DEFINITION OF A GLOBAL ARCHITECTURE FOR SMART GRID APPLICATIONS

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Foreword and Aim

This document presents a preliminary overview of data exchange and data format in the Smart Energy sector. Main goal is to understand how the energy system can transition to a Data Economy becoming part of the Digital Single Market. This document is intended as a working document where new ideas and results can be added up to reach the right level of maturity.

This document aims to identify the key issues that need to be addressed with the aim to make data exchange as easy as possible, for the energy sector and across sectors as a way to facilitate the development of new data-driven services. The aim is also to provide a state-of-play of discussions as a reference for ongoing and future Research, Innovation and demonstration activities.[1] This document is a document jointly prepared by stakeholders and open to comment, at the request of the European Commission but not binding on nor endorsed by the European Commission

Introduction

Modern grid applications regard the interaction of a variety of actors. The main goal of a smart grid implementation is the creation of an automatic process and then it is critical to define for every possible data exchange both the semantics of the information and the protocol of communication.

This task has been the focus of many studies and projects but, typically, each project has addressed the problem from a specific angle so that a comprehensive description of all the interactions are not collected and organized in a single document. This is the main purpose of this exercise.

As a *Comprehensive Architecture for Smart Grid (COSMAG)* we refer to the analysis and the *collection of specifications, which are able to define possible data exchange process among various possible actors. This exercise is intended to check if current standards offer the proper roles interfaces to enable business processes, including new ones and to identify where new standards may be needed.*

The definition of COSMAG is based on a set of fundamental requirements:

- The set of interactions are defined so to support the implementation of the vision of the European Commission as from the Clean Energy for all Europeans Package [1];
- The architecture is built in such a way to offer “open gates”, i.e. data interaction points that can be used for future expansions and novel use cases
- COSMAG does not introduce any new standards but rather exploits and collects results of previous projects or standardization activities.
- Interactions that create a single vendor or closed market situation should be avoided

A very important framework definition has been already offered in the work delivered under the mandate M490, which led to the definition of the Smart Grid Architectural Model (SGAM) that should be adopted to define any data exchange or communication solutions in the power grid (see Figure 1) [2] Practical experience in the use of the Use Case Methodology can be found in the reference [3].

[1] For example the Call on Big Data and Energy that will close on 2 April 2019 DT-ICT-11-2019

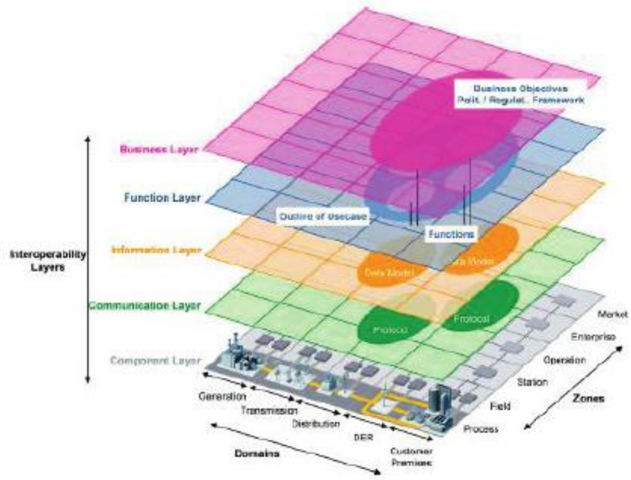


Figure 1: The SGAM architecture

Preconditions

The starting point of the analysis is the structure of the market and actor interactions diagram depicted in Figure 2.

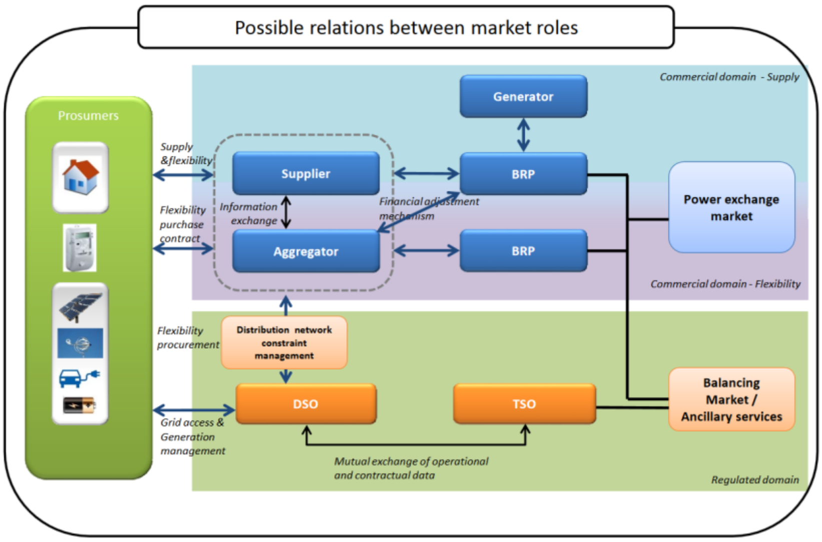


Figure 2: The structure of the market and actor interactions [4]

This diagram describes all the interactions envisioned in the modern electricity market and it is used as a starting point to identify all the possible communication pathways.

By using this diagram as a reference, we can analyze each flow one by one to understand the current status of protocol definition and data models. The main purpose of this analysis is to understand the maturity level per type of flow. This depends on regulations, business models involved, adopted technologies (e.g. IT Infrastructure), and so on.

Analysis of the data flows

To further structure the analysis, we considered each actor separately and consequently all the interfaces for each of the actors. From Figure 2 we can identify the following actors that are meaningful for this analysis:

- Prosumer

- DSO
- TSO
- Supplier
- Aggregator
- Wholesale Market

This list of actors (derived from Figure 2) is, in any case, not complete but it will be used for the purpose of this working document. It should be, anyhow, pointed out that other actors could be identified, such as community manager or data manager and others. A complete assessment of all the possible roles could be useful follow-up work, for example through a working group to be set up.

We do not consider classical generation given that the operation of such a player is already well established. All the interfaces to Wholesale Market are also well established and therefore not considered in this report. On the other hand, the Clean Energy package provides for new ways to incentivize the use of flexibility for network management purposes, in a coordinated way between TSOs and DSOs. It also introduces the concept of Energy Communities. Furthermore, the increasing number of connected objects and the availability of data may require an assessment of new roles and actors in a digitalized energy market. Therefore, it makes sense to consider for example a hypothetical new player called local market operator. This operator could potentially be the DSO but this identification is not yet in general accepted and then it makes sense to keep it a separate. The option of local market is anyhow already envisioned in Smart Grids Task Force - Expert Group 3, "Regulatory Recommendations for the Deployment of Flexibility: SGTF-EG3 Report" available at [5]

Following, an analysis for each actor is presented. It should be underlined that the analysis mostly focuses on the current status. Beyond the current discussion, other possible evolutions and interactions could also emerge.

TSO

The internal data flow for TSO has been structured for a long time now and no need for incremental considerations is envisioned.

TSO-Market

This interface is already standardized even though it is evolving, for example through the network code on balancing [6].

TSO-DSO

This interface is currently under development. A significant work is in progress in a number of ongoing H2020 projects, such as SMARTNET. A good analysis can be found in deliverable D1.3, available at [7].

DSO

The internal data flow for DSO can be considered as well-structured even if not all the DSOs are already adopting the most recent solutions. Very important is the development of IEC61850 both as an automation protocol and as a data model for substations. Other key element of data standardization is given by IEC61970-301 and IEC61968-11 that defines the main element of the so-called Common Information Model (CIM). CIM is a complete data model for power system used to exchange also data among grid operators (both at TSO and DSO level). The adoption of all these standards should be encouraged within the DSO domain and to support also TSO-DSO interaction. A complete architecture for DSO automation has been proposed and formalized in the EC FP7 IDEAL. A good reference document is given by deliverable D3.2 [8].

This document fully describes the implementation details and applies formally the SGAM methodology mentioned above. Figure 3 is an example of architectural documentation in SGAM methodology extracted from the IDEAL deliverable.

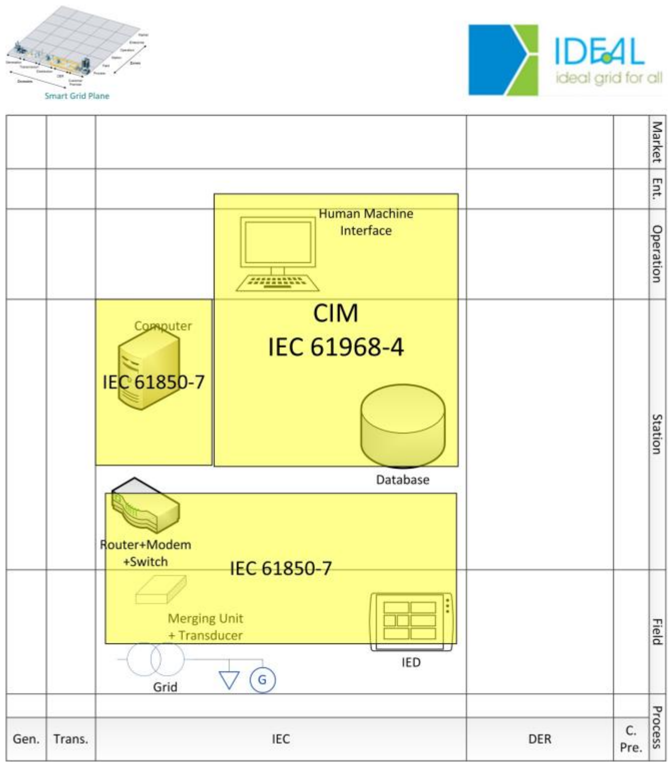


Figure 3: Example of definition of domain use for the most important data standard according to IDEAL deliverable D3.2

DSO-Local Market

This interface is at the moment not present given that local markets are not in place. Some reference solutions are proposed also for this interface in the SMARTNET deliverable mentioned above.

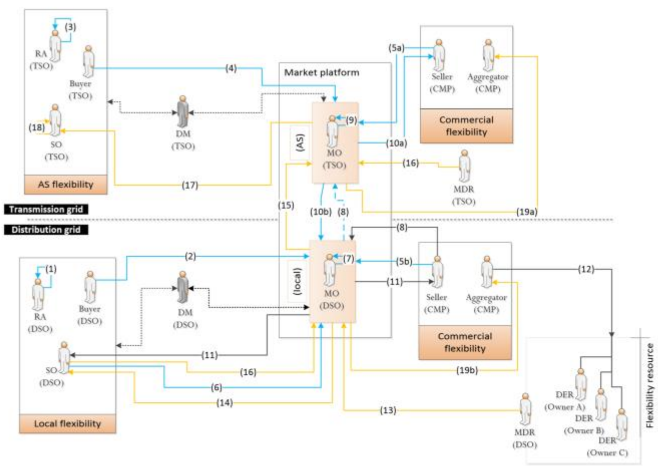


Figure 4: Example of local market structure according to the SMARTNET deliverable

DSO-Prosumer

This relation is still under development even though many experiments in this area have been already performed. The main reason for data exchange at this level is related to the generation control. Available solutions are given again by IEC61850-7 and in the case of wind turbines IEC61400-25.

Communication between DSO and prosumers (or consumers) arises also due to programmed or unexpected service interruptions. Maintenance work operation, allocation of interruptibility or outages are events that should trigger data exchange between both actors, including schedules and estimation time to service recovery.

In this case situations such as Demand Response are not included given that the channel DSO-Prosumer is here intended only for network operation and not for market services. This topic is still under discussion [10].

Aggregators

Aggregators is a new role, which have recently been introduced. Some real cases are available and they are mostly acting as link to the wholesale market. Here we will consider also the possible link to a local market, i.e. aggregator as support to the DSO operation [11].

It should be noted that, while an aggregator is a different role, such a role could be taken by other actors such as suppliers.

Aggregators-Local Market

Currently there are no standard for such interaction given that local markets are not present yet. A set of tools for local market implementation has been proposed in the FP7 Project FINESCE. A complete set of open source APIs, compatible with the FIWARE platform, have been proposed and are available at [9]. An interesting extension to the already proposed solution could be given by adopting the SAREF data modelling as a way to exchange the information.

Aggregators-DSO

This exchange is important to allow the integration of network constraints in the planning of an aggregator. So far, aggregators are operating under the “copper-plate” assumption but this option is supposed to lose value in the coming future. On the other hand a link between Aggregator and DSO will play a key role in a local market context: on the other accepted standards are not available yet. In the FINESCE project, ESB Ireland implemented a complete solution based on FIWARE technology but using proprietary protocols for the network management part. This case of data exchange is also covered in the USEF architecture [12].

In Nobel Grid project [13] the interaction between aggregators and DSO was demonstrated in terms of demand response requests to solve congestions in the network through a negotiation process based on USEF and OpenADR 2.0 protocol. The overall Nobel Grid architecture based on SGAM is described in D3.2 Smart grids reference architecture and data models v2 (downloadable from the project website).

Aggregators-Prosumer

In this area the emerging standard is given by OpenADR. IEC has approved OpenADR as Publically Available Standard (PAS) (IEC/PAS 62746-10-1) [14]. As part of this process OpenADR data model has been also mapped to CIM. This process is part of the wider IEC work PC118 (Smart Grid User Interface). Recent work from TNO has shown the possibility of integrating the OpenADR approach with SAREF. TNO has also released the so-called EFI (Energy Flexibility Interface) to model flexibility in support of all the market needs. Furthermore, a recent study, currently under finalization shown a great level of alignment of the SAREF approach with many existing standards [15]. This result shows the possibility to consider SAREF as an overarching ontology for data in Energy systems.

Other Prosumers

Prosumers-Retail

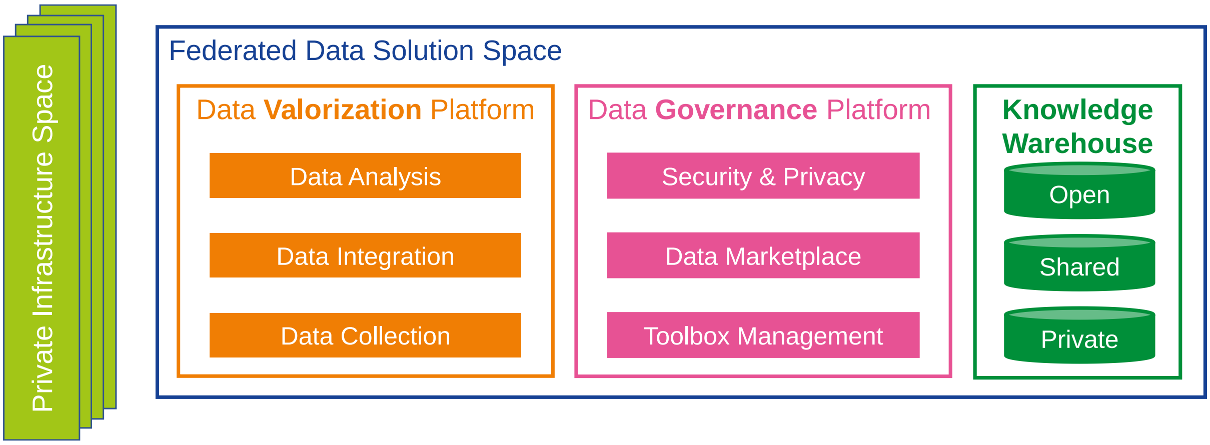
The main exchange is related to Metering data. Different standards have been proposed for Metering data and tariffs. The Open Metering System specification has developed proposal of standardization in this area (see [16]). Three protocols emerged as standard in this area: M-BUS, DLMS/COSEM and SML. Different scenario of data management from metering are currently present in Europe depending on the regulation of the member states. One critical topic is that data from metering could be used also for grid operation as proposed in projects such as H2020 FLEXMETER in which a cloud-based platform for smart-meter based services have been proposed. Open Source Domain Specific Enablers and API have been also proposed as open-source solution in the project FINESCE assuming a FIWARE based platform. This option would enable the possibility to integrate smart metering data in the larger context of Smart City.

Prosumers-Prosumer

Recently various project proposed solutions based on peer-to-peer markets (see later reference to DLT) which then requires a direct link among the customers and the possibility to define direct contract among the parties. This is for example considered in the on-going H2020 project SHAR-Q [17]. Most of the solutions proposed, assumed, in some way, the use of Blockchain technology for contract management. Similar developments have also been proposed in the project eDREAM [18] where a Blockchain base solution for Peer2Peer market is proposed.

Towards a data economy

The digitalization of the energy sector demands higher levels of operational excellence with the adoption of disrupting technologies to foster cross-domain data sharing and data-driven innovation. The upper layers of the SGAM architecture, Function and Business, are not so simple to integrate into a single data management solution. Their services cover a wide range of functionalities and their business opportunities affect various vertical energy domains. In this context, new energy actors are not the only newcomers in this re-invented market value chain, as they are also relying on incumbent actors that bring emerging technologies at ICT level. In turn, this new landscape entails more complexity and fragmentation to an already heterogeneous environment. All in all, the goal of reference architectures is to contribute to the creation of secure, trust and controlled collaboration spaces in which existing and emerging technologies could better exploit in safe and trustable ways the data provided by energy actors and the insights derived by data innovators.. Examples of existing IoT solutions are already available such as AIOTI, IoT RA.



One important aspect still relies on the interoperability between the key elements of each platform and space. Common standards, agreed data models and ontologies, comprehensive documentation and Open APIs harmonise the access to data and data processes, and facilitate the interactions among the different actors and platforms in the Federated Data Solution Space, ensuring the achievement of fastest adoption, continuous integration, deployment and evolution of the implemented solutions [19].

The following key elements in data management in support of a data economy can be summarized:

- **Data business model**: definition of an appropriate data model beyond a single sector is a keykey ingredient for interoperability
- **Data Commodity Monetisation**: how to create business models out of data in sectors such energy without violating privacy.
- **Semantic**: creating interoperability through clear and recognized data modeling
- **Context:** the definition of the context is a key ingredient for bridging through different verticals
- **Sovereignty**: to unlock the market, it is of key importance to offer the possibility to define who can manage the data and for which purpose to protect privacy and customer interest
- **Open API**: close solutions will not create a real open and competitive market. Open API offers the perfect bridge between private infrastructure spaces

Sector Coupling

The local energy community is an emerging solution that does not fit perfectly in the picture reported in Figure 2. The main characteristic of the local energy community is the integration of different energy vectors to increase the level of local flexibility. Such a solution requires going beyond the electricity sectors and this is the reason why it is currently not covered by IEC.

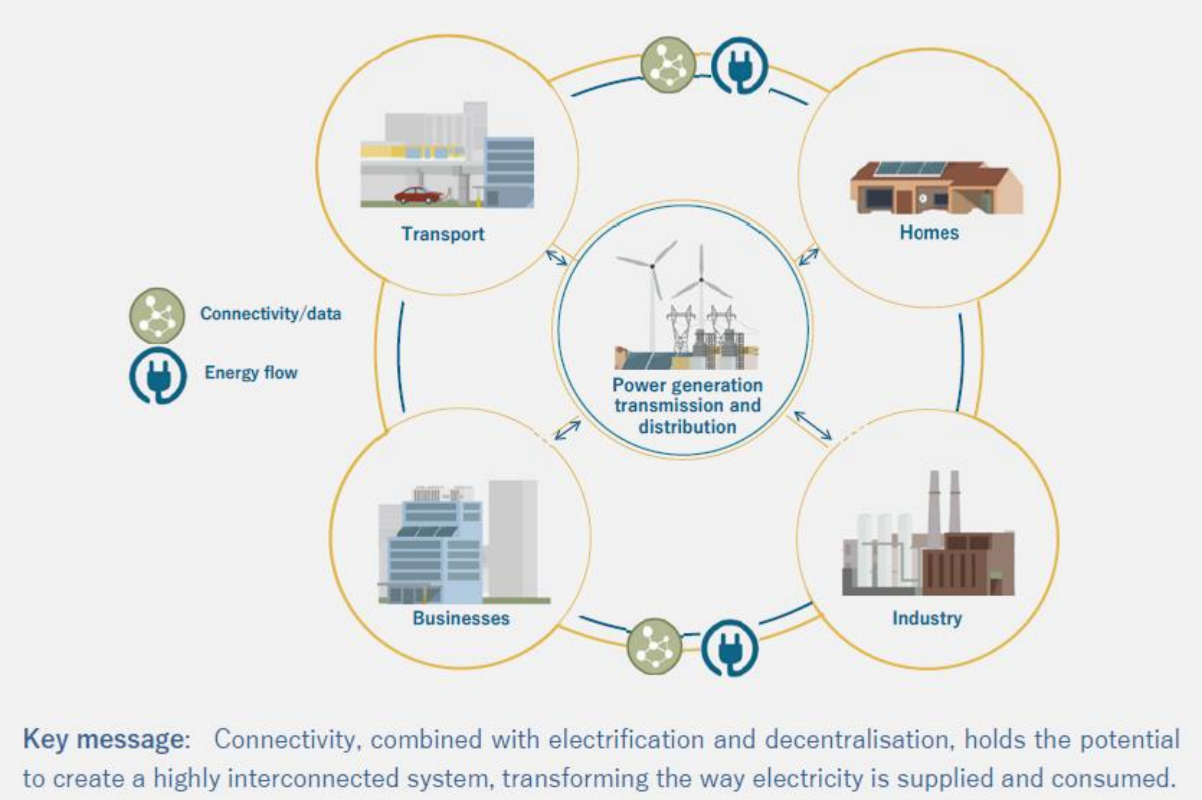
It may also require to go beyond energy and to look at future interfaces and data exchanges for new data-driven services with other sectors such as mobility, health, home security, etc.

Solutions such as the FIWARE Context Broker could support a seamless merge of sectors assuming to extend the set of Contexts present in the ETSI CIM standard. Such an extension could be built on top of the SAREF data modelling.

By breaking data silos, cross-domain opportunities will increase the potential impact and benefits coming from the energy sector. IEA has reported on what impact digitalization of energy brings to the transport, home, business and industry domains [20]. The new business models should accommodate not only those incumbent energy actors (DSO, TSO, Service Providers, Energy retailers and the installation and maintenance providers), but also the new ones entering the domain (prosumers, aggregators, PV and smart meter manufacturers…). Furthermore, those potential entrants coming from sectors such as transport, logistics, smart home or infrastructure managers should also be factored in.

The way the collaboration among all these actors take place is based on services benefiting from platform openness (see Open API in what above). In some cases, multipurpose platforms can act as the glue for the exploitation of the data coming from different domains such as FIWARE with its generic enablers [21] facilitating the collection of data from multiple sources. In other cases platforms drive the connection via Marketplaces such as the Open Data platforms. But in all the cases, the digitalization creates new opportunities, new services and new revenue streams for all the actors involved in this inclusive ecosystem, including the consumer that is the user or owner of the connected assets.

Business models also evolve and can be not only B2B or B2C as it was before, but also more complex ones such B2B2C and C2C. A service acting in a B2B2C scheme is for example weather forecasting, as it can serve a private customer or a DER operator. For C2C, we can envision a collaboration scenario between two prosumers transferring energy between them.



Src : IEA – Digitalization and Energy – 2017

Link to third parties

One of the interesting aspects offered by the availability of data platforms is the possibility to create open interfaces that could be exploited by third party providers which can bring innovative services to the energy domain. This is a typical area in which start-ups are particularly active. The project FINESCE developed a complete set of APIs in this direction that could be offered by data platforms such as the one collecting metering data to provide new and innovative services to the customers. As in the previous case the best option would be given by the extension of the Context Broker by introduction of a new domain for energy so that energy gets smoothly integrated in the Smart City scenario.

Link to Smart City platforms

As discussed in the previous paragraph this case could be easily covered adding the domain energy in the FIWARE Context Broker. This option is particularly interesting for the special case of sector coupling energy-mobility created by the e-mobility development. The open API interface would serve as a bridge also to possible proprietary solutions making the FIWARE the perfect glue among different context and providers while removing data silos.

One of the largest obstacle to the real exploitation of Big Data, is the fact that the majority of data are today locked in closed Data Silos. With Data Silos, data are not (or very rarely) shared outside their closed environment, leading to the loss of huge quantity of valuable information's (over 99%, source: McKinsey 2015).

In order to overcome this barrier and leverage the full potential of Big Data, data should be provided in free data streams through open and decentralized data lakes. In this data-sharing scenario, Decentralized Ledger Technologies (DLT) can be used to generate trust and make data readily accessible to authorized users in decentralized networks, paving the way for Secure Data Sharing across different business.

A distributed ledger is a shared database distributed across multiple sites on a network. The Blockchain is an application of this technology, used to create the peer-to-peer digital coin 'Bitcoin'' in 2008. All participants in the network have their copy of the ledger and any change to the ledger is reflected on all copies in seconds. The use of cryptography helps to maintain the security and the accuracy of all the assets stored on in the ledger. The algorithms underlying the Distributed Ledger Technologies (DLT) represent disrupting innovations that could radically change the delivery of public/private services and products.

In the Energy market, the use of DLTs could enable and simplify the creation data alliances between the many different energy actors (DSOs, TSOs, Service Providers, Energy retailers, Prosumers, Aggregators, etc.) operating in the energy production and supply chain.

Conclusions

This document presents a preliminary overview of data exchange and data format in the Smart Energy sector. Purpose is to use this document as a working document where new ideas and results can be added up to reach the right level of maturity.

Some conclusions can be drawn at this point:

- Many standards are available and data exchanges are already formalized. Nevertheless, emerging changes in the electricity market structure may bring some significant element of novelty (e.g. local markets)
- Most of the open points are around the customer/prosumers. Given the future role of these actors, the interfaces at this level are extremely important. In the future, it is expected that a large amount of data will be related to the customer level. In this respect data platform able to aggregate data are an important part of the picture. Those data will play a key role in every element of the energy system.
- Another important element to keep into account is the emerging role of sector coupling, making it critical to avoid data silos, not just between electricity, heat, gas etcetera within the energy sector, but also coupling of services with other sectors such as health, security, etcetera. In this respect new standards as emerged from the recent work of ETSI, e.g. the ContextBroker, are an important piece of the puzzle. .
- It is important that data platforms will be based on open standards to support open competition. In this respect solutions such as FIWARE can be considered as the right approach
- Data models are also a critical aspect. In this respect, SAREF extended to cover the whole energy value chain is a very valuable candidate.

Next Steps

This document should be considered as an open draft to be continuously updated to be sure that the opinion of each relevant stakeholder is included.

Some key actions can anyway be identified:

- A complete assessment of all the possible roles could be useful follow-up work, for example through a working group to be set up. Such a group could also identify the most promising new cross-sector business models and services (e.g. energy and health in smart homes);
- The focus should be placed on some of the key topics. The most compelling items are:
    - Definition of a strategy for data platform management and integration deployment of those platforms in the energy architecture
    - Integration of the IoT world in the energy context and vision
    - Definition of an approach for Peer to Peer solutions for customer aggregation

  With the aim to come to a definition of principles/requirements for data platform governance & management and integration of those platforms in the energy architecture;

- Organise follow-up discussions on the topics addressed in this paper and prioritised in the previous point, in particular through meetings and workshops to accompany the selected projects under the calls for ‘Interoperable and Smart Homes & Grids’ [22] and ‘Big Data and Energy’ [23].
- Coordinate research, innovation and demonstration projects in this area through the SET Plan Implementation Plans for Action 3.1 (Smart solutions for consumers) [24] and Action 4 (Smart Grids) [25].

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