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POLICY BRIEF

The Digital World Knocks at Electricity's Door: Six Building Blocks to Understand Why

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Highlights

• Digitalisation is invading the electricity sector. How will it play out? Six building blocks, grouped into three categories, can provide the analytical framework required to navigate through the emerging digital world and the transformations that are taking place in the electricity sector.

• Digitalisation builds on changes in infrastructure. Billions of digital devices interconnected by the internet provide the facilities to access the digital world and the multitude of digital products (*building block one*). Digitalisation also transforms physical networks in other industries and make them smarter, either to perform existing activities or to offer new and more interactive services (*building block two*).

• Digitalisation involves changes in markets too. A growing number of products are purely digital and the platforms providing them cannot be bypassed by consumers (*building block three*). Other digital platforms operate in two-sided markets: they do not create the product but act as intermediaries facilitating interactions between the sellers and the buyers of goods and services that are not necessarily digital (*building block four*).

• Digitalisation is a transformative process whose frontier is constantly moving. New technologies like the blockchain can offer disintermediated peer-to-peer transactions to digital communities (*building block five*). On the contrary, artificial intelligence and the Internet of Things can become unavoidable and automated intermediaries, replacing direct human involvement in thousands of decisions concerning the management of vast sets of assets (*building block six*).

Introduction

Digitalisation is one of the main trends of today's world. A clear understanding of its implications for markets, business models and public policies is still in the making.

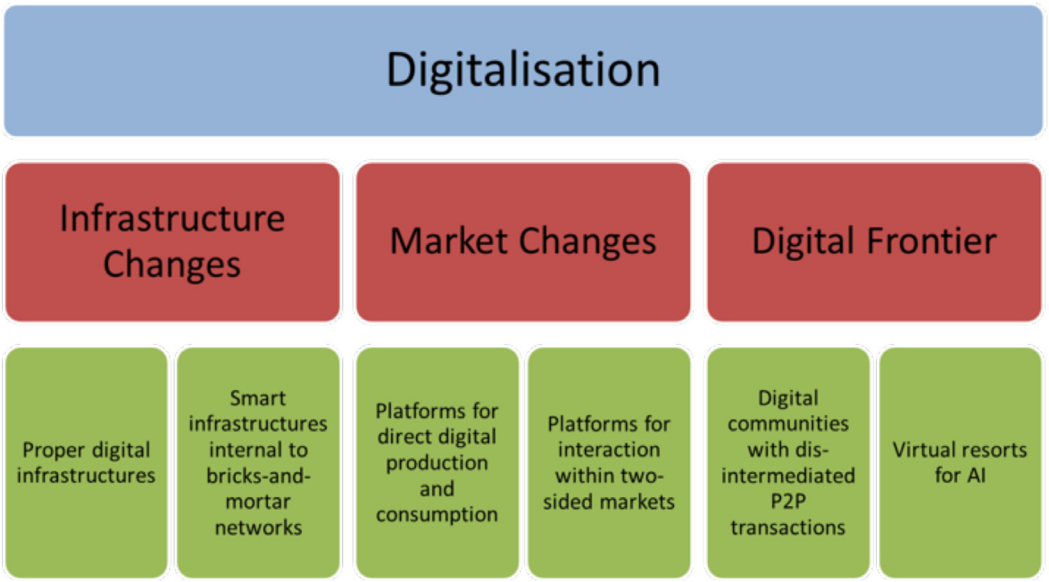
In this policy brief, we identify six fundamental building blocks that are driving digitalisation, and that can be used as an analytical compass to map the changes occurring in the electricity sector. They are (see Fig. 1):

1. infrastructure changes, which encompass the deployment of proper digital infrastructures, and the deployment of smart infrastructures internal to bricks-and-mortar networks;
2. market changes, which include the platforms for direct digital production and consumption, and the platforms for interaction within two-sided markets;
3. the digital frontier, which encompasses digital communities with disintermediated peer to peer (P2P) transactions, and virtual resorts for artificial intelligence (AI).

Building Blocks One and Two: Infrastructure Changes

The first building block is the deployment of "proper digital infrastructures" with the capability to transform data and pieces of information into series of zeros and ones that can be read, processed, combined, stored, transmitted, received and injected into a decision-making process, be it automated or managed by a human. This deployment started in the 1960s and 1970s with the early, expensive, disconnected and not user-friendly mainframes. It accelerated in the 1980s and 1990s with the first personal computers and the birth of the "internet", linking all the local digital networks. It is now proceeding at full speed with the introduction of billions of smartphones and tablets, plus optic fibre cables, Wi-Fi, 3G/4G wireless channels and cloud computing. This set of infrastructures, so different from that of 30 years ago, is ubiquitous and, in a sense, universal: internet and the Android-iOS duopoly are interconnecting all the various "particular universes" of different devices, software and alternative operating systems and making them interoperable.

Fig. 1: The Six Building Blocks to Understand Digitalisation.



Although essential, proper digital infrastructures are not the full story. Digitalisation also entails the deployment of "smart infrastructures internal to bricks-and-mortar networks". The following example is striking. Over the past decades, airline companies have digitalised their physical activities by enabling the sale of tickets and the fulfilment of check-in procedures online; they have also equipped their aeroplanes with sensors and control devices, making things such as predictive maintenance and automatic piloting possible. All of this represents a form of "back-office digitalisation", where physical assets and their operation become smarter and may allow better and cheaper delivery of pre-existing services. However, smart infrastructures can also re-frame the way assets are managed and used in the production process, ensuring the delivery of innovative and highly customised services not available before. A case in point of this more "transformative digitalisation" is the home delivery loop for online shopping that companies like Amazon have developed thanks to the full integration of digital technologies in their warehouses and distribution fleets.

These infrastructure changes allow growing interconnection and interactivity, cost reductions, increases in service quality and safety, more targeted offers and innovative solutions appreciated by customers. At the same time, they also pose privacy and cybersecurity threats and raise, in combination with the market changes described below, issues such as customer discrimination, market power and concentration.

Implications for the Electricity Sector

Computer terminals, price algorithms and the internet have already changed the electricity sector in the 1990s, by enabling the development of the first wholesale markets, as the Power Pool in Britain or PJM in the US, and their effective combination with system operation.

Sensors and control devices have been deployed on top of electricity grids, first at the transmission level and later at the distribution one. They form the by now traditional smart grids which look more like back-office digitalisation of the classical electricity system and markets. Smart grids and smart meters "1.0", for instance, allow distribution companies and energy suppliers to reduce the cost of metering consumption and to detect electricity thefts better. They do not create a universal, interconnected space of operation, and – more importantly – they do not offer radically new services or personalised options to consumers.

A new wave of smart grids and meters is now coming.[1] It is conceived to address radical novelties that are popping up, such as distributed generation, decentralised storage, micro-grids, electric vehicles, smart buildings and cities. This "smart grid 2.0" may lead to a profound transformation of the business model of electric utilities. However, progress so far has been slow – most of the smart meters being rolled out are still relatively "dumb." Meanwhile, the digital revolution seems to be brewing somewhere else: instead of the public grid, it may target the space "behind the meter" and disrupt the traditional system from there.[2]

Building Blocks Three and Four: Market Changes

Digitalisation brings profound novelties for markets. New trade arrangements and marketplaces emerge online when the production and consumption of digital products become more important and

1. Vadari S. (2018), *Smart Grid Redefined. Transformation of the Electric Utility,* Artech House.

2. See below the implications, for the electricity sector, of digital communities and virtual resorts for artificial intelligence.

valuable in economic terms. The key concept here is that of platforms which come in two types.[3]

The first type is represented by 'platforms for direct digital production and consumption'. Digital products are provided to and consumed by the users directly on the platforms. Classic examples are internet search engines, e-mails and instant messaging, online voice calls, data storage, digital maps, e-books and e-journals, online videos and audio tracks, etc. Providers may be for-profit organisations or not, like Wikipedia, and consumers cannot bypass them to access the "ready to use" digital products: they can, at best, replace one specific provider with another (e.g., substitute Gmail with Yahoo! Mail). Within this category we distinguish:

- 'fully centralised' platforms like Google Search and Google Maps, where the digital provider is the only producer of the product being consumed on the platform;
- 'half decentralised' platforms like Gmail, Twitter, Instagram or Wikipedia, where users interact to co-produce the digital product being consumed within the digital frame provided by the platform.

In the digital world, other platforms are 'platforms for interaction within two-sided markets'. They do not produce anything to be consumed directly on them, but act as specialised intermediaries, bringing together buyers and sellers of goods and services that are not necessarily digital. These platforms for interaction offer a digital marketplace, permitting to display/search for a particular product, to present/identify the product characteristics, to select/locate a trading partner that can be trusted into the delivery and settlement process, etc. Here again, we distinguish:

- 'low interaction' platforms which operate as a search engine coupled to a "home delivery loop" (typical of Amazon) or to a "direct online use" (as it is the case with Apple Music and the Apple App Store);
- 'high interaction' platforms which address, via sophisticated information and incentive mechanisms, the deadlock between buyers and sellers that George Akerlof – Nobel laureate in economics in 2001 – identified as frequently arising due to information asymmetry and transaction costs.[4] These high interaction platforms represent the backbone of the sharing economy and allow companies like Airbnb or BlaBlaCar to thrive.[5]

Implications for the Electricity Sector

Digitalisation clears a path towards new arrangements for electricity trade. It did so 30 years ago when the previous wave of digitalisation made the establishment of wholesale markets feasible. It is doing so again today. First, we have online retail via digital apps, where a customer can sign a supply contract and pay its bill entirely online. These applications look like the centralised digital platforms for direct production and consumption. They represent an interesting novelty, although it is not yet clear whether online suppliers with a light asset base can survive competition from more traditional market players.

Aggregators embody the next big novelty. They act as digital intermediaries, centralising the interactions between the wholesale market and the demand

3. Our use of the word "platform" is more intuitive and broader than that typically adopted by the literature on two-sided markets and network effects. See, among the several books on platforms, Choudary S.P. (2015), P*latform Scale: How an Emerging Business Model Helps Startups Build Large Empires with Minimum Investment*, Platform Thinking Lab, 2015.

4. Akerlof G. (1970), The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *Quarterly Journal of Economics*, vol. 84, no. 3, pp. 488-500.

5. Tirole J. (2017), *Economics for the Common Good*, Princeton University Press, 2017; Sundararajan A. (2016), *The Sharing Economy: The End of Employment and the Rise of Crowd-Based Capitalism*, MIT Press.

for balancing, or between the grid operators and the consumers. By aggregating the demand response or the electricity production of thousands of grid users, they reduce transaction costs and make possible exchanges that individually are not economically sensible.

Platforms for two-sided markets are possible and are emerging too. Although still at the demonstration stage, electric utilities in New York are developing distributed system platforms. Following the roadmap for "open grids" issued by the state authorities, they aim to provide a marketplace where buyers and sellers can manage, as they wish, their affairs for a full range of new products.[6] Going one step further, high interaction platforms could emerge and create trust among users, thereby making P2P transactions related to self-produced energy, decentralised storage, electric vehicle charging stations and the like possible.

Building Blocks Five and Six: the Digital Frontier

The last pair of building blocks represents the digital frontier, something more notional, being on the edge of both practice and knowledge. Nevertheless, so many radical innovations have already become a reality in the 21st Century that we should not restrain ourselves from looking in this direction.

Our fifth building block is "digital communities with disintermediated P2P transactions". Scholars like Elinor Ostrom – Nobel laureate in economics in 2009 – have shown that communities play a significant role in the economy and are as important as markets, companies and the state.[7] Under certain circumstances, individuals can and do eliminate intermediaries and third parties from their direct economic relations, relying instead on a community for the management of a common resource or the trading of a product. Recently, new technologies like the blockchain promise to make the possibility of direct P2P trading universal, without a central clearinghouse or intermediary. The beauty of the distributed ledger at the heart of the blockchain technology is its ability, thanks to abundant computing power and sophisticated cryptographic software, to trace all the direct P2P trades or any other form of transaction among the participants to the same blockchain network. All the members of this type of community are then able to verify whether a transaction occurred or not and whether or not the parties were entitled to make it.[8]

Once fully developed, pure blockchain networks pledge to generate the trust necessary to support economic relations among individuals, no longer resorting to private intermediaries and public third parties. However, the jury is still out and some scholars believe that the magnitude of the transaction costs associated to the use of the blockchain – e.g., the time and energy required to validate a transaction or manage errors and misinterpretations among a large number of parties – may limit the scope of the services offered by that type of networks and exclude their application to certain goods and

6. See, as an example, Consolidated Edison (2018), *Distributed System Implementation Plan*, available at: https://www.coned.com/-/media/files/coned/documents/our-energy-future/our-energy-projects/distributed-system-implementation-plan.pdf?la=en. The roadmap of the New York authorities was first presented in: New York State Department of Public Service (2014), *Reforming the Energy Vision*, case 14-M-0101.

7. Ostrom E. (2012), *The Future of the Commons: Beyond Market Failures and Government Regulations*, Institute of Economic Affairs, London.

8. Tapscott D. and A. Tapscott (2016), *Blockchain Revolution: How the Technology Behind Bitcoin is Changing Money, Business and the World*, Penguin.

services.[9] These concerns explain why less radical and more realistic blockchain networks appear attractive. By performing trades within a community of trusted peers, with an implicit or explicit set of rules and common governance, the complexity of pure blockchain networks can be reduced, and their operation simplified. Indeed, this hybrid form of blockchain is appreciated, and several companies and organisations are deploying private networks to deal, for instance, with subsidiaries and suppliers.

Beyond pure and hybrid blockchain networks, other types of communities can be built thanks to digital technologies and act as larger and less strictly organised entities with multiple purposes; examples include energy communities and smart cities.

The last building block to understanding digitalisation is somewhat intuitive, although not yet used as a concept by academics or practitioners. A 'virtual resort for artificial intelligence' is a space where a human being surrenders its autonomy to the algorithms behind the AI. The human, be it a producer or a consumer, can at best set some parameters. Then, it is the AI, not the human, to take the decisions and manage the assets within the boundaries of the resort, according to the rules and procedures defined by its developer. While intermediaries are no longer needed in a digital community with disintermediated P2P transactions, a virtual resort for AI promises the replacement of people with machines: within it, decisions and actions by the users cease to be necessary.

Resorts for AI can be 'single purpose', where the device benefiting from the AI has a specific goal to achieve in the best possible way (think of a driverless car), or 'multi-purpose', where AI is in charge of various goods and services, delivered by the operation of a set of interactive devices (think of a smart home). The Internet of Things is key to the development of multi-purpose AI resorts, while virtual personal assistants like Alexa from Amazon already show how to transform any human dialogue or interaction with the device into an AI automated, 'smart and learning' decision-making process.

Implications for the Electricity Sector

By creating the trust necessary for transactions to take place, pure blockchain networks or hybrid solutions developed within communities pledge to end the need for intermediaries and enable truly decentralised, P2P trade of electricity and other scarce products like green energy 'certificates'.[10]

In general, people can perceive renewable energy sources, distribution grids, storage assets, electric vehicles and the like as scarce local resources in need of a community approach and community governance. Digital technologies can support this perception and allow communities to manage and control the growing amount of assets located behind the meter.[11] The development of micro-grids, smart neighbourhoods and cities are among the many variants in which this possibility can materialise. Their impact on the current organisation of the electricity sector will be far from trivial.

Shortly, we could also see the flourishing of virtual resorts for AI just behind the meter of the public utility. Consider EVs and fleets of self-driving cars: sophisticated software will manage the batteries and interactions with the electric grid, charging or discharging the vehicles depending on the price of electricity or the system conditions. The input from human users will be reduced to the minimum, while

9. Arrunada B. (2018), Blockchain's Struggle to Deliver Impersonal Exchange, *Minnesota Journal of Law, Science and Technology*, vol. 19, no. 1, pp. 55-105.

10. An overview of the early application cases of blockchain technology to the electricity sector can be found in Livingston D. et al. (2018), Applying Blockchain Technology to Electric Power Systems, *Discussion Paper*, Council on Foreign Relations.

11. Boorsma B. (2017), *A New Digital Deal. Beyond Smart Cities. How to Best Leverage Digitalization for the Benefit of our Communities*, Boekscout BV.

the fleet will be professionally managed with algorithms as an integrated business. Similar instances will occur with smart buildings and distributed generation. People living in a smart building or owning a distributed generation unit will not be required to do much, as AI will take control of the various interconnected energy appliances and generation units, with the goal of optimising the use of local resources or minimising the overall cost of the energy service. Net-zero energy buildings that are mandated in jurisdictions like California from the next decade onwards will probably have to work in this way.

The establishment of these virtual resorts for AI can turn the electricity industry upside-down. Given the amount of energy consumed or stored by a fleet of thousands of EVs or given the amount of power that thousands of smart buildings can inject or withdraw from the public grid, it is likely that the companies developing and controlling these virtual resorts will play a major role in the electricity sector of tomorrow.

Conclusions

Digitalisation creates new opportunities and risks that consumers, companies and public bodies are obliged to confront. To navigate through such uncertainty, we need references that help us understand how the world is changing around us. The six building blocks presented in this policy brief are just that. Not a fully-fledged theory about digitalisation but rather a toolkit to identify the key issues at stake and where we might go in the future.

Digitalisation involves a concurrent set of changes in the infrastructure and market arrangements that we rely upon to produce, exchange and consume a large number of goods and services. Even more, digitalisation looks so transformative that it may herald, at least in some instances and under certain circumstances, the end of the traditional intermediaries and the active role of customers.

Electricity is no exception. The sector first experienced digitalisation 20 to 30 years ago, but now a second wave is on the verge of unleashing new and profound changes. A revolution at least as radical as that represented by the creation of wholesale markets in the 1990s seems to be in the making. The six building blocks provided in this brief can be successfully applied to the sector, allowing consumers, companies, regulators and policy-makers to understand what digitalisation means for them, and to better prepare and manage the inevitable changes it will bring.

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