Open Energy Marketplaces evolution

Beyond Enabling Technologies

March, 2021

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1 MAIN HEADLINES

The Recovery Plan for Europe will offer attractive opportunities for the digitalisation of the energy system, facilitating not only energy sector transition and transformation but also growth and job creation. Developing open energy marketplaces is at centre stage in this effort.

Scaling up of services across EU markets is imperative for the viability of the underlying platforms and services. The scaling up, on the other hand, will be possible only through significant investment in distributed digital infrastructures, data spaces and enhanced connectivity. Clear rules and a favourable environment are key to allow the required financing of those investments.

The paper identified several general dimensions to activate marketplaces development:

- Ensuring that the market design is fit to send the appropriate market signals for consumers to adopt and engage with these innovations
- User experience and interoperability are key to scale-up the innovations
- Fostering an innovation-friendly culture
- Public sector participation as an active energy prosumer through publicly owned buildings and sites that may contribute to fostering open energy marketplaces
- The enabling technologies are at high TRL level, dynamically evolving
- Governance is key for scaling up and integrations with market actors and grid operators

To operationalize the activation of transitions, the paper points at:

- Designing measures to channel private finance to the required infrastructure. Public policies have a role to play in this. The objective is allowing matchmaking between private sector finance and green and digital infrastructures
- Supporting Research & Innovation activities aiming at increasing the maturity level of the solutions (above TRL5) based on the use case approach
- Designing spaces where regulatory and policy experimentation can happen.
- Further experimentation needs to address three layers:
- Experimentation on data exchanges and interoperable interfaces
- Experimentation to define standard clauses for automated long-term contracts, and to study financial aspects associated with them, such as the bankability dimension
- Experimentation to identify and measure potential anti-competitive behaviours.

Experimentation will require methods to measure the results of the experiments. Standardizing measures/indexes to monitor the evolution of and potential barriers caused by current market designs and financial structures are of considerable importance. Hence, the efforts in the design of indicators would need to address three dimensions:

- Monitoring the ability of consumer-side players to find the required financial resources to undertake investments in assets for open marketplaces (bankability of demand-side projects)
- Contract clauses: How to map risk bearing among participants in an open energy marketplace, particularly in terms of conflict resolution
- Providing insight on the ability of consumers to decide on the development of the energy systems.

2 BACKGROUND AND SCOPE OF THE PAPER

This paper aims at sharing developments within evolving Energy Market places concepts and visions based on the input from contributing organisations, such as AIOTI, ENTSO-E and EIT InnoEnergy and SDA Bocconi Sustainability Lab and workshop outcomes, which were organized by the European Commission DG CONNECT and DG ENER through 2019-2020. The workshops tackled opportunities of smart energy services based on IoT for connected appliances, smart mobility, P2P energy trading and smart utilities. The main questions debated were "What are the needs and enabling technologies, what is an open energy marketplace and how regulation could support the development of such a concept into reality?".

Reflecting on the EU Industrial strategy aiming to lead the twin transitions towards climate neutrality and digital leadership introduced in 2020[1], in the energy sector, digitalisation is expected to help keep the transmission grid stable by balancing reserves from intermittent sources like wind and solar, facilitate decarbonisation of production and flexibility of demand and supply services. Consumers are placed at the centre of this transition. At the micro-level, connecting objects through the Internet of Things (IoT) makes every electric device a contributor to the energy system by bundling distributed energy resources into larger ecosystems, while consumer acceptance and adaptation of the new business models and services are instrumental to successful implementation. Active role of prosumers, their ability to participate in energy markets, provide services and generate value are fundamental to the success of these concepts development.

The main questions addressed in the paper are the identification of the fundamental building blocks necessary to unlock open energy marketplaces while providing the context and recommendation for the next steps in the efforts currently undertaken. Policy recommendations and regulatory perspectives are presented with the aim to identify barriers as well as suggest recommendations on the way forward. Contributions aimed at the identification of barriers for new players are presented through interviews with the startups providing the related services. Investment needs towards enablement of open energy marketplaces services within the recovery context are presented.

During this paper drafting, the world is dealing with COVID19, which is having a global impact on all sectors of the economy. New measures related to energy transition are being adopted among different countries and regions. The new funding plan called the Recovery and Resilience Facility has been set in the EU. "The Recovery and Resilience Facility (the Facility) will make €672.5 billion in loans and grants available to support reforms and investments undertaken by the Member States. The aim is to mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions."

1 https://ec.europa.eu/commission/presscorner/detail/en/ip_20_416

The following graphic[2] summarises the areas of investment that are also introduced in this document, which focuses on enabling Open Energy Marketplaces relying on the enabling technologies, such as connectivity, IoT infrastructures, DLT, smart energy infrastructures, digital platforms and the related solutions.

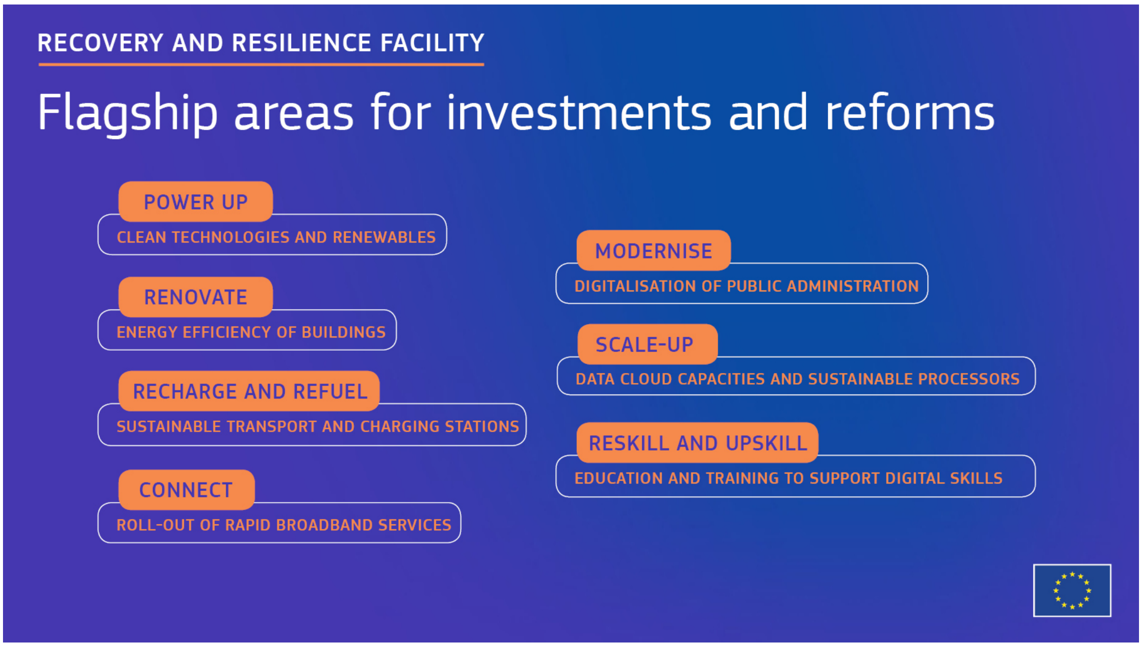

Figure 1. Examples of component of reforms and investments

Figure 1 outline areas identified by the EC that imply that significant investment is required, and much of it is related to investment in infrastructure. This creates a challenge faced by all network industries, service providers and others: how to finance such infrastructures and scale up the related services. Public policies have a role to play in this. Policies aimed at changing consumers' behaviour need to address the fact that those policies require investment in new infrastructures. Smart energy components forming participation nodes within open energy marketplaces; interoperable services towards energy efficiency and decarbonisation goals and the related data spaces.

In this context, public policies may facilitate investors to incorporate minimum criteria related to green and digital transitions in their investment policies. Theoretically, there is no reason not to incorporate minimum impact standards for financial vehicles involving either corporate or project finance. The question then becomes how to optimize the costs of implementing such control versus the potential gains through more favourable financing conditions. The objective, thus, is to match private sector finance and green and digital infrastructure. This constitutes, as we identify in the paper, an important arena for regulatory and policy experimentation.

[2]PowerUp:https://ec.europa.eu/info/sites/info/files/examples_of_component_of_reforms_and_investment_power_up_en.pdf

3 INTRODUCTORY REMARKS

The topics related to Open Energy Marketplaces enablement and significant components are currently discussed within several stakeholder platforms within the EU. ETIP-SNET in October 2018 published a paper on "Digitalization of the Energy System and Customer Participation", "which addressed the use and impact of Information and Communication Technologies as a pervasive tool along the entire value chain of the power generation, transportation and use, and mainly on enabling customer participation"[3]. The paper presents a comprehensive overview of digital impact within evolving smart energy systems that would observe, monitor, control, enable and protect the energy supply and use.

It is widely accepted that "the communication layer is a pillar of the energy system and radically changes the relation between the final user and the energy system"[4]. As to the enabling technology the advanced meters and modern appliances trigger the potential of active demand-response and enable new services for the energy user, where "customer participation in all stages of the development and expansion of the energy system is favoured by digital tools".

Internet of Things (IoT) Industrial Internet of things (IIoT), big data, blockchain, digital twin technology, are the building blocks of the evolving ecosystem and are expected to radically change system planning and operation while transforming the energy market.

The other work that was released in the month of March 2019 related to the topics mentioned above is the report "Towards Interoperability for Electricity and Gas Data Access & Exchange within the EU" that was prepared by the Working Group on Data Format and Procedures under the Expert Group 1 (EG1, 'Standards and Interoperability for Smart Grids Deployment') of the European Smart Grids Task Force.

It contains recommendations for "interoperability requirements and procedures for access to, and exchange of, data in Member States, building on national practices and with a view to facilitate the interoperability of energy services across the EU". Europe is well on its way to meet Clean Energy transition goals[5] as stated in the Eurostat report that shows that the EU is on track for reaching its renewable energy target for 2020.

The expected impact of DLT/Blockchain in the energy transition is discussed on many levels. Some of the related papers are referenced in the document, while others were discussed during the March 8th workshop. Related to the DLT/Blockchain topics the three main areas where blockchain tech is expected to have a major impact are the overall security of transactions, operating costs, as well as risk management. This can lead to economic value creation and reaching climate change adaptation goals.

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[3]https://www.etip-snet.eu/wp-content/uploads/2018/10/ETIP-SNET-Position-Paper-on-Digitalisation-FINAL-1.pdf
[4]https://www.etip-snet.eu/wp-content/uploads/2018/10/ETIP-SNET-Position-Paper-on-Digitalisation-FINAL-1.pdf
[5]https://ec.europa.eu/info/news/europe-leads-global-clean-energy-transition-latest-eurostat-data-confirms-2019-feb-12_en

On the consumer side, the expected impact is in reducing energy inequality, in a greater participatory role in the markets resulting in an increase of an overall efficiency while empowering consumers to buy and sell energy via peer to peer transactions or other sources of choice, while getting additional benefits from contributing towards decarbonisation. Energy efficiency, electric mobility along with emerging energy demand flexibility are evolving and drive new business models, which are expected to be facilitated by micropayments and through machine to machine operations.

The adoption of blockchain technologies by the public sector may require adaptation, which is not clear today. It is expected that blockchain enables solutions where everyone can participate and derive economic benefits using 'simple' interoperable and convenient platforms.

The four building blocks for more flexible energy grids of the future are based on enabling technologies coupled with regulatory environments enabling social adoption and resulting in impactful growth.

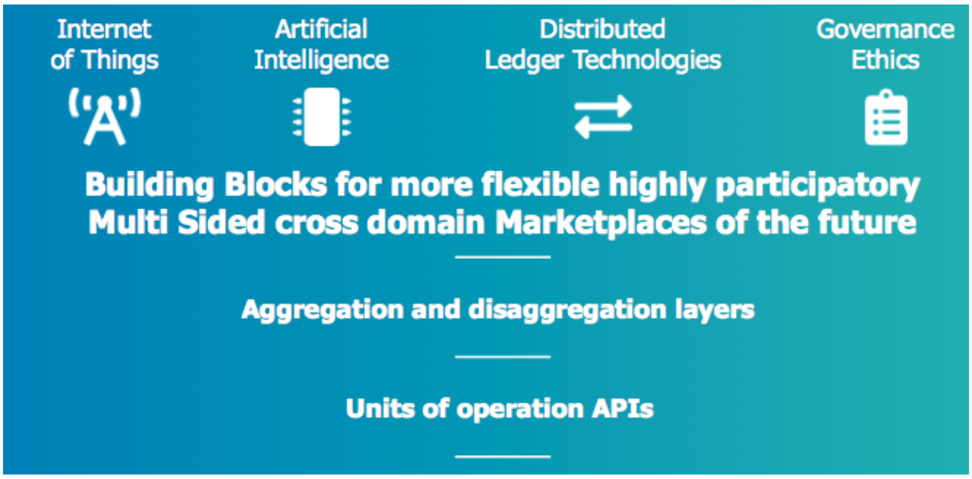

Figure 2 Four building blocks of flexible energy grids

This paper focuses on the context for policy recommendations towards DLT/Blockchain solutions within the energy sector while analysing the related ecosystem's development.

4 CONTEXT

4.1 Evolving ecosystem and Digitalisation within the EU Energy markets.

Digital innovation (also referred to as digitisation, digitalisation or digital transformation) is not specific to energy, but an on-going socio-technical process transforming all the sectors of our society, from health to education or administration, *including* notably the energy sector. **Digital innovation is at the core of the successful completion of the smart energy transition** due to several factors, such as:

- Physical factors, electricity requires a perfect equilibrium between demand and supply in real-time at all times, and a large imbalance on the grid can **instantaneously** lead to its collapse and thus to a blackout causing incapacity to supply the demand, potentially causing a blackout.
- Energy transition implies a tremendous increase of **variable renewable energy sources** (mainly solar PV and wind) as well as the **electrification** of a significant share of the energy system (including the heating and cooling systems and transportation). These two factors mean that the electricity system is progressively creating a need for increased **flexibility on supply and demand sides**.
- Demand-side management as a source of flexibility is closely related to the growing use of digital technologies.
- Electricity storage development as a source of flexibility on the supply-side, including via the deployment of electromobility, which can be seen, from the electricity system, as storage assets on wheels.
- Consumer empowerment is a clear objective of current EU energy policies and requires the development of digital solutions to incentivise the end-consumers' participation on the smart grid. It implies the deployment of smart metering infrastructure to get information about the real-time energy consumption and production (if present), which leads to increased awareness, understanding and involvement of citizens in their own consumption energy use. Empowerment is also seen as the ability of consumers to easily switch of suppliers, to be exposed to an understandable bill, and to get access to a certified and reliable comparison tool allowing them to take well-informed decisions[6].
- Economic, social, cultural and behavioural factors shape energy choices and need to be understood in order to secure consumer participation in energy transition. Special attention needs to be given to consumer vulnerability[7]. Vulnerability in the energy sector is not only related to affordability, but also access to information and the ability to comprehend different choices[8]. Energy poverty is prevalent in many European countries, where energy-poor households may be unable to invest in digital solutions without state support schemes[9]. It is important that Member States recognize and address this problem and prevent vulnerable consumers from falling deeper into energy poverty. The ideal of just transition and that "nobody is left behind" must apply also to the energy transition process.

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[6] For further information about these elements, see "ACER/CEER, Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets in 2016 – Consumer Protection and Empowerment Volume, October 2017"

[7] https://ec.europa.eu/info/sites/info/files/consumer-vulnerability-static-infographic_en.pdf

[8] https://ec.europa.eu/info/sites/info/files/consumers-approved-report_en.pdf

[9]https://ec.europa.eu/energy/sites/ener/files/documents/INSIGHT_E_Energy%20Poverty-Main%20Report.pdf

Digitalization of energy markets needs to be backed up by initiatives that address the situation of disadvantaged market participants and compensate for their disadvantages.[10]

- ☐ **Prosuming, Prosumeration** is defined as the electricity grid users who consume as well as produce energy. Examples include defined as the fact that energy consumers are also producing energy, such as with owners of rooftop-mounted PV panels, or wind turbines. This is a growing trend on the electricity system. This includes two main features for the European electricity system: the dramatic increase of the amount of power plants connected to the grid and the need to shift to a dispatchable demand. The first implies an increase in the system's complexity, once a conventional power plant is around 50.000 times more powerful than rooftop-mounted PV panels. The latter represent the need to shift from a traditional system, where a dispatchable supply can fit the demand, to a system where the demand will have to accommodate the available supply. Both prosumeration phenomena rely heavily on digital innovation.
- ☐ **The liberalisation** of the retail electricity markets which puts an extra pressure on incumbents beyond the "death spiral" caused by the combination of decentralisation, self-consumption and storage. The liberalisation is exacerbated by digital innovation which lowers the entry barriers for newcomers and enables the emergence of numerous offers on the market with various options (such as "green" electricity option or 'Time of Use' schemes).

4.2 New electricity market concepts

The virtualisation of energy and the collection of data from previously intangible assets is a great source of value creation. Enabling transactions between electrical and electronic devices, power machines, grid operators and energy regulators is creating intelligence beyond the traditional energy dispatch model aiming at truly revolutionising the electricity grids.

The concept of sharing economy[11] is undergoing profound development and has already revolutionised several industries. The notion of platforms evolved from a rigid pure ownership model, towards an access liberal business approach. The concept of an intangible asset in the form of digital twin, gathering and sharing data about its ability to supply energy, as well as transacting from node to node, even from platform to platform, is a recent phenomenon and has an immense potential for the energy sector.

One of the emerging technologies capable of enabling a true transactive energy grid is blockchain. Blockchain is an application of Distributed Ledger Technology (DLT) and is essentially a distributed and immutable ledger of transactions. As stated in the recent report by Eurelectric on Blockchain[12]

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[10]https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/leaving-no-one-behind-when-implementing-2030-sustainable-development-agenda-own-initiative-opinion

[11] https://www.investopedia.com/terms/s/sharing-economy.asp

[12] Blockchain in Electricity: a Critical Review of Progress to Date, May 2018, NERA, Eurelectric

> "Blockchain enabled solutions can unlock huge opportunities to have everyone participate and derive economic benefits in the new energy world using 'simple' interoperable and convenient platforms"

In the context of the electricity grid digitalization, potential applications of blockchain technologies are:

- ☐ Certification of origin and fulfilment services for various markets
- ☐ Network management, orchestration and security
- ☐ Electric vehicle charging and energy demand coordination
- ☐ Flexibility services
- ☐ Peer-to-peer marketplaces
- ☐ Integration of retail electricity markets and wholesale energy trading.

Blockchain was firstly introduced in 2009 with focus on cryptocurrency applications, such as the Bitcoin, and it was defined by Eurelectric[13] as Blockchain 1.0. After decoupling from the initial scope of cryptocurrency, developments were followed by Blockchain 2.0, focusing on smart contracts and programmability. Blockchains then evolved towards so-called Decentralised Autonomous Organisations (DAO) to a Blockchain 3.0, which are driven by the additional layer of laws and approaches while operating with a "high degree of autonomy".

4.3 Blockchain/DLT integration models

Integrating internal information technology (IT) processes with DLTs has proven to be not a straightforward task within the information and communications technology (ICT) sector. In the short term, it is expected that business service providers will advance this integration using specialised technology services providers rather than hiring blockchain developers.

Additionally, the technical integration requirements with DLTs could end up creating an entry barrier for new players. For example, if private blockchains do not have interfaces to other services providers, then they cannot interact with other platforms or ecosystems.

Related to DLT, other challenges were identified:

- ☐ Portability from blockchain to blockchain or to another service offered outside a DLT,
- ☐ Semantics and ontologies applied to DLT data,
- ☐ Data storage and its security imperative,
- ☐ Integration to identity services outside a DLT,
- ☐ Trust for data handling in a permissionless system,
- ☐ Interoperability of DLT consensus algorithms,
- ☐ On-line and off-line trust,
- ☐ Privacy features preserved over public or permissioned blockchains,
- ☐ Know Your Customer features for the participants in DLTs

Further discussion related to the above challenges needs to take place, but these are mostly ahead of the concept discussed in this Chapter. These challenges must also be addressed within the

[13] https://cdn.eurelectric.org/media/3115/paper1_blockchain_eurelectric-h-CB8D6920.pdf

context it is being applied to, for instance, integration to identity services outside DLTs might be necessary on billing services but might not be imperative on flexibility integration.

Blockchains have proven really useful to current IT systems by leveraging DLT applications to build systems which do not require a previously established trust relationship with other parties. Enterprise blockchain solutions attempt to solve the crucial issue of user/data privacy, albeit that blockchain and DLT were initially directed towards full transparency. In the context of Know Your Customer (KYC) standardization, a decentralized schema that enables user privacy protection on enterprise blockchains while at the same time allows the exchange of value between participants subject to the necessary AML practices and legislation is a very important topic in the energy market as well. Various recent efforts[14] are studying this issue and propose effective approaches that can be implemented with smart contracts in a broader DLT context.

Further on, DLTs can also be classified according to its access policy, being either of the following types:

- Public (permissionless), where access is not controlled in any form, meaning anyone on the Internet can participate as peers and/or visualise transactions.
- Federated (consortium), where a single or group individual(s) or organisation(s) are provided with an enhanced level of authority, such as access control, auditability or capability to enforce rules.
- Private (permissioned), where access is strictly controlled (normally determined upon network creation), meaning that transactions and smart contracts are only shared by a restricted group.

We propose to create a list of use cases and initiatives which is synchronised across the sector stakeholders. The categories should be expanded to reflect additional areas of sector interfaces, such as social energy, system resilience, climate neutrality goals, industrial and smart city platforms interfaces.

Policy sandboxing proposals can be added from each category to provide equal relevance of topics for further consideration.

Blockchain technologies at different levels of development are not homogeneous as to their benefits. The evolving blockchain, such as a DAO, adds additional layers of complexity and consequently potential benefits. Hence, a broad understanding of benefits and complexity of

[14] Kapsoulis, N.; Psychas, A.; Palaiokrassas, G.; Marinakis, A.; Litke, A.; Varvarigou, T. Know Your Customer (KYC) Implementation with Smart Contracts on a Privacy-Oriented Decentralized Architecture. Future Internet 2020, 12, 41.

4.4 Blockchain and the market context

A CGI-Group market research report on Flexibility services in the UK states that:

> "In the 2018 research, it was found that the most significant barrier to demand-side flexibility is the lack of a commercial or market framework to realise the value of flexibility"
>
> "…one of the key focus areas identified to accelerate the transition to a smart, flexible energy system is to deliver a market framework and infrastructure that enable this value to be realized"

Further on, CGI-Group suggested that a digital platform approach for trading demand-side flexibility was proposed as a way forward to offer further business opportunities by 2023. Hence, for the development of the marketplaces a "…holistic vision of how to enable this high volume of flexibility, and consideration about how to do this should already start today".

Provided the benefits of DLTs, already explored in section 3.2, we believe blockchain is one strong candidate of enabling technology for a Flexibility marketplace for the Energy sector.

An important aspect regarding the market context is the ability of blockchains and DLTs to facilitate the needs of liquid markets where demand and supply has to be matched in real-time and with a diverse set of requirements. Internet of Things (IoT) infrastructures and Advanced Metering Infrastructures (AMI) are the main source of data streams that feed DLTs along with other business value data which form the overall Data Ecosystem.

As the number of IoT/AMI sensors is growing, it is increasingly important to find ways to maximize the value of the data generated by those sensors. The future of the IoT depends heavily not only on the technological solutions that will affect security, costs and other issues, but also on the value that data will have for people and industrial stakeholders. One way to significantly increase the value of the data and the efficiency of the operations as well, whilst at the same time achieve economies of scale and reduced costs, is to share the available data[15].

In this context, the Energy Data Marketplaces will form the basis for the disruption of the Energy Market in the coming years. There are various approaches which are currently being implemented either in ongoing research projects that have as major focus the integration of IoT infrastructures and Data Marketplaces with DLTs or in academic research teams. For example, the M-Sec[16] the project aims to create decentralized IoT ecosystems and validate their viability and sustainability. It has within its objectives to define, design and implement a novel marketplace where smart objects can exchange data, energy and services through the use of virtual currencies, allowing real-time matching of supply and demand and the creation of liquid markets with profitable business models for all stakeholders in the value chain.

15 B. Buntz, "IoT Data: Strategic Sharing Will Yield Big Innovations," 20 6 2017. Available: http://www.ioti.com/strategy/iot-data-strategic-sharing-will-yield-big-innovations

16 https://www.msecproject.eu/portfolio/smart-city-data-marketplace-with-secure-multi-layer-technologies/

Moreover, the massive data that is associated with the energy market will account for new ways to manage them in a business meaningful way resulting, thus, in an excessive need of edge/cloud computing resources coupled with DLT. Quality of Service (QoS) and Service Level Agreement mechanisms have to be established so as to enable the cooperation of stakeholders in a business context. Speed and latency issues have been identified as the top barrier in this domain, while cost and reliability are the top and second most important factors for evaluating the services that can be offered in this context. The Pledger project[17] investigates among others the respective research area and the challenge of coupling modern edge computing approaches with emerging decentralised applications built on blockchains.

Based on the example of market framework approach, we suggest using DLT and Blockchain technologies in the context of evolving commercial and market frameworks.

Integration technologies are to be taken into consideration during the implementation processes, benefiting from the stakeholders community being engaged in the dialogue at the early stages.

The timeframes of the related underlying markets development should be agreed as soon as it is feasible. These should allow larger-scale pilots and the related sandboxing in the absence of fully-fledged market frameworks. On the other hand, current limitations of the enabling technologies also need to be taken into consideration to not hinder the evolution, whilst increasing levels of familiarity, stakeholders education and ultimately benefiting experimentation.

4.5 Challenges of the enabling technologies

There are several active topics of research within DLT and its related technologies. This is a continuously evolving field.

As presented in the graphical outline below, if the outcomes from the survey carried out by the DLT working group (WG) of AIOTI from 2018, the maturity level of implementation indicates early stages of Technological Readiness Levels (TRL) for DLT applications. The variety of funding sources for these implementations is an indication of an early evolution of maturity levels, demonstrating willingness to invest in pilots as well as investment in early development projects.

The results also show that a variety of blockchain systems are being considered within pilot projects across various industries. Figure 3 presents the preliminary results.

17 http://www.pledger-project.eu/

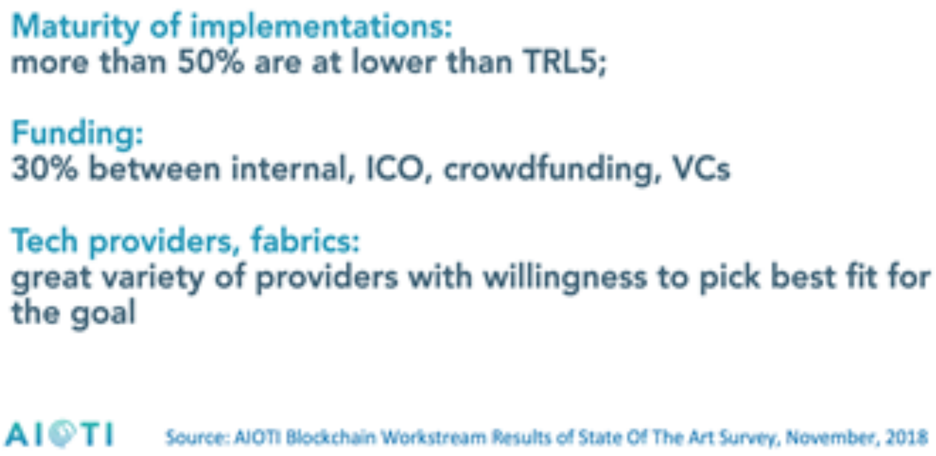

Figure 3 AIOTI survey, 2018

The main challenges of blockchain technologies are known as the 'Blockchain trilemma'[18]. Technological research within AIOTI DLT WG confirmed that choices must be made between decentralisation, scalability and security. In the current technical advancements of DLTs, only 2 out of 3 elements can be properly combined but will come at the expense of a lowered value on a 3rd element.

- ☐ **Decentralisation:** enables censorship-resistance and permits anyone to partake in a decentralised ecosystem without prejudice or central authority authorisation.
- ☐ **Scalability:** the ability to process transactions at a system-feasible rate. If DLT/blockchains are to be used by a large number of peers, they should be able to process transactions and requests without huge compromises to system performance.
- ☐ **Security:** maintaining the immutability of the ledger and its general resiliency to attacks, such as so-called 51%, Sybil and DDoS attacks (Distributed Denial of Service Attack).

Considering the needs of the energy domain, future DLT solutions will need to focus on all the above elements. Once again, deep understanding of the use cases requirements alongside the development of DLTs capable of handling the above three elements is necessary to extract maximum value for the sector.

Based on technical tests and market research, AIOTI DLT WG concludes the best way for energy markets digitalisation currently is via 'hybrid' models. Hybrid models entail processing computing expensive processes and/or stakeholder's individual and private processes outside DLTs. These individual processes would then integrate with a consortium or permissioned DLT network (providing therefore decentralisation, scalability and security) in order to build trust over an anchoring mechanism.

[18] https://www.forbes.com/sites/geraldfenech/2019/01/15/solving-the-bottleneck-of-blockchain-and-the-scalability-trilemma-through-sharding/#33b6822a6106

There might be a need for enhanced auditing within the energy domain to ensure platforms and smart contracts are certified by a 3rd party, for instance a regulator. Therefore, a federated blockchain is recommended.

4.6 Other challenges

Presently integrated commercial projects in the electricity industry lack the scale of implementations within broader marketplace scope. Whilst the experiments provide valuable insights; these can be viewed as proof-of-concepts rather than fully-fledged marketplaces implementations. These projects aim at solving issues which deliver immediate value to the ecosystem while leaving topics of interfaces to other components. Interoperability is a topic left for later stages of development, unless such interface is already part of the project scope.

Due to lack of research and standardization initiatives, large-scale DLT ecosystems still have high costs of implementation and the speed of transaction processing is usually slower than the levels required for a competitive transactive energy system. External factors, such as the reliance on other enabling solutions, such as smart meters with adequate data granularity, also represent limitations to an integrated DLT marketplace.

The energy sector has unique characteristics compared to other sectors which are adopting DLT at a faster pace, such as the finance and insurance sectors. In an energy context, the ICT and electricity grid layers have to operate seamlessly, so that the delivery of the energy transaction can be verified as well as the execution of the smart contracts can be completed. This integration is currently close to non-existing and hinders the adoption of DLT systems.

Therefore, scaling up pilots and addressing challenges related to non-technological aspects of DLT/Blockchain technologies related to off-chain verification and settlements should be addressed. In addition, custodian roles and other financial aspects should be discussed further.

Technology adaptation will require additional internal resources for scaling up pilots and participation in regulatory sandboxes. Digital assets creation and categorisation might require separate debate on the topic.
Create conditions and level playing field to facilitate adoption for all levels of market participants avoiding entry barriers.
Increase the efforts on sector-specific blockchain standardisation so that blockchains can unlock the values of a Flexibility marketplace.

Data marketplaces

It is a long transformation journey from infrastructure building, to local enablement, to the cross-domain marketplaces[19], leading to a multi sided, well-orchestrated energy marketplace. The four stages of IoT Marketplaces are presented in Figure 4, placing the enabling technology in relation

[19] Market Drivers and High- Level Architecture for IoT enabled Data Marketplaces, Omar Elloumi, Tom De Block, Natalie Samovich

to the stage of infrastructure development. The physical layer of smart energy components is the first building block in cross-domain data valorisation.

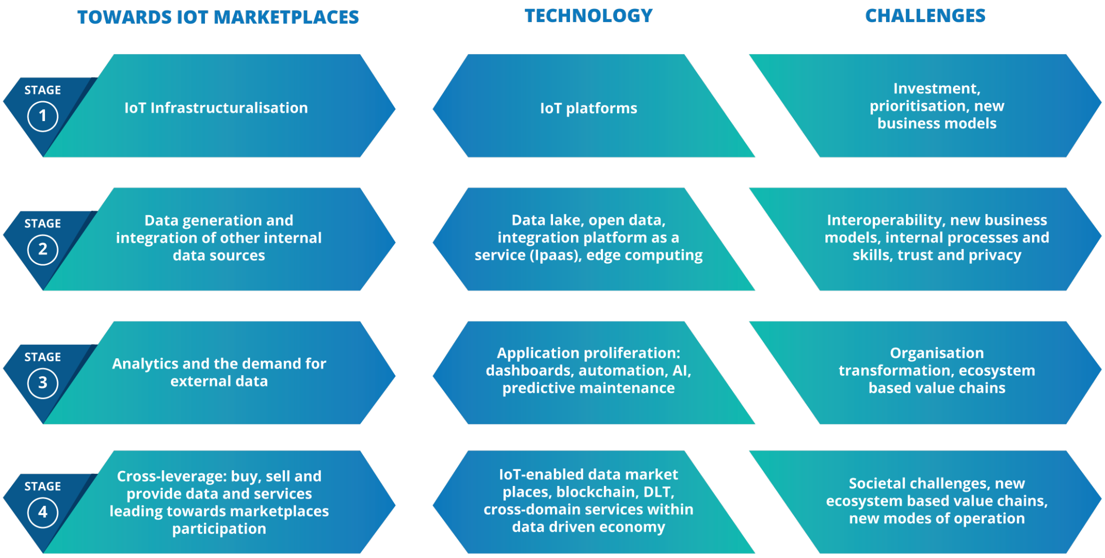

Figure 4: Stages of IoT enabled Data Marketplaces

The interoperability of platforms and evolving open-source 'plug-and-play' solutions allow for the creation and growth of marketplace ecosystems. Energy-domain organizations will then start to look for external data to leverage their business, as they will need new cross-domain data sources as well as an enrichment of their own data. This way, we can clearly identify the establishment of a bidirectional push-and-pull for internal and external data, enhancing the need for innovation in this area.

Platform Economy

The new evolving Platform Economy driven by new actors and new business models requires all market players to define their new evolving roles and responsibilities. What investments, what business models are needed to move forward and which enabling technologies to consider for scaling up are just some of the topics within the context of evolving *platformisation* in the energy sector.

Platforms in the energy sector are expected to be of large scale, to address sectoral challenges and to solve cross-industry or segment barriers, such as smart homes and smart grids, energy efficiency, renewable energy sources and others.

Platforms will allow multi-directional interactions. Transactions along the whole energy value chain should enable any customer to be active, progressively integrating wholesale and retail markets together with greater participation of end users. In turn, this greater participation of end users who will still hold rights to their digital identity, will unlock greater economic value, while introducing additional technological requirements for privacy.

Marketplaces in all sectors are driven by value created, liquidity, acceptance and participation—not purely on technological advancements. Marketplaces start with a simple focus and then grow in a number of services, scale and scope areas.

The continuous evolution of services of the leading marketplaces is a distinguished feature. A similar trajectory should be expected in the energy sector, mainly due to its multi-sided nature. Economic value creation is expected due to investments in the sector while striving to reach climate neutrality goals. Grid operators should focus on delivering various value propositions. An example of an Over the Top (OTT) service is the European Network of Transmission System Operators (ENTSO-E) where green energy is part of the mix of services available through the grid".

Meanwhile, the unique proposition of DLTs is the enablement of peer-to-peer exchanges and auditability features. Cross-domain marketplaces enabled by platforms within mobility, energy, smart cities are expected to evolve as well.

Connectivity

Before the 5G era, there was not an industry consensus about best connectivity technology for the Energy sector. This is reflected in the industry adopting a mix of connectivity technologies, given the vast availability of technologies. This was particularly true for LPWAN[20] (for example, LoRa WAN, Sigfox and NB-IoT). LPWAN technology filled the gap for low power and wide area connectivity, which was aimed to solve pretty much all the connectivity requirements of an Internet of Things system.

AIOTI classifies connectivity mechanisms in different categories depending on the application and device needs. This classification can be seen, in the case of wireless technologies, in the below figure.

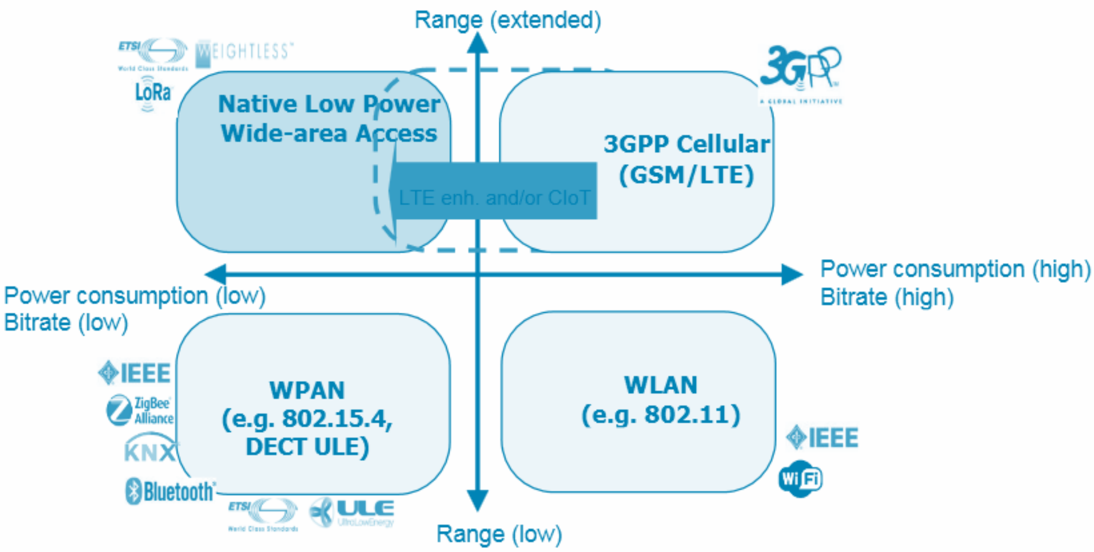

Figure 5 Wireless connectivity trends (pre-5G)

However, deploying different technologies comes at a certain CapEx and OpEx that should not be underestimated. A utility or a service provider needs to be mindful to not hugely expand the

[20] Low Power Wide Area Network

number of connectivity implementations, because that often comes at a cost that may rapidly become prohibitive over the long run.

5G, on the other hand, is unique in being a true multi-service network that can address the connectivity needs of virtually any smart application, including in the consumer, enterprise and industrial IoT spaces. 5G has been specified from the ground-up to support mobile broadband, massive IoT and ultra-low latency applications. In addition, it provides unprecedented levels of flexibility in building new services in a cost-efficient manner, thanks to virtualisation, network slicing and edge computing capabilities.

5G has been under development for a few years already and we have already started to see wide commercial applications in countries like the UK and Germany. Wide-scale deployment has ramped-up in 2019 and will continue to quickly expand in the coming years.

At the technology level, 5G main **core network advancements** include:

- ☐ New core network leveraging the principles of Service-Based Architectures (SBA). Its design adheres to network functions virtualisation (NFV) concepts and cloud-native principles to provide benefits like increased flexibility, high throughput, high availability and low latency. SBA is designed to provide oriented microservices where communications are performed using Web advancements, including REST-oriented communication patterns using HTTP/2 as application protocol and JSON serialisation.
- ☐ Network virtualisation and slicing: 5G was designed to be a true multi-service network. To achieve flexibility while mastering the total cost of ownership, the core network has been fully virtualised so that it can run on the existing communication service provider's (CSP) cloud infrastructures. Network slicing offers the possibility to build virtual network instances customized for a specific customer or vertical industry needs. The use of network slicing at radio access networks (RAN) and core network levels provides isolation, flexibility and reliability.
- ☐ Multi-access edge computing and application enablement: edge computing enables operators and 3rd party services to be hosted close to the field devices. The application intelligence would run on the CSP infrastructure (instead of in the centralised clouds) to provide low latency and get access to exposed network capabilities such as local routing, quality-of-service, and others.
- ☐ Exposure of network capabilities: while a not specific feature of 5G *per se*, the exposure of network capabilities to applications has been further enhanced and extended in the context of 5G. 5G developments in 3GPP (Release 15) introduce the concept of Network Exposure Function (NEF) which is an integral part of the SBA. Other network exposure initiatives are also worth mentioning:

    - Service Capability Exposure Framework (SCEF): designed in the context of 4G mostly to expose cellular IoT services including NB-IoT and LTE-M
    - Common application programming interfaces (API) framework (CAPIF) for 3GPP Northbound APIs: provides guidelines and common API functionalities to third-

party applications (e.g. authentication of API invoker, authorisation to access service APIs, the discovery of service APIs).

5G along with enhanced edge developments are two facets of evolving connectivity promise in the Energy services development.

The 5G technology promises multigigabit speeds and sub-millisecond latency while supporting distributed architecture and intelligent edge. In addition, the impact of ultra-high speeds for enhanced broadband and ultra-low latency for mission-critical applications will result in IoT devices integration with low power consumption while offering high data outputs. Fast development and close to 100% coverage are two additional enablers of open energy marketplaces. While the mobility sector is leading in terms of the use cases for both technologies, the benefits for the cross-domain of energy and smart cities cannot be underestimated.

Evolving related technologies and developments

One related technology which is relevant to the marketplaces development in the DLT space is quantum computing. Quantum computers can instantaneously simulate physical systems and optimise processes in the financial sector, both of which can enhance a DLT-powered marketplace. These are expected to be more efficient, of large magnitude compared to the existing processors, and are able to enable edge computing. Both technologies are expected to start being seen in synergy within the next two to five years.

Smart metering infrastructure is yet another key component within the evolving solutions and service offerings. The frequency of data transmission is an often-cited challenge for flexibility enablement, meanwhile, a traditional push architecture, where meters send their data to where it needs to be is being challenged by an evolving pull model, where authorised parties can fetch the data. This model can potentially allow for near real-time data exchange and decentralised scaling models.

Integration of renewable energy implies the need for more flexibility in the electricity system

Expansion of electrification, distributed generation and variable renewables will broaden the need and range of flexibility options.

Figure 6 shows the speed of adoption of variable renewable energy (VRE) in different countries along its share of the generation mix. It can be observed the European Union (EU) is moving towards a targeted investment-type in flexibility, exacerbating the need to adopt enabling technologies.

Figure 7 shows various different sources of flexibility for an Electricity grid. Therein, some comparison is drawn in terms of duration of availability as well as the location of the source. We can see the current speed of IoT in end-users and distribution systems adaptation projections. Nevertheless, it could also help with flexible generation and (smart) interconnectors in the future.

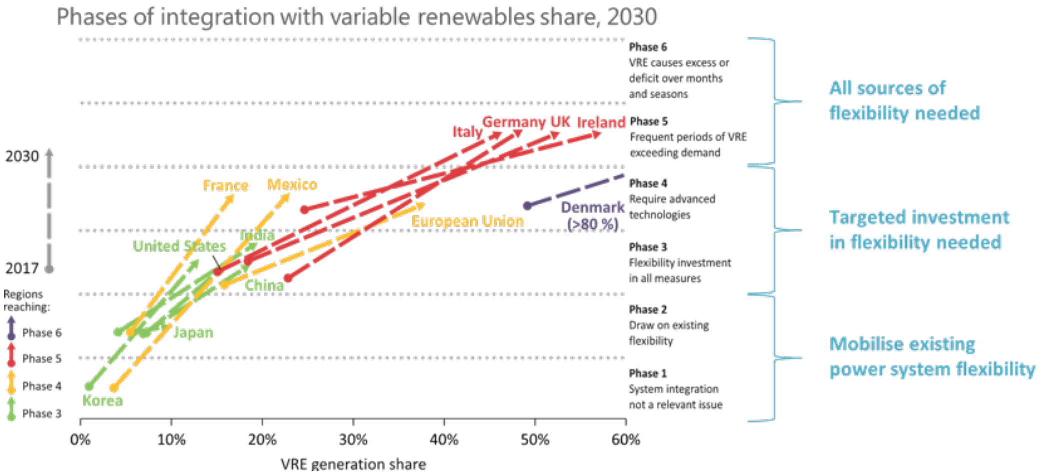

Figure 6 Phases of integration with variable renewables share 2030, IEA

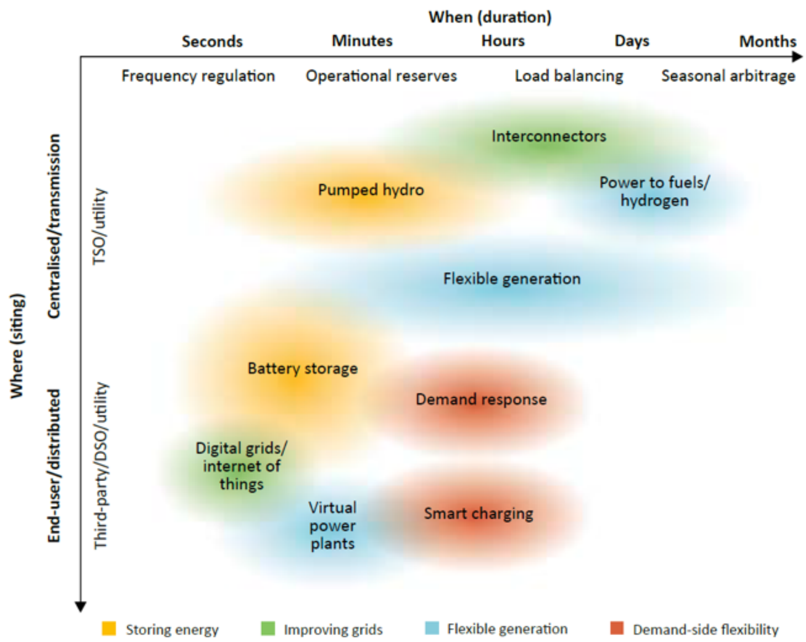

Figure 7 Flexibility sources options, IEA

The flexibility sources can deliver different kind of services, fulfilling different purposes, such as:

- Market trade to optimise portfolio and re-adjust forecasts in near real-time,
- System services to contribute to system frequency stability through frequency ancillary services (mainly for balancing the quality of energy),
- Grid services contribute to ensure operation of the grid within operational limits through congestion management and non-frequency ancillary services, such as voltage control and grid restoration, amongst others.

The physical interface between transmission and distribution service operators, TSOs and DSOs, in electricity networks is very heterogeneous across Europe and is reliant on national conditions[21]. This physical diversity implies that one fits for all solutions must be avoided.

Moving towards the integration of the physical with the digital layer, the integration of distributed energy sources (DES) is facilitated by higher observability and controllability. The network design has to evolve for DES connection from a deterministic to probabilistic approach.

In the "TSO–DSO REPORT – AN INTEGRATED APPROACH TO ACTIVE SYSTEM MANAGEMENT', three models are described, ranging from separated to combined market, and comprising hybrid alternatives, as seen on Figure 8.

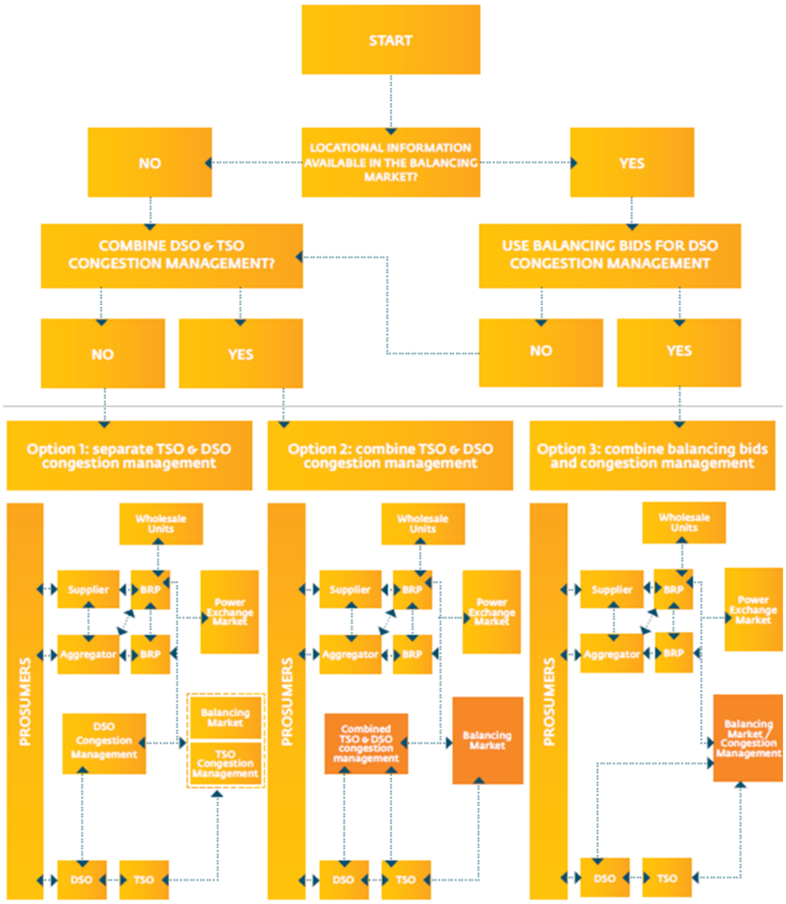

Figure 8 Integration approach options, TSO-DSO report

Principle for access to flexibilities for grid and systems needs:

In any of the possibilities, important challenges remain regarding the design of an adequate market framework for the use of flexibilities:

- avoid the creation of fragmented markets, guaranteeing enough liquidity, promoting competition,
- ensure that distributed flexibility resources can trade in different markets, according to their strategy and most valuable options,

[21] Based on partial results of H2020 TDX Assist project, the physical interface is characterized by different variables such as i) number of system operators; ii) Voltage level at the physical interface; iii) Electricity network topology; iv) Degree of distributed energy resources connected at or close to the interface.

- remove barriers and encourage the introduction of new actors, such as aggregators, to leverage the participation of distributed flexibility resources in the market,
- develop the necessary pre-qualification processes, including their requirements, for the reliable participation of distributed flexibility resources in the market,
- define a harmonised set of flexibility products and services, including their requirements, to be offered in the market and aligned with TSOs and DSOs needs,
- embed flexibility locational in bids information,
- ensure coordinated access to flexibility products between TSOs and DSOs in different market time frames,
- ensure the development of a sustainable flexibility market. This can be accomplished via evolved network design rules, replacing network reinforcements by flexibilities and securing their usage with higher observability, controllability and anticipation tools (via operational planning and automatisms).

Interoperability of platforms

Effectively, several options can be proposed for enhancing market models, its coordination and enablement of platforms. Interoperability is at the centre stage in all of these. A digital platform is defined as a software functionality, enabling a digital connection between different stakeholders of the energy system in order to allow them to perform tasks with other relevant actors in the system. Such platforms could be used for:

- creating products and services based on a wide range of assets and involving directly or indirectly with end customers,
- matching supply and demand for a specific service/market process,
- displaying, exchanging and analysing data,
- linking smart devices to physical infrastructure for operation and maintenance, through controllability and observability.

Today in Europe, many different actors, such as market regulators, consumers and system operators, have started to consider and to develop platforms for some of these functionalities. The variety of such projects require interoperability to operate, in order to maximise value. When platforms serve a common functionality, they should be able to communicate with each other.

De facto, we could describe two examples of interoperability as follows.

Market places:

Flexibility services can be traded in different marketplaces to value the services at most, such as the wholesale market from day-ahead to intraday, the balancing market or the congestion management market(s). These markets may be supported by different platforms. Interoperability of such platforms will ensure proper coordination between these market processes and concerned regulators.

For example, the TSOs are working on establishing platforms for exchanging balancing services across Europe. Such platforms would allow any flexibility service to contribute to national and cross-border balancing. But these flexibility services could also be used for national congestion management, which may be supported by another platform (national or local) and involving the DSOs for the congestion on their grid.

Hence, interoperability of platforms should ensure that such a flexibility service can be available on both platforms to serve both market processes, to avoid discrepancies (such as double activation of the same service and their counter-effects) and ensure the maximum value of the flexibility service. To avoid congestion in the distribution, data exchange between congestion management and balancing platforms grid is needed, because balancing action can lead to subsequent activation of distribution connected resources.

An example of a marketplace platform is the Research and Innovation (R&I) project Smartnet project which defines five options for ancillary services market models and defines the roles of the DSOs and TSOs in the different marketplaces schemes. It considers the distribution grid constraints and also defines the ICT architecture necessary to enable the coordination schemes and the exchange of information.

Data exchange platforms:

Data exchange platforms are being developed in several countries to manage data related to the energy system and to allow the exchange of the data between the various stakeholders. Such platforms could support the market through interoperability with market platforms (interoperability of market and data platforms) and could support European integration through interoperability with other national data exchange platforms (interoperability between data platforms).

In the first example (interoperability of market and data platforms), such interoperable platforms could allow a trading platform, matching flexibility demand with offer, to be linked and supported by a data exchange platform, displaying data such as metering, grid status and need, load and generation forecasts, amongst others. This would allow optimisation of flexibility procurement for system and grid needs, as well as the maximisation of value for the service providers. The Horizon 2020 R&I project INTERRFACE will propose such a demonstration project, linking the Estonian data exchange platform Estfeed with the Common Baltic IT platform (COBA) for balancing services.

In the second example (interoperability between data platforms), the connection between several national data exchange platforms would contribute to the development of cross-border data exchange models. These concepts would facilitate pan-European data exchange in the energy domain, including authentication and consent management and easy access to data (single entry gate to data).

The specific aim is to demonstrate how an interested stakeholder–e.g. an aggregator–can organize all its information exchange with other stakeholders (e.g. TSO, DSO) through a single access gate. This would include the situation where these stakeholders are in different countries.

Some examples of tools to allow interoperability:

ENTSO-E is developing a Communication and Connectivity Service Platform (ECCo SP), enabling communications between business applications and exchange of information between different live applications in the power system. This use case looks at the provision of a TSO communication and data handling middleware layer, but could also be consumed by other stakeholders (e.g. for TSO-DSO data exchange such as in the demonstrators of the TDX-ASSIST project). This platform aims at connecting actors together to allow them to exchange any kind of information. Applied to TSOs, it supports regional and European coordination of the TSOs functions. But the platform could be used by any other type of actor and to exchange different types of information. It provides the foundation bricks of a secure interoperability platform to allow communication from and to different data platforms.

The interoperability between TSOs, DSOs, market actors, the transport sector and other energy stakeholders is paramount to enable the development of services and platforms. This will be explored in the H2020 projects INTERRFACE and COORDINET.

The H2020 COORDINET project investigates the demonstration of the coordination schemes through which the activation and provision of services can be carried out. Standardised products will be defined and tested. Similar to the INTERRFACE project, COORDINET will look at interoperability of the development of TSO-DSO-consumer collaboration platforms which will be tested in different areas.

In this context, COORDINET, develops large-scale demonstrations of innovative network services for TSO-DSO through demand response, storage and small-scale distributed generation. Its main objectives are:

- Demonstrating the activation and provision of services through a TSO-DSO coordination,
- Defining and testing standard products that provide services to the network operators,
- Developing a TSO-DSO-consumer collaboration platform in demonstration areas to pave the way for the interoperable development of a pan-European market.

INTERRFACE is a European research project supported by Horizon 2020. The core objective of the project is the greater coordination between TSOs and DSOs. INTERRFACE project will design, develop and exploit an Interoperable pan-European Grid Services Architecture (IEGSA) to act as the interface between the power system (TSO and DSO) and the customers and allow the seamless and coordinated operation of all stakeholders to use and procure common services.

IEGSA aims to increase harmonization and transparency in the energy market. It provides:

- A TSO-DSO coordination platform: a platform through which the operators can exchange data through interoperable APIs with a view to facilitate their coordination for the procurement of flexibility services,
- A flexibility register for universal access: a module that allows flexibility service providers to bring their offers to markets and all grid users, and that ensures an efficient and secure collection and sharing of information on potential of sources of flexibility,
- A single interface to the market: one single gateway which communicates the operator's flexibility needs to the market, then returns and stores market results to the flexibility register,
- A settlement unit: a module allowing the energy and financial settlement according to the rules of each market and focusing on the efficient provision of all required data by all involved parties for the execution of calculations.

A number of EU platforms are working on various aspects of interoperability from device to the platform to platform level. In the second release of the paper in chapter 6 further recommendations will be incorporated.

5 VISION OPEN ENERGY MARKETPLACES 2030

5.1 Customer Centric Marketplaces

5.1.1 *Challenges and opportunities customer engagement*

EU startups active in the field were invited to participate in the workshop on March 8th, 2020, present their solutions and experiences, participate in the debate, as well as share their input as to existing barriers for services development.

Subsequently they were contacted and supported by EIT InnoEnergy to provide input as to the existing barriers for scaling up across the EU. The below two forms outline the comments on regulatory context and market conditions needed for scaling-up.

2U

www.power2u.se

Question 1: How is your company related to customer engagement?

Our main business is delivering digital energy management services to real-estate companies. We help customers (real estate companies) use energy in a better, sustainable, economic and fun way. We also help them do good for the whole system by e.g., delivering flexibility services to the energy system.

Question 2: Do you think that customer engagement can be considered as a sizable market to be captured by European companies? And if so, why?

Yes, we fully agree that customer engagement can be considered as a sizable market to be captured by European companies. In fact, over time we have realized that full customer engagement is the only way for us to commercially scale-up. In recent time we have made a major effort on making our products/offering simple, intuitive, easily understandable and most importantly 'inclusive'.

Question 3: What are the barriers you are facing in your commercial development and how the EU could contribute to lift them up?

One certain challenge is realization of smart energy communities or the so-called local energy systems. We see 'independence' (NOT off-grid) on top of the agenda for many customers. They would like to achieve this through establishing smart/local energy communities. The challenge here is unclear regulations and not completely developed business models. It would be of great help if more clear regulations can be put in place regarding establishment of local/smart energy communities including the role of traditional actors such as DSOs and energy retailers. The Clean Energy Package addresses this topic but country level interpretation is still not fully clear.

Furthermore, instruments/funding programs etc for designing, testing and verifying business models (in the form of regulatory sandboxes while regulations are not clear) for smart energy communities should also help.

FLEXIDAO www.flexidao.com

Question 1: How is your company related to customer engagement?

FlexiDAO helps energy retailers build innovative, service-driven business models for renewable energy sourcing through blockchain-based applications.

The company's first commercial product "RESpring" helps Energy Retailers offer a proof-of-impact value proposition to their corporate customers by proving, claiming and communicating key attributes of their renewable energy sourcing such as time-of-use, location and additionality. This answers the need of corporates to reach ambitious Corporate Social Responsibility targets by powering 100% of their operations with renewable energy. The frequently asked end-consumer question "What does it mean to be 100% renewable?" and the risk of being accused of green-washing, puts pressure on corporates to purchase renewable energy from sources that have low environmental impact, boost local economy and have high societal impact and, more importantly, to actually be able to prove it and showcase it to all their stakeholders and clients. This translates into sophisticated purchasing requirements that Retailers cannot meet through the official certification mechanisms. At the same time, it provides the opportunity for Energy Retailers to differentiate their offer by adding layers of value and decommoditise their green products.

Question 2: Do you think that customer engagement can be considered as a sizable market to be captured by European companies? And if so, why?

Our conviction at FlexiDAO is that buyers can be and should be choosers. This eventually leads to a de-commoditization of certain products, creating the opportunity for service providers like FlexiDAO to deliver value-added services and therefore to a sizable market.

Just as supermarket products have been de-commoditized (you can now choose between conventional and organic, locally grown vs. imported, etc.), many RE buyers care about the specifics of the renewable energy that they consume — like the generation device that it originated from, the grid region of that device, or the generation time frame — and ultimately fulfil the varying proof-of-impact needs of renewable energy buyers.

Question 3: What are the barriers you are facing in your commercial development and how the EU could contribute to lift them up?

When it comes to renewable energy, the detailed needs of energy buyers are expressed through Guarantees of Origin. Accommodating these needs and differences and enabling the efficient tracking and trading of very specific GOs is in a nutshell FlexiDAO's core business. In order to achieve this, (1) system operators should provide - through consumers' consent - easily accessible settlement data to service providers and (2) regulated entities in charge of GOs should provide basic means to exchange data with national registries.

Unfortunately, none of the two are currently implemented in a coherent and standardised way across Europe which limits the value that we can deliver to our customers and therefore their ability to be choosers.

5.2 Customer Centric Services

Project InterConnect[22] initiated a reflection on incentives for customers to become active players "means for Intrinsic motivation within grid services and the related solutions[23]. It is understood that if we do not solve these issues, all smart grid developments will be limited because of a small size of demand flexibility pool (i.e. little number of users being able to activate flexibility).

New services providers that can interface between grid operators, energy communities, flexibility providers within various domains and other energy services providers need to have possibilities to interface with grid operators through standardised interfaces and clear price signals that can incentivise services creation and provision. They also have to have clear market signals related to demand, so that consumers can be incentivised for participation and engagement in these new energy services.

These incentives are intrinsically related to business models of energy market players. Nevertheless an ecosystem approach for the flexibility market and the related business models enablement is a subject matter of a number of calls related to data and services marketplaces, new energy sector SMEs and startups.

A number of technological barriers should be mentioned. Real time multi sided marketplaces will rely on real time data and underlying high penetration sensors and smart energy components, such as smart meters. These currently do not deliver real-time data and have heterogeneous connectivity as well as fragmented data access across the EU.

The current challenge is to harmonise the approach as to how to enable access to third parties such as HEMS providers, energy and flexibility aggregators and new actors in this market and make data available to all energy sector players as well as to prosumers. New digitalisation enabled or digital infrastructures are evolving and the related data hubs models. The design and the operation principles listed in section 4.3 below should be considered for Customer Centric Marketplaces.

5.3 Balancing technology and social aspects

The following are some main related concepts from the "WORKSHOP DATA DRIVEN ENERGY SERVICES HOW TO ENGAGE CONSUMERS" related to data access, interoperability, role of energy communities and services provision.

"Novel business models should be developed to engage customers in the wide energy market promoting a consumer-oriented framework that provide monetary rewards (without excluding non-monetary such as green behaviour) for value provided to the system and help build an online community of like minded actors in order to increase the use of renewable resources in the energy mix".

22 https://interconnectproject.eu/

23 https://ieeexplore.ieee.org/document/9285206

"One of the main considerations was that, in order to shape a well-functioning market with smart consumers and new services, it should be taken into account that: "the integration of different resource types by different vendors on energy cloud platforms implies huge challenges, especially the technical implementation (smart meter, interoperability), legal implementation (privacy) and an enabling regulatory framework".

"Key questions: How to mobilize citizens for renewables? How to reach people for self consumption offers? Energy communities: what is the optimal interface between energy players and citizens?

Main Highlights:

- ☐ The discussion rapidly moved to bundling but consumer associations mentioned that it is not always the most wanted solution.
- ☐ Can we wait for the perfect solution before engaging with customers? This is not an option since the early adopters should be reached first, especially due to a need for transparency.
- ☐ Data access: Smart meters ok but accessing the data is still an issue (same problem for many years now).
- ☐ Interoperability
- ☐ Energy communities are considered the driver to mobilize people. Ongoing discussion on implementing the CEP vs tariffs." [24]

5.4 An integrated Governance imperative

An integrated system of system approach is a starting point towards well-orchestrated Open Energy Marketplaces. An off-chain governance is a first step towards large scale implementations of a variety of enabling technologies. Development of blockchain /DLT could be an enabler.

A system of systems approach is the basis, within which different roles and responsibilities are recognised and respected (market parties, technology providers, system operators etc.). Clean energy package outlined the roles of actors.
An efficient level playing field for market parties is a requirement, fostering new services and valuing flexibility services; neutral market facilitators will keep ensuring non-discrimination towards market parties.

An integrated system is not a synonym to centralisation; on the contrary, with more decentralization on the supply side, numerous and heterogeneous in size and scale actors to transact in the system (from big power plants to residential prosumers) while undergoing the development of sector coupling, the future may rather be a system of systems.

It will require coordination and orchestration of each layer and the related platforms, optimization of the resources to develop these platforms, equal access, further innovation incentives. Transparency between players and architecture considerations of the built solutions while operating within interoperability principles will be key drivers to such a vision. Blockchain/DLT could be one of the solutions, but not the only one.

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[24] https://ec.europa.eu/digital-single-market/en/news/workshop-data-driven-energy-services-how-engage-consumers

5.5 Marketplaces design and operations principles to ensure sustainability, security of supply and competitiveness imperatives

The evolving bidirectional marketplaces enabled by communication platforms that expect to give rise to well-orchestrated multisided platforms will require careful considerations regarding operational principles. The following are some principles for consideration:

Main pillars:

- ☐ Local to national to cross- border
- ☐ Cross-sector
- ☐ Integrating various scales and actors (TSO-DSO-aggregators-consumers)
- ☐ Integrating physical reality with market rules

Main drivers:

- ☐ Coordination and orchestration
- ☐ Optimization
- ☐ Transparency
- ☐ Interoperability

Principles:

- ☐ Trusted parties can access the resources
- ☐ Share data and visibility
- ☐ Operation and market perspective considerations as a holistic approach

An integrated system approach[25] should be a shared vision, to assess and reduce the risk of market fragmentation.

- ☐ An integrated electricity system approach is the basis, in which all actors' roles and responsibilities, from local to cross-border, are recognized
- ☐ Roles and responsibilities should be defined and shared, including clarity on market facilitators.
- ☐ A consistent model should be established to allow stacking value of flexibility across markets.

5.6 Services and architectures principles

Market processes should have sufficient coordination functions between them for economic efficiency and security of supply sake, especially when the same assets can provide different services to different market processes, and when timeframes overlap. In that sense, fully separated market processes should be avoided.

[25] See TSO-DSO data management report (2016).

Liberalisation of energy markets and integration of renewables into the electricity distribution grid implies participation of new incumbents, e.g. distributed generation owners, storage providers, aggregators, or consumers participating in demand flexibility programs, in addition to historical operators in the energy sector. Planning processes and transactions between integrated utilities are being replaced by multi-stakeholder contractual relations, requiring information exchange across the different stages of the electricity supply chain.

Data exchange and transactions among these stakeholders are envisioned to be intermediated by multi-sided IT platforms.

> Mechanisms for multi stakeholder approaches:
> For the open energy marketplaces to become a reality, it will be essential to define how the data about demand, supply, and potential flexibilities can be exchanged on the platforms in a neutral and non-discriminatory way

Furthermore, for energy marketplaces to stimulate innovation, new incumbents should have open access to data. At the same time, security and privacy requirements must be met to ensure sustainability of smart grids. Data sovereignty, i.e. rights of consumers to keep the ownership over individual data should be observed.

Defining governance of information management on energy marketplaces is, therefore, an imperative task. Governance of energy marketplaces is understood as a set of rules defining how data in smart grids is produced, stored, aggregated, verified, distributed and used for decision-making and business purposes. It encompasses physical flow of data, management of data exchange, roles and responsibilities of stakeholders, IT system and electricity infrastructure design.

Regulated governance models have already been implemented in a number of European countries. They take the form of delegation of data management either to the network operators (DSOs or TSOs) or to an independent third party mandated by the Government, under well-defined regulatory framework conditions. However, the scale of regulated governance models may be ill-adapted for popping-up microgrid projects functioning as hyper-local markets of peer-to-peer energy exchange (also known as energy communities).

The peer-to-peer energy communities are built on the premise that data and energy is a common good. The main challenge for such energy communities is to define self-regulating mechanisms ("self-governance") to effectively manage data and optimise local energy consumption and production. Typically, collective self-governance rules such as reputation, transparency and accountability shall replace trusted intermediary services offered by centralised IT platforms.

Pathways for Marketplaces Enablement

In this context, the following requirements should be considered for platforms supporting peer-to-peer energy marketplaces should include:

- ☐ **Openness principles:** platforms should enable the development of new collaborative applications by preventing the privatization of data storage and management
- ☐ **Federated identity management:** users should be able to interact with multiple centralized or decentralized services within and outside of the platform
- ☐ **Authorised Data access:** personal data remains under the control of their respective owners and is available to community or to third parties on demand
- ☐ **Privacy-preserving management** (indexing, aggregator & analytics): If a user (an individual or company) requests operations that need to access individual data, for example to compute statistical information, the platform executes in a decentralized and privacy-preserving fashion while respecting the rules set by data owners
- ☐ **Data and energy transaction support service:** the platform should support peer-to-peer transactions without trusted intermediary and associated reputation service as a decentralised "soft" enforcement mechanism
- ☐ **Self-Governance service:** platform should support collective negotiation and decision-making about collective resource/asset management without a central organizer

In this context, we recommend a hybrid governance approach combining "top-down" regulatory conditions (e.g. governing data security, privacy policies, standards, non-discrimination and neutrality in data management) and "bottom-up" governance in decentralized open energy marketplaces. This approach could better address local specifications while providing a homogenous institutional environment for information management.

- ☐ **Separation of roles and responsibilities** (governance, assets, data ownership, customer relation)

- ☐ **Curative actions** (feedback loops), sharing experience

5.7 Future vision

The future markets need to be open to more participants and many actors, they will require adequate connectivity and openness towards a multi sided system where each actor would be able to contribute (provide service and benefit from service).

The energy flexibility, the marketplaces and the platforms have to be seen in the context of integration of the digital layer with the physical layer of the network's connection.

The vision of the platforms in the energy system is not the vision of the single central platform. The platforms need to link through each other through **interoperable and modular interfaces**. The market places and platforms need to be integrated with the physical existing reality and to take into account the actors and roles.

The electricity system requires on one hand a **horizontal integration** between TSOs, cross border, region, towards European level. On the other hand, the **vertical coordination** with the DSOs and further with other actors (from homes to cities to regions) in a bidirectional way will allow the achievement of the Internal Electricity Market.

Digitalization will enable sector coupling. However, current activities in this field are very limited. There are several attempts at coupling transport and energy by means of electrification. As an example, the electrification of transport and the energy system result in projects like the integration of electric vehicles into the grid (The New Motion project), where a new market is set and opens up the interactions between complementary and competitive players will result in new cross-sector services.

This will enable the evolution of electricity, energy systems towards a **system of systems.**

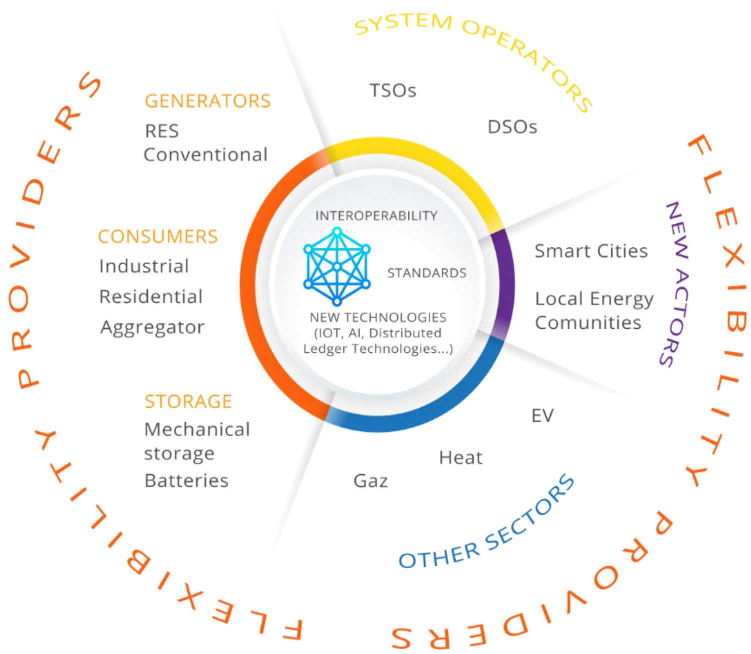

Figure 8 Technologies, Actors, Interfaces

6 SCALE-UP PARADIGM: MARKETPLACES, ENABLING TECHNOLOGIES AND CUSTOMER PARTICIPATION

Several ingredients are required to the scaling-up of innovative projects and businesses powered by digital technologies. Among those, **investment** is definitely one of them, but complementary ingredients have to be mentioned for the field of energy: the **cultural transformation** of the sector to facilitate various types of interaction between start-ups and well-established corporates, the development or acquisition of the **suitable set of skills in the Industry**, and, to a certain extent, the **education of investors** active in the field of energy about the new dynamics and the market fundamentals imposed by digital technologies. Only then scaling up of digital-based innovative solutions will be possible, leveraging the large amount of data generated in energy. Ultimately, this could allow Europe to compete with the US and Asia, and to escape from its current condition of "Digital colony".

> The development of market places and platforms in the energy sector will need to integrate the principles of development of market places while keeping the logic of development of platforms
>
> Value creation for different actors: efficiency and cost reduction for network operators, revenue streams for market participants, incomes or reduced bills for prosumers/customers
>
> Monetisation and the use of different technologies
>
> Openness to more participants and diverse parties for the core interaction
>
> Use the power of Application Programme Interfaces (APIs)
>
> Periodic re-evaluation of platforms

In addition the following barriers were identified within the following critical process

- Consent management
- Data flow communication
- Data quality process management

The associated challenges are linked to the lack of standardized interfaces per device category, lack of compatibility with two-way communication for device control, and overall security compliance. Related to data management GDPR compliance in many-to-many environments for microtransactions should be mentioned, CSV and REST protocols are not efficient to provide near real-time coordination and collaborative models development on a large scale. Technologically, graphQL is not mature enough and needs further refinement.

6.1 Evolving ecosystem

It is clear that the **energy landscape** is quickly evolving under the action of various forces, with digital innovation at the intersection. As an illustration, **new services for consumer empowerment** are emerging thanks to the liberalisation of the markets that created a shift from taxpayers to fully-fledged customers with rising expectations. Empowerment is about becoming more active in the energy system, i.e. being able to generate, self-consume, store or sell electricity, but it also opens the door to the contribution of **behavioural change to the energy transition**, notably for flexibility and efficiency purposes. Behavioural interventions are enabled by the use of digital technologies, involving strategies such as goal setting, commitment, feedback (direct and indirect), comparison to others, or information prompts, notably to create personalised and contextualised interventions.

Companies from the digital world, **mainly innovative SMEs and start-ups**, are developing solutions in this direction, to motivate users to change their energy behaviour[26]. In the same vein, from the incumbents' perspective, digital innovation is an opportunity to enrich the **customer relationship**, with additional and tailor-made services, and to increase the engagement of these customers, while the 2 main challenges faced by major European utilities in 2018 were respectively the **acquisition of new customer** (73%) and the **customer retention/reducing the churn** (60%)[27].

Beyond the specific case of consumer empowerment, boundaries in the field of energy are becoming blurry at the **level of organisations:** we can mention **newcomers on the electricity retail side** (for example, there are more than 30 electricity retailers in France even coming from other sectors such as Leclerc and Casino from retail, or from electro mobility with Volkswagen in Germany), the **electricity companies diversifying their portfolio of services**, notably related to **e-mobility** (for instance, Enel acquired eMotorWerks, Engie acquired EV-Box, EDF invested in Nuvve), and **Energy Efficiency and Demand Response** (Centrica acquired Panoramic Power and REstore, Engie acquired OpTerra and Ecova, EDF acquired Groom Energy and Hellocasa, and developed Aggregio and Sowee, and Enel acquired EnerNOC), the **new organizational structure** at ENGIE as of 2016 based on 24 Business Units and 4 "Métiers", the **creation of Enel X** for e-solutions by Enel Group around 4 fields (e-Mobility, e-Home, e-City and e-Industries) and, more generally, the emphasis of **"Digital" in Utilities' strategy**. The latter goes far beyond the mere inclusion of digital as a topic into their strategies: a study[28] based on interviews of senior-level executives from 29 leading utilities reveals that 70% of them said their **companies want to be digital leaders**, and 20% envisioning a day when they will match the capabilities of leading digital players across all industries.

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[26] For instance, thanks to the Linky smart meter currently deployed by the French DSO Enedis, new players like Wivaldy propose services to households, like a free 7-day diagnosis based on real consumption. Similarly in Sweden, Greenely develops a personal coach to guide users and provide them with tips and tricks to optimise their consumption. Other companies like Opower (acquired by Oracle in May 2016), Bidgely, Tendril, or Intelen can be mentioned.

[27] According to a study based on interviews with 200 senior business and technology executives from major European utilities: "CXP Group, Digital Utilities: From Behind the Curve to Innovation: How Europe's energy and water retailers plan to ride out the revolution in customer engagement, October 2017".

[28] PwC, The digitalization of utilities: There is a will, but is there a way?, Strategy&, September 2016

The further development and scaling-up of digital innovation in energy implies an effort to be made on **attitude (culture) and aptitude (skills)**: it requires to dramatically upgrade the business culture and to implement profound changes to create a working environment prone to entrepreneurial initiatives, based on collegiality, openness, flexibility, but also proactivity and responsibility, as well as to make sure that the workforce is equipped with a suitable skill set to either directly develop and implement or avoid the transplant rejection of a solution coming from elsewhere.

6.2 Ecosystem development within industrial innovation and start-up environments

The evolution in the energy ecosystem co evolves with the growing activity of European energy companies in the field of **corporate venturing**. There are various types of corporate venturing, which stretches from a purely **inorganic venturing** (such as the acquisition of start-ups through a dedicated capital venture funds) to an **organic one** (intrapreneurship, which means the implementation of internal processes to promote creative and innovative ideas in an organisation, and enabling employees to transform these ideas into breakthrough innovations with the support of the parent organization). The emergence of **corporate venture arms** at energy companies indeed plays a strong role in the dynamics behind the evolution of the energy ecosystem, which can be seen as part of a broader trend: **the innovation and entrepreneurial imperative** described by D. Kuratko[29].

Most of the corporate venturing initiatives in the field of energy in Europe are fairly inorganic ones. We can mention the **VC arms of utilities** like Iberdrola, Engie, EDP, Innogy, Eneco, Eon, Enel, Centrica, Statkraft, EnBW, and of other companies like ABB or BMW, as well as the venture capital funds Inven Capital established by CEZ group, Electranova Capital sponsored by EDF, or Valo Ventures sponsored by Fortum. The long-term success of such an initiative of acquiring or investing in start-ups depends on the ability of the parent company to incorporate these start-ups in their short-term operations as well as long-term planning and strategy. Otherwise, the start-up acquisition or investment cannot be considered as a solution to outsource and accelerate innovation, but as a financial investment or even as a marketing and branding solution, and the success of the scaling up is really doubtful or at least, will not necessarily be facilitated by the fact that investment comes from an energy company.

By nature, the energy sector is made of mainly large well-established companies, which have progressively developed and implemented internal processes to ensure that their structure is running smoothly, with an inherent risk-averse culture guaranteeing safety and reliability. For this reason, we can argue that the mutual **cultural discovery** between ventures and larger organisations not accustomed to the venture culture and specifically to the tech culture, characterised by agile methods like scrum, is an important **enabler of the industrialization phase** and thus the scaling-up of digital innovation in energy. More generally, a start-up acquisition is a failure when this entails a transfer of the corporate culture to the venture, and the corresponding rules and processes. That is why **developing a culture of innovation** inside the parent company is highly valuable in the long run and a necessary condition whatsoever.

[29] Kuratko, D.F., 2009. The entrepreneurial imperative of the 21st century. Business Horizons, 52(5), pp.421-428.

Between the venture acquisition that is purely inorganic corporate venturing and the genuinely organic corporate venturing where a corporate promotes and incentivises intrapreneurial initiatives to keep innovating and thus reap the corresponding competitiveness benefit, there is a full range of solutions **to make large corporates and ventures interact** and consequently **culturally influence** each other. From short interactions of half a day to long collaborations over several months, here is a glimpse of potential activities ranked by increasing level of commitment on the corporate side: the organization of a **simple workshop** with founders of start-ups, the participation of top executives in a **learning expedition** over several days, the mentoring of teams during a **hackathon** (around 2 days), the collaboration with a **venture development studio** (startup-as-a-service model such as Bundl), the establishment of or partnership with an **acceleration programme** (around 4 months, such as DataCity with NUMA, Startupbootcamp, Rockstart, or the Free Electrons programme which gathers 10 global energy utilities, including the Portuguese EDP, the Irish ESB, and the German Innogy), and eventually the setting up of a **corporate incubator** (incubation phase is around 2-3 years).

Finally, it is worth mentioning a more exotic way of grasping the essence and requirement of the "start-up culture" for an executive, which is the **reverse internship**, i.e. a manager spending time working as an intern in a venture. In practice though, implementing reverse internship requires access to a very large pool of startups willing to welcome an executive for a while.

6.3 Skills and training outlook

> "As the Fourth Industrial Revolution impacts skills, tasks and jobs, there is a growing concern that both job displacement and talent shortages will impact business dynamism and societal cohesion. […] A proactive and strategic effort is needed […] to manage reskilling and upskilling to mitigate against both job losses and talent shortages. […] Companies across all industries should consider a triple investment today – reskilling at-risk workers, upskilling their broader workforce and building structures for a learning organization".[30][31]

In the age of instantaneity, ubiquitous information and communication technologies, and almost zero transaction cost, **human capital** is becoming a fundamental element of competitiveness and of uniqueness of organisations, unlike technology or financial power: the individual became the basic building block[32] to find, develop, assess, and implement internal and external knowledge into an innovation process, but also to further valorise its outcome externally. From acquisition to development and retention of talents, **talent management** is thus a growing concern and a key strategic aspect[33] in all sectors, including energy, and companies are struggling with attracting and retaining highly skilled individuals.

> It has become a common place that digital transformation of energy is an **economic challenge** as well as a **technical one**, raising concerns about finding and developing new business models based on unchartered business and use cases.

[30] "World Economic Forum, Towards a Reskilling Revolution: Industry-Led Action for the Future of Work, January 2019"
[31] Upskilling refers to learning new competencies to stay in current role, while Reskilling refers to acquiring a complete set of new competencies to transition to a new role.
[32] One can refer to the Active Innovation paradigm, introduced in the literature in 2016. *Meissner, Dirk, and Maxim Kotsemir. "Conceptualizing the innovation process towards the 'active innovation paradigm'—trends and outlook." Journal of Innovation and Entrepreneurship, 2016: 1.*
[33] Phillips, Jack, and Lisa Edwards. Managing talent retention: An ROI approach. John Wiley & Sons, 2008.

To a certain extent, this is also a corporate governance challenge, as digital technologies enable more horizontal and collaborative decision-making processes, eventually enabling more agile behaviours (modular, multidisciplinary, multi-skilled, flat project-based teams, instead of hierarchically-structured with function-based structured companies).

> But **the human resources (HR) implication** is another crucial and yet barely mentioned challenge: as technological change is affecting or will shortly affect virtually **all jobs**, these companies have to operate large-scale employee upskilling and develop futureproof workforce strategies to secure their access to highly valued human resources.

The energy sector is definitely not the first one to be impacted by digital technologies, and examples such as the impact of the internet on businesses like AT&T[34], and the corresponding essential overhaul of their HR strategy can be a great example. The stake is literally huge, and **adapting the knowledge and skills of the workforce to the new challenges is not an option**. Digital transformation is not merely to embed new digital technologies in companies' operations, **but a sprint to reinvent themselves**.

> This HR challenge can be split into **3 main aspects**: a need of skilled **workers equipped with new competencies** (hard skills such as software development, data science, cloud-based computing or cybersecurity), a need of **cultural transformation** (soft skills such as collaborative processes, design-thinking to unleash a customer-centric approach) aiming at gaining in agility and being able to act as a start-up, and a **lack of attractiveness of the energy sector** for the suitable talents which catalyses the first 2 aspects.

Schematically speaking, there are indeed two main approaches to "update" the workforce: to replace the current workforce (firing and/or incentivizing resignation via redundancy plans) by hiring new employees already equipped with the necessary skills, or to retrain the existing workforce. In practice, hiring technical talents is not as straightforward as it appears on paper, due to a limited supply and high demand in all sectors for such talents[35], which is combined with a low level of attractiveness of the energy sector. Besides, due to the speed of change in skill requirements related to the Fourth Industrial Revolution, from a long-term perspective, it is more profitable to develop a culture of life-long learning in companies. In addition, offering learning and training opportunities is highly valued by employees, and life-long learning can thus be seen as a component of an overall attractiveness plan at the corporate level to attract new talents. On top of these 2 main options to get access to new skills, we could also mention the so-called acqui-hiring strategy, consisting of acquiring another company to access their human resources. This practice is well developed in the technology sector, but not widespread in the energy field, probably due to the cultural difference between the energy field and the technology one. Similarly, hackathons are also to be considered as a tool to identify, attract and eventually recruit talents.

There is also a need to reconsider the training and development methods to make it suitable for fields that are advancing too quickly for traditional methods. In this perspective, new training

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[34] The interested reader can refer to *"J. Donovan & C. Benko, AT&T's Talent Overhaul, Talent Management in Harvard Business Review, October 2016."*

[35] According to the WEF, 89% of US companies plan to adopt user and entity big data analytics technologies within the next 4 years, 80% to adopt Internet of Things technologies, 75% to adopt machine learning technologies, 71% to adopt cloud computing technologies, and 52% to adopt distributed ledger technologies.

formats blending online modules and face-to-face hands-on sessions are more practicable for professionals and enable a swifter application in daily professional life of trainees of the corresponding skills. Regarding digital technologies specifically, according to the WEF[36], it appears that most of managers have limited knowledge of new digital technologies and their corresponding uses and potential for their business, which implies that a targeted digital upskilling of management is the *sine qua non* first step towards the adoption of a life-long learning culture and to get prepared to the future of work in companies, which echoes the learning expedition mentioned in the previous section.

In this vein, EIT InnoEnergy has developed a 3-step methodology to offer **tailor-made in-company training** to accompany energy players in this journey. The **first step** is a 2-day challenge-based interactive workshop with the company, which has the same purpose as a learning expedition. Based on this workshop, an analysis of the required skills is realised, and modules of formal learning are developed and produced (usually to be disseminated online) in a **second step**. Finally, the **third step** is a hands-on phase giving the opportunity to trainees to apply the new competencies on concrete cases coming from their daily professional environment, via a 3 to 5-day physical session. On this approach, EIT InnoEnergy has notably created a blended programme dedicated to Internet of Energy, which was open to any company.

6.4 Economic and Investment imperatives synergetic programs view

At a macroscopic level, having an accurate figure of the market that digital energy represents is not easy, notably due to a difficult scoping exercise. However, having a fair order of magnitude is reachable.

According to the World Economic Forum[37], **digital in energy** represents over 1.3 tn$ of cumulative value for industry and over 1.7 tn$ of additional societal value between 2016 and 2025 (i.e. **130 bn$/y** on average of value for industry). Furthermore, based on Bloomberg NEF[38], the cumulative market size between 2017 and 2025 is almost 500 bn$ (and **64 bn$ in 2025**) in the **electricity system** worldwide. This figure can be compared and to the 47 bn$ of investment in digital infrastructure and software in 2016 worldwide according to the IEA[39] and to the 20 bn$ to be spent **by US utilities alone** over 4 years until 2021 (**5 bn$/y on average**) only on customer data analytics, as announced by GTM Research in November 2017.

To put these figures in perspective, we can argue that digitalisation of energy represents a decent portion of the overall investment required to implement the energy transition (cumulative investment of 120 tn$ between 2015 and 2050 or **3.43 tn$/y** on average according to IRENA 2050 roadmap[40], including 18 tn$ for power grids and flexibility or 0.51 tn$/y on average), and the amounts already invested to this aim over the past decade (global clean energy investment amounted to 332.1 bn$ in 2018, and 361.7 bn$ in 2017)[41].

Consequently, assuming that the different methodologies employed by the various organisations provide comparable figures, it can be concluded that overall, **50%** of the **130 bn$** to be invested

[36] "World Economic Forum, *Towards a Reskilling Revolution: Industry-Led Action for the Future of Work*, January 2019"
[37] "World Economic Forum, *Digital Transformation of Industries: In collaboration with Accenture*, 2016."
[38] "Bloomberg NEF, *Digitalization of Energy Systems : A white paper*, November 2017."
[39] "International Energy Agency, *Digitalization & Energy*, November 2017."
[40] "IRENA, *Global Energy Transformation: a roadmap to 2050*, 2018."
[41] "Bloomberg NEF, *Clean Energy Investment Trends 2018*, January 2019."

annually in digitalisation of energy goes to the electricity system, and that digitalisation of energy is 3.8% of the investment for the energy transition.

However, for this transformation to unfold, public and private sectors have to invest in human capital.

> On top of that, such a reskilling strategy can be implemented at the level of the entire sector to pool resources and to benefit from an effect of scale, and potentially get public support at national and EU levels.

Considering that the sector corresponding to electricity, gas, steam and air conditioning supply employs 1.53 million people in the EU in Q3 2018[42], and assuming a training investment of €2 k to €6 k per year per employee over a 5 year period in the context of a profound transition, and that 20% of the workforce would be involved in such large scale programme each year, reskilling this entire industry to exploit the full potential of digitalisation of energy and thus completing the energy transition while reducing the digital dependence on third countries, would represent between €612 mi and €1.84 bn per year in the EU. Hopefully, the cost-benefit analysis of such approach at the level of a given company is most probably positive: the cost of mis-hiring is in the range of 50 k€ to 100 k€ per person, and the benefits of talent management are broader than the direct business impact (such as in terms of brand image or of motivation and loyalty of employees). A player such as EIT InnoEnergy could be instrumental in this perspective.

To conclude, despite the relative absence of "digital champions" in Europe so far able to compete with players such as GAFAM and BATX in the USA and China respectively, the battle is not over, and digitalisation of energy would be a well-suited applicative sector to make such organisations emerge. Europe is weak on consumer/customer interfaces, and investment should be made in this direction, as the consumer interface dimension is essential for the emergence of a vivid ecosystem of services and solutions in position to compete with the giants.

[42] Data coming from Eurostat (ref : lfsq_eegan2) for the NACE code D. This NACE code does not include companies manufacturing electrical equipment (NACE code C. 27).

7 POLICY RECOMMENDATIONS AND REGULATORY PERSPECTIVES

Open energy marketplaces allow implementing consumer-centred transitions. Their main characteristics to enable these transitions is that distributed ledger technologies widen the set of regulatory solutions available to market "designers" because the rules, governance and consensus of part of the energy systems can be reached ahead in time. At the same time, as systems become more participatory, they allow a more intense learning process for regulation. However, adequate tools to facilitate the process need to be implemented.

In that sense, it is important to develop tools to understand the process and monitor the progress and readiness of nodes that are crucial to enabling integration of all the necessary components. We may identify two fundamental steps: i) identifying (creating a consensus on) which are the critical nodes of the digital transformation, and ii) identifying the existing barriers associated with those nodes. Once this is done, indicators to monitor the process can be created. Consequently, continuous experimentation across the industry is necessary to ensure bottlenecks are not missed.

The strategy we pursue in this chapter is to use the fundamental elements identified in chapter 3 to identify three layers of coordination needs. With this, we may map potential regulatory measures to facilitate the implementation of the VISION described in chapter 4 of efficient digital energy marketplaces, which in turn would allow the scaling-up described in chapter 5. In that sense, we aim at providing a map of the fundamental nodes of the design of open energy marketplaces, which in turn will allow analysing potential barriers that need to be addressed. To that end, we divide this chapter into two main sections: the first one defines the multi-layer perspective adopted in the analysis; the second one provides the regulatory consequences derived from the previous analysis.

7.1 Identifying regulatory needs: a three-layer perspective

A useful way to introduce the logic of the digital transformation of energy systems is to look at the telecommunications industry. The layers are: i) the infrastructure layer (Ethernet, ATM, etc.; before the internet, this layer was represented by telephone lines); ii) the rules for information encoding (IP protocol together with TCP or UDP); iii) the applications (voice, video…).

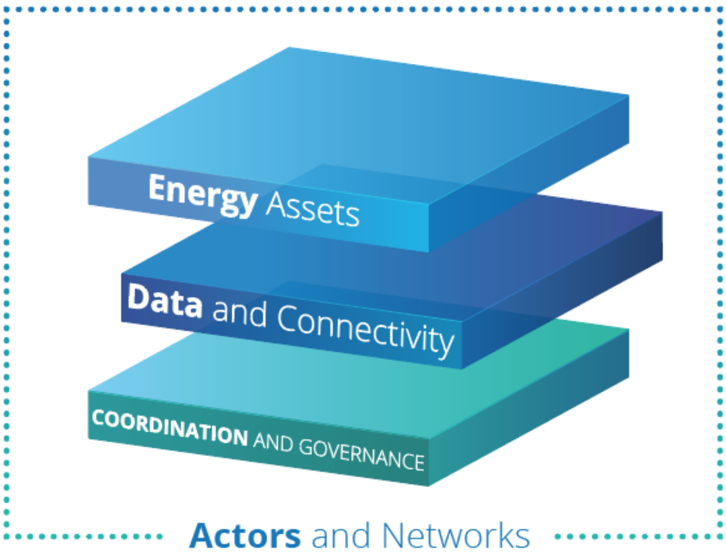
Traditionally, the way of organizing telecommunications industries, as in other network industries, was through a national company providing the services associated with all activities coordinated by a vertically integrated company. In that context, the potential services were relatively known (the technological trajectory was clear), so the main concerns were related to economies of scale (from a regulatory point of view).

Historically, in the telecommunications industry, the liberalization process began by the interest in enhancing retail competition, with a focus on service innovation for end-consumers. This interest drove the introduction of competition among firms (initially, typically still vertically integrated). After that, the technological trajectory changed with the development of the Internet. Incumbents not only offered telephony services but also broadband. Nonetheless, the offer of broadband services required TPA to the incumbents' infrastructure.
TPA allowed that, using the IP protocol to guarantee interoperability, the telecommunications industry did not require extensive physical interconnection among the networks (reducing the need

to guarantee large trunk lines connecting local networks). From the point of view of this chapter, the main idea is that, based on interoperability and access to new infrastructure, actors without internet infrastructure were able to offer services to end consumers.

Digital energy marketplaces are expected to reproduce, to some extent, this logic. In that sense, removing barriers to the use of digital solutions may facilitate the entry of new players (particularly, they may use digital solutions to provide distributed flexibility services). From the point of view of an "internet-like" evolution, one key issue is how platform-based trading (including trading based on distributed ledger technologies) may help in that transformation. Specifically, the importance of platforms as new ways of energy trading builds on the idea that they imply the existence of new players who do not own a large part energy infrastructure[43] but provide energy services. In that sense, these players would be the analogue of the platforms that characterized the transition of the telecommunication industry. In that sense, we may think of platforms as "multi-sided markets", where energy from typically distributed resources will be procured and sold to the end consumers, or wholesale market players.

In order to organize this chapter, and with the aim of identifying fundamental regulatory dimensions for potential designs of future platforms, one can identify three different conceptual layers for the definition of a digital energy marketplace.



Energy assets layer

In terms of energy assets, regulation needs to be primarily concerned with regulated energy assets. This means that, from the energy infrastructure point of view, behind the meter investment may need no specific regulatory measures to control allowed revenues.
The investments associated with regulated networks (distribution and transmission networks) will continue under regulation. In order to understand the aspects that will probably change the transformation of energy infrastructure to support digital marketplaces, let us provide a schematic representation of network regulation.

[43] They might provide smart energy components as part of the services behind the meter, for instance, but they would not own large generation or network infrastructures.

There are two basic kinds of relationships that arise in the context of network industries. They come from the fact that regulators have a role in the relationship between network companies and network users.

The first kind of relationship has to do with the regulator as the counterparty of network companies. Here, the focus is the design of the relationship between the regulator and the distribution company. In this context, regulated tariffs must pay for the required investment. However, after the infrastructure is built, there are incentives for players to behave opportunistically in a hold-up classical setting. The role of regulation, hence, is to guarantee that commitments are honoured and thus investments are paid. This traditionally established situation is modified by potential new actors in the digital energy marketplace. Energy communities, for instance, compete with what was understood as natural monopolies, casting doubt on whether distribution networks are still natural monopolies. In order to address this kind of challenge, there are two main questions to be addressed: i) how to design incentives for the distribution company to invest in infrastructure efficiently (including non-wire alternatives)? and ii) how to share the risk between users and the distribution company? Moreover, the mechanisms need to consider that risk bearing, effort and information are related.

The second kind of relationship has to do with the regulator as the counterparty of network users. This is the tariff design problem, where the decision has to do with the design of signals for network users. First: are the cost discrimination choices among users heterogeneous regarding the way of using the network? Second: can users also be heterogeneous in the way they value the risk and the firmness of the service? Figure 9 summarizes the previous two kinds of relationships.

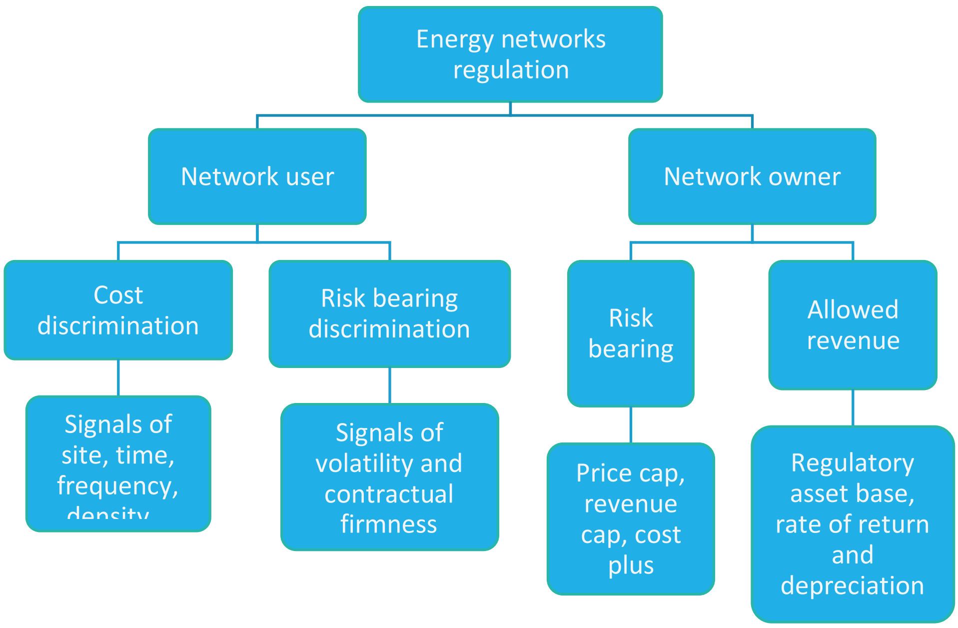


Figure 9. Main tasks of tariff regulation in electricity distribution activities. Source: Own elaboration.

Consequently, in most network industries, the idea is that there is a contract between network users and distribution companies that is defined (to some extent) by the regulator. That contract is usually a long-term contract defining, at least, the product contracted (some form of capacity) and the corresponding price. In electricity networks, where electrons cannot be traced, users cannot specify the capacity directly, so the product being sold must be defined by external rules (in the sense of common carriage systems).

Therefore, incentives for digital transformation, if they exist, will be associated with the definition of the allowed revenue (the relationship between regulators and network companies). In that sense, there exists two elementary approaches:

- Input-based regulation: either recognizing innovation efforts for digitalization through cost-of-capital or inclusion of investments in the regulatory asset base. The main advantage is that these mechanisms are relatively easier to define and evaluate.
- Output-based regulation: defining objectives instead of assets to be recognized (e.g. recognizing automation as a valuable output, so that assets facilitating automation are included in the regulatory asset base). This implies that services that do not involve an asset base may be procured outside the distribution business, as they should not be used to calculate distribution tariffs.

Data and connectivity layer

This layer encompasses, on the one hand, the investment prosumers need to undertake to be able to receive the signals that digital energy marketplaces will send; on the other, it encompasses aspects of revenue requirements of digital infrastructure (the associated with data gathering, as well as the one associated with facilitating responses of energy prosumers). In this chapter, we assume that either digital infrastructure is paid for by the market, by policies for digitalization external to the energy market, or by the allowed revenue discussed in section 0.

In order to analyse the way in which the data and responsiveness layer is dealt with, let us consider that one of the main elements of change in the internet industry was the IP protocol, which allowed interoperability without the need of physical interconnection. This in turn facilitated the creation of players offering internet services without owning enabling infrastructure, so the marketplace moved from one organized around infrastructure to one organized around digital platforms, defined as a hybrid of services and complementary (digital) infrastructures.

In that context, it is worth asking how many of the lessons drawn from the governance of internet industries can be transposed to the electricity sector. Electricity is not exactly like the internet, but for applying smart contracts in the sector the concept of platform and the importance of their governance may become central.

Electricity systems still need very specific ancillary services, which are typically coordinated by infrastructure operators (both TSOs and DSOs). Furthermore, the limits of interoperability without physical interconnection may be tighter for energy industries. In the second part of the brief we investigate potential architectures for digital marketplaces, taking into account only the energy side of the design, with the aim of identifying fundamental elements of their design, and the corresponding governance principles that we need to take into account.

Architecture of platforms

An important part of the role to be played by smart contracts will be defined by choices made in the design of platforms. Likely, one of the most discussed choices is between markets based on a centralized player as a counterpart of end-users (aggregator) or based on P2P trade implemented on a platform (or a combination of both). With the aim of investigating the role of policy making in this regard, we explore the characteristics of this choice, grouping its challenges under two broad headers: the ones associated with operational platforms, and the ones associated with market platforms.

Elements to define the architecture of digital energy marketplaces

Market operator	○ The question of defining the market operator depends largely on the kind of market one is considering. Nonetheless, the traditional view that energy markets are operated by third parties and ancillary service markets are operated by TSOs may be challenged. The reason is the need to integrate flexibility sources that are associated with very particular locations, and at the same time their availability depends on end-consumers' preferences. ○ One potential situation is a nested, multi-level architecture of digital marketplaces. In it, local resources are integrated gradually into upstream operation. That is, local resources are coordinated through the exchange of signals with regional (sub-, super- or national) markets. In this scenario, distributed ledger technologies would be of special use to the coordination of local resources, while upstream markets would remain reasonably unchanged (markets for energy or ancillary services). In this context, one main concern is the role of TSO-DSO cooperation, in the sense that it will be required to define the services to be sought locally, a common optimization of flows. ○ Another potential situation arises from a significant trading activity outside traditional, organized markets (what can be seen as Over-the-Counter trading). Distributed ledger technologies facilitate secondary trading, as the automation of contract transformation allows bypassing traditional "structures" (utilities, banks, etc.). In this context, alternative platforms would compete with traditional marketplaces. This kind of platform would appear at any level of the production chain (from local to supra-national), likely depending on the number of players connected to it (to benefit from network effects).
Participants of the digital marketplace	○ It is difficult to consider a digital marketplace without all energy resources being able to participate. ○ Likely, the most difficult question in this case is how to procure regulated services, i.e. TSOs and DSOs requirements of ancillary services. The debate revolves around the possibility of organizing dedicated platforms for DSOs' service procurement. Potentially, although separating markets may be suboptimal from an operation perspective, if there are data limitations to the joint procurement of TSOs and DSOs through smart contracts with end-users, increasing local flexibility might require sacrificing some operation efficiency.

Governance of platforms

When one discusses smart contracts, it is important to understand all things a contract does. Contracts are registers for trade, but there are nonetheless more functions to be performed. Depending on whether those other functions of a contract are relevant, decentralization would be a more or less strong force. Differently put, even if the trading is centralized through a platform, complex contracts that cannot be automated, may represent the preferred risk allocation mechanisms.

Moreover, the definition of the governance structure is highly relevant. As we have observed in financial markets, relying on private organizations for performing governance functions may result in fragile structures. Consequently, even for those simpler contracts that can be automated and traded through a platform, the governance of the platform must be looked at carefully. Potential governance structures are:

- The first definition would rely on a relatively low level of change in the reasoning behind current markets, in the sense that it would be integrated in evolving markets. In that sense, it can be thought of as an extended wholesale market, with the potential to accommodate contracts based on distributed ledger technologies. That is, the most demanding activity is defining the requisite new contractual forms (automated ones), as the new kinds of players that are allowed to participate in markets are defined in the Clean Energy Package.
- Another solution is to let "platform" players develop independently. In that scenario, platforms would compete among each other in the various levels of aggregation (from local to supra-national) offering matching services to players with or without energy assets. The economic characteristics of this competition, on the other hand, creates a tendency to a very oligopolistic market (because of network effects).

Coordination-of-services layer

There are two basic contracting layers that are relevant for the implementation of digital solutions: energy contracts and network-related transactions

Short-term energy contracts (Time flexibility)

An actual transition to a consumer-cantered industry should lead us from smart technologies (that any utility may implement by themselves to manage their assets) to smart contracts (all the players need to use the technology to improve the efficiency of industry coordination).

Short-term energy markets

Most of what it is discussed nowadays has to do with the question: is it possible to automate all short-term transactions? Distributed ledgers are a new technology that allows registering trade in a much cheaper manner (that is, decentralized trading becomes cheaper). Hence, the introduction of automated transactions, which in turn allows more participants (and hence assets) to participate in the market. In that context, the main challenges, from the energy side, are related to the data side of the question: how to deal with either a large number of transactions or a large number of payments. From the ICT side, challenges related to the need of new infrastructure are relevant.

From the energy market standpoint, the increased number of possible transactions are viewed as a source of detailed signals on system operation and end-consumers' preferences, which may represent valuable resources to unlock flexibility to cope with increased intermittency. In this context, we acknowledge that data management can be a challenge associated with smart contracts for short-term trading. The innovation in the big data and Internet of Things industries will play a key role to overcome it, and it may take some time. However, for this innovation process to be possible, market design incentives are necessary. That is, the organization of short-term energy trading needs to allow and to recognize the economic value of smart trading.

There are four main dimensions in short-term markets in which smart contracts can strongly add value: (1) Standardization of contracts; (2) Aggregators and P2P transactions; (3) Local flexibility; and (4) Short-term signals. If the design of digital energy marketplaces recognizes the economic value of the potential new services associated with these four dimensions, sector transformation through big data innovation and adaptation will become possible.

Digital energy marketplaces in the short run

Standardization of contracts	○ One of the main advantages of smart contracts is that a short-term market based on automated trading requires less standardization than traditional markets, because of the reduced transaction costs of signing contracts when they are automatic. ○ Hence, the number of products that can be offered in energy markets, without representing a significant drain of liquidity, increases. This allows creating a larger ecosystem of contractual solutions, representing both energy and flexibility services, and potentially other bundled services. ○ Nonetheless, there is a need to develop a standardized set of services that need to be procured by (coordinated) TSOs and DSOs. Likewise, the potential for encoding a larger number of services is facilitated by smart trading. As a large set of product types in the energy market does not seem to be a strong limitation for smart trading, separated "flexibility" markets do not seem necessary because "energy markets" would provide the requisite flexibility. Besides, one may expect that new products would rely on evolving digital platforms. ○ The amount and availability of data (granularity of data, connectivity, interoperability of the enabling components, enabling policies for services…) seems to be the crucial requirement in this step.
Aggregators and P2P transactions	○ Removing barriers to the use of digital solutions may facilitate the entry of new players (e.g. aggregators). These new players in turn may use digital solutions to provide distributed flexibility services. One key issue is how distributed ledger technologies may help in that task. We expect entry of new players (as aggregators) that own little energy infrastructure (e.g. they might provide smart energy components as part of the services behind the meter) but provide energy services. In that sense, we may think of them as players operating in "two-sided markets": purchase energy from potentially distributed resources and sell to the market. The environment where this kind of trading happens is a "platform". Additionally, P2P trading can happen also in

	this new environment. What is the change brought by smart contracts in this platform scenario? ○ One of the main liquidity challenges was that, once you agree to a contract, reselling it implied to find another participant willing to purchase exactly the same product. Smart contracts facilitate the task of converting the product you purchased into different products (using encoding). This enhances the liquidity of the market, as the ecosystem of potential counterparts is increased. ○ From this point of view, we may expect, in well-functioning platforms (or ecosystems of platforms if interoperability of platforms is ensured), frequent transformation from energy contracts into flexibility contracts and the other way around. That is, agents trading in digital energy marketplaces would have portfolios combining flexible and less flexible contracts (similarly to what one observes in telecommunication platforms).
Local Flexibility	○ The question is to choose between local markets and wide market areas. In principle, local markets tend to be illiquid, so it is difficult that they exist alone. Nonetheless, participation of local resources in system operation is crucial. Smart contracts, through automation, facilitate the coordination among different levels, from local to supra-national. In any case, granularity matters, since congestion can be solved on a local level and the type of required flexibility varies as well through the season; hence, flexibility pooling and the related contractual part could be bottom up. ○ One of the main concerns is to avoid fragmented markets (lack of liquidity may hamper the use of distributed flexibility resources).
Short-term signals	○ How will contracts produce short-term signals (signals for all types of uses of the power system, e.g. flexible consumer devices, local consumption prioritization and decentralised production)? ○ As the size of the available contract portfolio may be larger, locational signals at a very low level are possible and allow the potential participation of very small end-users. Consequently, the introduction of very detailed locational signals seems necessary to unlock the full potential for flexibility of the system demand-side. ○ Besides, the level of spatial detail of network tariffs is relevant as well, as there is interaction between network investment and many of the assets associated with distributed flexibility, because that flexibility is a substitute for network reinforcement. Moreover, smart contracts allow defining in a more detailed manner how long end-users are committed to network use (e.g. 10 years), so that cost allocation may be defined relative to that commitment and network planning may respond better to end-users' preferences.

The general idea is that markets need to respond to the fact that distributed ledger technologies allow reducing transaction costs associated with registering trades. For instance, aspects that are facilitated by automated contracts are: verification of trades, trust building, access to instantaneous responses, etc. This means that players that did not and could not participate in the past may see an opportunity in the digital marketplace. In particular, energy communities, peer-to-peer transactions, and in general services exchanged through platforms, may perceive easier their entry into the market. In order to let new players decide, a significant increase in the signals provided by the market needs to take place. Moreover, because automated contracting significantly reduces the costs of designing contracts, the need for standardization may be lower than it is in current markets.

Long-term energy contracts (Coordination of investment in generation assets)

The most relevant case for the use of distributed ledger technologies to coordinate investment in energy assets is the "smart Power Purchase Agreement". The rationale behind this potential solution is that developers of power plants (typically based on renewable sources) sign a long-term smart contract with end-users (likely industrial consumers, but they might also be residential consumers). This long-term smart contract would "tokenize" the ownership: the asset is codified into small parts, and then those parts are manipulated using blockchain (registered and traded). In this sense, dividing ownership into small parts is the same concept as equitization, or differently put, distributed ledger technologies favour the use of equity to finance investments in power plants and lines. Using equity is partly good because it allows risk sharing, but also increases transaction costs because of information asymmetry, incompleteness, etc. (in fact, currently equity is a relatively small part of large projects' financial structure). We explore whether smart contracts alleviate the challenges (transaction costs) associated with using equity as the financing vehicle.

In this sense, we will deal with a second question: Is the substitution of traditional contracts by smart contracts efficient?

There are at least three different dimensions that we need to consider when analysing the efficiency of using smart contracts: (1) contract performance, (2) financial arrangements and (3) consumer-driven participation. The potential efficiency gains of smart contracts will likely concentrate most of the improvement in consumer-driven investment. Nonetheless, the kind of project we expect is characterized by a relatively simple financial structure (contrary to most long-term investment).

Building blocks of a policy for long-term smart contracting

Contract performance	○ A Power Purchase Agreement, when associated with large investments, is normally very difficult to negotiate. Besides, it relies heavily on a continued relationship between the parties (the first contract is more difficult than subsequent contracts). Smart contracting would mean the automatization of that long negotiation process, and we may not have the tools to do that as of yet. ○ Long-term contracts are associated with considerable levels of potential conflict, and hence the need for conflict resolution tools. Hence, investment in large new assets for the energy transition (i.e. large renewable generation and grid capacity) will face significant challenges to use smart contracts as coordination mechanisms.
Financial challenges	○ Additional transaction costs are associated with the coordination of the parties involved in the contract. One cannot identify all future circumstances (hence also cannot write code for them), so the "ex post" transaction costs (information, incompleteness) are not changed by the smart contracts. Smart contracts imply the extensive use of equity, and it is not likely that large projects can be financed using just equity.
Consumer-driven investment	○ It seems difficult to foresee a future where consumers alone drive renewable investment as counterparts of long-term contracts (as a kind of crowdfunding of renewable projects), because of the challenges described above. Nonetheless, signals for this kind of smart contract may be relevant for projects, as they represent additional funding, however small in relative terms. ○ Moreover, end-consumers' portfolios represent a signal of end-consumers' preferences, which may incentivize the undertaking of projects to fulfill them. ○ Although end-consumers' smart contracts tend to be more expensive in infrastructure projects, as PPAs, in smaller projects as within a firm, a small neighborhood, etc. smart contracting may be less expensive.

In summary, some transaction costs may be reduced by digital energy marketplaces (the costs of registering transactions, i.e. of "signing" contracts), but others may be increased (negotiation and renegotiation costs, and agency questions). Balancing these two forces is part of what one needs to understand to design the transitions to new digital energy marketplaces. The choice between the efficiency of decentralized and centralized mechanisms will depend on the cost of signing the contract but also the expected costs of renegotiation (the smart contract decreases the former but not the latter).

Signals on networks use (Spatial flexibility)

The pricing of network services can be related to the previously discussed Figure 8, which we reproduce here:

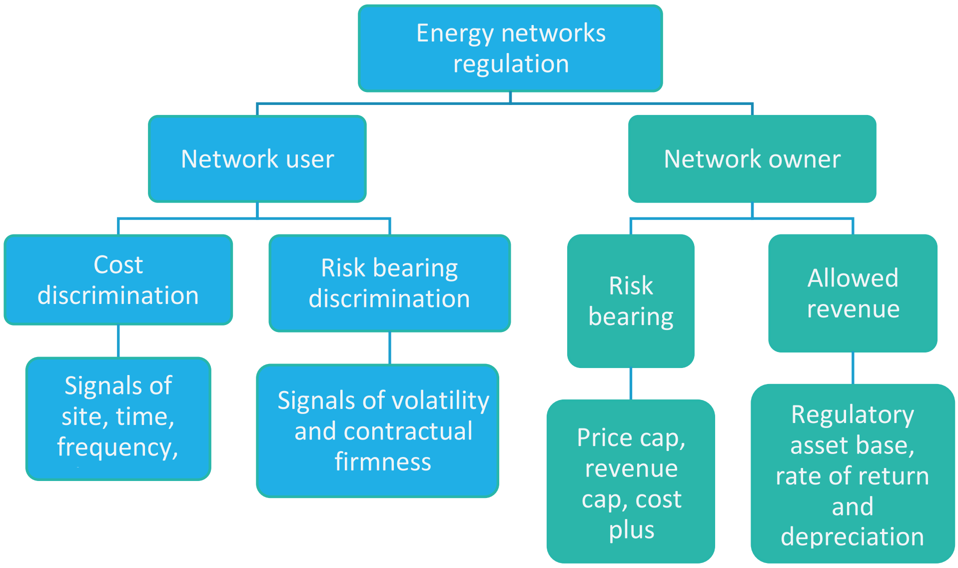


Figure 10. Signals aimed at network users. Source: Own elaboration.

In this case, nonetheless, we refer to the left side of Figure 10, the part where network users' signals are schematically represented. One of the first questions that arises is how to allocate fixed costs among network users.

As fixed costs are much higher than variable costs, the problem is fairly well resolved separating tariffs in: a) a charge for capacity, which accounts for the high fixed cost, and b) a usage charge for use. This would be a typical two-part tariff. However, the situation in some electricity networks is quite different. The reasoning can be traced back to the fact that, traditionally, electricity consumption was considered fixed, in the sense that it did not vary in response to changing network charges. So, the solution that was implemented consisted in variable charges (use) which were typically much larger than the variable costs.

The logic for that may be identified with the fact that it is possible to consider that the costs associated with separating fixed and variable charges were larger than the benefits. Consequently, it is common that electricity grid regulated tariffs were biased toward a cross-subsidy between capacity and energy. In practice, capacity issues were diluted in the energy component of the tariff setting. In that sense, typical tariff design implied that the capacity costs were significantly higher than the fixed ("capacity") part of the tariff: that is, capacity costs were 'variabilized'. That is the rationale behind the fact that most pricing solutions must provide signals for network capacity through the price of energy. The paradigmatic example is real-time pricing, where network costs are allocated exclusively according to energy only wholesale prices. Considering that distribution networks are dedicated assets, and hence the need for long-term relationships, energy only real-time pricing cannot play the role of a long-term signal[44]. Furthermore, put into the context of regulatory contracts, real-time pricing (or other 'variabilized' fixed charges) will consequently

[44] The so-called time-of-use tariffs follow the same logic, though they have longer periods of variation. In that sense, they can be interpreted as longer-term signals, but not as a fixed charge for capacity.

increase the uncertainty of the final electricity demand to be charged. That will increase the need for tariff adaptation, and hence transaction costs.

However, the digital transformation may affect the tariff system in two ways. First, changing the flow characteristics should change the required investment requirements. As a consequence, it will impact the regulatory asset base and possibly modify the revenues collected by the network company. Second, the introduction of new energy generation technologies (e.g. PV panels and electric vehicles) may increase the variability of electricity flows in the long run.

In the new context, current mechanisms in which regulators simplify long-term commitments to use the network and define a sequence of shorter-term tariffs (i.e. the variabilization of fixed costs) may become less efficient. The main consequence of the variabilization of fixed costs is that present network expansion is paid for by current network users, regardless of their expectation of future network use. When the volume of energy consumed did not decrease in time and capacity requirements are limited, the previous assumption may be approximate enough.

However, it is not clear that such an assumption is still valid in the new context introduced by innovations that negatively energy consumption and positively capacity requirements. Are the design tariffs robust to accommodate these changes and if not, how to transform the design tariff?

To illustrate this, consider that two different network expansions can be undertaken: the first one is optimal in the case that the amount of distributed energy (e.g. electric vehicles) is moderate, the second one is optimal in the case that the amount of distributed energy is significant. In such a situation, network operators need to guess which the most probable future demand is. Assume that the network company builds if the capacity to store energy is going to be moderate. As network users have no commitment, if they decide afterwards to store their own energy, the maladaptation of the network will be paid for only by future network users, in spite of the fact that the network was built to serve current users.

A consumer-centric view

Many of the challenges and new features of open energy marketplaces we are discussing in this paper have to do with the fact that end consumers will engage with energy services more than they have done in the last decades. The platforms are precisely the channel to achieve that engagement. Nonetheless, consumers' (or their extended versions of prosumers' or even prosumageurs') engagement could be active or it could rely more on the management of centralized third parties. This has profound impacts on the kind of platforms we would observe, and consequently on the need for regulation.

In order to identify the elementary building blocks of different solutions, let us consider two extreme scenarios for consumer-centric transitions, paralleling the analysis developed in the "Governance of platforms" section. The main dimension of differentiation between both cases is the agent in charge of managing consumers' responses:

- The first extreme case would consider engagement of consumers through a third party;
- The second case would represent active engagement of consumers, i.e. individual or community participation in local energy mechanisms.

Extreme scenario I: Delegated engagement

The idea in this first extreme scenario is that the main driver to activate consumer response is a relatively simple business model where the main goal is facilitating switching among utilities. This would be done by doing the switching on consumers' behalf. As this model requires relatively little change from the current design of power markets, it might rapidly gain significant market shares. Once established, and most importantly informed by customer data, these companies would start offering new services, namely smart products, micro-generation and energy storage, mobility, home services, etc. In that sense, a large share of consumers' flexibility would be controlled by centralized third parties.

Extreme scenario II: Active consumers

In contrast, the other extreme scenario would be driven by a prioritization of consumers' participation, so the focus would be on the development of local energy systems (in this sense, the principles would be those of the "sharing economy").

In this scenario, one of the main challenges is the coordination of community, long-term investments in energy assets (generation, heat, storage, shared mobility, etc.). Smart contracting is, in this scenario, of special importance in the sense that all these investments would be coordinated through "energy allowances" (likely tokenization). The evolution would be defined by the success of several experiences in local systems, which would facilitate the development of inter-community trade.

Drivers for each extreme scenario and (energy and data) needs

In order to understand the need for regulation, we reflect in this section on the elements that may favour one or the other extreme scenarios (thus understood as "trends" more than "results").

Rationales for the choice of business models

	Energy Side	Data Side
Drivers for consumer-centric models (shared by both scenarios)	○ Smart metering technologies ○ Lowering costs for DER ○ Facilitation of switching among suppliers ○ Consideration of alternatives to the incumbent model	○ Data generation and integration of other internal data sources
Drivers for delegated engagement	○ Considerable complexity of P2P trading ○ Consumption patterns improved without too much effort	○ Analytics and the demand for external data
Drivers for active-consumer scenario	○ Demand for energy satisfaction in remote communities ○ Local energy, environmental and industrial policies (e.g. cluster policies to improve sector characteristics in a given region)	○ Cross-leverage: buy, sell and provide data and services leading towards active consumer participation

In this sense, different scenarios motivate different regulatory needs. The different business models described in this section can be adapted to the different governance structures outlined in section "Governance of platforms". In particular, the "delegated engagements" scenarios would present more "natural monopoly" characteristics, i.e. more essential services controlled by centralized agents. In that sense, those agents, as described in section "Governance of platforms", would probably be regulated similarly as regulated retailers. On the other hand, the active-consumer scenario would need a careful design of contracts, and a tight monitoring on potential anti-competitive behaviour.

7.2 Regulation and regulatory adaptation

In times of innovation, regulation needs to adapt to changes but it also needs to be stable to provide a facilitating environment for (potentially) long-term investment. It may seem a trade-off adaptation versus predictability. However, the logic needs to change here. In an environment with constant innovation, the predictability should be achieved through a transparent and well-designed process. The lack of adaptation may be one of the most disruptive choices in a time where the technologies everywhere (other industries and other countries) are constantly moving. Sandboxing is often proposed as a stable tool to support the regulatory process of innovations. As every tool, it has its own limits, and it may suffer from similar challenges associated with other innovation processes: it is not clear how to go from "regulatory experiments" to "scaling up" the experiments. When thinking of the main regulatory adaptations for smart contracts, it is key to understand the implications on market design, and on network and platform regulation.

Regulatory implications	
Market design considerations	○ From the first part of this chapter, market design aspects of the introduction of smart contracts are essentially related to removing barriers for the participation of distributed resources in all markets. To that end, one needs to consider the potential two sides of a platform integrated in a wholesale market: on the side of the traditional wholesale market, contracts may be automated or not, but in any case, it will be a player dealing with standard contracts. ○ On the side of end-consumers, the products offered may be varied and in general be designed by the platform. Anti-competitive behaviours may arise in this environment, and structural measures might be considered. Actually, one important advantage of smart contracts is that they are typically easier to monitor. They also provide verification mechanisms.
Network regulation considerations	○ Related to the points raised in the short-term analysis of this brief, the need for augmented short-term signals apply not only to market players but also to regulated players. This includes providing locational signals (as detailed as possible, to allow as much disaggregation as possible), and time signals. In the case of network companies, time signals mean to establish defined periods when the tariffs are in place, so that agents can decide whether to invest in alternatives to grids. Smart contracts allow organizing logistics in a more efficient manner, so substitutes for grids become a more interesting alternative.
Regulation on platform governance principles	○ From the viewpoint of data sharing, one of the most relevant issues is to have standard data sharing protocols for TSOs and DSOs in different jurisdictions. It would be a significant barrier for the Internal Market, a situation where each network company had a different protocol to participate (or manage) each platform. In the limit, it may be considered a solution where all network companies procured jointly data services from common data providers. ○ Besides the data dimension, unbundling requirements is an additional question to be addressed. In principle, the owners of energy production assets may be

interested in the creation of a platform. They have a portfolio of generating units and, typically, a portfolio of clients to whom they sell the energy. In this situation, if they are allowed to manage the platform, there might be an incentive for them to drain liquidity from the platform, or to offer less services or contractual forms than expressed by platform users. If the number of inelastic clients in the platform is large enough to compensate for potential competition from other platforms, the inefficiency might be considerable. In this case, an unbundling requirement (unbundling service providers from platforms) may be necessary.

- Another relevant aspect of platform governance is its access regime. Traditionally, network infrastructure was obliged to offer third-party open access (negotiated or regulated). The rationale behind that measure was that economies of scale created incentives for networks operators to behave strategically, and hence regulation needed to be implemented. In the case of platforms, one typically does not face an economies of scale question. However, economies of network are present, so the case for third party access may be discussed in similar terms.

We may think of the digitalization of energy industries as made up of three levels: i) challenges of data production and management; ii) the design of a digital energy marketplace; and iii) the consumer side of the new marketplaces, i.e. how these changes add value to consumers.

In this note, we dealt with changes in market design. Our proposal is to articulate the analysis on smart transactions, in the sense that they represent the bridge between the data side and the consumer side of the change associated with the digital transformation. From the analysis above, one may conclude that there is a fundamental need to address whether centralized trading is more expensive than decentralized trading. To that end, it is necessary to consider all costs, not just "tokenization" costs, i.e. the costs of decentralizing the decision-making process associated with energy assets.

The smart contract approach allows establishing a connection between transaction cost theory and the application to digital energy marketplaces. If we use the elementary idea of transaction cost theory of using conflict resolution abilities as a driver for the choice of transaction arrangement, we may identify that:

- When conflict is difficult to solve, decentralization tends to be more expensive
- When conflict is less relevant, decentralization can be less expensive

A typical example of the former situation is an infrastructure project (as the one typically governed by long-term, complex Power Purchase Agreements). A typical example of the latter situation is a transaction within a single firm, or transactions involving small neighbourhoods ("communities").

To decide ex ante whether most transactions can be decentralized or not, which in turn affects significantly the choice of architectures and governance of platforms, is typically not possible. Consequently, the adaptation requires some level of experimentation. In this note, without discussing potential tools for experimentation, we identify several dimensions where such experimentation may be of use:

- Experimentation on data exchange: to define the needs of data that is not available, and to disseminate what data is available but stakeholders do not know. In this category, sandboxing also acts to discuss and better understand rules that need no change, as they already allow digital businesses.

- ☐ Experimentation on potential conflicting interests, or potentially anti-competitive behaviours.
- ☐ Experimentation to define standard clauses for automated long-term contracts, and to study financial aspects associated with them.

In any case, the required experimentation needs to be understood in the context of a multi-faceted innovation process. Consequently, we should not rely only on experiments to implement the change, as "scaling up" the successful "experiments", as in other innovation processes, may face specific challenges, as a system-wide view becomes increasingly necessary.

Tools to facilitate transitions require experimentation

In order to facilitate the transition from current markets to open energy marketplaces, we propose three different sets of measures to be developed, and consequently measures that require experimentation.

Marketplace Readiness Indicators. The idea of this dimension is to standardize and organize the way in which we look at marketplaces functioning. We may rely, in that context, on the analysis developed in section "Coordination of services". In that sense, the efforts in the design of indicators would need to address three dimensions:

- ☐ Finance: One important dimension to monitor is the ability of consumer-side players to find the required financial resources to undertake investments in assets for open marketplaces. Particularly, this dimension of the indicator would measure the bankability of projects under the current rules, and the potential improvement of bankability under different rules.
- ☐ Contract clauses: Related to the previous point, experimentation would need to help in designing effective contracts to allocate risks among open marketplaces participants, including the analysis of the potential for the automation of those clauses.
- ☐ Consumer participation: Finally, the indicators would need to provide insight on the ability of consumers to decide on the development of the energy systems. In particular, the idea is monitoring to what extent central planning is required when consumer-centered decision-making processes develop.

Organizational and Experience Readiness Indicators

Establish interface with Industrial Platforms and Smart Cities marketplaces initiatives

In general, one basic goal of the experimentation requirements will be the development of these kinds of indicators and initiatives. If the objective is the scaling-up of digitalisation initiatives, facilitation of market creation for services in the energy sector, including sector integration services between energy sectors in response to the EU Sector integration strategy[45].

45 https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf

8 CONCLUSIONS

The Recovery Plan for Europe will offer attractive opportunities for the digitalisation of the energy system, and public funds could be made available by Member States (and regions) through the Recovery and Resilience Facility or the Just Transition Fund for new services and solutions for energy services prosumers driven as well as grid operators driven that can be enabled through open energy marketplaces. These would unlock significant benefits for the energy transition, but also for growth and job creation, in a context of unprecedented crisis. The technologies mentioned in the paper would serve as the enablers augmented by data sharing principles and the related new data infrastructures, including data spaces, which are critical components for successful scale-ups. Especially within the Recovery and Resilience Facility, it is worth mentioning the PowerUp document, with different components related to the energy sector.

Open Energy Marketplaces are expected to play an important role in increasing decentralised renewable production while enabling the Green Deal goals, demand response enabling solutions facilitating renewables integration into smart grids as well as the related demand-side flexibility and markets. Scaling up of services across EU markets is imperative for the viability of the underlying platforms and services. This can happen through unlocking investments needed for distributed digital infrastructures and data spaces and enhanced connectivity. In addition to the infrastructures topics related to data governance within European data spaces, the need for accessible data, clear rules for data-sharing and the related harmonisation across the EU.

Monitoring of the related developments could be done through the addition of the observatory task on the related developments within BRIDGE. In general, the paper identified several elementary dimensions to activate marketplaces development:

- ☐ **Ensuring that the market design** is fit to send the appropriate market signals for consumers to adopt and engage with these innovations. In that regard, further efforts to enhance the participation of consumers in the energy system would be welcome.
- ☐ **User experience is key to scale-up the innovations:** The solutions to be endorsed should be simple and convenient, taking into account the diversity of consumers both in their willingness and their ability to participate more actively in the energy system, otherwise, the solutions put forward will be unable to reach critical scale. Similarly, interoperability is a must-have for the rapid deployment of the solutions.
- ☐ **Fostering an innovation-friendly culture:** The development and deployment of innovation requires an adequate culture, especially agile methods, whereas the energy sector is structured around well-established utilities with a risk-averse culture (catering for the imperative of security of the energy system). It is, therefore, crucial to foster cooperation between these utilities and ventures to facilitate the emergence of a dynamic innovation environment, resulting in solid business models for blockchain-based solutions.

- ☐ **Public Sector involvement:** It is important to include the public sector in the equation. Public administration owns a great number of buildings and sites that can contribute to increasing energy systems flexibility. They may act as energy producers (e.g. with photovoltaic panels in buildings owned by them or windmills in different public spaces) They are also large energy consumers. Moreover, public policies may have a significant impact on the pace of implementation of digital marketplaces. Consider public policies as the "energy poverty initiative" or the program "no-one-left-behind": public administration may change market rules to protect vulnerable people. Using digitalization to facilitate the implementation of these policies (e.g. "smart affordable housing" in Ceará, Brazil) may have a considerable impact on the development of digital marketplaces. We need to consider, on the other hand, that public sector adaptation may not be as fast as market adaptation.

- ☐ **Investments** may be focused on increasing penetration of IoT infrastructures; smart energy components forming participation nodes within open energy marketplaces; interoperable services towards energy efficiency and decarbonisation goals and the related data spaces. The societal challenges require new digital infrastructures, new and further development of business models, consumer-friendly solutions. Incentivising greater adaptation of solutions delivering decarbonisation goals by prosumers and consumers could be done through the valorisation of data share and multi-sided services provision within digital platforms and the related Open Energy Marketplaces.

In addition, the paper identified areas where public support will be Important. In particular, the European Union can contribute to accelerating the development of blockchain-based solutions primarily by: i) supporting Research & Innovation activities aiming at increasing the maturity level of the solutions (above TRL5) based on the use case approach; and ii) ensuring, notably through regulatory experimentation, that business models can be designed, tested, validated by innovators.

Specific measures from regulatory authorities to facilitate transitions

The paper identifies several dimensions where regulatory authorities may facilitate transitions to open digital marketplaces. Specifically, the paper identifies four different layers of regulatory and policy experimentation (possibly through sandboxing) that may be of use for the development of digital marketplaces:

- ☐ **Experimentation on data exchange**: to define the needs of data that is not available, and to disseminate what data is available but stakeholders do not know. In this category, sandboxing also acts to discuss and better understand rules that need no change, as they already allow digital businesses
- ☐ **Experimentation on potential conflicting interests**, or potentially anti-competitive behaviours;
- ☐ **Experimentation to define standard clauses** for automated long-term contracts, and to study financial aspects associated with them;
- ☐ **Monitoring the regulatory unclarities** that may hinder further development of the solutions. We identify three levels of action in this respect: i) Market design; ii) Network regulation; iii) Regulation of platform governance.

In any event, as in any other experimentation process, the implementation of regulatory experiments will require methods to measure the results of the experiments. In that sense, the definition of standard ways to look at the performance of digital marketplaces is a building block of the design of regulatory experiments that help evolving marketplaces. Consequently, standardizing measures/indexes to monitor the evolution of and potential barriers caused by current market designs and financial structures are of considerable importance.

Hence, the efforts in the design of indicators would need to address three dimensions:

- ☐ **Monitoring** the ability of consumer-side players to find the required financial resources to undertake investments in assets for open marketplaces (bankability of demand-side projects)
- ☐ **Contract clauses**: How to map risk bearing among participants in an open energy marketplace, particularly in terms of conflict resolution
- ☐ **Providing insight** onto the ability of consumers to decide on the development of the energy systems. In particular, monitoring to what extent central planning is required when consumer-centred decision-making processes develop.

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10. Contributing stakeholders

1. About AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT Innovation in Europe, bringing together small and large companies, start-ups and scale-ups, academia, policy makers and end-users and representatives of society in an end-to-end approach. We work with partners in a global context. We strive to leverage, share and promote best practices in the IoT ecosystems, be a one-stop point of information on all relevant aspects of IoT Innovation to its members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of IoT Innovation in society.

AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies. We also put them in practice in vertical application domains with societal and economic relevance.

2. About ENTSO-E

ENTSO-E, the European Network of Transmission System Operators for Electricity, represents 42 electricity transmission system operators (TSOs) from 36 countries across Europe. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising the gas and electricity markets in the EU.

The role of Transmission System Operators has considerably evolved with the Third Energy Package. Due to unbundling and the liberalisation of the energy market TSOs have become the meeting place for the various players to interact on the marketplace.

3. About EIT InnoEnergy

EIT InnoEnergy is a multi-scale and multi-stakeholder network-based and open innovation organisation, dedicated to accelerating innovation towards sustainable energy in Europe. It is a European Public-Private Partnership supported by the European Institute of Innovation and Technology (EIT) established in 2009, grounded on the full integration of the three dimensions of the Knowledge Triangle (Business, Research and Education) via 3 main activities which catalyse innovation and entrepreneurship focusing on sustainable energy: support of innovation projects (145 products and services supported), incubation and acceleration of start-ups (330+ start-ups accompanied) and Education programmes (1,100+ graduates from 8 Masters' programmes, executive courses and online or blended courses).

EIT InnoEnergy supports and invests in innovation at every stage of the journey – from classroom to customers, to accelerate the energy transition. The company operates in 17 EU Member States from 6 regional nodes (France, Iberia, Sweden, Poland, Benelux, Germany) around 7 thematic fields of energy (energy for circular economy, energy storage, energy efficiency, energy for transport and mobility, renewable energies, sustainable and efficient buildings and cities, smart electric grid, nuclear instrumentation), and counts 24 organisations as shareholders from the 3 dimensions of the Knowledge Triangle and over 500 partners, mainly SMEs.

4. About SDA Bocconi Sustainability Lab

SDA Bocconi Sustainability Lab is a research centre that aims to develop and disseminate innovative and influential research to support both the private and the public sector in the journey towards sustainable development.

The Sustainability Lab builds the scientific evidence base to help organizations to maintain and review their current and future market positioning, by integrating the environmental, energy and social challenges into their strategies and practices.

It also contributes to building organizational skills and leadership capabilities to favour the organizational change required by the UN Agenda 2030. Moreover, the Lab's faculty members teach in most courses related to sustainability and energy at SDA Bocconi School of Management. Finally, the Sustainability Lab participates in the academic debate with the publication of papers, articles, reports and books.

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