Supporting interoperability in electricity sector: how to steer the European regulatory framework?

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As the electricity sector integrates more decentralized energy sources and smart devices, achieving interoperability is essential for improving efficiency, reducing system costs, and supporting the broader transition to a green energy economy. However, the diverse interests of stakeholders and the complexity of current systems demand a comprehensive regulatory and policy framework to incentivize and coordinate efforts toward interoperability.

This E.DSO Innovation Brief identifies and explains the main challenges that hinder the adoption of interoperable solutions in the sector. These challenges include the lack of adequate standardization for new services, such as flexibility markets and smart home devices, insufficient governance frameworks to foster collaboration, and cybersecurity and privacy concerns related to the increased exchange of data. The document also highlights the absence of harmonized market processes and roles across different countries, which further complicates the development of a seamless, interoperable energy market.

We also include a set of high-level principles for developing a policy and regulatory framework that can facilitate interoperability. These principles focus on removing existing barriers in legislation, establishing clear incentives for all stakeholders, fostering innovation, and creating governance mechanisms to monitor and update standards. By addressing these key areas, the document aims to provide guidance for the development of an effective framework to support interoperability and drive the digital transformation of the energy sector.

E.DSO - European Distribution System Operators
Association Internationale Sans But Lucratif – AISBL

Registered Office/Siege social:
Rue de la Loi 82, 1040, Brussels, Belgium
Registration no/N° d'enregistrement: 825.054.581
Banque Carrefour des Entreprises

1. What is interoperability and what role it plays in the electricity sector?

The digitalisation is increasingly going hands in hands with the green transformation of the energy sector. In the electricity sector, the newly connected decentralised sources of energy have the potential to be controlled efficiently through a layer of digital communication infrastructure. The same goes for consumer and industrial assets, be it a large industrial load or a smart home device or charger for an electric vehicle.

As basically every asset in the energy supply chain is being digitalised, great quantities of data about their behaviour are being produced as well. Making sense of these data and using them as a basis for control of grid-connected assets would enable more flexibility and efficiency in grid operation and planning. This in turn, can help to reduce the investments in enhancing the capacity of electricity grid which are needed to integrate the additions of new renewable energy sources and electrification of other sectors, such as transport.

In this context, the term interoperability has gathered a lot of attention of the energy sector, as a key enabler of the digitalisation and as a mean to make the energy system work efficiently. As there are multitudes of different initiatives and stakeholders aiming to improve "interoperability" in this sector, the aim of this article is to take a high-level perspective on the issue of facilitating interoperability in the electricity sector. This article includes an analysis of the biggest challenges and barriers to implementing interoperable solutions for the sector and presents some general considerations of the available tools for fostering the interoperability. The article presents the summarised results of work carried within the int:net project, which were published in the int:net Deliverable 4.2 – Regulatory Framework Relevant for int:net.

Interoperability definition

The exact meaning of the term "interoperability" has not been fully defined yet in the context of the energy sector (in fact, the work on the definition is currently ongoing in the int:net project as well). However, to for the purposes of this article it can be defined as the capability of two or more networks, systems, devices, applications, or components to exchange information among them and to use the information so exchanged. In the context of electricity sector, this can mean exchanging information about the operation of the grid and the connected assets and being able to send and receive control signals to adapt the behaviour of the assets.

For the seamless exchange of information across the whole energy system, interoperability needs to be considered in multiple dimensions, from the interoperability of concrete devices on the ground, the data formats and information models used, to the overall harmonisation of business processes and regulatory frameworks. To capture this, the Smart Grid Architecture Model has been adopted, distinguishing between these layers – the model is presented in the Figure 1 below.

It is important to keep in mind that interoperability has these diverse dimensions, which must be nevertheless working in harmony. It means that the analysis of the barriers that are impeding the adoption of interoperable systems in the energy sector needs to consider technological, economic, and regulatory aspects all together.

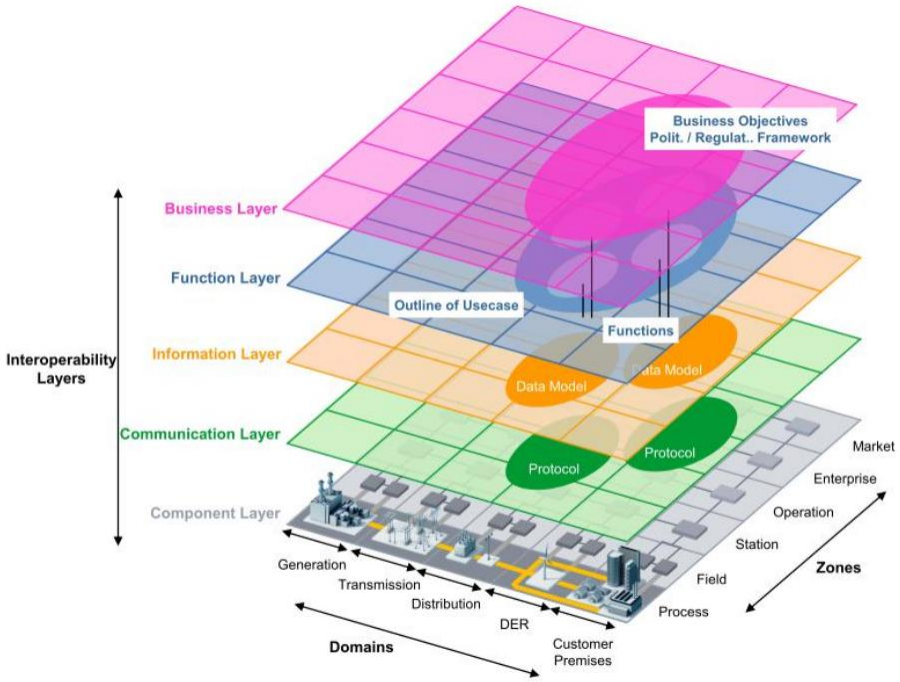

Figure 1 Visual representation of the Smart Grid Architecture Model (Source: IEC)

2. Why do we need policy framework for supporting interoperability?

Since fostering interoperability can have clear benefits for the energy sector by making the entire system more efficient and reducing costs for many stakeholders, one might conclude that everyone should be motivated to pursue adoption of interoperable solutions when digitalising the energy sector. However, on a closer look, the incentives and motivations for certain stakeholders are not so clear.

Despite the promise of reducing costs on a systemic level, the benefits might not overweigh the costs for concrete actors. For example, Consumers might not be motivated to buy an interoperable, but more expensive, smart home appliance if there is no possibility to making money in flexibility schemes. Consequentially, manufacturers of such devices might not feel the need to sell interoperable devices if there is no demand for them. There are also some actors, such as grid operators, whose activities are strongly regulated and might find it challenging to adopt interoperable digital solutions withing the existing regulatory framework.

As there are divergent interest between the energy sector actors, and since the already existing regulatory framework poses some barriers to interoperability on its own, it is important to further develop the policy framework to incentivise adoption of interoperable solutions. The policy framework should primarily:

a) Remove existing barriers in the legislation for actors pursuing interoperability;
b) Define and harmonise role and responsibilities of stakeholders;
c) Support creation of clear incentives for interoperability for all stakeholders;
d) Foster innovation which will enable creating new opportunities and applications in the energy sector based on interoperability.

The aim of this paper is to support the policy framework development by analysing the main challenges to interoperability, followed by formulation of high-level principles for the development of the policy framework. The challenges and the high-level principles are presented in the in the following sections. Although the text is based on the findings of the int:net project deliverable, it should be noted that the learnings also draw heavily on the results of Horizon Europe projects OneNet, Interconnect, CoordiNet and INTERRFACE. E.DSO has contributed to the first three of those.

3. Challenges for interoperability in the electricity sector

In this section, we explore several challenges hindering the adoption of interoperable solutions in the electricity sector. A key issue is the lack of adequate standardization for new services like flexibility markets and smart homes. The absence of a coordinated governance framework further slows collaboration and harmonization efforts. Growing digitalization raises cybersecurity and privacy concerns, with current data protection standards falling short. Additionally, varying market designs across countries create barriers and reduce efficiency. Finally, we examine the concept of a European energy data space, aiming to ensure interoperability between decentralized platforms and sectors while addressing governance and scalability challenges.

Key interoperability challenges
Standardisation
Governance of interoperability
Cybersecurity and privacy issues
Standardisation and harmonisation of flexibility services products
Creation of European energy data space

3.1. Standardisation

Developing and adopting an adequate set of standards for data exchanges is a key requirement for interoperability of the new services and products for the energy sector. Standardisation also helps to reduce overall system costs due to economies of scale.

The energy industry has done a lot of work in this field and has introduced several standards covering certain aspects of energy system operation. For example, Transmission System operators use the Common Information Model (CIM) and related standards for enabling cross-border electricity exchanges and coordinating balancing services. There are also standards focused on operation of smart home energy appliances.

However, these standards do not cover yet all the newly developed use cases (for flexibility, digitalisation etc), or might be not fitting for them (for example, the CIM based standards might be too complex to be used for management of smart homes).

At the same time, most of the actors in the electricity sector are already using some kind of digital solutions and software, which might be not necessarily interoperable with others. In the absence of the interoperable standards, they might be not incentivised to update their systems (which might

require significant investment of time, human resources, and capital), or might even adopt new solutions which are not interoperable and would require an update in the future.

One significant aspect of standardisation are metadata. These are the reference data which provide attributes of the information it describes, such as format, author, creation date etc. Metadata ensure that all actors involved in the data exchange understand them in the same way, which is an additional level of understanding beyond the IT systems being able to exchange data without errors in structure of format. Therefore, metadata definition is an important part of any standards for interoperability and should be given particular attention in the standardisation process.

3.2. Governance of interoperability

The previous section has shown the importance of having proper standards supporting interoperability in the electricity sector. These standards should be developed jointly by the actors in the sectors, so that they include the different perspectives and best industry practices.

The electricity sector is currently missing such a framework for the identification of best solutions, reaching the consensus between various actors and for monitoring the relevance of existing standards – a certain form of governance for interoperability.

There is no central authority to enforce the use of common standards, leading to fragmented efforts, multiple standards, and increased complexity. While similar solutions exist across the EU, there is no framework for stakeholders to share best practices or collaborate on harmonization. Standardization processes are lengthy, rigid, and often outdated by the time they are operational. Moreover, final consumers and other stakeholders are not sufficiently involved in these efforts, limiting their influence on data formats and protocols.

3.3. Cybersecurity and privacy issues

The continuing digitalisation of energy sector, as well as the efforts to increase interoperability will lead to increased levels of collected and exchanged data, including personal information about consumers and their consumption behaviour. These higher volumes of data exchanges mean that the cybersecurity threats are increasing.

The privacy issues refer to the management of access to personal data, for example about ones' energy consumption patterns. All actors should have the control over who and under what conditions has access to their data and be able to revoke such access. This right needs to be ensured throughout the whole energy sector supply chain. Another prominent issue is the efficient data anonymisation, making data anonymous enough so that they cannot be identified with an individual consumer or other actors.

Currently, the main challenges are that the energy sector with many distributed actors is complex, so the data management and security requirement are also quite complex for stakeholders to develop and adopt. Moreover, the necessary standards for third party data access and consent management are not fully developed yet. Upgrading IT systems to be able to deal with these complex demands, as well as to maintain the high level of cybersecurity needed, is also quite costly for many actors.

3.4. Standardisation and harmonisation of flexibility services and products

Ensuring that the IT infrastructure is working well to enable data exchanges is however not the only aspect of interoperability. From a more market-focused perspective, there also needs to be a common understanding about the various products and services that are being used. Although the development of local flexibility markets serving the needs of local grid operators means that there needs to be a certain level of specificity, the design of these local markets and services could be standardised or at least harmonised. In such case, there could be also standardised IT solutions and market models, which would also make it easier for all actors to participate in those flexibility schemes.

One of the elements that could be harmonised is defining roles and responsibilities of different market participants, independently of specific real-world entities (for example, what is the role of market platform operators, which functionalities are their responsibility). Moreover, there could be a common definition of the business process and its phases (prequalification, bid selection, activation, evaluation, settlement etc). Currently, both the roles and responsibilities and business processes are defined on national level, or even more scattered. This is a barrier for actors who might want to enter multiple markets across countries. When the different market processes are not aligned, it also makes it harder to gather information about the market functioning, which is a barrier to informed decision making of market participant and therefore it reduces the efficiency of the markets.

3.5. Towards energy data space

The electricity sector is a complex space, involving many actors working of deployment of interoperable solutions, coexisting with already deployed (legacy) systems, which have different level of interoperability with outside world. At the same time, the need to have localised solutions for specific local challenges in the grid means that the system can never be fully standardised. Therefore, the future data layer of the electricity sector will still consist of multitude of different decentralised platforms and systems for exchange of specific data. However, there is a need to ensure some level of interoperability between them, according to the principles described above. Moreover, the electricity system exists in the wider context of the whole energy sector and is also connected to many other sectors of human activities. The concept of energy data space aims at ensuring the minimum required elements of interoperability between all the decentralised platforms and actors, to enable the seamless flow of information. The main challenges for establishment of the European energy data space are: the standardisation of the minimum interoperability requirements; the scalability of the data exchange platforms to support the increased data flows in the data space, and the governance of the system, working on definition and implementation of the standards for the data exchange, roles and responsibilities of stakeholders and so on.

4. How to facilitate interoperability in energy sector? High-level principles for policy and governance support

The list of challenges for interoperability explored in the previous section shows that it is a complex problem on the interface of technology, economy, and society. Therefore, the are no easy solutions or recommendations how to adapt the regulatory framework and solve the issue right away. Rather, we offer a set of potential activities focused on different actors in the sector, which should, all together form the basis for an environment where interoperability can be taken as the basic principle for all future activities.

High-level principles for supporting interoperability	Identifying incentives for various stakeholders
	Enhancing governance frameworks
	Developing standards tailored to specific use cases
	Mandating minimum interoperability requirements
	Making data exchanges more efficient

4.1. Identifying incentives for various stakeholders

As already highlighted in previous sections, implementing interoperability requires major efforts, including investment costs, from many of the stakeholders in the energy sector. However, not all actors have the clear incentives to invest the needed resources, and it might even endanger their existing business model; they might not perceive the interoperability benefits as adequate to the invested resources, or simply they see their core business model elsewhere. Therefore, identifying the right incentives, as well as the ways how to make them available to the right stakeholders, is a crucial building block for supporting interoperability.

In the energy sector, it is possible to distinguish regulated actors (or rather actors with regulated roles) and non-regulated actors.

4.1.1. Incentives for regulated actors

The regulated actors are mainly the network operators, while some other actors have more or less regulated roles (for example, operators of market platform). The network operators are renumerated for the resources they invest in developing the electricity grid, but currently the main model of remuneration is focused on capital investment, for example in expanding grid capacities. Although there is already ongoing shift towards regulatory frameworks that reward system operators for reducing the overall network operation costs, this does not provide clear incentives for them to engage in innovative activities towards interoperability, which carry inherent risk of failure and

might also require increased level of investment in certain areas. Therefore, more targeted innovation incentives, focused not only on cost reductions, should be promoted to support interoperability. For example. the regulatory framework design can mandate interoperability requirements, but also can anticipate development of innovative solutions with incentive-based regulatory framework.

4.1.2. Incentives for non-regulated actors

As for the non-regulated actors, it is only possible to create indirect incentives for interoperability. This can be done by developing an adequate environment supporting interoperability development. The design of harmonised flexibility services and flexibility markets across EU seems to be the most important building block, which will unlock the potential of interoperable services for many stakeholders and will send a clear signal about the interoperable nature of future energy system. Standardised business processes, data exchanges and other aspects can also help to move the investment decisions of non-regulated stakeholders towards interoperable solutions, as they will more clearly see the economies of scale and potential for expansion into wider scale of energy markets.

4.2. Enhancing governance frameworks

The governance framework for interoperability should include policies on both national and European level, as they both are relevant. The framework should ensure that the governance of common and reference data models ensure the integrity, consistency, and reliability of information exchanges across Europe. The framework should establish clear governance of ownership, responsibilities, and processes related to the creation, maintenance, and usage of common data and reference data. Network codes, methodologies and standards are the main documents to be continuously monitored and updated by the governance framework to facilitate innovation and to secure the continuous compatibility and interoperability of the developed solutions for energy sectors.

4.3. Developing standards tailored to specific use cases

To cover the innovative use cases deployed by various energy sector stakeholders, often to answer specific needs in specific local context, the existing standards need to be extended, and a certain level of customisation needs to be allowed. However, the technical and semantic interoperability still needs to be maintained. One of the available solutions is to focus on the interoperability of communication interfaces for data exchange between different stakeholders and IT systems, which still allows for internal customisation. A second solution is to define some key interfaces and functionalities, for which the adoption of a common standard is necessary. For example, under German law, the Energy Industry Act mandates that all controllable units connected to the grid must be able to reduce their output upon request of grid operators in the event of grid overloads. This is a crucial functionality enabling secure operation of the grid, while keeping other possible use cases open to different initiatives.

4.4. Mandating minimum interoperability requirements

A complementary solution to developing the tailored standards for specific use cases is introducing minimum interoperability requirements. Besides the already proposed minimum requirements ensuring that the data exchange interfaces between different applications are interoperable, the minimum requirements can be also targeted at certain actors in the energy system or the roles assigned to them. For example, the proposed Network Code on Demand Response assigns certain interoperability requirements to the network operators as well as to other actors in the role of flexibility register operator.

Moreover, the interoperability obligations can also target actors with identified significant market power. For example, these could be manufacturers of certain equipment crucial to enabling information exchange, such as smart meters.

4.5. Making data exchanges more efficient

Not only is it expected that the general volume of exchanged information will increase, but the experience also shows that various non-interoperable systems can be very inefficient in data exchanges, potentially duplicating existing data due to various reasons (different data standards; privacy and access consent) and further exacerbating the problem.

Interoperability standards can of course help to increase the efficiency of data exchanges. Next to that, testing and certification also play a crucial supportive role. Testing confirms that specifications meet requirements and continuously demonstrates the validity of test models, ensuring they adhere to standards. Real-world testing is crucial to verify that developers comply with specifications, helping to achieve interoperability objectives effectively. A centralised approach with adequate funding would ensure the consistency and effectiveness of testing procedures.

4.6. Labelling

As interoperability and related challenges are a quite a complicated issue, many actors in the energy system have not full understanding of it, leading to information asymmetry between different players. For example, consumers should not be expected to understand which information exchange standards are used by devices they are buying an if they are compatible with other devices they already own. On the other hand, the equipment manufacturers should not misuse their knowledge about the interoperability issues and mislead customers about functionalities of their products. Certification systems and easily understandable labelling, focused on consumers can facilitate easier adoption of interoperable solution. Labelling can be also focused on industrial and commercial actors, helping companies and producers make more informed decision on the equipment or services they are buying, which also improves the efficiency of the industry and helps to promote adoption of interoperable solutions.

5. Conclusions

Supporting interoperability in the electricity sector is vital for realizing the full potential of digitalization and the green energy transition. As the sector becomes increasingly reliant on data exchange between diverse systems and stakeholders, the need for interoperable solutions grows. However, achieving this requires coordinated efforts across technology, policy, and market dynamics.

The complexity of the regulatory framework, diverse business interests, and technical challenges underscore the need for a well-designed policy and governance framework that fosters interoperability. This includes creating incentives for both regulated and non-regulated actors, developing tailored standards for specific use cases, and mandating minimum interoperability requirements. Additionally, addressing cybersecurity and privacy concerns is crucial to ensure secure and trustworthy data exchanges.

Moreover, effective governance mechanisms must be established to monitor and update standards, ensuring they remain relevant and promote innovation. Labelling and certification systems can further support the adoption of interoperable solutions by reducing information asymmetry and enhancing transparency for all stakeholders.

By focusing on these high-level principles and actively engaging with all relevant actors, the European regulatory framework can steer the electricity sector toward a more interconnected, efficient, and resilient future.