invite him to help with home improvement. He typically refuses money as his main needs are remaining active and staying connected to his community. One day Marc, a neighbor with rooftop solar photovoltaic panels, shows Tom an app that is used to share renewable electricity with neighbours. In exchange for Tom’s help, Marc offers Tom a fixed share of solar energy during the following summer. Tom knows a young family in his community that could benefit from the solar energy. He gladly accepts Marc’s offer and transfers his share to the ledger associated with the smart meter of the family. The family uses the energy to power their laundry machines, air conditioners, and other appliances during sunny days, significantly reducing the family’s electricity bill.

Insight for policymakers: The combination of energy communities and demand response offer opportunities to strengthen social and energy systems, and to decrease bad debt and electricity system costs. Policy could allow for these exchanges to happen as they support the economic strength of communities, thus leading to improved citizens’ lives, economic growth and lower emissions. It is however important to keep incentives and responsibilities proportionate and fair for everyone.

4.2 “The ‘S’ in IoT stands for Security”

As Lucas enters the kitchen for morning coffee he steps into a puddle. The touchscreen of his first-generation smart refrigerator flashes with “SEND US 0.1 BITCOINS OR YOUR BEER WILL BE WARM TONIGHT!!!” He sighs and disconnects the WiFi that was distributing spam from the fridge to the internet. Hoping to avoid further cyberattacks of this type, Lucas shops for a new “blockchain-connected” refrigerator, with a highly secure, blockchain-based firmware-monitoring system. He finds a refrigerator and is reassured by the fact that it uses the same regulated hardware-wallet-technology as his bank and insurance company, based on a dozen redundant crypto-chips. He is further reassured by the fact that his utility installed a blockchain-enabled tamper-proof smart meter and an alarm system.

Insight for policymakers: The cybersecurity of “Internet of Things” (IoT) devices is of increasing concern. Innovative integration of blockchain with hardware might help to make such devices more secure. Regulation might establish minimal standards and require best practices for maintaining cybersecurity.



4.3 “DIY done right”

Maria is in the market for a heat pump for her parents. She finds a quiet heat pump unit with the parameters that she is looking for. It includes blockchain-based insurance that instantly requests a payout or repair order if sensors on the unit identify an equipment malfunction. Moreover, the heat pump supports blockchain-based cross-border demand response coordinated with the DSO, TSO, and aggregator, and is compatible with the seven-year-old smart thermostat in her parents’ home. Finally, Maria enlists her parents’ home in a utility-administered energy efficiency program with guaranteed energy costs savings; their electricity use is monitored and they are billed over a transparent and user-friendly blockchain-based app. Maria is not a technical expert but is reassured that due to EU standards, heat pump manufacturers frequently provide product updates for the lifetime of the product to ensure compatibility with EU-wide electricity sector standards.

Insight for policymakers: Energy equipment generally stays in use for much longer durations than smartphones, which quickly become obsolete. Setting standards and ensuring the long-term compatibility of appliances with other devices might help with the development of markets for demand response, DER, and energy efficiency programs.

4.4 “Candle-lit dinner”

Johanna and David are preparing their first holiday dinner for extended family. As David sets the oven the display reads, “Not enough green energy in the community battery.” Johanna opens a P2P community energy app and discovers that the recent cold spell exhausted the community battery and, moreover, contributed to nationwide energy prices as high as €3000 per megawatt-hour. At current prices, it would cost Johanna and David more than €100 for the 50 kilowatt-hours required for dinner. Fortunately, David owns a portable electricity generator that he and Johanna use to cook dinner—holiday celebrations “saved”! Johanna decides that next winter, she will support propositions within their P2P community to increase the reserve capacity of the community battery and to allow for automated demand response of certain appliances—all enabled by compatible blockchain-based apps.

Insight for policymakers: Energy communities will require adequate safeguards for resiliency against extreme conditions. These safeguards will need to be balanced against other priorities such as low energy costs and low CO2 emissions. Regulations to ensure appropriate levels of backup capacities might become necessary. Regulators may also act as “certification authorities,” permitting or not permitting proposed energy community rules.

4.5 “Fresh air in the mine”

Eva leads the Association of European Digital Industry, a role she accepted after founding a successful digital infrastructure provider. Her company started in late 2010s by providing secure and energy-efficient computing for specialized applications. The service offering became competitive with the dominant US and Chinese firms when electricity was exempted from taxes for high-tech computing purposes, similar to traditional energy-intensive industries. The company rapidly grew by starting with activities such as cryptocurrency mining and blockchain platform services, accompanied by rapid innovation in machine learning and artificial intelligence. Eva’s company benefited from sources of clean electricity, including hydro power plants, solar and wind farms.

Laura governs the region in which Eva’s company grew. Laura has been focused on reinvigorating the local economy. She oversaw the emergence of the local high-performance computing infrastructure, that induced adjacent innovation in advanced material science, 3-D printing, virtual reality, biotechnology, and cyber-research. New businesses were mutually augmented by the region’s communication infrastructure and academic environment, expanding the region’s economy.

As other regions benefitted from a similar industrial symbiosis, Europe was propelled to the forefront of global digital innovation, developing secure, scalable, and efficient systems. With shifts towards the economy of the fourth industrial revolution, progress was eased with the first step: granting the same tax benefits to industries that emerged in the 21st century as to the ones that shaped the 20th century.

Insight for policymakers: Demand for data centers for various purposes will increase exponentially with the advent of the fourth industrial revolution. In order to be competitive and to have a level playing field with other markets, policy needs to adapt in order to reflect the industrial nature of this business in analogy to current energy-heavy industrial production (e.g. steel, aluminium, etc.).

5. Conclusion

Blockchain technology presents both opportunities and risks for the electricity sector. It has potential to add value to electricity customers, evidenced by the amount of investment and number of active projects. Potential applications for blockchain tech span the entire electricity sector from local, retail, and wholesale electricity markets to network support services, electric vehicle integration, and environmental attribute markets. Nonetheless, blockchain technology poses significant risks to the electricity sector. In particular, blockchains are burdened by high costs, unproven security, the lack of responsible parties, a lack of flexibility, and unresolved user-friendliness challenges.

Policymakers and regulators have taken first steps to support the development of blockchain applications in Europe. These include European Commission efforts to standardise and build consensus around blockchain technologies, the provision of funding for blockchain-based pilot projects, and efforts related to the financial technology sector that could improve crowd-funding opportunities for blockchain projects. Nonetheless, as the "customer journeys" in Section 3 of this paper illustrate, continued and additional policy and regulatory foresight is required to enable blockchain technology to realize its potential without putting electricity customers at risk. To that end, policy and regulatory consideration should be given to:

Continued innovation funding: Through Horizon 2020, the European Commission has provided €83 million in funding for blockchain-related projects and could commit up to an additional €340 million from 2018 to 2020. The continued testing and piloting of blockchain projects will lead to important learning and enable the technology to continue to mature.

Regulatory "sandboxes": In addition to innovation funding, policymakers could consider the continued and increased use of "regulatory sandboxes." Regulatory sandboxes enable blockchain projects to expand in controlled environments that replicate features of the electricity system, coordinated with the relevant grid operators.

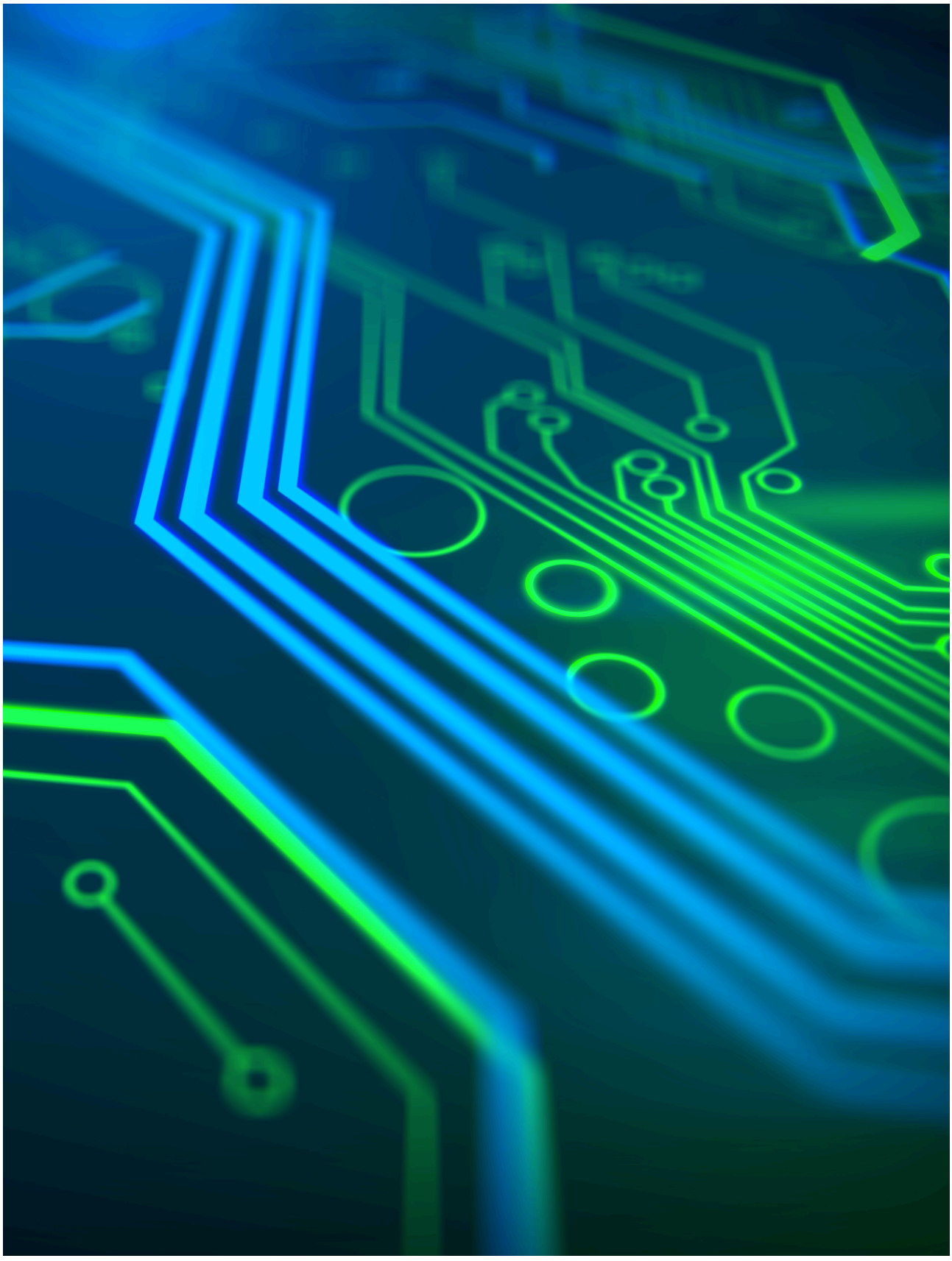
Standards and interoperability: Standard-setting for blockchain-enabled technologies will be an important part of future policy and regulatory efforts. Setting standards and ensuring the long-term interoperability of blockchain-enabled devices (appliances, thermostats, electrical meters, distributed generation equipment, etc.) with other devices, might help with the development of markets for demand response and DER and other power sector objectives. Establishing standards for interoperability across industries will also be critically important as the power sector becomes more enmeshed with adjacent sectors such as the transportation, heating, and other sectors. Yet, before technological standards can be set, significant additional testing and piloting is required to allow blockchain technologies to mature. In addition to technological standard setting, regulators might also consider setting "blockchain responsibility" standards. It is unclear who bears legal and technical responsibility for the blockchain when there are security breaches (e.g. loss of keys, errors in blockchain updates, smart contract malfunction) and other unforeseen events (such as electricity price spikes). Without standards on liability that solve the "blockchain responsibility problem,"[18] users are fully exposed to the risk of such events.

Safeguards against security risks: The security of a blockchain or blockchain-enabled application is unproven until it has grown enough to be attractive to cyber-attackers. Thus, from a security perspective, emerging blockchain technology in the electricity sector would do well to either: (1) grow slowly and organically over time so that software can mature before significant value is stored, or (2) piggyback off of existing general purpose blockchains that have a track record of security. Policymakers and regulators might help facilitate either of these paths by, for example, setting up a regulatory stage-gate-process in which a particular application is not permitted to grow until it has proven its security (and, of course, its economic value) in a smaller-scale "sandbox".

The pros and cons of a common (EU-wide) versus many interoperable blockchains. There is currently no consensus about whether a common (EU-wide) blockchain, or many interoperable blockchains, is the best way forward. On the one hand, an EU-wide electricity sector blockchain could benefit from significant economies of scale. For example, it may prove more costly for a DSO to interact with many blockchains than with a single one in performing grid operation and market functions. Organisations such as the European Distribution System Operators' Association (EDSO) and the newly-created "EU DSO Entity"[19] could help DSOs coordinate their use of blockchain applications. On the other hand, introducing a common blockchain for electricity in the near future poses challenges and risks that policymakers should be wary of. For instance, blockchain technology is still not mature and it would be very difficult to establish consensus on even the most basic technological parameters. Moreover, electricity sectors within the EU are not uniform but rather vary considerably in their characteristics and policy priorities. A blockchain that might work well in one system might not in another, for example because that system experiences high electricity theft and/or has regulations that do not allow peer-to-peer energy trading.

18 As Blockchain is decentralised, liability cannot be clearly assigned to a given party.

19 Eurelectric, "DSO Entity," https://www.eurelectric.org/media/2451/dso-entity-finaldocx.pdf (last accessed April 25, 2018).



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