# Leveraging IoT and Edge Computing Infrastructures to foster Energy Flexibilities through next energy sectorial integration

## Release 1.0

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# Executive Summary

The present document provides a comprehensive overview on the ongoing developments and directions of flexibility services in the energy domain, focusing on the Internet of Things (IoT) and edge computing infrastructures that foster the system advancements.

Introduction in **Section 1**, explains the ongoing transformation of the electrical systems and the existing regulatory barriers for the digitalization of power grids

In **Section 2** the role of IoT and edge computing devices enabling flexibility use cases is presented, analysing the essential role of big data platforms and their characteristics.

**Section 3** continues by addressing the large scale flexibility, in particular:

(i) the challenges for the flexibility regulatory framework, the role of sub-metering data and the necessary harmonisation

(ii) the advancements in the regulatory framework for flexibility markets (including standardisation and incentivisation aspects)

(iii) the impact of data reliability on grid observability.

**Section 4** addresses the interoperability frameworks, which constitute the baseline for the implementation and realization of flexibility. Among others, the different interoperability layers, the systems-of-systems approach and the Minimal Interoperability Mechanism (MIMs) concept are presented together with the ongoing standardisation activities. The section also focuses on the status and deployments of information interoperability, in particular the Common Information Model (CIM) and the SAREF semantic interoperability. Moreover, the document discusses the role of data spaces in the energy domain and the cross-sectorial approaches for interoperability.

**Section 5** continues by addressing the concept and role of Virtual Power Plant (VPP) in illustrating its configuration, the different VPP types and the impact in the deployment of energy flexibility.

in **Section 6** are addressed the position of energy consumers and their engagement, focusing on the perspective of the network operator and customer as well as the analysis of various tariff schemes and control incentives for flexibility (including the reference to CO2 emissions).

In the final **Section** the **conclusions and recommendations** are presented; they are sub-divided according to the target category: policy makers and regulators, researchers and industry, utilities and energy distributors.

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# 1. Introduction

## 1.1 Background

Energy grids play a crucial role in ensuring a secure, and economically fair energy transition for societies. While the EU energy transition has significantly accelerated over the past 12 months, the recent energy crisis is demonstrating the European vulnerability and dependency on fossil fuel supply. Main conclusions are to diversify the supply chains and to further accelerate the introduction of renewables throughout the energy system. With that, new security of supply and flexibility constraints are arising for energy system operators whether for grids or other boundary energy sectors whose operation needs to be further coordinated.

In particular, the electrical system needs, on one hand, to integrate larger quantities of horizontal cross border energy flows to maximize the reuse of intermittent renewable sources throughout Europe and, on the other hand, to vertically better integrate across TSO and DSOs to enable active participation of all distributed flexibilities spread at the edge of the energy system.

Such new approaches indirectly question the methods used for infrastructure planning – going towards cross sectorial cost benefit analysis as initiated with Power & Hydrogen – as well as tools used for coordinated system operation where grid flexibilities will have to be searched across sectors, hence requiring a proper definition of cross sectorial interfaces and interoperability principles.

The future energy domain will consist of one coordinated system of interconnected systems, whose interaction will need to work seamlessly together and where each system will need to self-discover the flexible capacity of its peer by making use of digital twins that interact with each other. Each sectorial system will have to optimize through its own boundary constraints while opening new “coupling interfaces”. The associated digital infrastructure will therefore evolve from central monolithic legacy control room environments into new IoT – edge computing - hybrid cloud platforms where ontologies, data interoperability and open Application Programmable Interfaces (API) will become key building blocks to ensure cross sectorial flexibility integration.

With the accelerate development of EVs and the further electrification of the heat sector, specifically, demand side flexibility has a growing impact on the grid through the accelerated adoption of virtual power plant (VPP) and demand side response aggregation. This means new flexible distributed energy resources (DER) will soon be available to support the system balancing and, thus, requiring the development of real-time digital connectivity to the lowest voltage levels at the edge of the electrical system. Over the coming years we should expect a rapid shift of market participant interactions: from a limited number of large power plant entities – where manual operator interactions are still largely used - into a future where decision support through digital twins becomes the norm in grid control rooms.

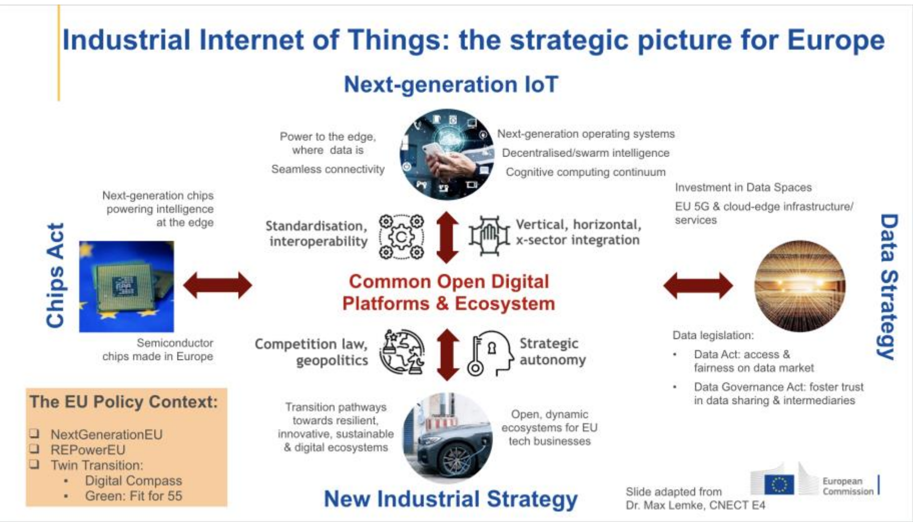
## 1.2 Regulatory barriers

In the meantime, the energy sector is facing a challenging regulatory framework slowing down the deployment of digital infrastructures. In general, the national regulations are late in adopting the new Clean Energy Package regulatory framework, as highlighted through recent SmartEn report, hence the energy sector regulation needs to be further harmonized to accelerate adoption of best practise deployments across countries, as well as market and grid data interfaces.

Permitting issues impose significant constraints on the speed of grid expansion as compared to other developments happening at the edge, such as the deployment of EV charging, PV, storage and heat pump (incentivized through different regulations). As a consequence, grids are becoming congested and, thus, need to set up new flexibility markets to incentive new smart behaviours. The regulatory sandboxes can foster the deployment of market flexibility mechanisms, addressing the lack of innovative frameworks.

The need for harmonisation of flexibility markets requires flexibility in product definition, striking a balance between organic growth from bottom-up pilots through national demonstration projects and the needed European level harmonization, in order to ensure liquidity and market access from all flexibility service providers across Europe. For this reason, engagement of consumers in flexibility schemes is crucial to demonstrate viability of associated business models and confirm the associated impact.

Finally, the disruption in supply chains and ongoing geopolitical events are affecting components and systems availability. These disruptions spotlight need for a value chain and ecosystem approach starting from EU manufacturing capacity scale up needs. Represented in Figure 1 Strategic perspective of Industrial Internet of Things for Europe Coordinated efforts between all of the components, such as Data Strategy, Next Generation IoT, Chips act and the related New Industrial Strategy are closely interconnected and progress of IoT and Edge Computing Infrastructures implementations needed to foster Energy Flexibilities is contingent to the orchestration of the progress of all the components.



**Industrial Internet of Things: the strategic picture for Europe**

**Next-generation IoT**

Power to the edge, where data is

Seamless connectivity

Next-generation operating systems

Decentralised/swarm intelligence

Cognitive computing continuum

**Chips Act**

Next-generation chips powering intelligence at the edge

Semiconductor chips made in Europe

Standardisation, interoperability

Vertical, horizontal, x-sector integration

**Common Open Digital Platforms & Ecosystem**

Competition law, geopolitics

Strategic autonomy

**Data Strategy**

Investment in Data Spaces

EU 5G & cloud-edge infrastructure/ services

Data legislation:
- Data Act: access & fairness on data market
- Data Governance Act: foster trust in data sharing & intermediaries

**The EU Policy Context:**

❑ NextGenerationEU
❑ REPowerEU
❑ Twin Transition:
  - Digital Compass
  - Green: Fit for 55

Transition pathways towards resilient, innovative, sustainable & digital ecosystems

Open, dynamic ecosystems for EU tech businesses

**New Industrial Strategy**

Slide adapted from Dr. Max Lemke, CNECT E4

European Commission

Figure 1 Strategic perspective of Industrial Internet of Things for Europe[1]

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[1] Source: European Commission, DG Connect, IoT Unit

# 2. IoT and Edge Computing use cases

This section provides a brief description of key use cases in the energy sector where IoT and edge computing and new hybrid cloud architectures represent a significant accelerator to the needed energy transition.

## 2.1 New Prosumer multisided IoT platforms for Distributed Energy Resource orchestration

New generations of IoT platforms have started to be deployed in prosumer environments offering new sensors and submetering devices, complementing DSO smart metering with detailed measurements and information that can be used to accurately observe activation and performance of flexibility behind-the-meter. Such sensors are becoming increasingly important to supplement baselining and settle distributed flexibility according to real measured performance criteria instead of theoretical estimates. These new approaches are notably key for explicit demand response aggregation that are managed by flexibility service providers and positioned into grid ancillary services.

In the context of the forthcoming Implementing Act on demand response data access, TSOs (through ENTSO-E) & DSOs (through the EU DSO Entity) have started to work on expanding interoperability requirements beyond simple electricity smart meters, opening new options to consider broader connection point datasets such as “virtual metering channels” from relevant IoT sensors for the settlement of explicit demand response and grid services (making use of the IoT and edge computing deployed in distributed energy resources such as EV chargers or residential heat pumps). This will ensure a more comprehensive coverage of both price-driven (implicit) and incentives-driven (explicit) demand response schemes, while ensuring a fair and level playing remuneration of all flexibility resource throughout the system, offering in-depth observability to system operators when required.

As investigated in (1), digital platforms will evolve towards multisided approaches:

- Seamlessly incorporating relevant open non-sensitive data from grid infrastructures – related to the carbon footprint of the electricity delivered or the level of congestions in each system branch;

- Integrating necessary data controls and portability to guarantee prosumer data protection as well as managing the sharing of relevant information with market parties, given the prosumer consent.

Moreover, as identified by the Digital Working Group 4 of ETIP SNET through its “Big Idea” use case, new platforms should be developed to enable data exchange and contributions across key actors of the energy value chains, such as:

1. Prosumers and energy communities, who gather all necessary energy and carbon footprint data and make most appropriate investment decisions while benefitting from all new regulations related to customer data protection (in term of data ownership, interoperability, and portability). This environment should particularly allow to:

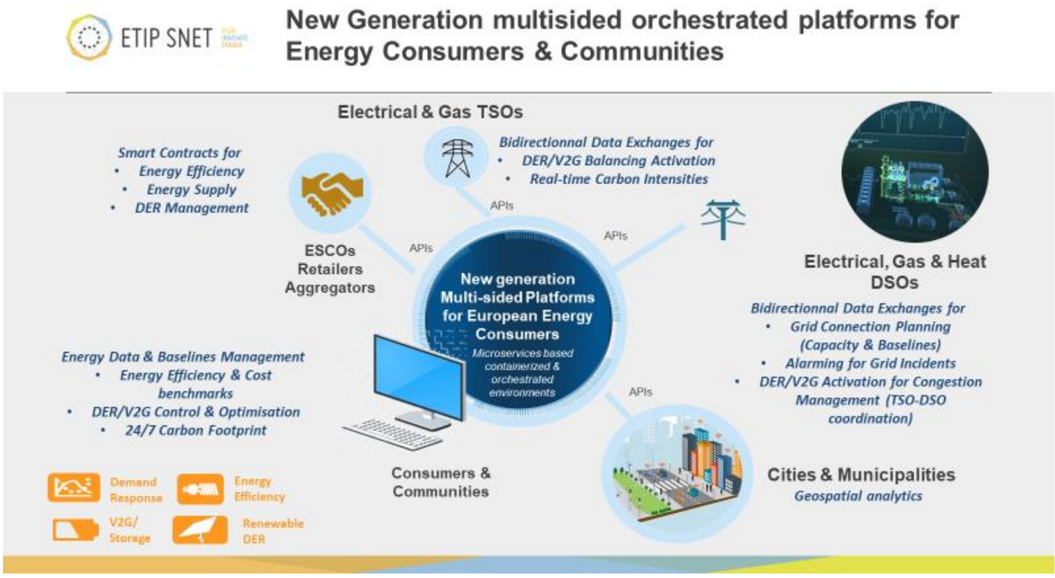
   a. Harmonize APIs for prosumer energy & carbon data exchange across domains;

    b. Be able to compare and benchmark consumer energy costs and associated carbon footprint according to historical baselines as well as through consumer communities (while maintaining the necessary level of anonymization);
    c. Plug & play connect with relevant home IoT devices (smart heating, smart charging, demand response IoT) to enable the automation of energy optimization strategies at grid edge.

2. Energy system infrastructure planners (TSOs & DSOs), to access more granular bottom-up data per customer segments and refine associated energy profiles taking into account consumer investment decisions & technology adoption rates (as individuals or through energy communities facilitating their investment decisions). The associated interface should allow to properly plan needed connection capacity of all electricity, heat and gas energy networks on several year time horizon as well as define relevant consumption & energy efficiency baselines. It should in particular take into account the adoption of new energy efficiency programs as well as DER technologies. and also allow the optimization of flexibility use for cost efficient planning and in longer run to optimize infrastructures investments.

3. Energy system infrastructure operators and service providers (TSOs, DSO, retailers, aggregator, data providers), to define most relevant energy supply contracts and DER program management strategies according to specific prosumer profiles. The interface should be designed to:
    a. Facilitate customer opt-in/opt-out;
    b. Offer transparent benchmarks of the cost implications taking into account reference baselines for energy consumption, self-generation as well as EV/V2H/V2B;
    c. Once a contract is opted in, to allow real-time energy data exchange (as required for both implicit and explicit demand response types of contract) with relevant IoT devices.

4. Cities, to provide data and geospatial analytics to anticipate and coordinate the parallel deployments of energy (gas, heat & electricity) and transport infrastructures (EV charging or hydrogen fuelling stations). The platform should provide aggregated energy maps for energy efficiency, renewable penetration as well as progress on carbon footprint improvements.



ETIP SNET

New Generation multisided orchestrated platforms for Energy Consumers & Communities

Electrical & Gas TSOs

*Bidirectionnal Data Exchanges for*
- *DER/V2G Balancing Activation*
- *Real-time Carbon Intensities*

*Smart Contracts for*
- *Energy Efficiency*
- *Energy Supply*
- *DER Management*

ESCOs
Retailers
Aggregators

New generation Multi-sided Platforms for European Energy Consumers

Microservices based containerized & orchestrated environments

Electrical, Gas & Heat DSOs

*Bidirectionnal Data Exchanges for*
- *Grid Connection Planning (Capacity & Baselines)*
- *Alarming for Grid Incidents*
- *DER/V2G Activation for Congestion Management (TSO-DSO coordination)*

*Energy Data & Baselines Management*
- *Energy Efficiency & Cost benchmarks*
- *DER/V2G Control & Optimisation*
- *24/7 Carbon Footprint*

Consumers & Communities

Cities & Municipalities
*Geospatial analytics*

**Figure 2 High level view of the platform interactions, (source: ETIP SNET)**

The Figure 2 offers high level view of the platform interactions as well as the main system functions associated to the proposed business use case.

## 2.2 Control room architectures for future grids

Market deregulation has significantly increased the number of market participants that interact throughout the systems, which is expected to grow continuously and exponentially with the emergence of new prosumer-centric market designs. This requires rethinking the architecture of control room environments, to open up traditional SCADA system to larger volumes of data streams that incorporate lower granularity timeseries, evolving from minutes down to second, while the system inertia reduces. New control room developments need to incorporate data processing outside their traditional system boundary through critical event streaming to enhance grid operator situational awareness and further automate critical decision making by relying on digital twin interactions throughout sectors. Sample architecture is shown in Figure 3.

The new EU Green Deal objective further accelerates the integration of intermittent renewables into the grid on all voltage levels growing the complexity to forecast and observe distributed energy resource injections across the end-to-end T&D system.

Classical renewable and load forecasts therefore require adaptations to reach higher granularity for timing as well as locations. The closer forecasts to get real-time the smaller can be the amount of grid security margins required to manage security of supply hence releasing more capacity to market participants.

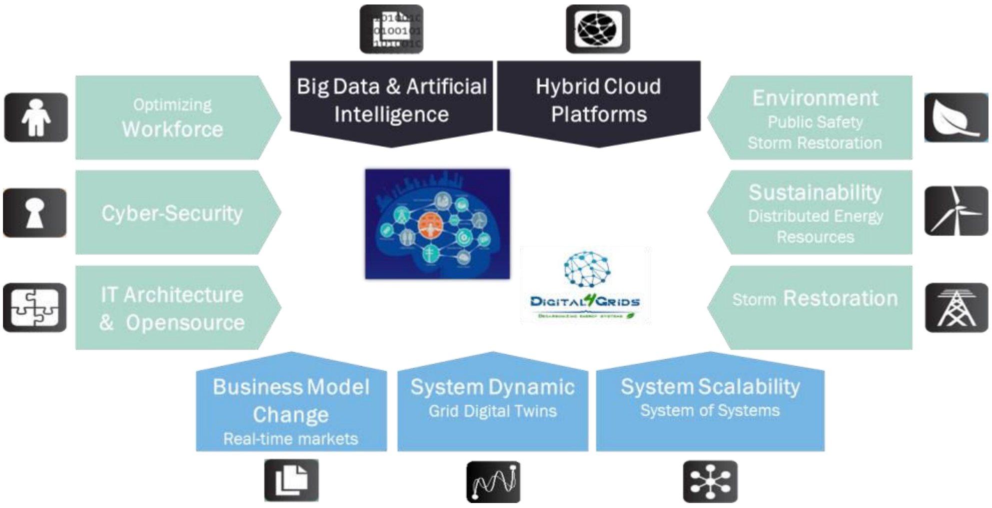


**Figure 3 Future Grid Control Room architectures, (source: Digital4Grids)**

Beyond improvements of compound forecasting methods, it is becoming essential to enlarge observability across energy sectors. The high volatility of renewables infeed and prosumer net consumptions in the future will need to be observed through real-time measurements, requiring the development of new data exchange platforms such as the one currently prototyped through key Horizon Europe projects such as INTERRFACE[2], Platone[3], OneNet[4], InterConnect[5], as well as the new projects launched on European data spaces. Ultimately, future control rooms will evolve towards newer generation situational awareness environments providing control room operators several digital twins of the grid state – through steady state and dynamic transient calculations while incorporating all relevant real-time data collected from new fast data streaming environments.

The evolution of digital technologies and the extensive usage of IoT in the industry brought a boosting effect for the development of Industry 4.0 which has also led to the emergence of Energy 4.0. Artificial Intelligence (AI) assisted systems together with interconnected devices and machinery can help to improve both the flexibility and efficiency of the industry (1). AI is preferred in the analysis of data which is containing a large number of irregular information, is long or is complex and in processes where human perception or equation-based mathematical methods may encounter difficulties in reaching the result. In case the problem is highly nonlinear and very difficult to model, neural networks (ANN, DL) which is a subset of AI can be a very promising solution if data is “enough” for a proper training of the network that shows the how much it learned from the data and how it can generalize through the data.

Exponential increase in data storage and processing results in big data which is vital for prediction and modelling of any given system that is highly nonlinear, real time operating and complex. As renewable energy generation is growing, digital transformation is inevitable to consider energy storage for flexible loads.

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[2] INTERRFACE H2020 project

[3] Platone H2020 project

[4] OneNet H2020 project

[5] Interrconnect H2020 project

According to (2) energy flexibility can be seen as the ability to manage a building's demand and generation according to local climate conditions, user needs and grid requirements. In this research it is also mentioned that depending on how the price profile is constructed, load shifting can constitute a valuable form of energy flexibility. (3) states that the optimal operation of storage systems in buildings with Integrated Energy Systems (IES) is affected by exogenous factors such as weather, energy demand patterns and electricity prices which all vary over time. For a more sustainable energy future these tasks should be handled with interconnected and intelligent technologies where IoT and AI are two of the major driving forces.

However, IoT sensors and AI algorithms are vulnerable to cyberattacks. False Data Injection (FDI) from attacks on IoT systems causes effects that reduce system accuracy and impair the results obtained for system operation. In FDI attacks, the device is intercepted through physical access or sensor measurement results are changed over various communication media (Bluetooth, Wi-Fi, cellular networks) (4). The accuracy of measurements from IoT sensors is unreliable if the system does not have a "bad data" detection mechanism. Therefore, it is crucial for the reliability of the digitalized energy ecosystem to take into account the risks of cyber-attacks and to integrate the prevention mechanisms for the detection of attacks into the system.

# 3. Large Scale Flexibility

## 3.1 Challenges and Alignment on Flexibility regulatory framework

While the Clean Energy Package has defined a positive regulatory framework to facilitate the development of new Flexibility Service Provider (FSP) models, several key improvements are yet to be completed as currently analysed through the new flexibility code, listed below.

### The definition of an independent aggregator model

While this role has started to emerge in some countries for large demand side asset, it is yet to be refined for smaller scale distributed energy resources typically deployed at residential levels. New interoperability layers are required across distributed energy resource data and aggregator to ensure a seamless 'Bring your own DER' approach letting prosumer to opt-in for their preferred aggregator platform. Interfaces from DER platforms should therefore be further aligned to ensure plug-and-play discovery and integration across edge and cloud infrastructures. This new development needs to be analysed and facilitated, particularly, through the new European data spaces.

### Sub-metering (IoT) data

Baselining methods need to be revisited to incorporate data provided from submeters. The role of metering data hub needs to evolve to take into account new data provider roles of DER manufacturers and their integration of new IoT sensors and edge computing data. New orchestration and governance layers should be established across data hubs and market participants to ensure consumer protection, cyber security as well new streaming interoperability.

### Regulatory harmonization for flexibility

Regulatory frameworks remain disjoined throughout European Member States. Since there is no definition for, e.g., congestion management and voltage control on EU level, these services are also not harmonized across EU Member States. The differences have for instance been illustrated with Figure 4 by the deliverable D6.4 "Scalability and replicability analysis of the market platform and standardized products" of CoordiNet project[6]. Furthermore, there are few incentives for DSOs to procure flexibility services in national regulatory frameworks, since economic regulation is mostly CAPEX-biased. Finally, also the development of TSO-DSO-FSP coordination varies throughout member states. Although flexibility providers should be enabled to participate in all balancing markets, only some countries have adopted a legal definition of aggregators as market actors so far. Similarly, frameworks for responsibility-sharing with, e.g., Balancing Responsible Parties are fragmented. While there are reasons for different regulatory frameworks, such as different energy mixes and needs for infrastructure, they also hinder knowledge-sharing across countries and the efficient use of resources by restricting the replication and scalability of use cases.

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[6] CoordiNet H2020 project – Deliverable D6.4 "Scalability and replicability analysis of the market platform and standardized products"

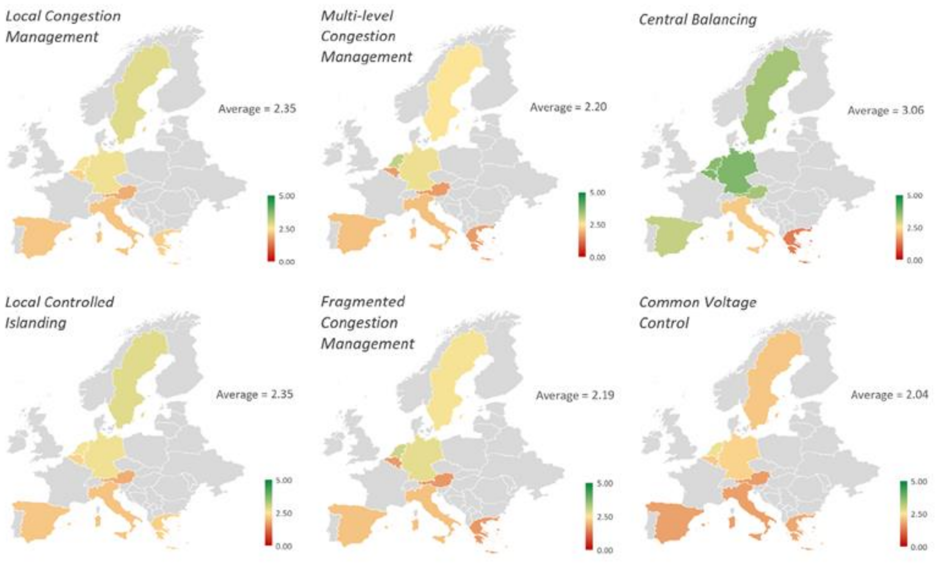

**Figure 4 Regulatory Compatibility of Selected Generalized Use Cases**

A main finding in line with this was made by the deliverable D1.3 "Overview of regulatory aspects that impact the solutions tested in the demos in European countries" of Platone project[7]: "many laws and updates might risk putting national legislators under pressure and consequently reduce the quality of the transposition into national laws." Interestingly, this was written already before the energy crisis and, e.g., RePowerEU.

A particular challenge on Member State level is the diverging roll-out of smart meters, required by the Third Energy Package in 2009. Yet, Member States were allowed to derogate from it if they could provide valid reasons. Currently, about 50% of European consumers have advanced metering infrastructure installed. To efficiently use Demand Side Flexibility (DSF), the uptake of Smart Meters and sub-meters will have to be accelerated across all Member States.

### Incentives: Considering flexibility during grid planning stages

It is mentioned that there are often few incentives for DSOs to procure flexibility services since economic regulation is mostly CAPEX-biased. Nevertheless, not taking flexibility into account during the planning stage also means over-investing in excessive security margins (sometimes withstanding power overloads of 100% the nominal value). This ends up increasing the low-voltage distribution network's fixed costs, which also have an impact in increasing costs for final customers. Thus, even if the activation of flexible resources is considered during the operation stage, the marginal benefit is too narrow to compensate the initial fixed costs, and thus the benefits of flexibility are reduced significantly. Users won't have the necessary motivation for releasing their personal data or giving control of their active resources to DSOs if they don't perceive a direct or indirect benefit. Therefore, the benefits of flexible resources activation can only be beneficial if flexibility is considering during grid planning stages as well (5)

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[7] Platone H2020 project – Deliverable D1.3

A clear example of this is the massive penetration of electric vehicles chargers in the domestic environment. Single-phase EV chargers normally do not exceed a peak power capability of 11kW, being normally limited down to 7.2kW for domestic installations. As petrol-based mobility is progressively being replaced by E-Vehicles, it won't be an irreal scenario to assume that users might want to recharge their vehicles at the maximum permissible power, thus reducing the charging time but causing a great instability in the grid. In this case, slow AC charging might come handy: With an average 70kWh capacity battery for electric vehicles, a charging point of 7.2kW is able to fully recharge a vehicle in a maximum time of 10 hours. Many users would easily agree on having a flexible charging scheme: Instead of getting the maximum available power when connecting their vehicles, DSOs or aggregators might reduce the available power and extend charging periods. With the increased developments in V2G research, in the future DSOs might also be able to discharge electric vehicles and inject power to the LV grid, thus providing additional support. Related use cases are deployed in the projects InterConnect[8] and FLOW[9].

Flexibility on the other hand can be activated by different means. Starting from behind-the-meter and ancillary services, aggregation of flexible resources opens new operation possibilities. This concept has been also introduced in the Go4Flex document, which describes an overview of the Flex-Offer concept and addresses the fact that the flexibility provided by individual loads might be too small to be considered, and thus an aggregated scheme is the best way to manage flexibility.

## 3.2 Roadmap towards efficient regulatory framework for flexibility markets

While the flexibility in energy sector might have a broader set of use cases, the recommendations here relate mainly to provision of flexibility for the purpose of system services, used by grid operators. For that, improved cooperation between transmission network operators, distribution network operators and flexibility providers (also described in section 6 of this document) is a necessity. In accordance with the European electricity market design, the role of flexibility providers also needs to be open to the widest possible group of participants.

Based on real-life experience from three demonstration sites across EU, the CoordiNet project has devised four main areas for the regulatory design of future flexibility market.[10] These areas are:

A. Incentivising the evolution of system operator roles and the creation of flexibility markets.

B. Enabling market access for all flexibility service providers.

C. Managing system operator requirements and flexibility service providers capabilities through standardisation.

D. Adaptation of market phases for new products and actors.

Each of the listed areas are described in details in the following sections.

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[8] InterConnect H2020 project

[9] FLOW H2020 project

[10] CoordiNet H2020 project – Deliverable D6.7 "Roadmap towards a new market design including the implementation of standardised products for system services"

### Incentivising the evolution of system operator roles and the creation of flexibility markets

As the paradigm of network operation shifts from the centralised distribution model to a more decentralised system with bi-directional flows of energy, decentralised energy resources and actors assuming multiple roles, network operators need to develop new market solutions to manage the rapidly changing system. However, the responsibilities and incentives for system operators to do so are not clear. The regulatory framework should be adapted in the following aspects:

- **Investment needs and economic incentives:** The current national economic regulation does not allow DSOs to recuperate their investments and costs for new market solutions for system services. To enable this, the cost of establishing these markets and mobilising flexibility must be recognised in DSOs remuneration schemes.
- **Roles and responsibilities:** It is recommended to define clear roles and responsibilities in new established flexibility markets including both actual and new agents involved in these processes. To support this, a common EU-level definition of roles and responsibilities should be included in the new network codes for the distribution level. National regulatory authorities should also support including the consideration of flexibility markets as alternatives to grid reinforcements in the network development plans. Only in 2021, the BRIDGE projects publicly acknowledged the function of FSPs for the first time. Thus, an examination of the Harmonised Electricity Market Role Model was offered in several projects (7). There, an FSP is defined as "A party providing flexibility services to energy stakeholders via bilateral agreements or flexibility markets. An FSP can also be a Balancing Services Provider if enabled to the LFC services." Furthermore, it is noted that an "FSP offer services potentially to all the system operators, directly or through market operators." A Resource Aggregator, on the other hand, is "A party that aggregates resources for usage by a service provider for energy market services." In light of this logic, an FSP and vice versa may occasionally be regarded as Aggregators. The SO associations' Active System Management report[11] uses a similar terminology for FSPs (CEDEC, E.DSO, ENTSO-E, Eurelectric, and GEODE). More specifically, FSPs may offer flexibility services to flexibility procurers (such as DSOs), whereas aggregators might not provide services to the same extent. Prosumers in a household or energy communities may also be regarded as flexibility providers. However, the HEMRM report should be regarded as the current state of affairs since it is the most recent definition. Nevertheless, developments within the OneNet project revealed that the definition remains a topic of industry-wide open discussion.[12] The definition of roles and responsibilities should occur on the European level while allowing for regional variations.
- **Increased system operators' coordination:** Higher coordination will help to limit the potential negative effects of flexibility procurement on other voltage levels, and in the long-term enable flexibility markets to scale up. In addition, higher coordination will result in maximising the overall efficiency of service procurement – also when applied in network planning.
- **Market design and coordination schemes:** To facilitate liquidity and attract FSPs in the early stages of flexibility markets development, simple market coordination schemes should be supported. With time, a more complex approach should be explored, where both DSO and TSO have access to the same markets and resources, as it could result in more efficient market optimisation.

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[11] TSO-DSO Report – An integrated approach to active system management

[12] OneNet H2020 project – Deliverable D2.5 Recommendations for the Harmonized Electricity Role Model

## Enabling market access for all possible flexibilities

The European electricity market regulatory frameworks requires that all actors should have access to all electricity markets and that the market design should be technology neutral. Enabling the participation of all potential actors in the flexibility markets would allow to achieve the most economical use of the available resources and bring down the overall system costs. However, in the early phases of flexibility market developments the markets might suffer from lack of liquidity. To attract more flexibility services providers, it is necessary not only to open the markets, but also to offer attractive business cases for them:

- **Viability of the flexibility service provision business case** should be strengthened by reducing the participation costs in the markets. This can be done by reducing the technical costs of participation (increased level of automation), but also by promoting transparency about the market prices. This can in turn support the predictability of revenues and reduce the investor uncertainty.
- **Ensuring access and setting transparent rules for participation for all market actors:** Review of regulatory barriers to participation of all technologies in flexibility markets is necessary, especially on the national level.
- **The role of independent aggregators:** Aggregation is an important avenue for ensuring the participation of smaller actors and individual consumers. Although the regulatory framework for aggregators is defined on the EU level, the national implementation is missing in many EU member states and should be adopted without further delays, since this reduces the active participation within flexibility markets.
- **Consumer awareness and perceptions**: Currently, there is low level of awareness and understanding of grid related issues and potentials for flexibility service provision. Providing clear and reliable information for FSPs on how to access markets via user friendly and well-designed platforms and interfaces will be important to bridge information gaps on market opportunities. Clear and transparent provision of information regarding potential for market participation will be important to help new market participants and utility customers understand their electricity consumption profile and what their flexibility is worth across markets and across time.

## Managing system operator requirements and flexibility service providers capabilities through standardisation

While other parts of this paper explore the requirements for harmonising data exchanges, interoperability, and others, it is necessary to keep in mind that the flexibility markets will be integrated to the highly regulated environment of network operation, where standards and practices are already long-established. It will be necessary to carefully balance the need for harmonisation with the existing markets and the need to create a more open regulatory framework for flexibility markets, which are by nature more localised solution reflecting the local specificities.

To enable the uptake of flexibility markets, the first step requires the EU-level standardisation of flexibility products and their attributes. Products for network balancing are already well established but should be revised to strengthen their technology neutrality. Voltage control and congestion management products require a greater level of variability due to their localised application. Secondly, the principles for product prequalification should be highly harmonised to reduce market complexity and lower market entry barriers.

The adoption of novel market-based solutions should be made possible with the harmonization of communication protocols and data exchanges between TSO-DSO and consumers. Various local market schemes and FSPs require interoperable solutions, as discussed in the following chapter. Further, the added value from harmonizing the communication between aggregators and flexibility resources should be examined, which should particularly include small DER. All points must account for privacy (e.g., GDPR) and security (e.g., NIS2, Network Code on Cybersecurity) aspects.

### Adaptation of market phases for new products and actors

As suggested in the section above, the newly designed flexibility markets must be aligned with the existing energy markets and network operation procedures. However, there is currently no fit-all solution, and local characteristics, such as grid topology, the design of the flexibility products and their specifications, and entrance costs to the markets need to be considered:

- **Timing aspects and integration of new flexibility markets**: The sequence of energy markets can influence the decision of market players on where to commit their resources. When the utilisation of multiple markets is coordinated as a sequence of market windows, forwarding of bids could be realized which might affect, the economic attractiveness of the flexibility market but also the liquidity in all connected markets. The timing of market closure also affects the time to network operators to evaluate of grid status. However, since these aspects are not completely harmonised for other electricity markets, market timing does not need to be standardised on EU level and should be tailored to national specificities.
- **Product prequalification** should be automatised to the largest extent possible. In addition, prequalifying for a service with more strict requirements could entail automatic qualification for services with less strict requirements to avoid duplicating processes.
- **Flexibility service procurement and activation:** The location of the flexibility provider is an essential factor for congestion management and voltage control. As a result, the optimal use of the offered flexibility in flexibility markets requires a critical assessment of network constraints and resource location needs. Insufficient grid representation in the market could thus impact pricing due to sub-optimal bid selection. The regulatory framework should facilitate adequate grid representation in the future flexibility market designs.
- **Settlement processes**: Measures should be taken to ensure transparency in data exchanges necessary for settlement processes in flexibility markets to increase trust among all stakeholders. In some cases, this might call for an independent third-party performing this process, which could be subject to external auditing.

## 3.3 Grid observability impacts on data reliability and regulatory implications

In this document, we describe many trends in the digitalisation of energy sector and how the increased participation of many actors will increase the availability of data useful for more efficient grid operation and utilisation of renewable energy sources. However, this increased availability of data provided by actors and devices on the grid edge also creates some risks. This data will be in many cases generated by devices operated by other parties than grid operators, who are the sole responsible party for the safe grid operation and have been so far also the guarantor of the reliability of the measured data. With the availability of third-party data, the consistency, reliability and safety of the exchanged information could be potentially compromised and therefore clear rules and governance system has to be set up.

From the grid operator perspective, it is imperative that smart meters (at grid user interfaces) remain the reference point for measurements, especially for the purpose settlement of energy transactions (be it flexibility services or other). Data generated by other devices (behind-the-meter data) can bring multiple benefits, but in this sense should be an addition to the consistent and reliable data from smart meters, certified by grid operators, as elaborated in the Go4Flex report[13]. Smart meter functionality could be enhanced to not only handle measurement and exchange of data, but also enable controlling signals for connected devices, potentially on multiple channels (to allow for different control signals for different connected devices).

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[13] E.DSO TF1 Active Network Management - Grid observability for Flexibility

DSOs, as independent parties responsible for the secure management of distribution networks, must have the right to access to behind-the-meter data and to be the only responsible party for its validation in case those data would be used for settlement or even forecasting model. It is therefore necessary for behind-the-meter devices to communicate with smart meters through open protocols and shared communication standards and procedures, facilitating manufacturers of grid edge devices to develop products that are compatible with the widest possible range of existing smart meters.

The current regulatory framework should be enhanced to confirm and enforce the central role of DSOs in terms of data collection, management, and validation also under the light of new market entrants with the upcoming new behind-the-meter applications. This should also enable DSOs to have full control of relevant data on grid usage, being also able to implement adequate cyber-security measures to avoid system breaches, ensuring the safety of the power system.[14]

While the abovementioned information concerned mainly the developments in low voltage networks, the increasing deployment of flexibility will have also consequences for the operation of medium and high voltage distribution networks and the observability and controllability of these networks will also need to be enhanced. This is a significant technical challenge, which has not been fully explored yet. The Go4Flex report has recently detailed many of the proposed solutions, but it is necessary that the regulatory frameworks will enable the grid operators to make the necessary grid investments and that the frameworks facilitate the grid adaptations for flexibility in the network planning process.

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[14] E.DSO (2022) Unlocking the potential of the grid edge for DSOs

# 4. Interoperability framework

## 4.1 Introduction: needs for Interoperability

The success in achieving the targets of the Green Deal will require harnessing energy from low-carbon sources and scaling up massive investment in renewables, to power our homes, businesses, and vehicles. In pursuing this, millions of installations — including solar panels, battery storage, heat pumps, boilers and electric vehicles will need to be seamlessly integrated onto current electricity networks. The ongoing transition of energy sector, towards decarbonised power systems, is unprecedentedly revolving the traditional paradigms. Additionally, the central and dominant role being acquired by renewable energy sources must be accompanied by the digitalisation of the energy domain.

This move to a more decentralised energy system will create millions of energy data points, needed to manage more complex energy flows, which will rely on the digitalised exchange of data to be managed efficiently and in real-time across different domains like mobility, buildings, retail, energy and industry. This digitalised data exchange facilitates an energy system which can accelerate, automate, plan, and anticipate processes far better than at present. Hence, in an efficient and systematic data exchange (for monitoring and control of smart grids), not only the field devices but also processes and systems must deploy seamlessly IoT interconnection capabilities. The interoperability at each system level and application is the key ingredient to achieve a full digitalisation of energy sector.

The report "Digitalising the energy system - EU action plan" [15], published by the European Commission in October 2022, highlights the importance of interoperability mechanisms stating that "the key enabler for a digitalised energy system is the availability of, access to, and sharing of energy-related data based on seamless and secure data transfers among trusted parties". Interoperability is also a booster, by overcoming technical barriers, to foster the entrance in the market of innovative services and players and, consequently, the avoidance of vendor lock-in conditions that slow down the energy digitalisation. The same report includes the centrality of interoperability in the objectives of Digital for Energy (D4E) working group as part of Smart Grid Task Force (SGTF), particularly in association with transparent procedures to access metering and consumption data; these data acquisitions are of paramount importance to set demand response actions and, hence, deploy flexibility mechanisms. Moreover, the achievement of interoperability mechanisms constitutes the fundamental basis for the design and implementation of a common European energy data space, in which governance schemes are ensured and full exploitation of digitalisation opportunities are pursued.

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[15] "Digitalising the energy system – EU action plan"

## 4.2 The approach of "Interoperability Network for Energy Transition (int:net)"

The alignment of connectivity, not only for the electricity applications but for every related process and product related to energy domain, is addressed by the project int:net (Interoperability Network for the Energy Transition) [16] of the Horizon Europe programme. Complex interfaces, costly adaptation efforts, incomparable data sheets and not open-standards hinder adoption of advanced solutions; the key scope of int:net is the harmonisation of interoperability activities on energy services throughout Europe by forming an interdisciplinary network of stakeholders, which engages in a constant exchange on the topic during the project lifetime and beyond.

Specifically, int:net impacts the interoperability landscape for energy services by achieving the following objectives:

- **The creation of a common knowledge base for interoperability activities on energy services in Europe:** increase interoperability of energy services, data and platforms, both at the function and business layers by establishing and maintaining a knowledge base of interoperability actions and best practices.
- **The design of a comprehensive and accepted Interoperability Maturity Model (IMM):** ensure continuity of the ongoing interoperability of energy services related activities by developing an interoperability assessment methodology and the related IMM.
- **The deployment of a framework for interoperability testing in a facilities network:** starting from the outcomes of various European initiatives (as ERIGrid and ERIGrid 2.0 projects), support and disseminate a common framework for testing interoperability across running projects by harmonising interoperability testing procedures and creating a self-sustained and formally institutionalised distributed "network" of interoperability testing labs.
- **The establishment of a community network for a European interoperability ecosystem:** ensure horizontal coordination and support, sustainable up-take of the energy services related to interoperability, data spaces and digital twins by actively involving legal and regulatory framework setters in cross-domain modelling and interoperability testing exercises.

## 4.3 Versatile system-of-systems aiming at full flexibility

As the grid ecosystem become more and more complex, the systems supporting the digitalization process need to become more and more versatile, by adding new equipment that facilitate communication and data transfer inside the energy grid.

Having in mind a plethora of technologies, use case functionalities and Information Technology (IT) and Operational Technology (OT) convergences, the system needs to aim at providing full flexibility. In adapting and integrating functionalities, the technology providers should consider the possibility of improving and adapting their tools, to make them ready for an integration in a common environment. OT infrastructure is already protected by a security mechanism and the access is limited to specific areas. The access to OT infrastructure could be addressed by designing and implementing a federated architecture, whose tools have the possibility to address specific areas of the system[17]. A federated system facilitates an assembly of tools easy to be deployed on different sites. Thus, a toolkit based on building units configured for optimal performance allows for on-site deployment and use of only necessary tools and interfaces. In parallel with designing a replicable integrated toolkit, technology providers may consider adapting their tools to address the needs of the involved energy actors, while also considering to what extend the functionalities of the tools could be implemented in a domain-agnostic manner.

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[16] Interoperability Network for the Energy Transition (int:net)

[17] EnergyShield toolkit whitepaper, 2022

## 4.4 Interoperability Layers in Data Architectures

Analysis of interoperability solutions is directly connected to the development and use of architectures in deploying system's functionalities and services. The design of reference architectures relies on the necessity to find common structures and functionalities among multiple, different architectures. By addressing and integrating these commonalities, in relation to a standardisation process, the interoperability-by-design is worth to be deployed, in order to obtain required interoperability capabilities among specific building blocks or in data exchange processes [18].

According to standard ISO/IEC 21823-1, interoperability corresponds to the ability, for two or more components or systems, to exchange specific data and to elaborate as information the exchanged data. The deployment of interoperability originates from:

- the justification and agreement of data exchange, named interoperability case
- the occurrence of an interoperability point: a location in a process of the system in which information is exchanged among two entities.

The combination of interoperability case and interoperability point leads to the creation of an interoperability profile. The development of an interoperability solution is depicted in Figure 5 (considering a particular example for digital twins), for which the consequent steps are: the identification of an interoperability point (a location in the system where interoperability must be achieved), the description of the justification and agreement as interoperability case and, finally, the design of an interoperability profile used to create interoperable systems.

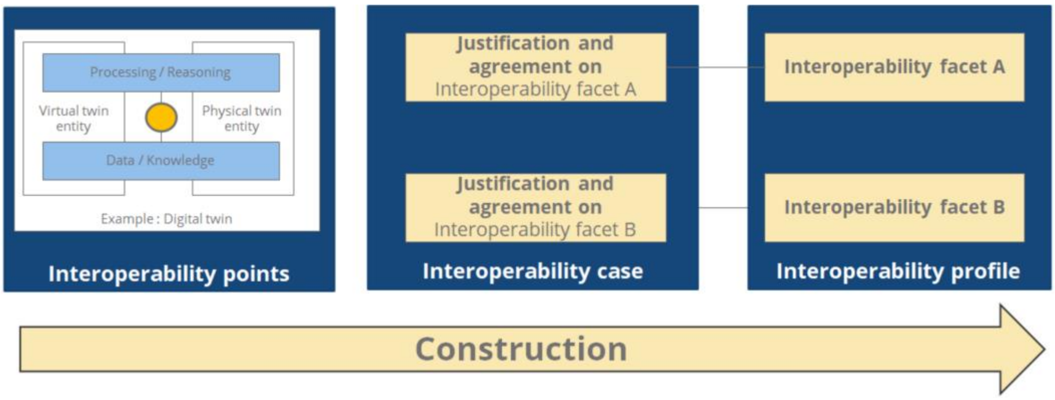

Figure 5 The interoperability-by-design process

Additionally, an interoperability framework is defined as a structure of processes and rules used to deploy interoperability mechanisms. The characterization of an interoperability framework considers the different aspects of the system: the sector to which the platform is applied, the technological specific needs (e.g., the use of IoT, Digital Twin of Artificial Intelligence solutions) and the interoperability facets (communication, syntactic, semantic, policy, etc.).

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[18] Reference Architectures and Interoperability in Digital Platforms – OPEN DEI project

Considering the definition of interoperability facets, the National Interoperability Framework Observatory (NIFO) defines the interoperability model 19 shown in Figure 6, which is applicable to digital public services and relies on the interoperability-by-design approach. The constituting layers are defined as follows:

- Four different layers, corresponding to:
  - **Legal interoperability**, ensuring that organisations operating under different legal frameworks, policies and strategies are able to work together.
  - **Organisational interoperability**, aligning their business processes, responsibilities and expectations to achieve commonly agreed and mutually beneficial goals.
  - **Semantic interoperability**, including syntactic aspects, ensuring that the precise format and meaning of exchanged data and information is preserved and understood throughout exchanges between parties.
  - **Technical interoperability**, defining interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols.
- As cross-cutting component, the transversal layer on **integrated public service governance**, which addresses the coordination and governance by the authorities with a mandate for planning, implementing and operating European energy services.
- As background layer, the **interoperability governance**, which refers to decisions on interoperability frameworks, institutional arrangements, organisational structures, roles and responsibilities, policies, agreements and other aspects of ensuring and monitoring interoperability at national and EU levels.

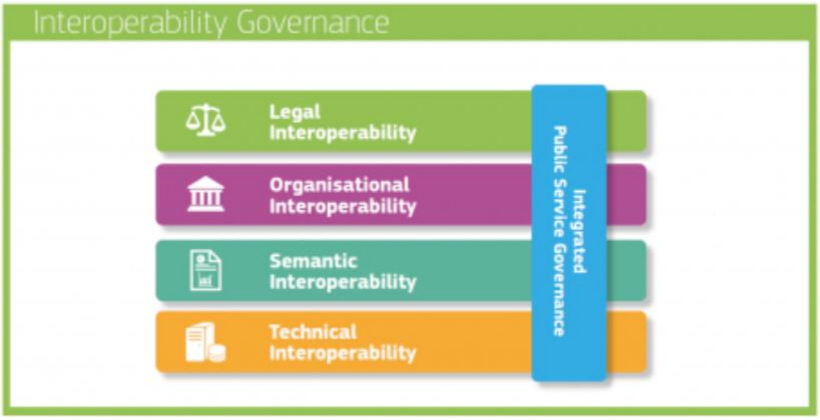

**Figure 6 The NIFO interoperability model**

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[19] Interoperability layers, NIFO – National Interoperability Framework Observatory

As additional fundamental reference, the Smart Grid Architectural Model (SGAM) focuses on supporting a neutral positioning towards the creation of smart grid use-cases, allowing a representation of interoperability viewpoints in a technologically neutral approach. The four interoperability layers proposed by SGAM are: **component**, **communication**, **information**, **function** and **business.** The provision of interoperability (at different levels) enables the exchange and creation of data driven use-cases to monitor, forecast and provide control over the energy domain. For example, key standards arise such as the IEC 61850 providing guiding principles for communication interoperability among substations components in the distribution domain; additionally, the IEC Common Information Model (CIM) is one of the key data models for data exchange at the information layer, defining a common vocabulary and a basic ontology for the systems in electric power industry.

The flexibility can be defined as the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system[20]. The power system resources that are involved in flexibility mechanisms belong to different categories: supply side (including energy storage), network side (with DSOs and TSOs plying a crucial role in ensuring network reliability) and demand side (with the active participation of prosumers' premises). Moreover, the orchestrated execution of flexibility mechanisms, involving multiple systems and geographical areas, leads to interoperability cases that go beyond the technical and semantic facets (in the SGAM model, identified by component, communication and information layers) and require the alignment also on business, legal and organisational aspects. Particularly, trans-national schemes (for energy exchange at transmission level among different countries) require alignment on business and functional layers that include European and national legal frameworks. It is then necessary to involve member states in the definition of economic and legal framework and consider actions to scale up national best practice for an "European energy market design". Hence the interoperability cases resulting from flexibility deployment must maintain a holistic view that spans across the different interoperability layers, necessary to interconnect the devices, applications and systems.

## 4.5 Minimal Interoperability Mechanisms (MIMs)

In dealing with interoperability for flexibility in smart grids, the concept of Minimal Interoperability Mechanisms (MIMs) 21 plays a cardinal role. MIMs refer to the basic set of interoperability cases to interconnect different systems: they take into account the different backgrounds of systems and allow them to achieve interoperability based on a minimal common ground. The concept originates from smart cities applications and it can be accordingly extended to smart grids services.

Considering the flexibility mechanism to be deployed, the minimum set of interoperability profiles to be achieved, for each facet, is identified and addressed. Implementation can be different, as long as crucial interoperability points in any given technical architecture use the same interoperability mechanisms. The MIMs, which are deployed, are then vendor-neutral and technology-agnostic, meaning that anybody can use them and integrate them in existing systems and offerings.

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20 Eurelectric, 2015, Flexibility and aggregation-requirements for their interaction in the market, IEEE Transactions on Power Systems, vol. 30, p. 13

21 Minimal Interoperability Mechanisms (MIMs), Open & Agile Smart Cities (OASC)

## 4.6 EEBUS Standardization towards Interoperability and Energy Flexibility

Today's accelerating energy transition demands eco-systems to reach a critical mass. As these eco-systems consists of a complex compilation of multiple energy relevant and controllable devices from numerous buildings, the applied communication interface must be technically standardized. EEBUS initiative develops and standardizes such communications and interfaces to allow the interconnection between energy management relevant devices as well as corresponding control systems. EEBUS contributes with the experience and results from joint development of standards in important standardization bodies and plays a key role in shaping future standards. An overview of EEBUS standardization activities towards interoperability and flexibility is shown in Figure 7 and described in the following:

- **CENELEC EN 50631:** This European standard specifies how different products from different manufacturers can exchange information with Home & Building / Customer Energy Management Systems located in a home network or in the cloud/IoT. It defines a set of functions of household and similar electrical appliances covering energy management, remote control and monitoring. There exist different networking technologies for interoperability in Homes and Buildings. Regardless of the communication technology, they all have rules or standards (collectively known as protocols) that define the syntax, semantics and synchronization of communication and error recovery method. This standard defines Use Cases with the focus on capacity management and energy flexibility related to White Good and HVAC devices. The communication protocols: Smart Premises Interoperable Neutral-Message Exchange (SPINE) and Smart Home IP (SHIP) are described as well.

- **VDE AR 2829-6:** This German national standard specifies a possible implementation of power control at the grid connection point using a communication protocol by one or more "controllable customer installations". This standard defines Use Cases as well as SPINE and SHIP communication protocols. The focus is here on capacity management and energy flexibility between the grid connection point and the energy management system using power limitation and incentive tables. This Use Cases are currently under discussion to be consider in the new edition of IEC TR 62746-2.

- **IEC 63380:** This international standard specifies a standard interface for connecting charging points and/or charging stations to local energy management system. It defines use cases, the sequences of information exchange, the data models and the communication protocols to use and cover all aspects of local energy management of charging stations. This standard is under development and interoperable with the Japanese ECHONET Lite protocol.

- **ETSI SAREF4ENER:** This European standard specifies data model in terms of ontology. It is meant to enable the interoperability among various proprietary solutions developed by different consortia in the smart home domain.

EEBUS is partnering with leading alliances and consortiums in Europe and the US: the common goal is to push forward the international harmonization of the energy landscape for interoperable solutions. Data point mapping of OpenADR/IEC 61850 and EEBUS can be made e.g., in the grid gateway, which is in charge of the DSO. The integration of EEBUS, therefore, stands for reduced development costs and investment security for manufacturers.

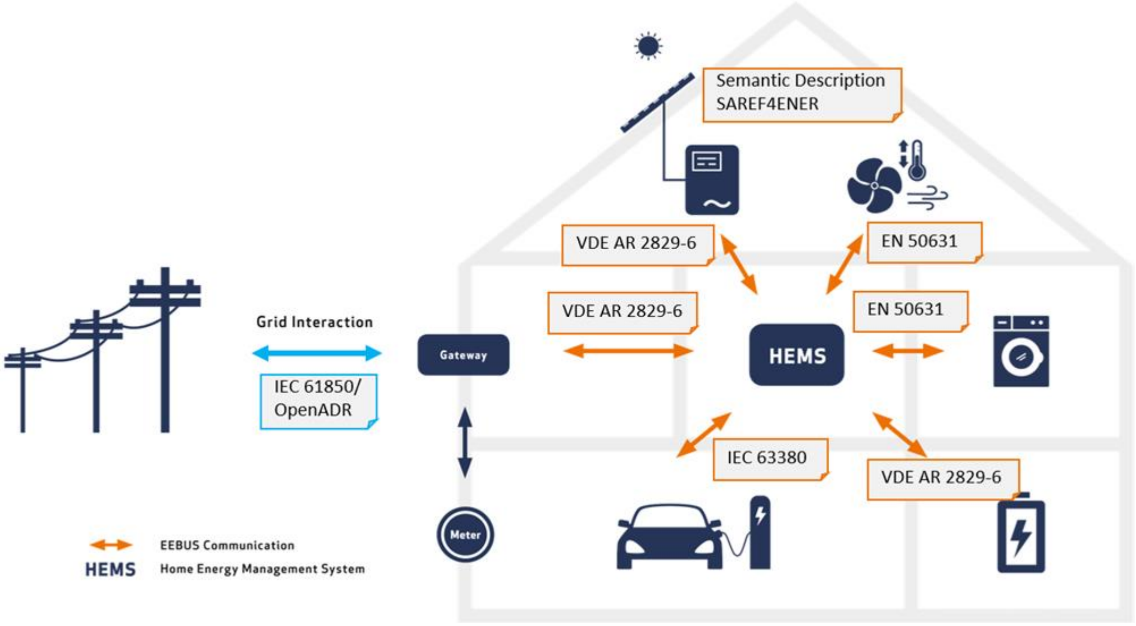

**Figure 7 Overview of EEBUS standardization activities towards interoperability and energy flexibility**

## 4.7 Common Information Model (CIM), the reference Power System of System ontology

### Moving towards a Power System of Systems

Without doubts the future energy system will consist in one coordinated system of interconnected systems working seamlessly together. Each sectorial system will have to manage its real-time operation through the boundaries of its own set of operational requirements however establishing new "market coupling interfaces" making use of best available standards and enabling flexibility trading across these markets. Hence the digital infrastructure required to support such transformation is evolving from central monolithic vendor protected environments, as historically observed in SCADA control rooms, into new "platform of platforms" architectures with real-time data streaming across virtual control room environments down to grid users.

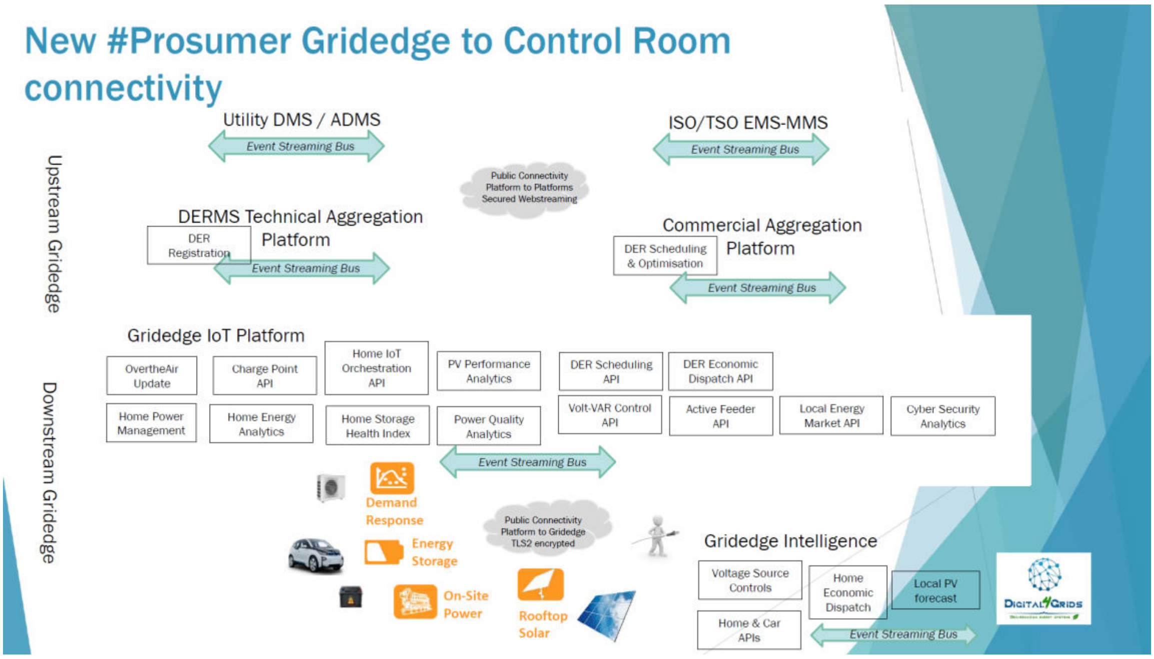

Figure 8 Architecture of connectivity between Prosumer Grid edge to Control Room

In such platform data streaming, interoperability and open API, will become most critical components, offering real-time data access across actors of the energy value chain and transacting flexibility products across the system – directly or through independent aggregators acting as virtual traders and power plants.

### Expanding data integration boundaries across Power subsystems and Microgrids

There are no doubts future data platforms will evolve towards distributed architectures as several key system operator functions are evolving towards coordinated energy management processes across TSO and DSO down to grid-edge, raising new challenges in term of control room technology migration as well as integration strategies and interoperability. To avoid the fragmentation of marketplaces and data exchange platforms across Europe and to ensure the best usage of flexibilities across sectors, an essential design element is to ensure interoperability, real-time data orchestration and a level playing access to all electricity market participants across the value chain. Interoperability must therefore be enforced across Europe while the number of market participant increases:

- **Horizontally between marketplaces, TSOs and regional security coordinators across Europe**, as largely initiated through the integration of Pan European market processes such as flow-based market coupling on day ahead and intraday as well as coupling of European balancing platforms. The CIM IEC61970 data standard with associated semantic and ontology has been largely used through the recent development of common grid model exchange process which has become a default data standard.

- **Vertically between TSO and local DSO marketplaces** to ensure the coordinated operation of flexibility from highest voltages down to residential prosumers on lower voltage. Such coordination should cover all aspects of DER flexibility registration and qualification processes as well as baselining and real-time activations for fast acting flexibilities such as for storage resources; while data exchanged have not been fully defined yet, several Horizon Europe projects such as EUSysflex[22], TDX-Assist[23], INTERRFACE as well as OneNet have been working on expanding CIM ontologies where needed, such as for smart inverter controls.

- **Between System operators, market participant and consumer**, to ensure that DER deployed at the edge of the grid behind the meter are able to participate at level playing interactions with other wholesale resources. ENTSO-E and the new EU DSO entity are currently working through the Expert Group 1 to propose harmonize data exchange across TSO and DSO flexibility markets taking advantage of the CIM IEC62325 data standard with associated semantic and ontology as already used through current wholesale market process.

As highlighted by SmartEn through its digital committee implying key flexibility market participants, future marketplace designs need to consider interoperability as an essential prerequisite aiming at uniform published APIs across Europe taking advantage of open standards to further promote open competition. Considering the large usage of CIM based APIs across the grid and market platforms - such as Xbid as well as the new electricity balancing platform - flexibility services are expected to be traded through different marketplaces (day-ahead, intraday, balancing and frequency response markets as well as local flexibility markets) and enable revenue stacking to ensure a proper flexibility remuneration to prosumers. For such marketplaces to scale across Europe without fragmentation, further efforts should be made by TSOs and DSOs towards market interface interoperability and control room integration so that all marketplaces and market participants can access relevant information under consistent real-time data formats (as currently developed through the ENTSO-E transparency platform framework).

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[22] EU-SysFlex H2020 project

[23] TDX-Assist H2020 project

## 4.8 Large-scale semantic interoperability in the Interconnect project with SAREF

The main challenge for the success of the future energy system, which will consist in one coordinated system of interconnected systems whose interaction will need to work seamlessly together, is to raise the concept of interoperability from the currently commonly used technical (syntactical and communication) level to the semantic (information) level, where ontologies are used as common vocabularies to share and reason about data that can be encoded in different specific protocols and syntactical standards.

On the one hand, some industry, e.g., smart appliances manufacturers, already understood the impact that ontologies can have to enable the missing interoperability, also as a result of significant standardisation efforts such as SAREF in ETSI[24]). SAREF and its extensions for Energy, Building and City are a solid example of mature, standardised and sustainable ontologies that can be used as basis to configure Data Spaces for energy, home and mobility.

They provide the technological basis to enable distributed knowledge federation on top of which data spaces can be established with data sovereignty and governance. On the other hand, concrete guidelines and successful stories of semantically interoperable large-scale implementations that can be (easily) replicated are still missing for the practitioners. In this context, promotion, experimentation and roll-out of interoperability innovation based on mature, standardised and sustainable ontologies such as SAREF is essential.

To that end, an important contribution is provided by the H2020 InterConnect project that, by using the SAREF suite of ontologies as its main pillar, has brought semantic interoperability to the next level, deploying large scale solutions in operational environments for connecting smart homes, buildings and grids with active involvement of industry. The core of the InterConnect innovation lies in a Semantic Interoperability Framework (SIF) which is capable of bridging the integration gaps “within” and “between” the IoT and the energy domains, providing distributed enablers that interconnect different devices, platforms and services, enabling them to exchange data and instructions in a uniform and secure manner, while relying on widely adopted interfacing technology (RESTful). Exchanged data is not stored or processed anywhere in between communicating parties.

A number of new ontologies have been developed as part of the InterConnect SIF that extend SAREF in order to cope with the variety of use cases and services implemented by the seven InterConnect large scale pilots. These use cases and services include, among others, smart appliances monitoring and control, energy flexibility, consumption/production forecasting and EV charging in residential and commercial buildings. A key result reached with the InterConnect work is the creation of new modules fully dedicated to energy flexibility[25].

In particular, the ic-flex ontology (which is in the process of being integrated in ETSI in the future release of SAREF4ENER) describes the main concepts of Flex request, Flex offers and flex instruction. A flex request allows to request flexibility options, a related flex offer allows to provide flexibility alternatives to this request, while a flex instruction allows to activate a certain plan chosen amongst the various alternatives provided in the offer. In particular, ic-flex:FlexOffer represents a flexibility offer (or schedule) as a combination of multiple time-series, data-points and forecasts.

For example, we can create a "semantical and SAREFised" flexibility offer that includes a time-series of power values, combined with a time-series (or a single datapoint if the costs are the same for all the power values in the offer) of associated costs. It is also possible to specify a creation time, validity period and provenance for the offer. A DSO interface that provides SAREFised flexibility services according to this ontology has been recently released in the project.

The process of standardizing in ETSI the newly developed ontologies by InterConnect in order to officially extend the current SAREF suite of ontologies has been initiated in March 2022 and is currently ongoing.

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[24] SAREF in ETSI

[25] IC Flex

## 4.9 Energy Data Spaces to enable Flexibility

The strategy of European Commission towards the enhancement of data exchange solutions in the energy domain leads to the "data spaces" concept [26]. The definition of data space is associated to data integration concept which does not require common database schemas and physical data integration, but it is rather based on distributed data stores and integration on an "as needed" basis on a semantic level. In addition to this technical definition, a data space can be explained as a federated data ecosystem within a certain application domain and based on shared policies and rules. The users of such data space are enabled to access data in a secure, transparent, trusted, easy and unified fashion. These access and usage rights can only be granted by those persons or organisations who are entitled to dispose of the data, via authentication and authorisation mechanisms.

Data collection and usage are acquiring a more and more dominant role, since several years, in the energy sector. The installation of new smart meters, capable of providing accurate electrical measurements with high time granularity, became fundamental as well as, for example, the integration of weather forecasts in precise locations and meta-data associated to mobility and smart-city services. In general, smart grids started to be increasingly data centric, for which utilities, renewables plant owners, and retailers rely on vast data lakes. Anyway, the use of centralised data-hubs is still dominant and modern infrastructures via open innovation ecosystems are needed. The soft infrastructure of data spaces will facilitate the sharing and exchange of energy related data between various sets of stakeholders (as prosumers, local energy communities, utilities or system operators) based on a framework of agreements and grid codes.

Flexibility mechanisms relies on the availability of a large amount of data, necessary for the operational control of networks, that is exchanged among different organisations and, eventually, between different countries. A level playing field for data sharing and exchange will allow players in the energy sector to cooperate on the design and maintenance of the soft infrastructure underlying data spaces. Additionally, the demand-side flexibility, which corresponds to the active role of prosumers in supporting flexibility requests by means of time-shifts of loads (possibly in combination with storage systems usage), makes the prosumers fundamental players in the energy data space; consequently, dedicated components for data sovereignty and governance have to be implemented as well as solutions for the appropriate remuneration of the offered services and data value.

Various initiatives at European level are pursuing the deployment of data spaces in the energy sector. The project Data Space Support Center (DSSC)27, from the Digital Europe Programme, sets up and operates a stakeholders contact centre to operationalise the European strategy for data.

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26 Design Principles for Data Spaces, OPEN DEI Position Paper

27 Data Space Support Center (DSSC)

DSSC facilitates common data spaces that collectively create an interoperable data sharing environment, to enable data reuse and secondary use within and across sectors, fully respecting EU values, and contributing to the European economy and society. Specifically focusing on the energy sector, the grounds for a common European energy data space are aimed by five projects of the Horizon Programme: Data Cellar[28], Enershare[29], Omega-X[30], Synergies[31] and EDDIE. Use cases deploying flexibility solutions are deployed in the large-scale pilots, providing the components for energy data space that suit the smart grid requirements.

**Device interoperability. Case study on smart meters**

Smart meters are one of the devices that are ubiquitous in the development of smart grids and generally any integrated power system. The specific case of a device that basically does the same thing but in many different ways, through deferent architectures, features and coming from a plethora of manufacturers is perfect for a discussion on interoperability at device level. This particular measurement device is also very well suited for this study due to its dual nature, on one side being an actual device as part of the grid, and on the other hand being a part of the data models and internet of things concepts. As part of [1], a specific analysis on this subject was performed starting from SGAM and deals with different types of meters available at the time of the research also available in a public report [2].

The Smart Grid Architecture Model (SGAM) - developed as part of the reference architecture framework specified in EU Mandate M/490 [3] - is a representation of Smart Grid solutions and is popular among Smart Grid stakeholder (utilities and research institutes) [4]. The SGAM defines a set of architecture viewpoints, informal concepts, and a method to map use case information to architectural elements. It provides a structured approach for Smart Grid architecture development. The five interrelated architecture viewpoints, addressing business, functional, information, communication, and component layers are core of the SGAM (see Figure 9).

The scope of the interoperability layers proposed by SGAM was applied to interoperability issues related to smart meters. According to a strict layer definition for smart meters is only relevant to the Component layer of SGAM. But, taking a broader view, within a Smart grid, all the layers of interoperability are affected by meters. This is the only device sending data to the utility/DSO in an Advanced Metering Infrastructure (AMI) or in a customer system. AMI applied to electricity distribution networks exploit smart control and communication technologies to automate metering functions that are typically done manually. These include electricity meter readings, service connection and disconnection, tamper and theft detection, fault and outage identification, and voltage monitoring. AMI also enables utilities to offer new rate options that incentivize customers to reduce peak demand and energy consumption[5].

The European Smart Metering Industry Group (ESMIG) has adopted a set of open standards (originating in the European Commission) to which members' products must comply to ensure interoperability. The Smart Meter Coordination Group (SMCG) that acts on the M/441 mandate[6], defines interoperability as the ability of a system to exchange data with other systems of different types[7].

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[28] Data Cellar HEU project

[29] Enershare HEU project HEU

[30] Omega-X HEU project

[31] Synergies HEU project

In all smart grid topics beyond interoperability aspects, **interchangeability** is the new goal of technical and commercial arrangements and defines the ability to exchange one device with another without reducing the original functionality. To achieve interchangeability, several additional conditions must be met beyond the conditions for interoperability. Interchangeability requires devices to support the same functional behaviour on their communication interfaces or allow changes in functionality to be supported by the relevant communication protocol [8]. Thus, interchangeability deals with several additional conditions concerning the functional behaviour of devices at their communication interfaces

The GWAC (GridWise Architecture Council)[9] has looked at, interoperability between components of the same system, or between different systems and highlights the need of data consistency, coherence, standardization and quality providing that (1) devices exchange meaningful information, (2) there is a shared understanding of the exchanged information, (3) consistent behaviour complies with system rules and (4) a quality of service is in place to check reliability, time performance, privacy, and security.

The study referred and described in [10] focussed on the communication layer and information layer of interoperability, addressing, for example, data formats (e.g., XML) for energy usage information and data exchange protocols to facilitate automated data transfer (e.g., PLC). Communication interoperability uses standards and protocols for data acquisition and data exchange. Most of the analysed smart meters were compliant (at the time) with the standards required for interoperability at communications layer. The architectures and functionalities adopted in EU in smart metering applications are briefly summarised in several reports at H2020 project levels [11].

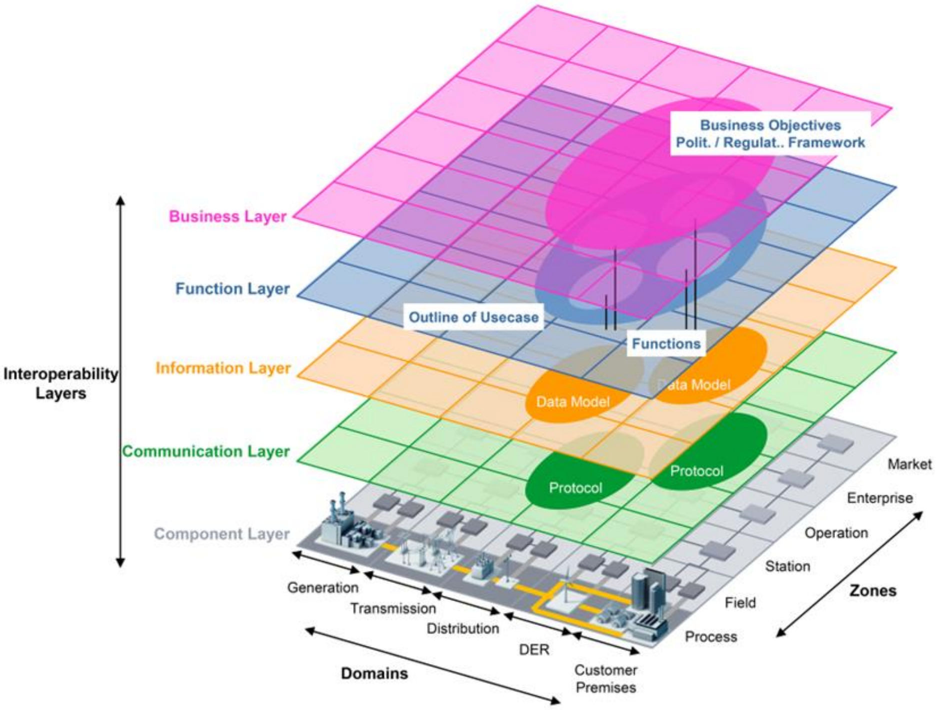

Figure 9 SGAM Framework – Component reference architecture[32]

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[32] Source: CEN-CENELEC-ETSI Smart Grid Coordination Group Smart Grid Reference Architecture

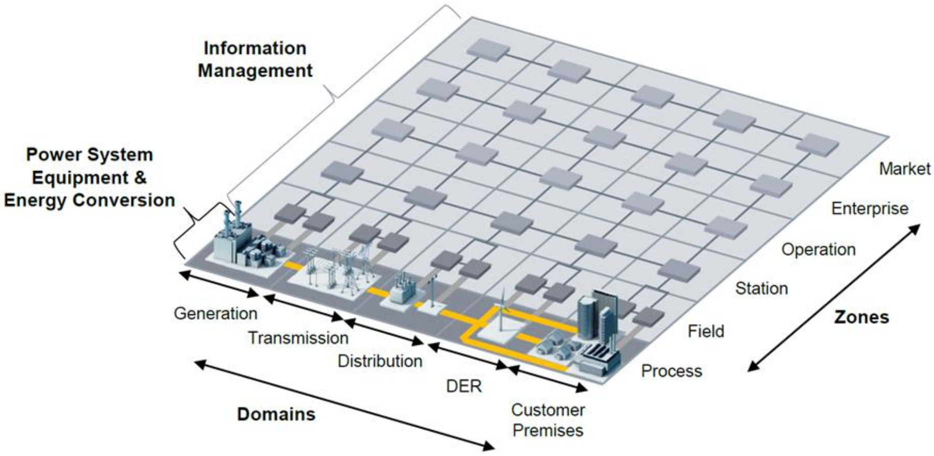
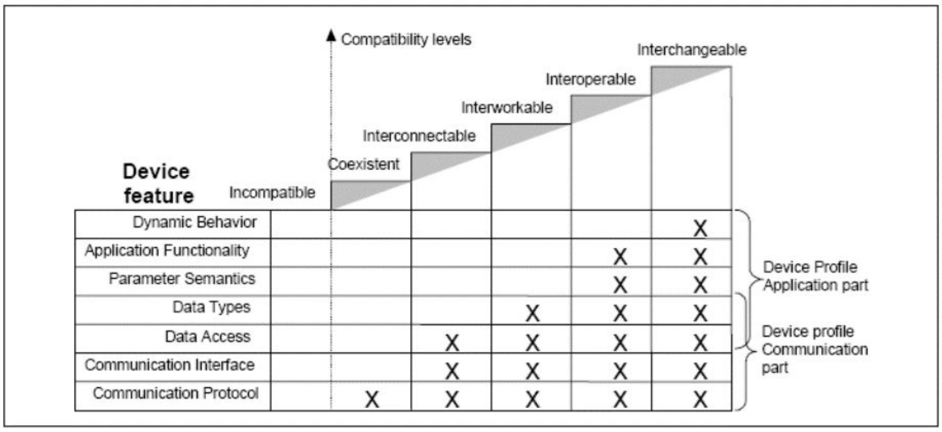


Figure 10 Smart Grid plane - domains and hierarchical zones



| Device feature | Incompatible | Coexistent | Interconnectable | Interworkable | Interoperable | Interchangeable |
|---|---|---|---|---|---|---|
| Dynamic Behavior | | | | | | X |
| Application Functionality | | | | | X | X |
| Parameter Semantics | | | | | X | X |
| Data Types | | | | X | X | X |
| Data Access | | | X | X | X | X |
| Communication Interface | | | X | X | X | X |
| Communication Protocol | | X | X | X | X | X |

Figure 11 Levels of compatibility according to TC65/920/DC

## Information layer (data type and measurements)

The **information layer** describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models (e.g., XML, html). These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.

Two broad categories of data formats/models which may be taken into consideration for the provision of data within the "My Energy Data"[1] initiative is: (1) **human-friendly** format (like CSV/XLS/PDF), that the end user can access to view or download his smart metering data and use with common IT tools or (2) **machine-friendly** format (like XML/JSON/CSV) that is used to exchange energy data with other 3rd parties.

## Function layer (functionalities)

The **function layer** describes functions and services including their relationships from an architectural viewpoint. As defined in [CEN12], functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.

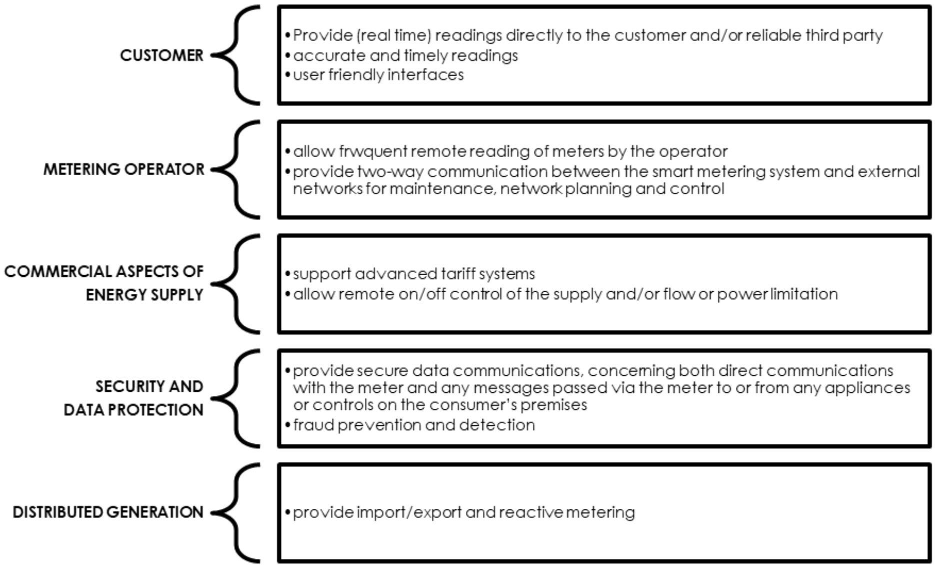


**Figure 12 Common minimum functional requirements recomended for smart metering systems**

To decide upon a compatibility level, the following parameters of the identified smart meters were considered: (1) Dynamic behaviour; (2) Semantic interoperability; (3) Number of tariffs; (4) Import/export formats; (5) Remote ON/OFF; Demand response; (6) Demand interval report; (7) Communication protocols [2].

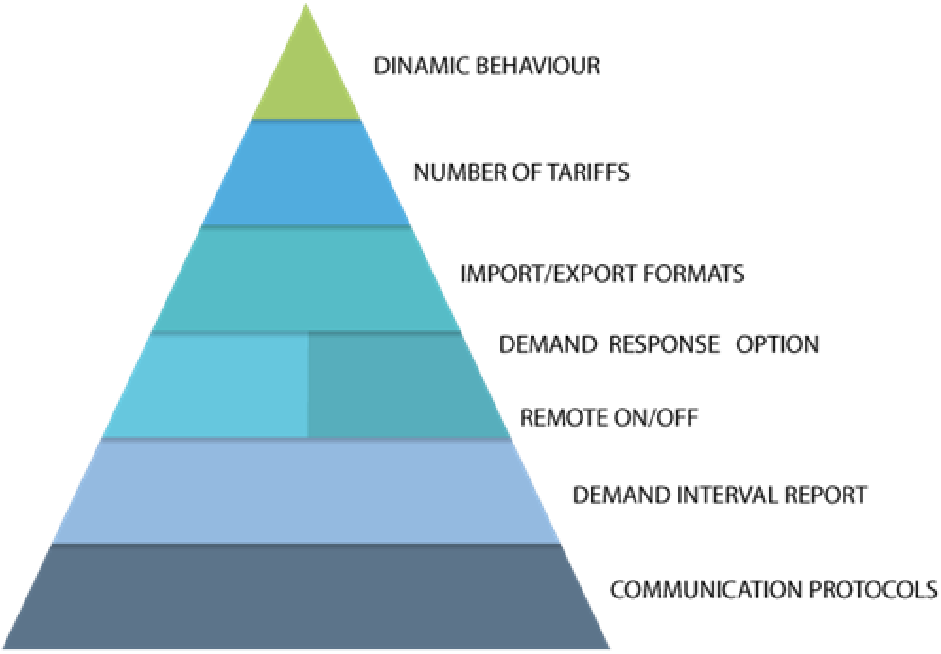


**Figure 13 - Conceptual assessment of identified smart meters**

Based on this information provided by smart meter producers in their products data sheet ~~and~~ on the levels of compatibility as defined in TC65/920/DC [1] and applying the conceptual assessment presented in Figure 12, above, the smart meters may be grouped in three major categories:

- **Interchangeable** (level 1) - can be readily integrated to the DLMS/COSEM suite to achieve semantic interoperability
- **Interoperable** (level 2) - *Due to lack of info considering type of data and data access separating between interworkable and interoperable was not possible*).
- **Interworkable** and interconnectable (level 2) - meters able to transmit data using wireless communication and the ones only able to transmit information by wired communication.

Considering the second layer of the pyramid presented in Figure 16, above, all studied meters can be considered interoperable since they all have available the standard 15 min reporting rate. If it is necessary, when demand interval is lower, the information can be aggregated. This is most likely the case for all commercially available digital meters.

For the 3rd layer (demand response), there was not enough public information as there was not and still isn't no large-scale demand response service implemented by DSO in EU-28.

For the layer 4 (import/export data) and 6 (dynamic behaviour), there is still not enough information to draw a definite conclusion. This is mainly due to this type of information being usually use case specific and not a necessity for most applications (billing, typical curves).

Most of the investigated meters had, at the time, varying tariff procedures ranging from 2 tariffs (day/night) to complex or comprehensive structures with multiple parameters (working days, week-end, holidays, seasons etc.) and the limitations are more based on the specifications of the countries in which the meters were deployed than the technology itself.

It is to be mentioned that the referred study had a limited scope and the situation is dynamic but it is a good starting point for the general study of interoperability of devices in smart grids.

## Cross-sector interoperability

The achievement of Green Deal targets depends on the re-shape of complex energy flows, involving different sectors (like mobility, buildings, retail, energy and manufacturing) and relying on the digitalised data exchange to be managed efficiently and in real-time. This digitalised data exchange facilitates an energy system which can accelerate, automate, plan, and anticipate processes far better than at present.

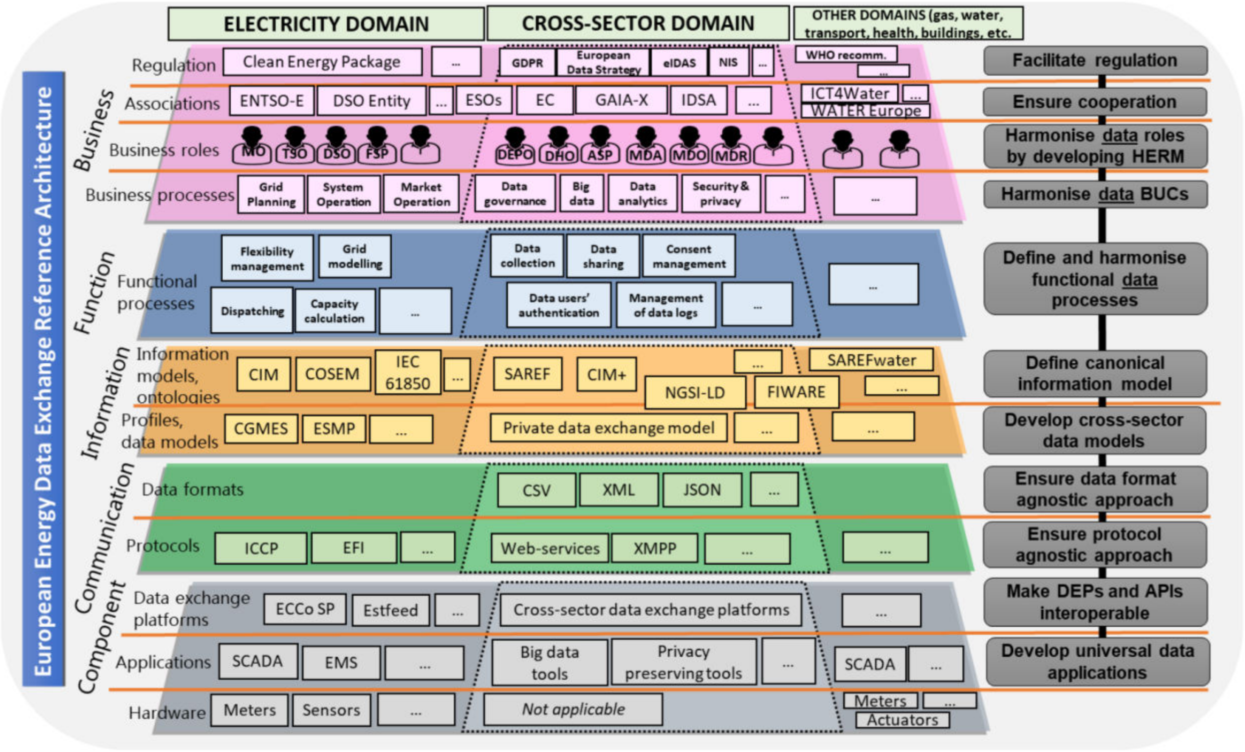


Figure 14 Data Exchange Reference Architecture proposed by BRIDGE initiative

The alignment of different digitalisation strategies is crucial to the European Commission, ensuring that EU policies create a momentum on the market rather than become a burden and delay the digital transformation of industry. The development of an energy data space cannot be delivered as a single platform but must be built incrementally, meaning that applications and systems must be capable to interoperating and exchanging data across different data spaces. As fundamental use-case, the interconnection of smart grid domain with building and mobility sectors has to be addressed, resulting in a well-balanced eco-system[33]. Rooftop solar generation, the availability and capacity of energy storage, EV chargers, smart thermostats and other flexible demand response assets are currently operationally invisible to utilities. These devices will gather the consumers' data and use market information about the carbon footprint of a service, availability of power and cost. The Data Management working group of BRIDGE initiative has analysed the data exchange solutions for cross-sector applications, proposing the high-level SGAM based reference architecture [34] depicted in Figure 14. While in the left side of the architecture the components are specifically deployed for electricity applications, the central and rights sides of the architecture indicate component that are used to interconnect different domains and achieve interoperability at the different layers. The architecture allows to highlight the key components to be furtherly developed for the European pilots.

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[33] Data Spaces for Energy, Home and Mobility, OPEN DEI H2020 project

[34] BRIDGE: European energy data exchange reference architecture

# 5. Virtual Power Plant (VPP) role

## 5.1 Introduction

The introduction of Renewable Energy Sources (RES) is a declared strategic goal and a priority for the EU member states that will transform the energy networks. This has created a widespread transformation – already under way – of the way energy is produced, transferred and utilized along the whole value chain, that ultimately will redefine our relationship with the environment and reshape the economy and society itself. The characteristics both specific but also general, of this energy transformation have started to appear. The core elements of this transition are the technologies that promote renewable energy generation and the technologies that safeguard energy efficiency in terms of transport and usage preferably in the largest scale possible.

## 5.2 What is a VPP – Virtual Power Plant

A Virtual Power Plant (VPP) is essentially a network of decentralised, medium scale power generating units and also flexible power and/or storage power systems from consumers. The concept of the virtual power plant has been introduced in 1997 by Dr. Shimon Awerbuch as “virtual utility” who proposed the creation of small systems capable of levering on the advantages of DERs – Distributed Energy Resources. The emergence of Virtual Power Plant (VPP) can be attributed to the major boost of distributed energy resources (DER), which satisfies the changing needs of modern society on energy industry.

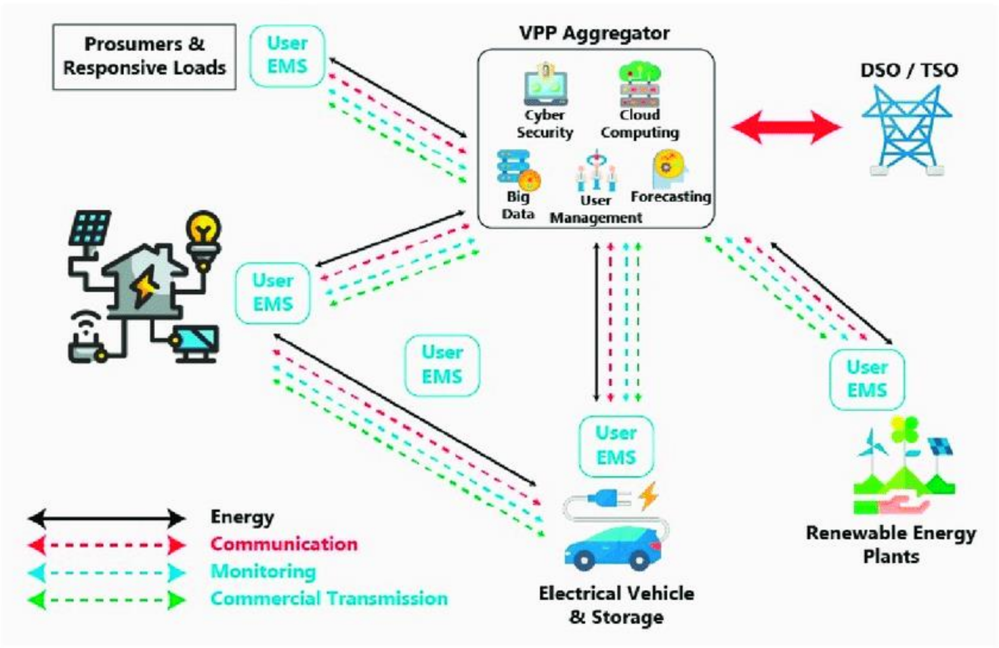

Figure 15 VPP Schematic Diagram[35]

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[35] Optimal Dispatch Strategy of Virtual Power Plant for Day-Ahead Market Framework

Since the term VPP has evolved to a more integral definition which essentially encompasses the different operating approaches and services that a VPP could offer to the EPS (electrical Power Source). Its specific role is visibility and the technical and commercial integration of DERs in the power system. It is capable of grouping and managing the technical potential of different DERs (microgrids included), regardless of the voltage level at which they are interconnected with the network and without a geographical restriction between the elements. It is modelled as a single virtual element associated with the distribution network to guarantee a safe, efficient, cooperative and complementary operation between its elements, both in commercial and technical aspects. The VPP has the capacity to participate in the electricity market as a manager of controllable loads and as a provider of energy, power reserve and ancillary services.

The set of sources that a VPP could be composed can form a cluster of different types of dispatchable and non-dispatchable, controllable or flexible load (CL or FL), distributed generation (DG) systems that are controlled by a central authority and could include:

- microCHPs,
- natural gas-fired reciprocating engines,
- small-scale wind power plants (WPP),
- photovoltaics (PV),
- run-of-river hydroelectricity plants,
- small hydro,
- biomass,
- backup generators, and
- energy storage systems (ESS).

## 5.3 Types of VPPs

The main types of VPPs are the following:

A. **Market participating VPPs:** Market-participating VPPs are typically run by electricity retailers to deliver more value to themselves and their customers. They can include a single type of asset (e.g. a solar only VPP or battery only VPP), or a mix of assets (solar, battery, EVs). They are able to inject energy into or extract energy from the grid to earn money or mitigate price exposure risk through spot price arbitrage or frequency response support.

B. **Network Service VPPs** These VPPs are used to dynamically support local electricity grids as a complement to or replacement for traditional 'poles and wires' assets. They take advantage of local resources (which may be customer-owned, owned by the network operator or a third party) to help ensure that the lights stay on in the most affordable way possible for everyone while also allowing solar & other DER system owners to use their assets as originally intended, without strict feed-in restrictions or system size limits.

C. **Emergency Response VPPs** An extreme version of a network service VPP, this is an emergency mechanism that protects grid stability by giving the operator the ability to turn on controllable loads or turn off solar inverters in large groups. As VPP technology and deployment becomes more sophisticated, these emergency response VPPs may be replaced by other more flexible options like, for example, dynamic operating envelopes for flexible export programs.

## 5.4 VPP applications for Energy Flexibility

As was described above, a VPP is a digital platform which allows numerous application cases and business models in a decentral structured energy economy. Thus, it facilitates and controls the usage and marketing flexibility through the networking of solar and wind parks with other generating technologies (biogas, hydropower, conventional generating technologies), storage systems and energy consumers.

**Marketing Flexibility:** A further example of the broad spectrum of possible implementations of the Virtual Power Plant is a project run by the Swiss energy company Alpiq. The Swiss electricity generator and energy service provider uses the concept of Virtual Power Plant to connect biogas facilities, forming a power plant group with marketing flexibility in the German intraday and day-ahead markets: energy production is increased or decreased by remote control depending on the price signal in order to optimally utilize the chances for return[36].

**Trading Flexibility:** With VPP software, decentralized energy generating facilities, storage and controllable consumers are connected, coordinated and monitored via a common master display. Here it is able to participate in various energy markets as a conventional power plant. Through the combination of optimized power predictions, fluctuating, decentralized generators of electricity can be optimally integrated into the power grid and efficiently marketed on the power exchange. More VPP application projects can be found at (6)

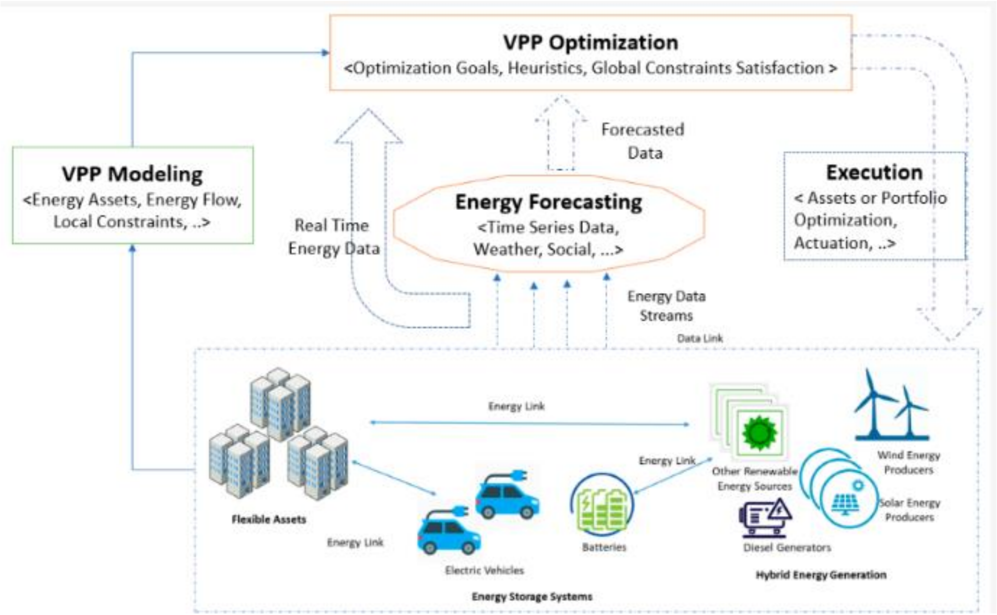

Figure 16 VPP concepts and technology usage[37]

In effect, the aggregation of distributed renewable energy (RES) generation and batteries enables their participation in balancing, wholesale or flexibility energy markets. In addition, aggregation services can provide prosumers and small generators with the necessary technology and control. The aggregator acts as a responsible partner in the power and flexibility markets. Thus, the small-scale flexibility resources which otherwise could not have participated in the energy value chain, can now offer to the TSOs and DSOs their flexibility.

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[36] Reference: https://www.energymeteo.com/customers/customer_projects/virtual-power-plant_flexibility-marketing.php

[37] Reference: Ref: https://www.mdpi.com/1999-5903/14/5/128/htm

# 6. Consumer Engagement

While power utility operators and enterprises are intensifying their transformation processes, they find hard to monitor and essentially address customer expectations in the new landscape that develops almost simultaneously. As a stakeholder in the value chain of the new energy landscape, new characteristics for the consumer / customer have appeared and enlarged roles have emerged that the energy utilities enterprises need to understand and manage. Customer engagement and empowerment offers opportunities to save energy for customers and to operate the grid in a more efficient, flexible and reliable way for grid operators. Grids can benefit from changing consumer behaviour – mainly from shifting or reducing energy consumption during times of peak load (or in case of local network congestion), so they have engaged and empowered customers to do that by proposing some benefits.

Attempts to engage customer involvement, just have started to appear mainly because the built trust between energy sector and end user is low and still rest in a relationship that is erratic, often based on negative interactions gravitating around the settlement of the energy bill. Consumer engagement mean that this trust is built in a consistent and transparent way. So far this has taken the forms of a quicker reaction to the customer need or problem, frequent interaction and introduction of service options such as 24/7 web portals, or chatbots in order to not only differentiate the service provided but also reduce the cost of delivering it.

As the energy ecosystem will be expanding and will become more interactive (and thus presumed by many as more complex, there is need to address the issue of energy visibility and transparency. It should not be left unmentioned that the average consumer has next to zero understanding of his own energy consumption and energy bill. This situation needs to be altered if it is to be expected that the consumers will actively be investing in new energy technology to benefit from the savings this technology and the services-based Ion it will bring.

Producers, regulators, retailers and more importantly consumers need to be engaged. In the recent past the technology led approach in many European countries, namely smart metering implementation did not produce the widespread result that it was hoped. However, there was a differentiation with the approach, chosen by the UK:

*"The UK did things a little differently. Firstly, it put the onus on energy retailers to install smart meters in an opt-in roll-out. The UK programme has had its challenges, but one thing this approach has led to is more effective customer engagement initiatives by energy retailers. In their attempt to encourage consumer take-up of smart meters, they have been able to design processes that have demonstrated the consumer benefit and captured data sharing consents as part of the smart meter installation journey. Secondly, the regulator stipulated that an in-home display was offered to all households with a smart meter installation. This enabled consumers to receive an immediate benefit from having a smart meter installed as they could monitor their energy use in near real-time, thereby building a more informed populace as a step along both axis towards the new energy nirvana represented by the top right quadrant of the chart."*[38]

No matter how the approach, it is essential that the customer understanding must be enhanced and this needs to be done by certain method and tools already available. Important ones are the energy visualization and bill itemization.

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[38] LCP Delta – Engaging different customers in the energy transition

The consumer engagement should be considered a continuous process that leads to a mentality of a more active customer, and all begins with how the consumer is led to understand the way their choices and actions impact upon their energy consumption ad their energy footprint.

A structure framework approach is suggested with the following stages:

- Engagement
- Empowerment
- Collaboration

**Engagement of Consumer.** Energy companies are utilizing energy data to get insights in order to help explain the consumers their energy consumption. Basic month–to-month comparison, AI-driven projections and graphs on bills is a well-used tool array.  Utility companies are trying to communicate data (historical data, disaggregation and visualization) that are as much personalized as possible.

**Empowerment of Consumer.** This stage passes the simple understanding of past behaviour and targets the need of the consumers to not only make saving in the energy consumed but control it in a more comprehensive manner. The information provided is becoming more personalized so do the tools so as the consumer can take informed decisions on the spot. Empowerment motivates the consumer to act.

As an example, it is mentioned an App, currently available to the consumers of Denmark that uses ML algorithms from past behaviour and statistical data from weather patterns in order to produce personalized heat and electricity budgets. Smartphone Apps in the form on energy coach is the generally understandable way to bring to the customer actable solutions. This, when done in a consistent way it will enhance the trust of the consumer to the emerging energy ecosystem.

**Collaboration of customer.** The next phase of consumer participation in the energy value chain brings them to the position of co-creating the energy future. Even though we are not there yet, as the energy transition is clearly under way, as new and flexible RES sources are participating in the ecosystem, the consumer is given the opportunity to become producer (i.e. prosumer), the benefits for the whole ecosystem of producing personalized energy data for individual consumers and giving them the capability to act upon them is becoming clearer for all stakeholders involved. The consumer will be treated as a new and valuable partner in the chain.

Well established business and sales tools will be in use by the energy utility companies. Technology will display the new solutions that energy companies will have to package them and communicate them ( even using marketing tools such as gamification for example) but the above mentioned challenges do exist and will not be quickly overcome, as what is required , is to build trust , a consistency of communication and reliability of information between the consumer and the energy operator for the long run with the purpose of  changing old consumer mentality and ultimately introduce energy awareness, encourage and enhance new behaviours.

## 6.1 Consumer engagement from the perspective of network operators

From the perspective of grid operators, the active participation of consumers is crucial especially on the local level. Wide-scale consumer participation could help to achieve the required volume and liquidity in flexibility markets and other schemes, necessary to have a significant impact on grid management. Currently, the experience from DSO pilot projects suggests several barriers to consumer engagement.

Firstly, the availability of flexibility service providers is limited, especially on medium and low voltage levels. One reason might be lacing regulatory incentives for DSOs to procure flexibility services. This hampers the pace of deployment of flexibility schemes and markets

Secondly, the business case for FSPs is not always viable, due to high cost of participation in flexibility schemes significantly reducing the profit margins; significant variation of flexibility demand on a yearly and seasonal level increasing the investment uncertainty and making the investment decision less attractive (active consumers may also prefer long-term contracts with guaranteed revenues); and low understanding of the concept of flexibility - the active consumers usually make investments to lower their energy costs, while the connection between flexibility and lower energy bills is not established. Independent aggregators are a good opportunity for small-scale resources and consumers to participate in flexibility schemes, but not all member states allow their existence yet.

## 6.2 Flexibility Trading through FlexOffer

Flexibility of DER assets is becoming an integral part of the efficient and reliable operation of the energy system. Through Directive (EU) 2019/944, the use of flexibility has been also established, as an alternative to traditional network investments by DSOs (when cost-efficient). Following a bottom-up approach in the value chain of flexibility, it's important to transform the different operational states of asset, whilst respecting the preference of producer/prosumers/consumer to value offerings towards the optimal operation of the energy system.

To this end FlexOffer concept has introduced an extensible solution for communicating flexibility in electricity demand and supply. FlexOffer is an application protocol and data format describing energy flexibility which can be aggregated and exchanged across several actors. Different constraints are modelled enabling a detailed modelling of the prosumer's asset's operational scenarios, as well as the aggregation (staking) from the side of the aggregator.

FlexOffer has been used in over 15 projects in Europe and beyond and is endorsed by the FlexCommunity[39] initiative, which aims to facilitate interoperability through wider adoption of the solution.

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[39] FlexCommunity

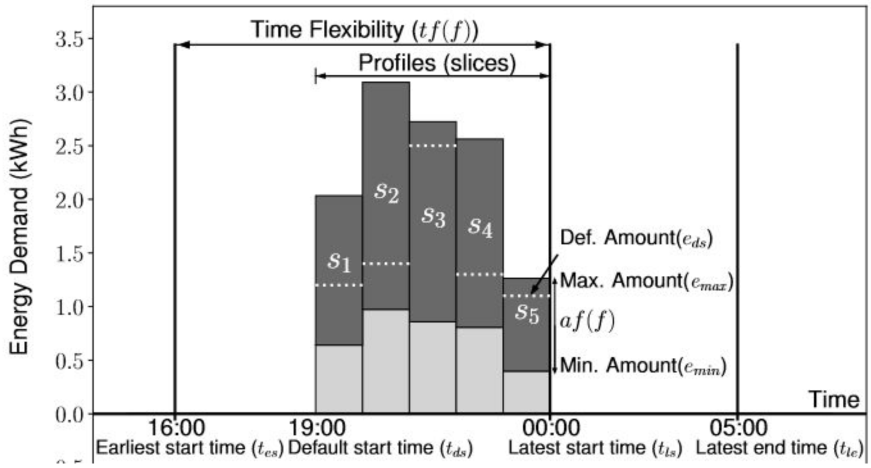

**Figure 17 FlexOffer Visual Representation** [40]

## 6.3 Control incentives for flexibility: CO2 incentives and dynamic prices

The flexibility services for the grid management can be acquired by different means. The EUniversal project[41] defines the following main categories[42]:

- Flexible access and connection agreements
- Dynamic network tariffs
- Local flexibility markets
- Bilateral contracts
- Cost-based mechanisms
- Obligations

All these mechanisms have their benefits and drawbacks, some of the main are:

- The allocative economic efficiency of bilateral contracts, cost-based mechanisms and obligations is limited;
- Local flexibility markets and bilateral contracts are dependent on the availability of FSPs, thus not suitable in cases there are low FSP numbers;
- Technology neutrality cannot be achieved via obligations
- The biggest entry barriers exist for local markets, cost-based mechanisms and obligations

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[40] Flexibility Modeling, Management, and Trading in Bottom-up Cellular Energy Systems
[41] EUniversal H2020 project

[42] EUniversal Deliverable 5.1: Identification of relevant market mechanisms for the Procurement of flexibility needs and grid services

- The complexity and related implementation costs are higher for local markets, cost-based mechanisms and dynamic tariffs

- Bilateral contract and cost-based mechanisms are not fully in line with the European regulatory principles of market-based flexibility acquisition

From the short overview it is clear that the flexibility acquisition mechanisms have different strengths that are applicable in different situations. Although the long-term regulatory goal is to have fully competitive flexibility markets with low entry barriers for all participants, the technical and economic realities on the ground today might require another instrument during transition periods. This calls for a dynamic, step-by-step approach:

- Acknowledge the different situation in member states when designing regulatory framework (for example the different level of smart meter deployment, different level of RES penetration)

- Apply the simpler mechanisms (such as dynamic network tariffs, bilateral contracts) first, to alleviate the grid problems existing today

- Continue supporting the research and innovation activities designing and deploying flexibility trading platforms

- Allow network operators to recover the investment in flexibility markets deployment through their regulated income

- Support regulatory sandboxes and other types of regulatory experimentation to find the best practices in flexibility acquisition

A closer look at Time of Use (ToU) or dynamic tariffs indicates drawbacks. The EU Clean Energy Package comes with expectations to which harmonizing distribution network price structures across Europe is not a viable response. The environment in which DSOs function varies greatly, and various strategies might be suitable in various areas. However, suppliers or aggregators may employ ToU pricing in addition to network fees. Conflicting time signals may result from this, especially if one or both are dynamic. There is a possibility that the peak load will shift to the beginning of the low-price period when static ToU network rates are implemented. This can even be unproductive, particularly when the number of EVs rises and many EVs begin charging at the same time. Additionally, decentralised generation should be taken into account for setting up tariff schemes. Subscription-based tariff models with an allocated power range might be a possible solution to this challenge.[43]

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[43] See the E.DSO Guidance on “Future Distribution Network Tariff Structures” (2021).

## 6.3 FLEX-Tariffs: Flexibility schemes from the customer perspective

The adoption of complex market solutions from the customers' perspective is normally quite low. Thus, a complex market solution for adopting flexibility might result in a reduced marginal benefit for end users when supply and demand are matched. Nowadays, a large part of the incentives for users are based on dynamic modification of the electricity price according to certain hours of the day. Although these types of incentives might have a positive benefit, they are normally not attractive enough and imply the active participation of customers, willing to adjust their consumption to certain times of the day, but without some "smart" algorithm that might help them.

The work proposed is what can be defined as FLEX tariffs: Without directly addressing the energy bill's variable cost (i.e., the energy consumption term and the associated price), the focus is on the fixed term. Fixed cost for final customers is mainly represented by the contracted power. Given the fact that E-Mobility in domestic environments will have a large presence in the upcoming years and taking into consideration that charging stations are normally designed for power ratings not below 3kW while typical households in the Iberian Market have a contracted power between 3kW and 5kW, the fixed term costs will undoubtedly be representative in the upcoming massive electrification.

What it is proposed is to give the customers the possibility to contract a fixed power term capable of fulfilling their fixed loads (traditional passive customers) and adding a FLEX term for flexible loads (heat pumps, EV chargers and battery storage systems). This flexible term should be reduced in price in comparison with the fixed contracted power, but at the same time it can be regulated by the DSO itself. In this case, it is also proposed that flexibility activation can be done by means of an aggregator or the DSO directly.

## 6.4 Differences between FlexOffer and FLEX TARIFFS

The concepts of Flex Offer and Flex Tariff share the same principle, but they are different in essence. On one side, FlexOffer (7) (8) is a proposed format by the European project MIRABEL for a common representation of flexible loads. Energy amount flexibility is an introduced concept that represents the difference between the minimum amount of energy that a flexible resource needs to provide its services (e.g., the minimum power that a domestic EV charger may provide, 4kW for example) and the maximum amount of energy that It can fulfil maintaining functionality constrains (again, for a domestic charging station, a limit of 7.2kW has been considered in most of the designs). Therefore, the difference represents the energy amount flexibility that it can be controlled, in this case, 3.2kW in a certain period of time determined by the application.

On the other hand, a FLEX TARIFF is a concept introduced with the goal of reducing the associated cost to the contracted power for end-customers. As described in Figure 18, for a normal household, requesting a domestic EV charger could implies not only a logic increment in the consumed energy during the bi-monthly period, but also a significant increase in the contracted power, which could have a large impact on the costs. Flex Tariff offers the possibility of separating the contracted power in two parts:

- On one side, the fixed contracted power would remain the same, which won't affect the fixed costs translated to the end customer. This part of the contracted power is reserved for "passive loads" consumption, but the remanent power (when not consumed) may also be used with flexible loads.
- On the other hand, a flexible term, the end-customer can make use of it in certain periods of time when flexible loads may draw more energy from the grid, but at the same time leaving the controllability to the DSO or the aggregator, in case that congestions in the grid may happen.

* Data obtained from a Iberian Market bi-monthly typical bill, for a contracted power of 3.45 kW and a consumption of 268 kWh.

** Estimations done on the basis that a domestic charger draws an equivalent of 7.2 kW, which implies having a contracted power equal to 10.65 kW in total. With a battery capacity of 72 kWh, 4 full charges every two monts are considered for estimating the overall consumption.

*** FLEX tariff proposed, where the fixed contracted power is left as before, but an additional FLEX power tariff is considered for flexible loads. In this case, only the EV charger as a representative flexible load is taking into account.

**** Symbolic price estimation. The idea is to reflect that a Flex Tariff would have a much lower price compared with a fixed contracted power tariff.

**Figure 18 Representation of FLEX mechanisms**

# 7. Conclusions and Recommendations

With respect to the concepts presented and discussed in the previous sections of the document, the conclusions and recommendations addressing different categories are listed below.

## 7.1 Policy Makers and Regulators

1. The deployment of flexibility mechanisms requires agreements not only at technical level but also on economic and legal frameworks. It is therefore key to involve member states in the definition of such frameworks and consider to scale up national best practices through progressive alignment steps towards a "European energy market design". Particularly, use cases focusing on the integration of flexibility across grid, building and mobility sectors are noteworthy and require attention from various Ministries across different policy streams; the follow-up alignment of national and European levels is then fundamental to scale up.
2. Current baselining methods need to be revisited to consider all new flexibility data made available through the new IoT – edge computing platformed embedded in new distributed energy resource deployments. Baselining methods should be proposed by aggregators on the basis of the IoT device certification. When possible baselining methods should be avoided considering new approaches such as DER self-nominating their planned schedule on the basis of their edge computing capability.
3. Advanced smart metering Infrastructure is the cornerstone for linking consumer data with grid operators. An accelerated smart meter roll-out throughout all EU countries is the basis for the uptake of grid edge solutions.
4. Data interoperability should be defined down to submetering levels taking into account the on-going work performed by the Expert Group 1 of Smart Grids taskforce as well as revisiting DER connection codes, i.e. the Requirements for Generators (RfG) and Demand Connections (DCC) codes. Connectivity to new European dataspaces for energy should be mandated for any IoT device wishing to provide flexibility to the system (agreeing on different service level agreements depending on the type of flexibility to be offered to the system).
5. The current regulatory framework should be enhanced to confirm and enforce the central role of DSOs in terms of data collection, management, and validation also under the light of new market entrants with the upcoming new behind-the-meter applications. DSOs have to implement adequate cyber-security measures to avoid system breaches, ensuring the data sovereignty and safety of the power system.
6. Regulatory incentives for grid operators are necessary to increase the utilisation of flexibility services, which could delay infrastructure reinforcements. Remuneration schemes should consider the need for investment for the procurement of flexibility for optimal grid operation and planning.
7. EU-wide dynamic tariff models are no viable solution. However, new tariff schemes must account for the impact of decentralised generation on management and operation of distribution grids. Subscription-based tariffs with an allocated power range could ensure that benefits for prosumers are created without unintended consequences.
8. Policymakers, regulators and system integrators should invest in introducing digital tools into their operations. DSO would need to "virtualize" the grid (ideally aiming for an end-to-end visibility and control as widespread as possible down to the grid edge) using software platforms. Such platforms should be able to work with standards and protocols that support interoperability, visibility and hierarchical control over the grid. Instructions to such tools should be easily available and understandable for DSOs.

### 7.1.1 Policy and Regulations for Consumers

1. The role of consumer engagement in accelerating energy transition will become more prominent; without convincing and involving them, energy digitalisation as well as flexibility mechanisms and data economy cannot be effectively achieved. Policymakers, regulators and energy utility enterprises need to take this into consideration when forming policies and energy offerings to their customers. While technology will offer the tools to proceed to a desired energy transition, technology alone cannot and will not bring a behavioural change which is essential what is required. Investments have to target the people's trust in data exchange and to raise the people's confidence and expertise towards their digital devices and energy services.

## 7.2 Researchers

1. Digitalisation could support local data exchange and decision-making to carry out local flexibility, keeping data at the source. Decentralised and local flexibility services can rely on sub-metering data from third parties for grid operations. Such deployments require innovative governance schemes (centralised or decentralised) to trustfully access sub-meter data. In developing such infrastructure, interoperability needs to link the static electricity system with the dynamics and physical behaviours of the field components behind the meter.
2. Large-scale deployments are fundamental to test the prototype research, under Horizon Europe programme, and they shall be accompanied by new regulatory sandboxes for energy. These projects should foster deployments of, at least, several thousand of devices as well as the test and validation of associated business model (to de-risk necessary regulatory evolution).
3. Accelerate the harmonization of key data models and ontologies such as the CIM and SAREF4Ener to progressively evolve towards semantic base interoperability, enable cross sectorial IoT self-discovery on flexibility as well as deployment of new generation knowledge and AI engines.

## 7.3 Industry, Utilities and Energy Distributors

1. Foster the use of open-source components (in combination with the related repositories) have been proved to foster innovation and developments, enhanced by the employment of open standards that guarantee the agreement and implementation by all stakeholders. Additionally, forums to exploit the momentum of communities can play key roles in building reference architectures and interoperability-by-design.
2. As Distributed Energy resources (DER) extend their foothold in the energy supply mix, by replacing conventional, fossil fuelled power plants, a promise for a cleaner, cheaper and more resilient power grid emerges. However, the aggregation of DERs has to be deployed by means of VPPs, in order to exploit their full potential. Offerings by all stakeholders in the energy value chain need to be thought of and communicated to the consumer in a simple, transparent and reliable way in order to attract and incentivize the consumer / customer as a willing participant in making use of energy services ranging from home energy management to every aspect of daily life.
3. Stakeholders need to think in terms of introducing a customer energy framework rather that "once off" or fragmented "customer opportunities" when presenting their policies or offerings. This framework will need to be applied along the above-mentioned axes of simplicity and clarity but also with consistency and honesty, since the ultimate target is earning the trust of the consumers and their confidence to change behaviour in utilizing energy in their daily life.

## 7.4 Consumers

1. As mentioned earlier in this document, as DER installations increase exponentially and prosumers become involved with new and innovative two-way grid services, so will their interactions with network businesses.
2. Offerings by all stakeholders in the energy value chain need to be thought of and communicated to the consumer in a simple, transparent and reliable way in order to attract and incentivize the consumer / customer as a willing participant in making use of energy services ranging from home energy management to every aspect of daily life.
3. Stakeholders need to think in terms of introducing a customer energy framework rather that "once off" or fragmented "customer opportunities" when presenting their policies or offerings. This framework will need to be applied along the above-mentioned axes of simplicity and clarity but also with consistency and honesty, since the ultimate target is earning the trust of the consumers and their confidence to change behaviour in utilizing energy in their daily life.

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# Contributors

**Editor:**

Alberto Dognini (RWTH Aachen University + Fraunhofer FIT)

**Reviewer:**

Damir Filipovic (AIOTI)

**Contributors:**

Alberto Dognini (RWTH Aachen University + Fraunhofer FIT)

Laurent Schmit (Digital4Grids)

Isidoros Kokos (Intracom Telecom)

Monica Florea (Simavi)

Laura Daniele (TNO)

George Hallak (EEBUS)

Dimitris Botsis (Uni Systems)

Revna Acar Vural (Yildiz Technical University)

Roman Korzynietz (VDI/VDE Innovation + Technik GmbH)

Ondrej Cerny (E.DSO)

Sebastian Vogel (E.DSO)

Natalie Samovich (Enercoutim)

Jussi Numinen (Wirepass)

Asbjorn Hovsto (Hafenstrom)

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## About AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT and Edge Computing Innovation in Europe, bringing together small and large companies, 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 and Edge Computing 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 and Edge Computing Innovation in society. AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT and Edge Computing ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies.