ENCOURAGE

Embedded iNtelligent COntrols for bUildings with Renewable generAtion and storaGE

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D2.3 – ENCOURAGE platform reference architecture

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2.2	03.10.2012	Luis Miguel Pinho (ISEP)	Incorporation of inputs from GNERA, AAU and ATOS. Incorporation of review inputs.

Executive Summary

This document describes the reference architecture of the ENCOURAGE platform, together with the interconnection of the platform with the external environment. The document is the outcome of task 2.3 (Design of System Architecture) of the ENCOURAGE project, and sets, together with the remaining documents produced in work package WP2, the framework for the detailed specification activities to be developed in the technical work packages of the project (WP3-WP6).

In order to provide the required background for the ENCOURAGE platform reference, the document describes the most relevant standards and standardization initiatives, in the areas addressed by ENCOURAGE. Also, related existing architectures are analysed for consistency and state-of-the-art survey. This allows for ENCOURAGE to build on current practice, innovating in its modularity, scalability and support for seamless interoperability of heterogeneous (both new and legacy) systems, by abstracting from the technologies within the buildings and supporting multiple independent gateways, creating the notion of a single abstract interface.

The document defines the overall architecture of the ENCOURAGE platform, presenting the structure and functionalities of the modules of the architecture logical blocks. Furthermore, the document defines the main interface standards to be used for interoperability. These functionalities and interfaces will then be specified in detail in work packages WP3-WP6.

Finally, the document provides the mapping of the requirements identified in Task 2.2, identifying which modules must implement the underlying functionality.

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1. Introduction

In the past years, the energy grid has evolved from a unidirectional production-transmission-distribution-consumption pipeline to a complex system where every level of the pipeline comprises multiple actors that can produce and consume energy, as well as exchange it with any other actor.

Different solutions have been proposed for these smarter grid architectures, with the goal of facilitating the management of such a complex systems, where the energy grid can interact with the final users to control their energy consumption, by either direct control on some of his appliances (for example, the washing machine) or indirect control by varying the cost of the energy at a given day and time, such that the final user tunes up his own schedule for the energy consumption.

One of the common points of a typical Smart Grid system is related to its size and complexity. In fact, a Smart Grid usually serves a large number of users by providing them the energy they consume. This characteristic and the fact that each actor responds to an independent entity, end up in organizing Smart Grids using component-based architectures.

In this context, this document is the result of the work performed within task 2.3 (Design of System Architecture), and defines the reference architecture of the ENCOURAGE platform, together with the interconnection of the platform with the external environment, providing:

1. The structure of the ENCOURAGE building blocks (applications, enablers, middleware, devices), as presented in Figure ***1***. This document provides the identification of the fundamental modules, standards and technologies to be further detailed in work packages WP3 to WP6.
2. The main functionalities, interfaces and attributes of these blocks, specifying how they interface and interact to assess both internal and external data and information.
3. A platform based on standard, service-oriented, technologies, for energy management and supervisory control applications at customer sites.
4. The mapping of the High-Level Requirements [1] of the ENCOURAGE project to the specified architecture.

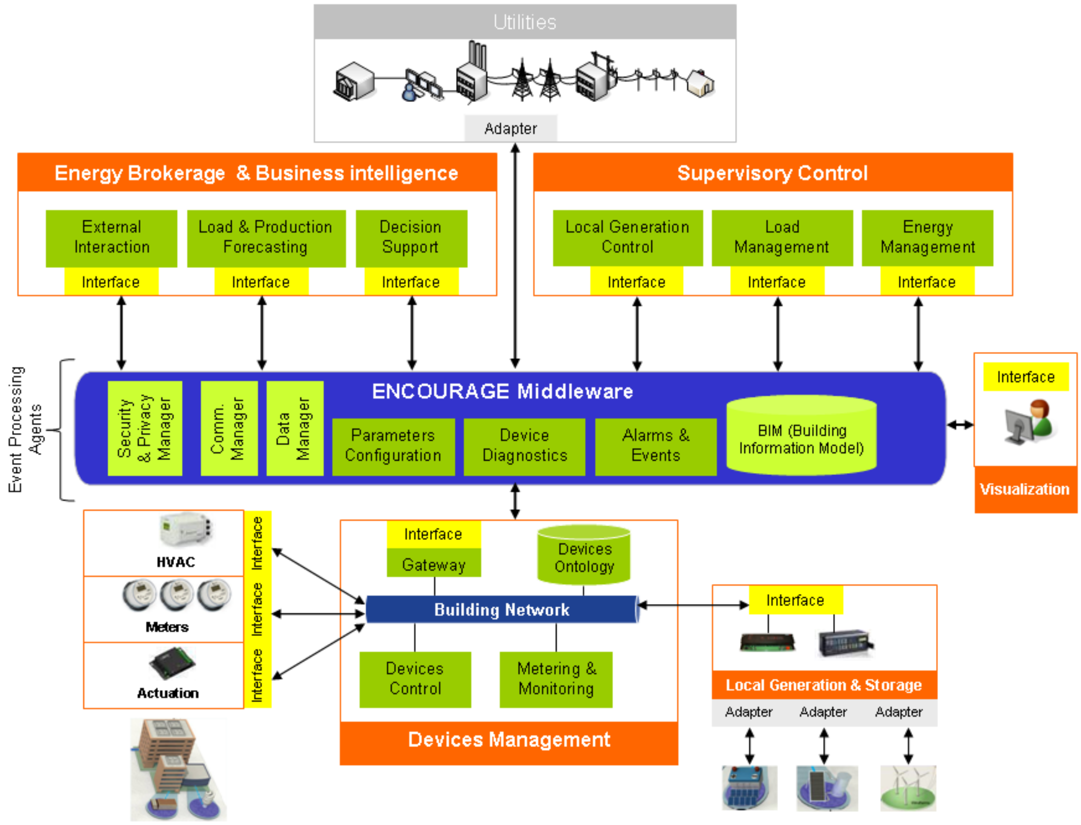


Figure 1 – ENCOURAGE reference architecture

As specified in the Technical Annex, the ENCOURAGE architecture is divided into the following logical blocks (Figure 1):

- **Devices Management** objective is to provide access to, and control of, devices – i.e. access and integration mechanisms for the various heterogeneous devices that either reside inside the building (HVAC equipment, sensors, actuators, meters / sub-meters, etc.) or located in the exterior spaces like the local generation and storage equipment.
- **Middleware** represents an event processing system that takes the data from the building network and processes it as a stream of events. The middleware can be seen as being composed of multiple event processing agents that exchange information between event producers, event consumers, and other agents. This approach will not only handle simple events but it will also allow for inference of complex events by combining simple ones. The middleware will be able to host various applications, such as the device diagnostics.
- **Supervisory Control** applications will take advantage of the device integration and data processing capabilities provided by the middleware. They will be receiving meaningful events /data needed for performing the energy optimization, which will be focused either on

supply side (local generation control), demand side (load management), or combination of both (energy management).

- **Energy Brokerage and Business Intelligence** components will provide services that will take advantage of the collected historical data. Based on previous consumption patterns as well as load and generation forecasts it will be possible to make decisions in short term about the participation in the energy brokerage, or in long term about possible retrofits, equipment replacements and other capital investment actions.

The architecture is designed to be highly modular and distributed, so that the information sharing among networked fixed and mobile appliances can be supported. In addition, high emphasis is put on scalability issues, so that the system can be used in residential and non-residential environments. The requirements of portability, fault tolerance, interoperability, independence between the different ENCOURAGE conceptual blocks, are also taken into consideration in this design.

This deliverable, together with the remaining documents produced in WP2, sets the framework for the detailed specification activities to be developed in the technical work packages of the project (WP3-WP6).

The document is structured as follows. Part 1 provides the relevant background material for the ENCOURAGE reference architecture. Chapter 2 presents the description of relevant standardisation initiatives and applicable standards, while Chapter 3 surveys the current state-of-the-art reference architectures. Research efforts in Europe have led to designs and deployments of Smart Grid systems, which make heavy use of information to provide a better intelligence in the grid operations. ENCOURAGE will thus build up on previous experiences to create innovative and scalable Smart Grid architectures.

Part 2 provides the definition of the ENCOURAGE reference platform. Chapter 4 provides a general overview of the architecture, together with the reasoning behind the major design decisions. This Chapter also provides the description of the necessary underlying infrastructure. Chapters 5 to 8 then present the specification of each one of the logical blocks (Devices Management, Middleware, Supervisory Control and Energy Brokerage and Business Intelligence). Particular focus is given to the Middleware, which is the central block of the platform.

Finally, Appendix A provides the mapping between the High-Level Requirements of Task 2.2 and the modules defined in this document.

PART 1 – RELEVANT RELATED WORK

2. Relevant Standards and Initiatives

2.1. Introduction

The landscape of Smart Grid standardization initiatives worldwide is widespread. This domain is not only very broad, but also many of the concepts vary between countries or regions, impacting the standardization process. Nevertheless, from all the current national and international standardization initiatives, and with the goal of addressing international interoperability, this chapter focuses on the three main ones from:

- The International Electrotechnical Commission (IEC).
- The USA National Institute of Standards and Technology (NIST).
- The joint work of CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization) and ETSI (European Telecommunications Standards Institute).

The chapter also provides some information on other relevant standards and initiatives which were analysed in the definition of the ENCOURAGE architecture.

2.2. Standardization Efforts

The IEC effort on Smart Grids is structured around the Strategic Group on Smart Grid (SG3) [2], which is responsible for monitoring new ideas and technologies, capable of being the basis for new standards in the area. The group is responsible for more than 100 standards, among them being particularly relevant the IEC 61970 and the IEC 61968 standard, which defines the Common Information Model [3] and the representation of physical entities in the software model, and the IEC 62056, which defines the data exchange protocols for meter reading. Further discussion on the IEC standards is provided later in Section 2.3.1.

The National Institute of Standards and Technology (NIST) [4] is also putting forward an initiative to coordinate the Smart Grids' standardization process in the USA. Its efforts are coordinated by the Smart Grid Interoperability Panel (SGIP) and by the Smart Grid Federal Advisory Committee, where the first is mostly responsible for the standard definition and the second is mainly responsible for the strategy and evaluation of the NIST effort. This organization is endorsing [5] efforts to standardize version 2.0 of the Smart Energy Profile (usually referred as SEP 2.0) [6], which, as it is relevant for ENCOURAGE, is further detailed in Section 2.3.2.

The CEN/CENELEC/ETSI [7] effort started with a Joint Working Group (JWG) on standards for Smart Grids, which produced in March 2011 a report addressing the landscape of standards [8] and recommendations for standardization in Europe [9]. In March 2011, the European Commission issued a standardization mandate M/490 requesting these organizations to develop the European standards framework in the field of Smart Grids. For that purpose, the three organizations created the CEN/CENELEC/ETSI Smart Grids Coordination Group (SG-CG), based on the previous working group. The current goal of the SG-CG is to provide the first set of standards by the end of 2012. Meanwhile, the group has already delivered a report on the Reference Architecture, with a conceptual model and a general Smart Grid Architecture Model (SGAM) [10], which extends the NIST model with support for distributed energy resources.

2.2.1. The NIST model

NIST has been pushing forward efforts to bring together manufacturers, consumers, energy providers, and regulators to develop interoperable standards for Smart Grids. Therefore, the main objective of NIST is to enable several different Smart Grid systems and their components to work together. Interoperability is built upon a unified framework of interfaces, protocols, and other consensus standards.

The most important efforts are described in the "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0" [11], where a reference architecture is proposed. It also contains an analysis of the requirements of the Smart Grids and how existing standards are able to cope with these requirements.

Their framework conceptual model comprises 7 different domains, as depicted in Figure ***2***, defined as follows:

- Customer: The end users of electricity, which might also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: residential, commercial, and industrial.
- Markets: The operators and participants in electricity markets.
- Service Provider: The organizations providing services to electrical customers and to utilities.
- Operations: The managers of the movement of electricity.
- Bulk Generation: The generators of electricity in bulk quantities. May also store energy for later distribution.
- Transmission: The carriers of bulk electricity over long distances. May also store and generate electricity.
- Distribution: The distributors of electricity to and from customers. May also store and generate electricity.

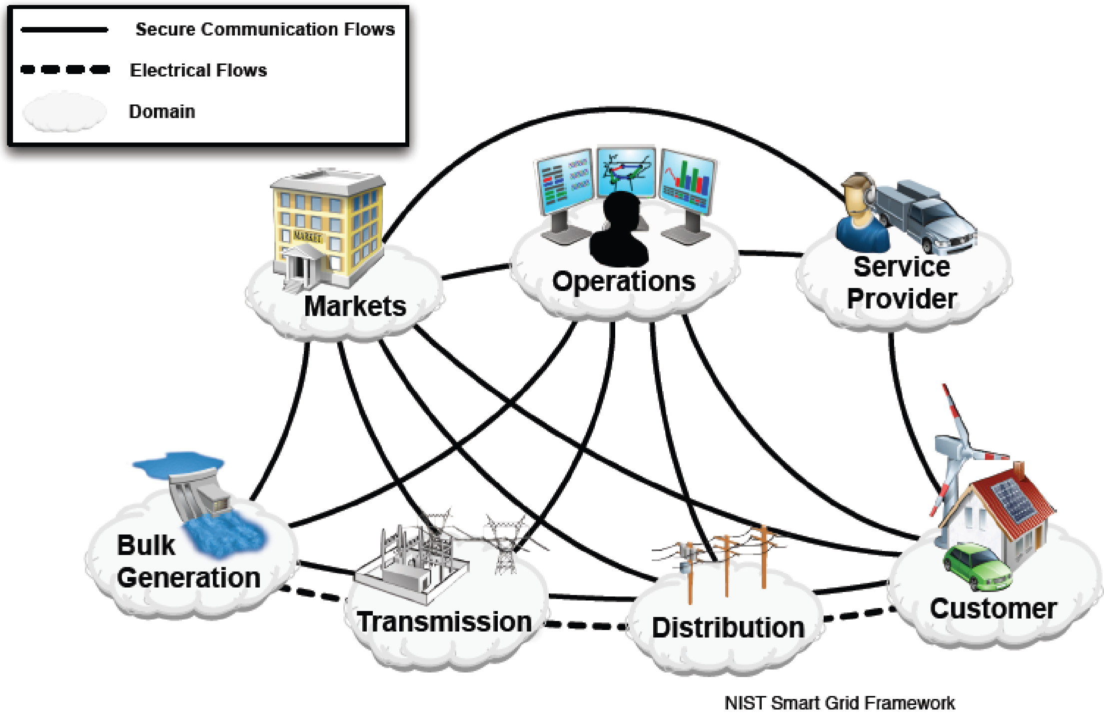


Figure 2 – NIST operational domains [11]

Figure ***3*** illustrates the conceptual model showing some of the interfaces between domains.

The Customer domain comprises a set of different networks, which can be based on standards protocols. These networks are connected to the networks of other domains by specific gateway devices, which translate between protocols. Generally, these networks have hierarchical structures, based mostly on the IP protocol. It is also an important goal of NIST to address security issues and to support to the extent possible that all networks run the IP protocol.

Most of the work provided by NIST consists of determining from large set of international standards which of them address specific issues in a particular domain. The list of applicable standards can be consulted in [11].

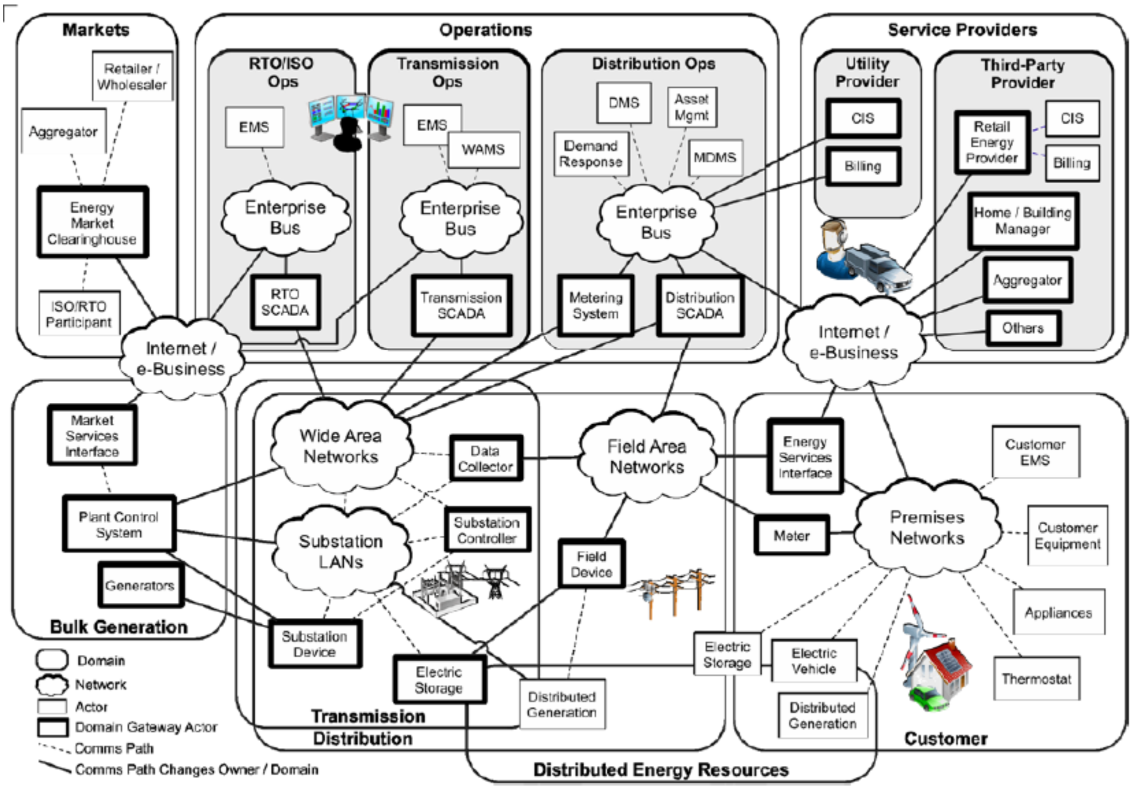


Figure 3 – Conceptual model for Smart Grid ICT [11]

2.2.2. *EN/CENELEC/ETSI Reference Architecture*

Considering the decentralised model for generation which is expected to be increasingly preeminent, the EN/CENELEC/ETSI reference architecture [12] proposes an EU Conceptual Model (Figure 4), based on the NIST Model, but extending it with a new Domain (DER – Distributed Energy Resources) to fulfil the European requirements. It allows the description of both a totally centralized grid and a totally decentralized grid, as well as a mixture of both.

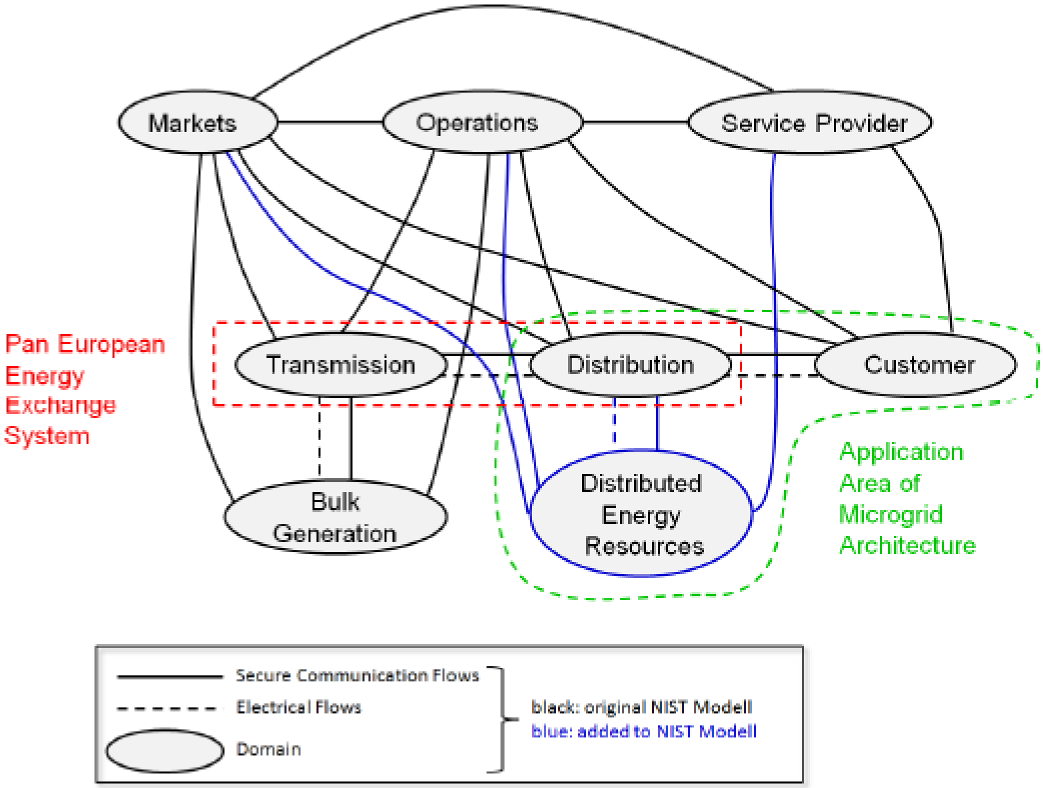


Figure 4 – Extension to the NIST model [12]

This extension is important for ENCOURAGE, since the goal of the project is a step forward in providing distributed local generation of energy. ENCOURAGE also deals with the Customer, Service Provider and Markets domains, but a fundamental objective is to support distributed local generation.

Nevertheless, it is not an objective of ENCOURAGE to support the full layering of a Smart Grid system. As depicted in Figures ***5*** and ***6***, ENCOURAGE addresses the Technical and Informational drivers of the interoperability categories introduced by the GridWise Architecture Council [13].

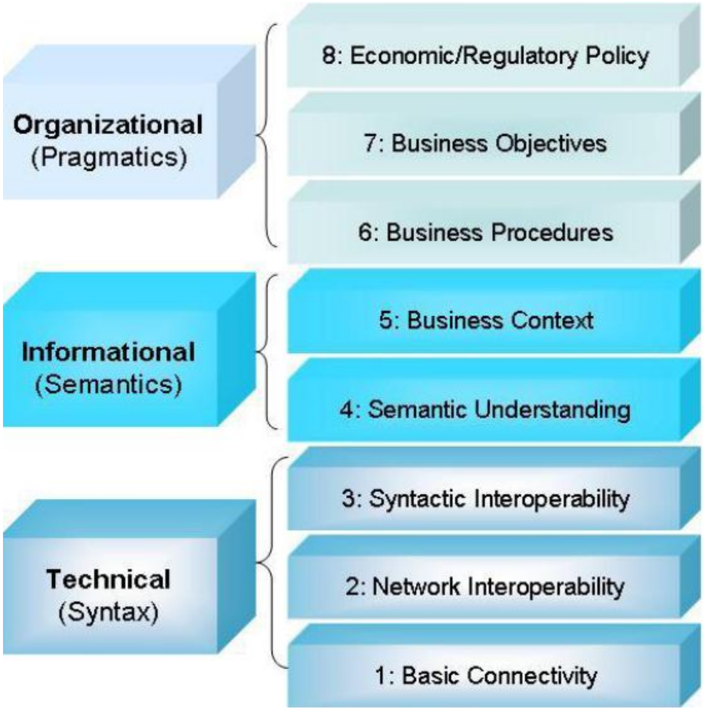


Figure 5 – Interoperability categories [13]

The interoperability categories of [13] are further refined in the Smart Grid Architecture Model (SGAM) Framework proposed in [12], depicted in the left of Figure ***6***.

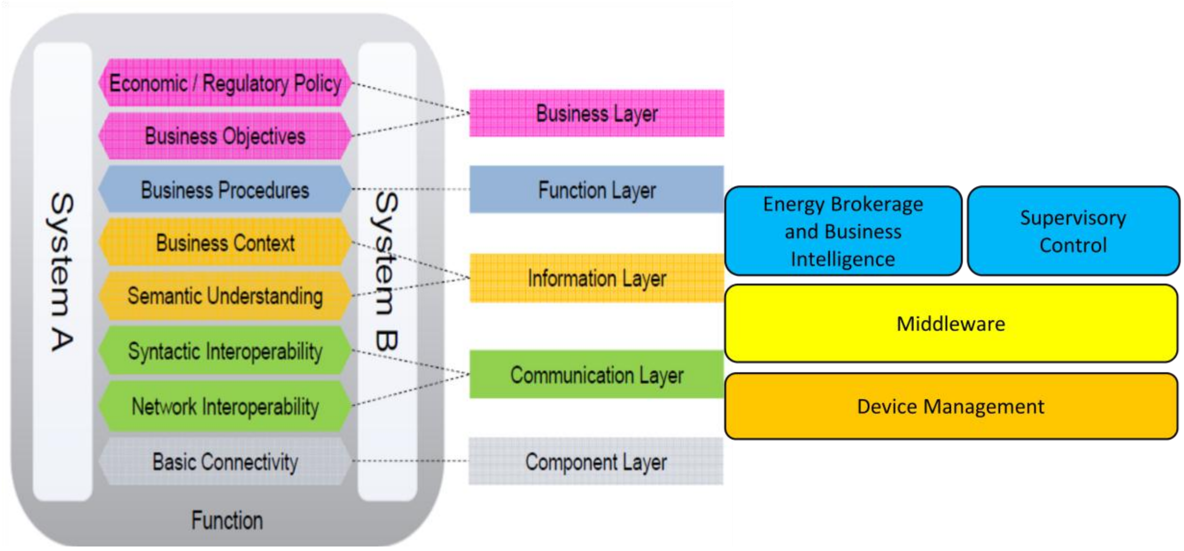


Figure 6 – Relation of interoperability layers [12] with ENCOURAGE main building blocks

In particular, ENCOURAGE will provide support to the Component, Communication and Information layers, and partially to the Function Layer. ENCOURAGE's Devices Management block provides the access and integration in the system of the various heterogeneous devices responsible for local consumption and generation control. The Middleware transforms data into semantic information, exchanging this information between event producers, event consumers, and other agents. Finally, the Supervisory Control and Energy Brokerage and Business Intelligence modules will process and control business contextual information, while the latter module will also support some business procedures related to the energy market.

Considering the Energy Plane model of [12], depicted in Figure 7, ENCOURAGE addresses the Customer Premises and DER Domains, in all Zones, and up to the Function Layer.

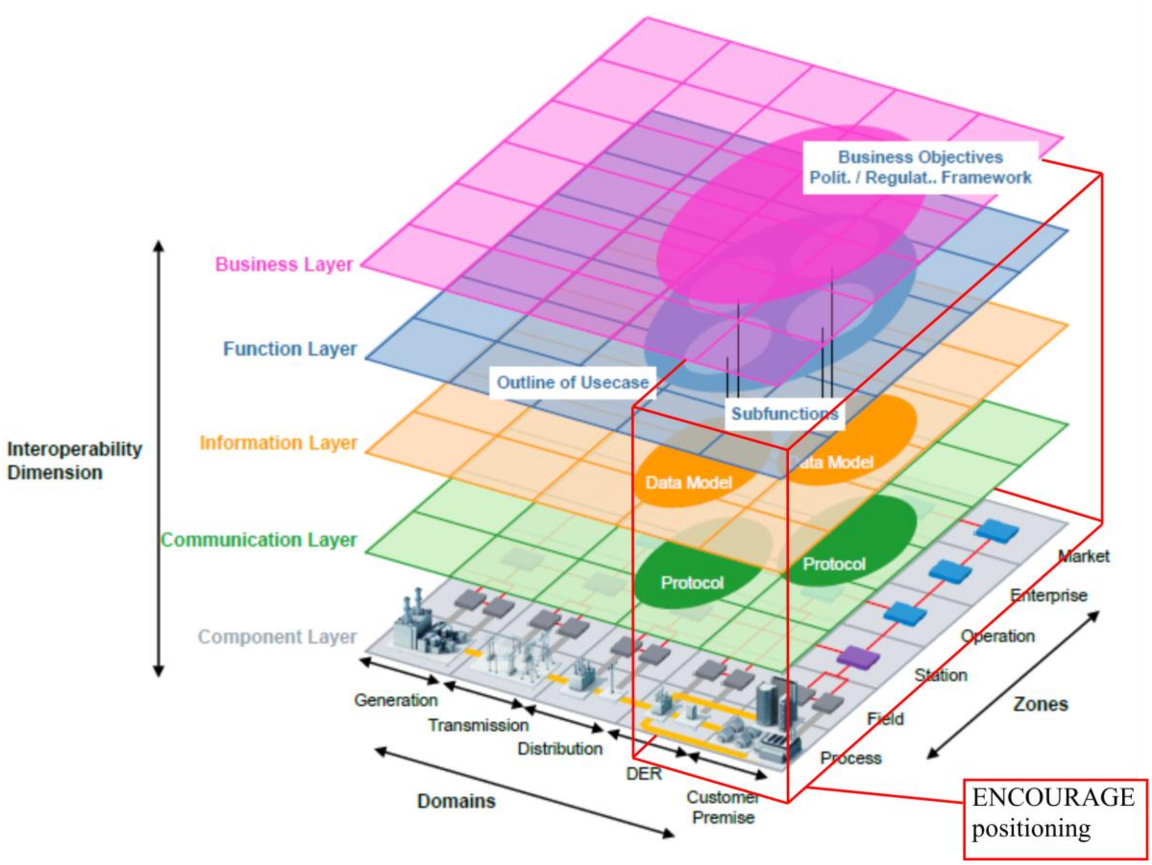


Figure 7 – ENCOURAGE in the Smart Grid Architecture Model Framework

2.3. Applicable Standards

Smart home and building automation topics are still not fully addressed by the existent reference standards, work being performed in this regard. There are numerous standards (and de-facto standards) for this purpose, but it is not clear how these can be incorporated in an overall, holistic scenario, which is the goal of these initiatives.

Of the three standardization initiatives considered above, ENCOURAGE intends to address particularly the European framework (CEN/CENELEC/ETSI), and the Common Information Model (CIM) object model (from IEC). In order to support this objective, ENCOURAGE requested, and was granted, Project Liaison status with the CEN/CENELEC/ETSI Smart Grids Coordination Group (SG-CG), to be able to observe and collaborate with the work which is being undertaken.

The NIST framework is being also followed up, in particular the potential use of the Smart Energy Profile (SEP) 2.0, for interoperability with the in-building devices and the Smart Grid. The current focus of the project is to use a (reduced/augmented) version of SEP2.0 and CIM.

2.3.1. Common Information Model (CIM)

In power grid systems, the information needs to be shared among different platforms with different types of information systems. The management of these systems is an important aspect especially with the increasing number of users, applications, services and information sources. In order to effectively exchange data among different information systems and protocols, the Common Information Model (CIM) has been developed [3].

CIM is an open standard for representing power system components and networks which has been primarily developed by the Electric Power Research Institute (EPRI). The standard is officially adapted by International Electrotechnical Commission (IEC) to represent common components within power systems which can be used by Energy Management System (EMS) and Application Programming Interface (API) [14]. This standard mainly specifies the interfaces between components, therefore allowing different software modules, from different vendors, to communicate with each other.

The CIM architecture is based on the Unified Modelling Language (UML). It defines the components of a power system as classes and the relationships between them. This gives the base for a common model to describe all situations of a power system, independent of any specific proprietary data standard or format, which facilitates the interoperability among software applications.

Exchange information within Electricity Grid System is always significant. IEC 61970, IEC 61968; specify a Common Information Model (CIM) for utility data exchange. Certainly IEC 61970, IEC 61968, and IEC 62325 CIM Model now are one of the core standards for the future Smart Grid [15]. Each of these standards has its own characteristics and support different tasks within the grid. Nevertheless, all of them contain several sub parts which are under development by different working groups; Figure 8 shows an overview on the CIM parts for this three standards series. The roles of the three standards series are described next.

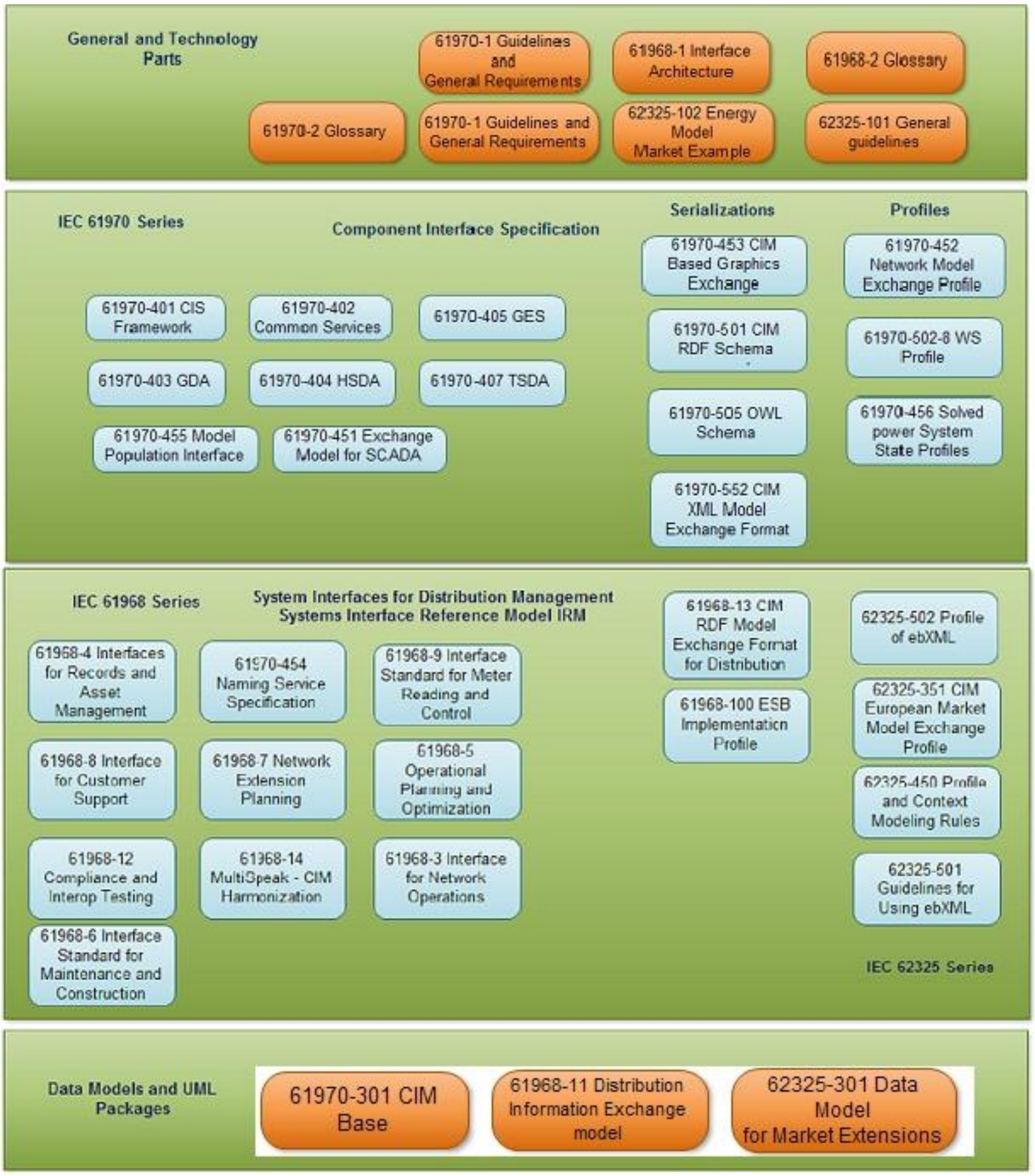


Figure 8 – IEC standards 61968, 61970, and 62325 relationships

IEC 61970 is a series of standards that describe information of energy management system and provide a set of instructions to simplify:

i. Integration of multi-vendor applications

ii. Exchanging of information to systems outside the control centre including transmission, distribution and generation systems that need to exchange real-time data with the control centre.

iii. Provide adequate interfaces for data exchange across legacy and new systems.

The standard series include the generation and transmission parts of the Common Information Model (CIM); represent power system model exchange and other information exchanges, and XML file format standards for information exchange (Working Group 13).

IEC 61968 is a series of standards that has been derived from IEC 61970 and aimed at simplifying inter application integration and at supporting distribution management system. It is intended to support the integration of a utility enterprise that requires connecting different applications that are either legacy or new. It is closely related to loosely coupled application with heterogeneity in operating system, protocols, language and management tools. IEC 61968 supports applications that require exchanging data on an event driven basis and is intended to be built with middleware services that broker messages between applications. The addressed interfaces include message exchange for network operations, operational planning and optimization, records and asset management, network extension planning, customer support, maintenance and construction, and meter reading and control. The standard series is limited to the definition of the interfaces. Therefore, technologies and method used to implement these interfaces are out of its scope.

The CIM base data model specified in IEC 61970-301 is expanded with additional objects within IEC 61968-11 (Working Group 14). Figure 9 shows the different models which were standardized by IEC 61968/61970.

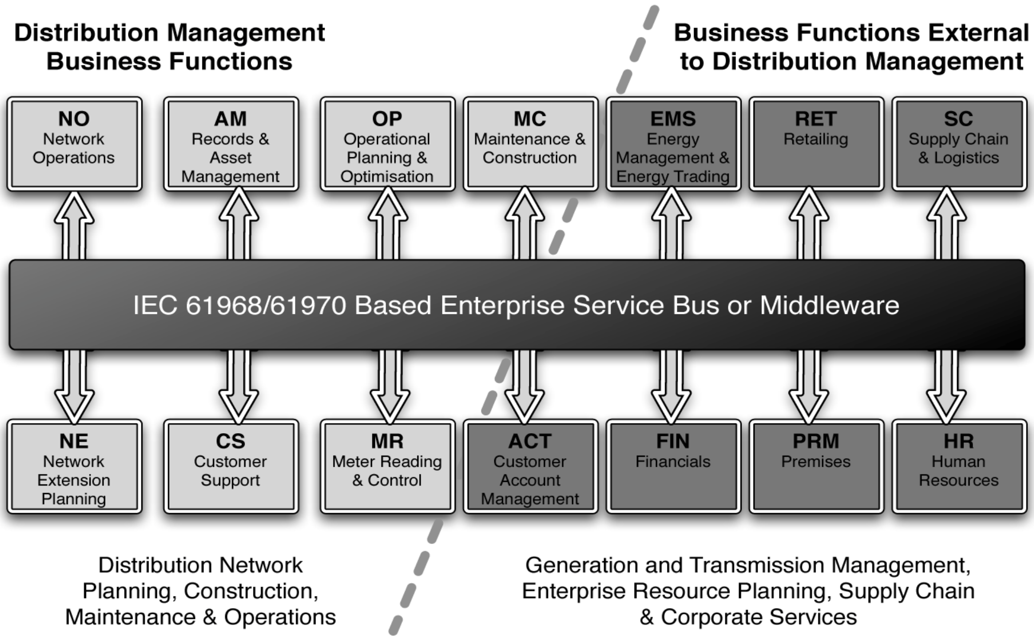


Figure 9 - Interface Reference Model

IEC 62325 is a series of standards that defines energy market models and communications using CIM. The objective is to evolve standards for electricity market communications. It describes the communication formations of all e-business in energy markets and system operation. Communications among market consumers and market operator as well as communication between markets operators are included [15]. Business operation encompasses system applications with interfaces between different market participants in trading, consumption, market services and billing. Real-time communication of energy systems and definition of a full and detailed energy market model are beyond the scope of the IEC 62325 series.

The IEC 61970-301 standard is a part of IEC 61970 series that describes the components of a power system, Application Programming Interface (API) and the relationship between each components. This standard consists of various packages that provide a logical view of the physical aspects of an Energy Management System. The Core, Wires and Topology packages accommodate all the basic classes for describing the physical features of a power network.

IEC 61968-11 standard is a part of IEC 61968 series that extends the CIM for the need of distribution management system including customers, metering, load control, and others. The information model is defined by using UML that create a message payload in different formats. By this way, this standard will not be affected by either proprietary means or by the development of a next generation infrastructure. IEC 61970-301, plus IEC 61968-11 standards are defined by Distribution extension of the CIM model (DCIM). DCIM in IEC 61968-11 adds several packages to support: i) information exchange associated to network operations and planning in the context of the all utility companies; ii) physical description of network elements [16].

Standards related with the Common Information Model

The IEC 62357 standard (Seamless Integration Reference Architecture) is one of the more all-inclusive standards from TC 57 technical committees. It includes several IEC standards for electric power system management, which compose extensive reference architecture. The main goal of this standard is to define reference architecture to describe how different standards within IEC 57 can be combined with each other.

The IEC 61850 standard series consists of 10 parts; it provides interoperability for the exchange of information among devices in substations [14]. The standard series has evolved to become automation and control standard at the field level [15]. The standard uses TCP/IP as the basic transmission protocol, and the Manufacturing Messaging Specification (MMS) standard which is defined in part by IEC 61850-8-1 for client-server communication. Those two are known as peer-to-peer services for real-time communication which directly use the Ethernet protocol for:

i. Faster transfer of samples according to standard IEC 61850-9-1.
ii. Transmission of Generic Object Oriented Substation Events (GOOSE) messages as part of the standard IEC 61850-8-1.

IEC 61968-9 is a part of the IEC 61968 standard and describes the information content of a set of messages type for metering reading and control. These messages encompass end device event messages, end device control messages, metering reading messages, metering service requests, and payment metering service messages. The objective of this standard is the exchange of information between a smart metering and other systems within the utility scheme, not covering the specific details of the communication protocols. Nevertheless, this standard is focusing on a model of the generic capabilities that can be provided by smart metering such as two way communication capabilities, dynamic pricing, load control, outage detection. In this way, it will not be affected by either proprietary means or by the development of a new generation of smart metering. Therefore, there is no risk that the standard becomes disused [17].

IEC 61968-9 defines several end device control messages to send instructions to the end devices using XML schema. Load control system allows end-use customer loads to be changed in response to specific events such as the variations of electricity prices periods (real time pricing). Moreover, it disconnects and reconnects customers in case of non-payment, or change of customers program (meter reconfigured). Load control commands are issued by Load Management System (LMS) in network operation domain to load control system through metering at the end-use customer domain. This standard extends Common Information Model (CIM) to support the exchange of information through the smart metering [17].

IEC 62056 is a series of standards that deals with the data exchange for meter reading, tariff and load control using DLMS/COSEM specifications. DLMS stands for Device Language Message Specification. It is an application layer specification. It was established to support messages exchanges among distributed devices. It has been driven forward for modelling of object-related services, meter data exchange, and remote control. COSEM stands for Companion Specification for Energy Metering and defines a number of standard interface objects for modelling the communicating energy metering equipment. DLMS/COSEM provides an object model for describing the functionality of the meter interfaces. The standard comprises of the following series:

- IEC 62056-21: Direct local data exchange (3rd edition of IEC 61107).
- IEC 62056-42: Physical layer services and procedures for connection-oriented asynchronous data exchange.
- IEC 62056-46: Data Link Layer Using HDLC protocol.
- IEC 62056-47: COSEM transport layers for IPv4 networks.
- IEC 62056-53: COSEM Application layer.
- IEC 62056-61: Object identification system (OBIS).
- IEC 62056-62: Interface classes.

IEC 62351 standard addresses the information security for power system control operations. The goal of this standard is to handle the security of the communication protocols defined by TC57 including the IEC 61850, IEC 61970 and IEC 61968 series and others. It specifies the security requirements for power system management and data exchange. IEC 62351 contains sub-standards as following [18]:

- IEC 62351-1: Data and communications security - Part 1: Communication network and system security - Introduction to security issues.
- IEC 62351-2: Data and communications security - Part 2: Glossary of terms.
- IEC 62351-3: Data and communications security - Part 3: Communication network and system security - Profiles including TCP/IP.
- IEC 62351-4: Data and communications security - Part 4: Profiles including MMS.

IEC 61508 is a set of standards addressing the functional safety of electrical, electronic and programmable electronic equipment. The standard applies to theses system regardless of their application. The objective is to build a system able to prevent critical failures or to control them when triggered. Examples of such failures as the following [19]:

- Failures of hardware or software
- Incorrect specifications of the system
- Human error
- Supply system voltage disturbances
- Incorrect specifications of the hardware or software system

IEC 61508 standards provide the requirements to minimize these failures and improve safety and performance in safety-related systems. IEC 61508 is a set of series that contains seven sub-standards as the following:

- IEC 61508-1: General requirements
- IEC 61508-2: Requirements for electrical/electronic/programmable electronic safety-related systems
- IEC 61508-3: Software requirements
- IEC 61508-4: Definitions and abbreviations
- IEC 61508-5: Examples of methods for the determination of safety integrity levels
- IEC 61508-6: Guidelines on the application of IEC 61508-2 and IEC 61508-3
- IEC 61508-7: Overview of techniques and measures

2.3.2. Smart Energy Profile (SEP) 2.0

The Smart Energy Profile [6] version 2.0 is the result of the joint work of the ZigBee Alliance and the HomePlug Powerline Alliance. It has been developed to map directly to IEC 61968, the Common Information Model (CIM). This protocol follows a RESTful architecture.

The SEP 2.0 Application Protocol is a layer seven protocol built on top of an Internet Protocol (IP) stack. Depending on the physical network in use (802.15.4, 802.11, Bluetooth, etc.) a variety of lower layer protocols may be involved in providing a complete solution. It is intended to be used in Smart Grid applications such as metering and home area networks. The device types supported by the Smart Energy Profile include gateways (also called Energy Service Interface (ESI)), metering devices, In-Home-Displays (IHD), Programmable Communicating Thermostat (PCT), load control devices, etc.

The RESTful architecture assumes the existence of clients and servers. The server is the device that hosts a resource, and the client is the device that obtains, extends, updates, or deletes representations of that resource. Although, it is important to note that devices may be both clients and servers at the same time.

Clients poll servers to obtain the current state of a resource. SEP 2.0 also allows the use of the publish/subscribe model, in order to reduce polling. In this model, clients (subscribers) can subscribe to a resource, being notified by the server (notifier) whenever a change occurs.

SEP 2.0 uses the Multicast Domain Name System (mDNS) and DNS-Service Discovery to discover SEP 2.0 compliant devices on a local network. Security is ensured by the use of Transport Layer Security (TLS) for communications between devices, thus ensuring that the protocol meets the necessary security requirements needed to protect sensitive consumer information, at the same time ensuring the integrity of Smart Grid transactions.

The functionality provided by SEP 2.0 is divided in function sets: demand response and load control, metering, pricing, messaging, billing, Prepayment and Distributed Energy Resources Control.

Demand Response and Load Control - provides an interface for Demand Response and Load Control, where client devices are usually thermostats and any other devices that support load control. Server devices include ESIs and premises energy management systems that may be acting as a proxy for upstream demand response load control management systems and subsequent data stores. Servers expose load control events called End Device Controls (EDC) to client devices. All EDC instances expose attributes that allow devices to respond to events that are explicitly targeted at their device type.

Metering Function Set - provides interfaces to exchange metering information such as reading type and meter reading between devices. Pricing Function Set supports application-specific tariffs for devices (e.g., PEV, DER), and special event-based prices like critical peak price (CPP). It has been designed to stand on its own but can be paired with the billing function to provide additional benefit to users. The Pricing Function Set is not intended to provide all the information necessary to represent a premises' bill.

Messaging Function Set - provides an interface for a text messaging service.

Billing Function - There are several resources that are used to support billing related functions. This relates to truing up consumption or costs on an end device and providing estimates of future consumption, or holding historical consumption information. In addition to consumption and costs that would be back end calculated and shared with the end devices, billing also provides a mechanism to allow the service provider to push down targets or challenges to encourage energy conservation. A target could be a percentage or fixed value of reduction to meet within a defined time frame.

Prepayment Function - defines a mechanism for the conditional delivery of services based upon outstanding credit or debt.

Distributed Energy Resources Control - In specific cases, energy MUST be provided to and managed by the grid. In these cases, energy load, area capabilities, costs and transfer of energy timing impact the management of accepting power. Management of the necessary energy is achieved according to the scheduling of energy via requested and accepted energy transfer transactions. This function set provides an interface to control Distributed Energy Resources, e.g. solar inverters, fuel cells, generation units and battery storage systems. Server devices of this function set include ESI's and premises energy management systems.

SEP 2.0 also provides a set of functionalities for application layer support: Capabilities Function, Base Function and Software Download Function.

2.3.3. Other Standards

M2M
The Machine to Machine (M2M) [20] standard for smart meters is being developed within the activities of the ETSI TC M2M. It will mainly be an application profile of the M2M standard applied for smart metering. M2M is based on a RESTful approach, where operations on resources, Service Capability Layers (SCL) and between SCLs are supported by specific methods. The protocol defines the API, its resources and the use of existing protocols.

The timeline for this standard is as follows. The M2M protocol has been released at the beginning of 2012, containing documents related to its architecture (TS 102 690), to the interfaces and protocols (TS 102 921) and requirements (TS 102 689). ETSI also published a document related to Smart Metering Use Cases (TR 102 691), but no clear definition of the functionalities has been published (some clarifications are still pending).

Open Smart Grid Protocol (OSGP)
OSGP [21] has become a de-facto standard for smart meters, since presently there are around 3 million OSGP smart meters in Europe and 30 million use the same power line communication technology of OSGP.

The protocol is based on the master/slave communication paradigm, being a communication initiated by a master concentrator, routed by several proxy repeaters until reaching the addressed OSGP device. It mainly defines commands for the retrieval of smart meter readings, time settings, display, logs, etc. It also supports a limited number of functions to control the connection and disconnection of loads by the use of at most two internal contactors and one external relay.

The standard also foresees the use of two communication ports: M-Bus and bidirectional multipurpose expansion port (MEP). The first enables the connection to at most 4 M-Bus devices and the second depends on the smart meter manufacturer.

Its utilization within the ENCOURAGE project can be somewhat limited since this standards is more focused on meter reading over power line communications with limited bandwidth and the number of loads which can be controlled using this standard is also very limited.

2.4. International Initiatives

Apart from the standardization efforts, there are a few international initiatives relevant for the definition of the ENCOURAGE architecture.

The European Technology Platform (ETP) for Electricity Networks of the Future [22] [23] intends to foster and support the deployment of Smart Grids in Europe by advising and coordinating the stakeholders, not only producers and consumers, but also prosumers, energy service providers and virtual power plant operators, ensuring that platforms' strategies are consistent with the global EU policy. It foresees a future (Figure ***10***) of distributed and service oriented grid environment, and sets the goals of standardization, flexibility and scalability, to which the ENCOURAGE architecture must comply.

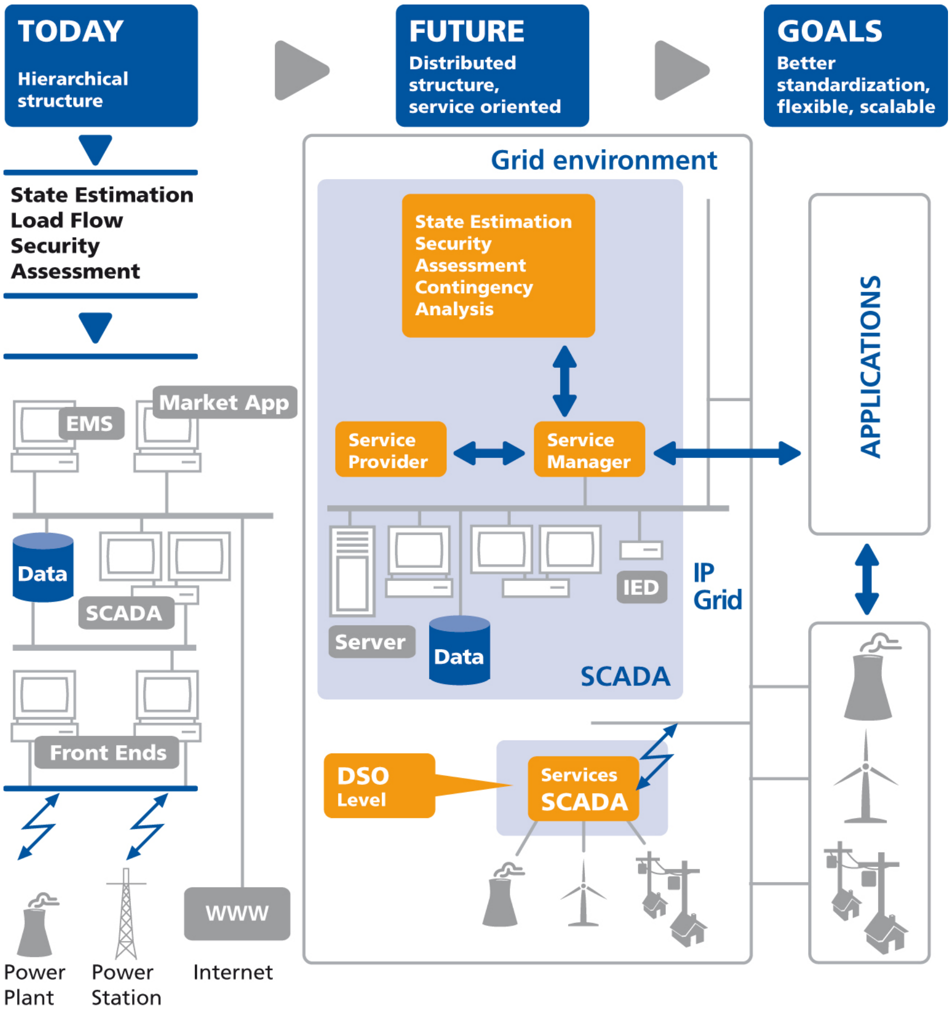


Figure 10 – Future Distribution Network [23]

The ICT4SMARTDG (ICT for Smart Distributed Generation) Thematic Network [24] goals was to foster and promote the development of ICT solutions which could encourage large-scale integration of domestic and distributed micro generation and therefore improve energy efficiency through the implementation of smart technology into local power grids. The TN provided insight of existing and innovative ICT technologies available for smart distributed generation, identifying technical solutions available.

It identified several important issues, which are relevant to ENCOURAGE:

- The need to support legacy applications and protocols
- The need to support other applications that will be expanded or developed for energy and grid management, such as retail energy markets or demand response

- Communication network performance (including Quality of Service), reliability, and security must be managed, with IP as the networking protocol
- Need for new data management architecture
- Need for standardization of ICT requirements in the standardization efforts

These are requirements which are applicable to the ENCOURAGE architecture.

The FINSENY (Future Internet For Smart Energy) project [25], part of the Future Internet Public-Private Partnerships (PPP) European programme, intends to define new solutions and standards, and a large scale pan-European Smart Energy trial.

It also focus on the integration of distributed and intermittent generation sources, like combined heat and power generation, solar and wind power overcoming grid constraints, and Smart Buildings and Microgrids, and intends to empower the private and commercial customers to take a more active role in the energy market.

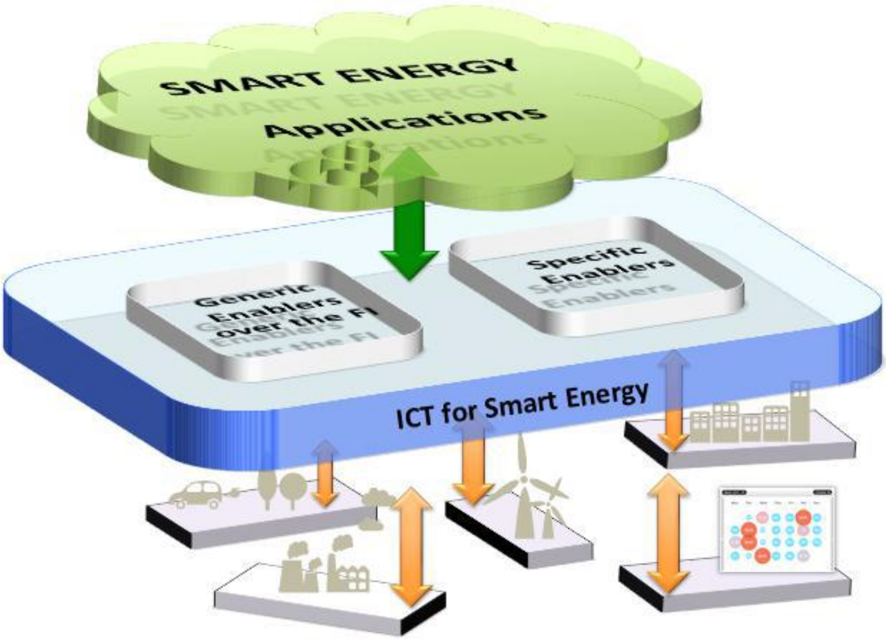


Figure 11 – FINSENY Smart Energy ICT Layer [26]

FINSENY will rely on an information and communication framework that will in fact define open and standardised APIs based on Generic and Domain-Specific Enablers [26] of the Future Internet (FI) platform. It is expectable that ENCOURAGE interacts with FI enabled systems, and this interoperability should be addressed through the use of standardized technologies.

3. Relevant Architectures

3.1. Introduction

Although numerous projects and architectures exist, in this document we focus on the more relevant ones, which, together with the architectures being put forward by the standards and initiatives of the previous chapter, have provided inputs to the development of the ENCOURAGE architecture.

3.2. eDIANA

As specified in the project's overview, the main goal of the eDIANA project (Embedded Systems for Energy Efficient Buildings) [27] was to enable sustainable urban life through rationalisation in the use of resources while increasing comfort in urban environments by means of embedded intelligence and integration technologies. The eDIANA approach is to achieve greater efficiency in use of resources, prioritising energy as scarce resource, more flexibility in the provision of resources and better situation awareness for the citizen and for service and infrastructure owners.

The architecture as specified in this project [28] provides functionalities for scheduling of automated energy management tasks, user awareness, behaviour and comfort levels, energy trading, devices control, generation and storage support, etc.

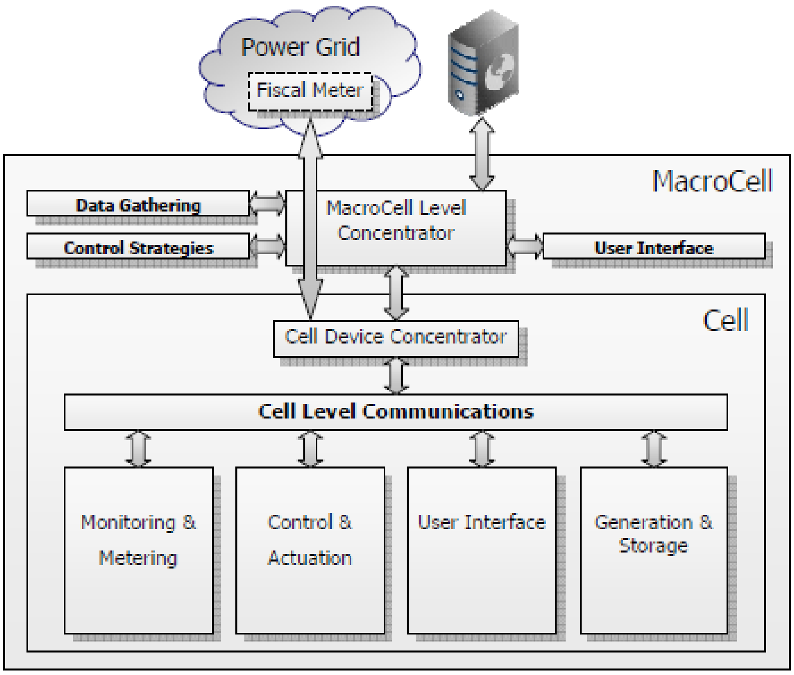


Figure 12 – eDIANA Platform [28]

The eDIANA Platform further enables the interoperability of heterogeneous devices at the Cell and MacroCell levels [28]; definitions which are reused by ENCOURAGE. A Cell is a living/working unit (one house, one office, one shop, one workshop, etc.) and includes the collection of devices that operates in that unit: household appliances, sensors, energy generation and storage devices, etc.

At Cell level, the following devices can be found:

- Cell Device Concentrator (CDC): For gathering and processing data and interfacing with higher levels (MacroCells).
- Monitoring and Metering: Sensors such as temperature, lighting, sun radiation, people presence, energy generation, smart meters of plugged devices, etc.
- Control and Actuation: Actuators such as light dimming actuators, blind actuators, smart appliances (household appliances), etc.
- User Interface: User Interface Channels to interact with the eDIANA system (see overall consumption/generation data, see comfort conditions, modify user's preferences, etc.).
- Generation & Storage: Energy generation and storage systems.

At MacroCell level, the following components can be found:

- MacroCell Level concentrator (MCC): For providing communication means with Cell level concentrators, controlling them and enabling MacroCell level energy management operation as well as interacting with external utilities such as fiscal meter, electricity market operator, utility companies, weather forecast service, etc.
- Data Gathering Component: For harvesting data from Cells and external utilities.
- Control Strategies: For the implementation of complex energy management policies.
- User Interface: User Interface Channels to interact with the MacroCell.

A MacroCell is a domain including one or more Cells, such as a residential or non-residential building (usually composed of several Cells) and it will provide the hook to connect the building as a node in the producer/consumer electrical grid. In terms of energy-efficiency, Cell is in charge of all dynamic control and handling of the connected devices, whilst the MacroCell is in charge of all static (slow timescale variation) and physical (building information like walls, orientation, etc.) phenomena that can be controlled and handled from a building perspective. The MacroCell also owns the connection to the grid, and holds the "contract" with the utility.

In terms of supervision and control, the MacroCell incorporates the most sophisticated energy-efficiency control algorithms (such as Demand Side Management) and can derive energy-saving actions from information derived from one or more connected Cells plus all the building specific physical phenomena. The Cell, in the other hand, has dynamic control on the devices attached to its concentrator (plug&play, discovery, etc.).

ENCOURAGE goes further by allowing multiple hooks to be provided for a single Cell or MacroCell, being the ENCOURAGE platform capable of abstracting a single domain from the multiple hooks. Also, ENCOURAGE supports systems where Cells individually have a connection to the grid, thus holding a contract, whilst, if also arranged in a MacroCell, try to optimize in conjunction the local efficiency of energy.

Similar to ENCOURAGE, the eDIANA Platform describes a number of logical devices and functions, but that can be physically implemented in a variety of forms. Nevertheless, contrary to eDIANA, ENCOURAGE only specifies the interfaces provided by the building gateways, and the functions of the devices themselves. As in ENCOURAGE, the meter is out of scope in the eDIANA platform.

3.3. ENERsip

The ENERsip (ENERgy Saving Information Platform for generation and consumption networks) project [29] goal is to optimize energy demand, by coordinating consumption and generation. ENERsip provides an integrated architecture for near real-time generation and consumption matching in residential, commercial buildings and neighbourhoods [30].

This platform provides functionalities such as monitoring usage patterns, controlling energy generation, providing recommendations to users on how to optimize usage. It also integrates at neighbourhood level demand and generation, and provides mechanisms to integrate with other energy grids.

In order to define a fine-grained architecture that helps break down the development and implementation complexity of the ENERsip platform, the ENERsip system has been divided into four different domains (Figure 13):

1. Building Domain
2. Neighbourhood domain
3. Information System Domain
4. User Domain

As ENERsip, ENCOURAGE addresses the same domains, although ENCOURAGE assumes the in-building domain to be abstracted through the gateways (end points as defined by ENERsip). Furthermore, ENCOURAGE addresses the simultaneous integration of Buildings in a higher-level domain of energy generation and consumption, but still allowing the local control and interaction.

ENCOURAGE also specifies an M2M infrastructure, which allows to interoperate several different gateways, in multiple domains. Nevertheless, the ENCOURAGE infrastructure provides a complex event processing mechanism which allows to simplify the tasks of the control, brokerage and business intelligence (in the Information System domain), capable of detecting asynchronously, independent incoming events and generating a complex event.

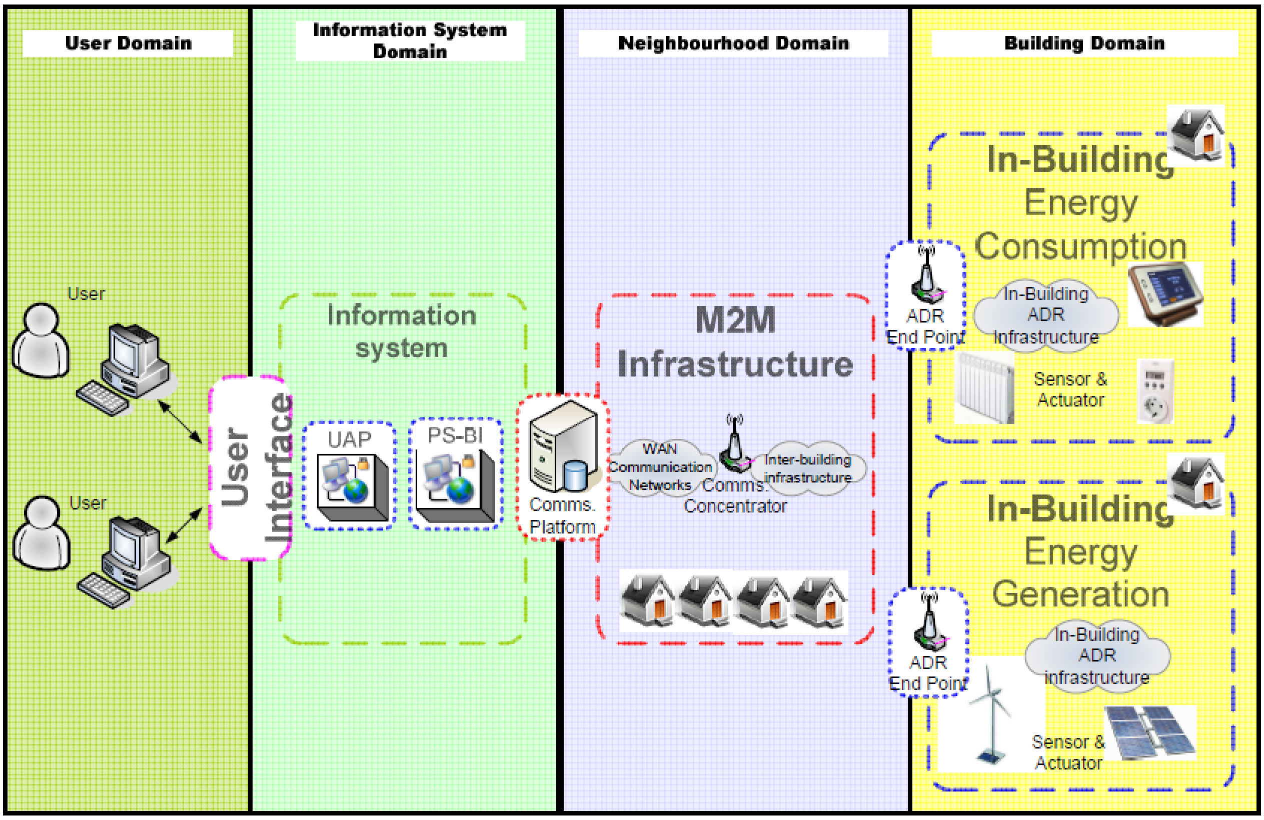


Figure 13 – ENERsip global architecture [30]

3.4. ADDRESS

The ADDRESS (Active Distribution network with full integration of Demand and distributed energy RESourceS) project's [31] main focus is on solutions to enable active demand exploitation.

To allow this, ADDRESS proposed to:

i. Develop technical solutions both at the consumers premises and the power system level

ii. Identify the possible barriers against active demand development and develop recommendations and solutions to remove these barriers considering economic, regulatory, societal and cultural aspects

Point i) is related to the ENCOURAGE project.

Figure ***14*** shows the scope of the project and its simplified representation of the architecture [32]. The project integrates the customers' premises, which have electrical appliances ("pure" loads such as fridges, boilers …), distributed generation (such as Photovoltaics or micro-turbines) and thermal or electrical energy storage systems, which can be controlled and optimised by means of a gateway (called the Energy Box). This is the interface with the external world, and in particular with the Aggregator.

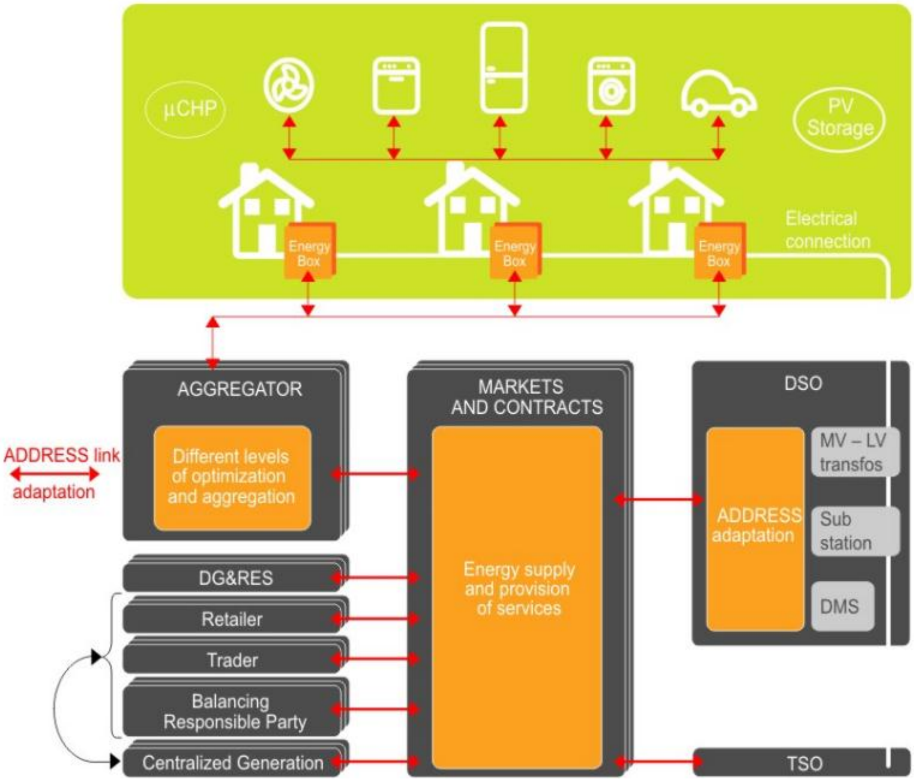


Figure 14 – ADDRESS architecture [32]

The Aggregator is the mediator between the consumer and the markets and plays a central role:

- It collects requests and signals coming from the markets and the different power system participants.
- It collects the "flexibilities" and contributions provided by the consumers.

- The basis for this interaction between the power system participants will be the exchange of two types of signals: real-time price signals and real-time volume signals (mainly power signals)[1].

Local optimization is needed to meet the requirements of the topologically dependent services that are requested. The architecture foresees intelligence at the consumer, aggregator and DSO levels, although it is not specified how the intelligence at the aggregator interacts with the consumer.

ADDRESS has a dimension not present in ENCOURAGE, as it deals also with the operation of the grid, addressing algorithms for network management. Contrarily to ENCOURAGE, the focus is more on the network operators and market sides, whilst ENCOURAGE intends to allow local optimization of resources, through local energy trading, before this optimization is done at a higher-level with the market and DSOs.

3.5. SERA

The Microsoft SERA (*Smart Energy Reference Architecture*) [33][34] intends to specify a smart energy ecosystem, providing an overview of its relevant components and standards. Its main goal is to serve as a bridge between the work which is being performed by NIST (presented in Section 2.2.1), addressing the problem of too many standards, and specific Microsoft products and technologies.

This reference architecture defines the integration (Figure ***15***) of multiple, interacting functionalities:

- **Visualization -** The ability to integrate information from many sources into a visual representation in a location agnostic manner is a primary tenet of the reference architecture.
- **Analysis -** Electric utilities perform a variety of electrical network analytical computations in the course of their everyday work managing the grid. Some of these computations are very highly specialized and complex and often involve taking a model and applying current, historical or possible future states using a diverse set of data sources.
- **Business Intelligence -** Utilities use business intelligence to help executives and managers acquire a better understanding of the commercial context of activities, thereby improving the value of their decisions and enhancing their decision-making capabilities.
- **Reporting -** In addition to business intelligence tools, a utility, market operator or service provider may define, create, maintain, publish and/or use a variety of reports.

[1] “Real time” means a time scale of 20 to 30 minutes ahead

- **Collaboration -** By collaboration, it is meant the need for consumers, organizations, applications and/or devices to actively participate and interact upon sets of inter-related business processes.
- **Orchestration -** The term orchestration is usually applied to more complex, long running processes that coordinate the execution of multiple Web services into automated business processes and may have many steps and require user interaction (whereas the term workflow is commonly applied to a set of coordinated short running tasks).
- **Notification Infrastructure -** Collaboration requires the ability to notify a user or group of users whenever there is a condition of potential interest so that, if necessary, they can take appropriate actions.
- **Chain of Command – Notification plus Workflow -** Combining notification with managed workflow can be an effective way to organize human process within the smart energy ecosystem.

The overall architecture (Figure ***16***) foresees [34] a variety of communications approaches, event processing as close to the source as possible, integration via core technologies, abstraction and intelligence, where the CIM model is leveraged both as the basis of message definitions as well as a direct contributor to the schema for data marts or data warehouses.

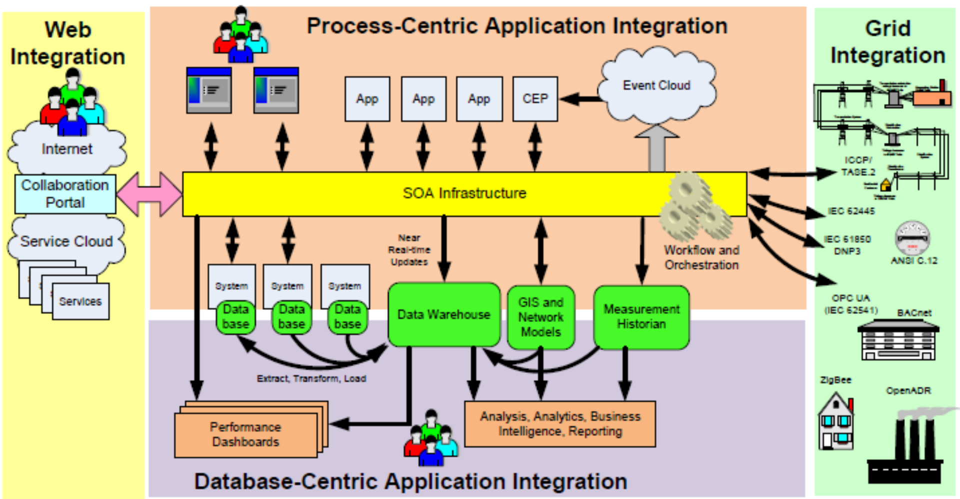


Figure 15 – SERA integration [34]

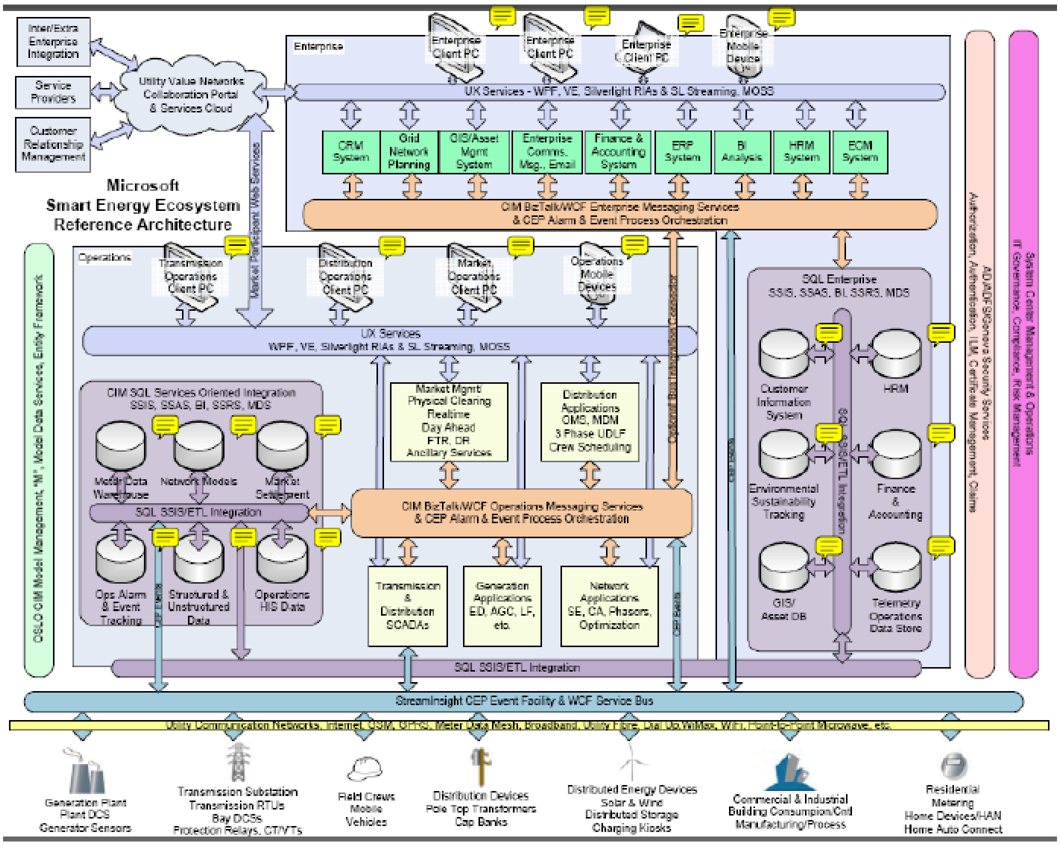


Figure 16 – Overall infrastructure [34]

Although based on a proprietary technology, and thus not applicable to ENCOURAGE, this reference architecture defines a set of interacting components, such as the Event Cloud or the Service Oriented Architecture (SOA) infrastructure, which are important for the definition of the ENCOURAGE architecture. It also denotes the importance of Business Intelligence, a fundamental component in ENCOURAGE.

PART 2 – ENCOURAGE Architecture

4. Architecture Overview

4.1. Introduction

The proposed architecture for ENCOURAGE tries to fulfil the needs of current and future large-scale Smart Grid applications. Consequently, its development is driven by the following principles: interoperability, scalability and creation of new market opportunities.

ENCOURAGE encompasses several modules (which will be further developed in the technical work packages WP3, WP4, WP5 and WP6); these modules will work together to create the necessary synergies for a functional and effective platform to empower Smart Grid applications. The interoperability between modules and with external entities/applications is entrusted to the abstraction created by the communication bus and, when possible, adhering to existing standards. In fact, in this project we intend to use existing standards, to the extent possible, with the necessary adaptations, to fit the ENCOURAGE requirements. The ENCOURAGE platform should also be capable of providing the necessary functionalities to allow its connection to any standardized protocol.

The ENCOURAGE project will have four small scale demonstrators, as described in deliverable D2.1 [35], but this platform envisages to be able to support large scale Smart Grid applications, where the control of thousands of houses, each one with tens of devices, is required. Scalability is provided by engineering the interaction between the subsystems, to reduce their complexity. For this purpose, ENCOURAGE will leverage on the use of a Middleware layer that interconnects ENCOURAGE applications: Supervisory Control, Energy Brokerage and Business Intelligence, and the Devices Management systems (Gateways). The Middleware and the application are supported over a cloud-based infrastructure.

Additionally, the middleware is based on a distributed publish/subscribe architecture, thus easily allowing for transparent implementation of distributed applications. ENCOURAGE will also allow multiple different gateways in each home or building (e.g. one controlling energy production, one controlling home automation devices, and one controlling the energy production), which can then be logically aggregated in a single entity (a Cell) and exposed to the control applications. These Cells can then be aggregated (MacroCell) for combined energy management.

The ENCOURAGE project will also be capable of providing extended market opportunities since its services can be provided from any entity capable of offering the services envisaged by the higher layer modules - Energy Brokerage and Business Intelligence, and Supervisory Control.

4.2. ENCOURAGE Hierarchy

Existing home automation and smart building infrastructures are usually constituted by separate automation systems (HVAC system, building/home automation, water/gas/energy metering). Each of these systems usually has its own user interface and gateway. This constitutes an interoperability issue, also identified by the eDIANA project, where a hierarchy of **Cell** and **MacroCells** has been defined [28].

In ENCOURAGE we define a Cell as the logical aggregation of multiple gateways, which control consumption and production equipment within a living/working environment – e.g. one house, one building. A Cell is indivisible from the point of view of the user that manages/owns/lives and works in it.

A **MacroCell** aggregates several cells, which may exchange energy, thus with a joint EB&BI and SC functionality. A **MacroCell** can also be viewed as a group of cooperating users.

An example of a Cell is depicted in Figure 17, where three different gateways exist, one that controls energy production using photovoltaic panels, one for the management of home devices, and one for the control of the heating system. The Cell Abstract Interface behaves as a logical aggregator, central to the ENCOURAGE architecture, and is responsible for allowing multiple gateways per Cell (thus leveraging legacy systems), abstracting the remaining components which can interact with a Cell as a single entity.

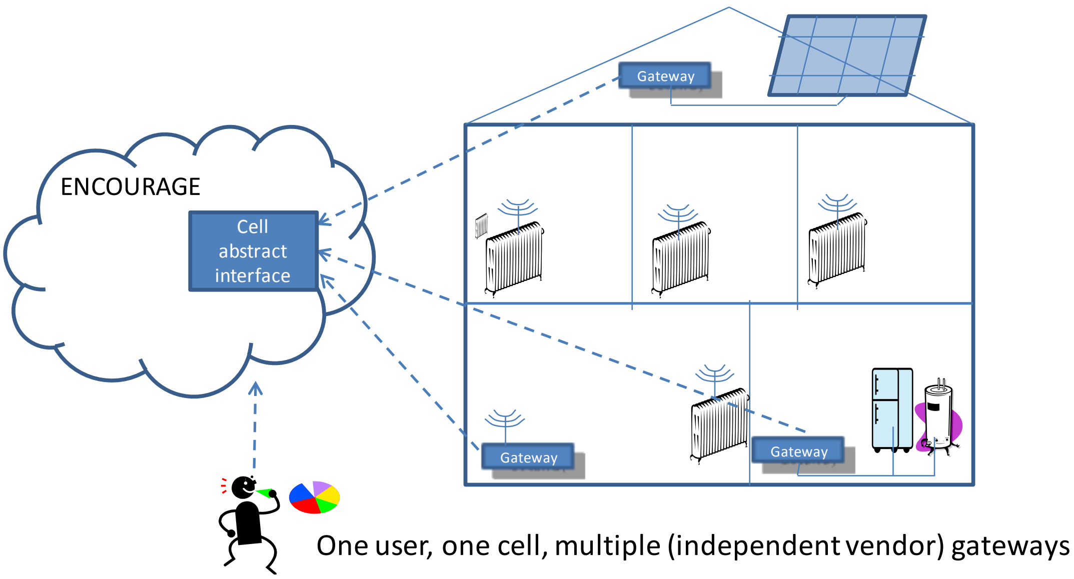


Figure 17 – Example of a Cell

An example of a MacroCell is depicted in Figure ***18***, where a group of houses is logically joined together, at the middleware layer. This aggregation allows for the execution of specific control policies, which allow these houses to cooperate on energy production and storage.

One indivisible building (from metering and control perspective) is a Cell and multiple buildings are a MacroCell. One building with multiple individual units (e.g. apartments) can be a MacroCell, if, for example, each apartment belongs to a different user. Each unit is a Cell owning individual metering and consumption control systems. Additionally, the MacroCell structure allows for the execution of operations to perform load shifting between the different energy-consuming devices located in a particular geographical area.

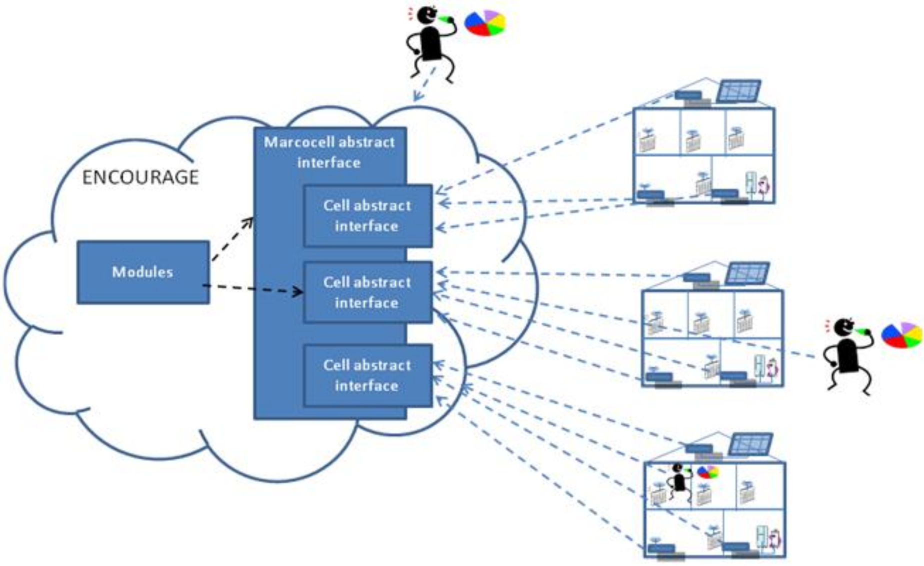


Figure 18 – Example of a MacroCell

4.3. ENCOURAGE Logical Blocks

The basic architecture of ENCOURAGE, previously presented in Figure ***1*** (Chapter 1), presents the positioning of the ENCOURAGE's blocks. The **ENCOURAGE Platform** is defined as the set of services that perform communication and computational work inside an ENCOURAGE-enabled system.

In terms of these higher-level blocks, **Devices Management** (to be further developed in WP3) is identified with the execution elements. WP4 is responsible for the development of a **Middleware**, whose main functionalities are to provide a uniform data communication and processing bus between the ENCOURAGE platform elements. WP5 and WP6 develop the decision elements; in particular, WP5 is responsible for the **Supervisory Control** (SC) module, which will be responsible for the control of individual execution elements within a Cell or a MacroCell and execute the orders received via the ENCOURAGE Middleware. WP6 will develop adequate strategies for **Energy Brokerage and Business Intelligence** (EB & BI), involving short and long term decision, taking into account the historical consumption data and production forecast.

In terms of the interfaces between system components, the Middleware has the goal of linking together not only all the other elements of the architecture, but also to offer interfaces to applications for visualization of the status of the system, to interface with the external entities, like Utilities, to get information required for business-efficient and energy-efficient choices (e.g. energy prices). On the other hand, execution elements have direct interaction with physical objects; hence they have interfaces to sensors and actuators. The interaction with devices will be actually with the gateways of different providers of energy-efficient technology, which on their part will develop modules to create a communication abstraction from the proprietary message encoding, therefore building a unique ontology (SEP 2.0 [6]) to import and export information and commands into the ENCOURAGE system.

Each module is made up of a number of components, as provided in Figure 19. More details on these components (and interfaces) are given in Chapters 5 to 8.

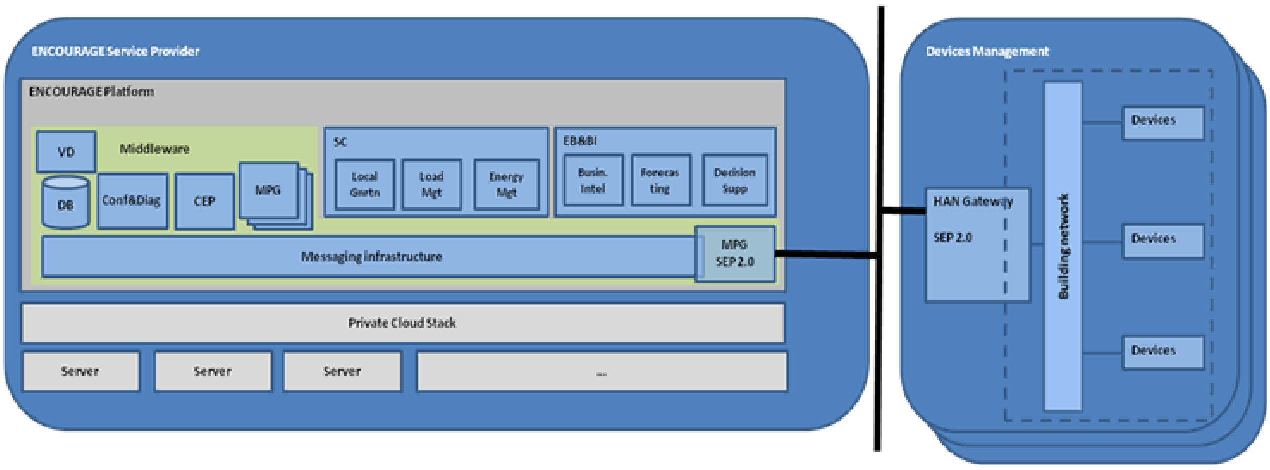


Figure 19 – ENCOURAGE architecture

The components of ENCOURAGE which are not part of the ENCOURAGE service provider, are the set of interfaces that perform protocol translation between the ENCOURAGE messages and the home/building automation protocols used by devices. In fact, the ENCOURAGE interfacing with devices is done through one (or more) **Home Area Network Gateway** (HANGW), which translate from home automation, open or proprietary protocols, for the representation protocols to be used in ENCOURAGE (an expanded and adapted version of SEP 2.0 [6]). This HANGW can range from a gateway of a fully fledged Zigbee network, interconnecting multiple sensors and actuators in the building, to a controller of a specific system or device (e.g., a HVAC machine). Furthermore, ENCOURAGE allows for specific plug-ins to be integrated in the middleware to interface with external applications (e.g., control of legacy systems), abstracting these as virtual devices. As previously noted, ENCOURAGE supports multiple different systems in the same house or building, abstracting those in the notion of a Cell.

The **Middleware** is composed by a **Messaging Infrastructure**, **Database**, **Configuration and Diagnostic** and **Complex Event Processor** modules**,** and **Middleware Plug-ins**.

The **Messaging Infrastructure** links the different ENCOURAGE modules, enabling the exchange of messages using different communication paradigms (e.g. client/server and publish/subscribe) and it provides the interconnection with the interconnection plug-ins. This module, central to the ENCOURAGE Middleware, facilitates the interaction between the decision elements and the execution elements, which are two categories used to implement the division of the system components into the traditional pair “politics” and “mechanisms”. The execution elements (mechanisms) collect data from the surrounding environment, and act on the environment to implement changes. The decision elements (politics) contain logic to perform computations based on the information received by the execution elements. After getting data from execution elements, and processing the data, the decision elements send commands back to the execution elements, to implement energy-efficient and business-efficient changes. The Messaging Infrastructure is intended to be provided by a standard technology. Figure 19 provides a logical structure of the Middleware – the Messaging Infrastructure may be (or not) integrated within the Cloud Platform, as long as it is scalable to support messages from components outside of this platform (see Section 4.4).

The **Database** contains the current status of the virtual representations of sensors and actuators of the system, it also stores historical data of interest to other ENCOURAGE application (e. g. cell consumption data for energy consumption forecasting). This last module works in close cooperation with the **Virtual Device** (VD) module which takes care of making available a representation of each device, Cell and MacroCell for the ENCOURAGE applications.

The **Complex Event Processor** (CEP) is a component that processes events in real-time and correlates them to generate new events, called “complex events”. It can be configured by external applications, which supply it with “rules”. These rules define how the multiple incoming events are consolidated into outgoing complex events. For example, alarms that are triggered by multiple events and conditions, when these are evaluated true at the same time; the results of the alarms are messages sent to external applications and/or commands sent to actuators.

The **Configuration and Diagnostic** component is responsible for the interaction with the configuration system used inside ENCOURAGE Cells. The ENCOURAGE system might also need to interface with external applications or information providers. To handle those connections, **Middleware Plug-ins** (MPG) translate from the external protocol to the protocol used within the ENCOURAGE Middleware.

Connected to the Middleware, there are decision modules, which are logically aggregated in the **Supervisory Control** (SC) and the **Energy Brokerage & Business Intelligence** (EB&BI) blocks.

The **SC** is built upon three modules: **Local Generation**, **Energy Management** and **Load Management**. The **Local Generation** module takes care of local energy production by renewable sources. The **Energy Management** module is responsible, in cooperation with the EB&BI modules, for the execution of the energy brokerage plan. The **Load Management** module supports demand side management – i.e. supervisory control of individual energy consuming devices/loads in the building.

On the other hand, the **EB&BI** block manages the participation of a Cell/MacroCell on energy brokerage or in long term about possible retrofits, equipment replacements and other capital investment actions. These functions are supported by the Forecasting, Decision Support and Business Intelligence modules. The **Forecasting** module (FC) is in charge of predicting the quantity of energy that will be used and produced in a certain time frame based on historical data and real-time data (such as weather forecasts). The **Decision Support for Energy Brokerage** (EB) module is capable of taking informed decisions on exchanging energy between buildings that have overproduction and ones that have underproduction. The **Business Intelligence** module (BI) is in charge of delivering reports, Key Performance Indicators (KPIs) and non-real time alerts to enable the analysis of the whole ENCOURAGE platform's operation.

This block also depends on the **Middleware Plug-ins**, which are responsible for the communication with external entities and applications, e.g. to obtain data relevant for the energy brokerage process or the energy forecasting (the utilities, the market places or weather service providers), and then publish the data on an adequate format through the Messaging Infrastructure.

4.4. Underlying infrastructure

The ENCOURAGE Platform will be able to use the computational power of a cloud; hence it positions itself over a Private Cloud Stack. Together with the cloud on which it resides, the ENCOURAGE Platform constitutes the **ENCOURAGE Service Provider**. Furthermore, ENCOURAGE foresees that the Private Cloud can be extended to make use of External Cloud Providers for scalability (Figure ***20***).

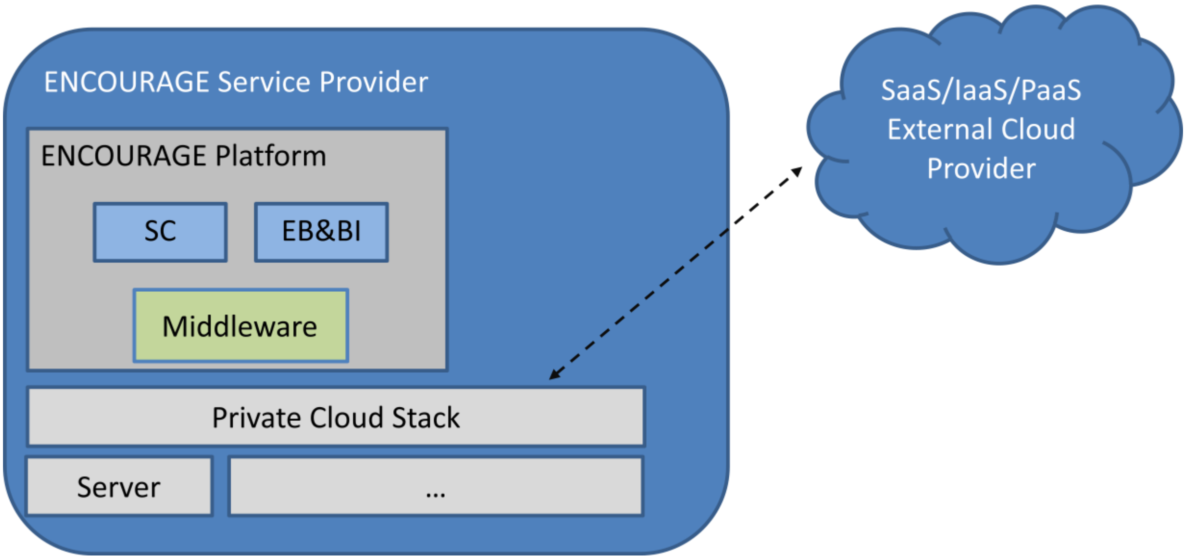


Figure 20 – ENCOURAGE Cloud Architecture

It is nevertheless important to note that the architecture is flexible enough to allow applications of the system, e.g. the SC or EB&BI modules, to be executed in servers which do not support the **Private Cloud Stack** (but must be able to connect to the Messaging Infrastructure). In this case, the Middleware's Messaging Infrastructure must extend to the particular server (Figure ***21***).

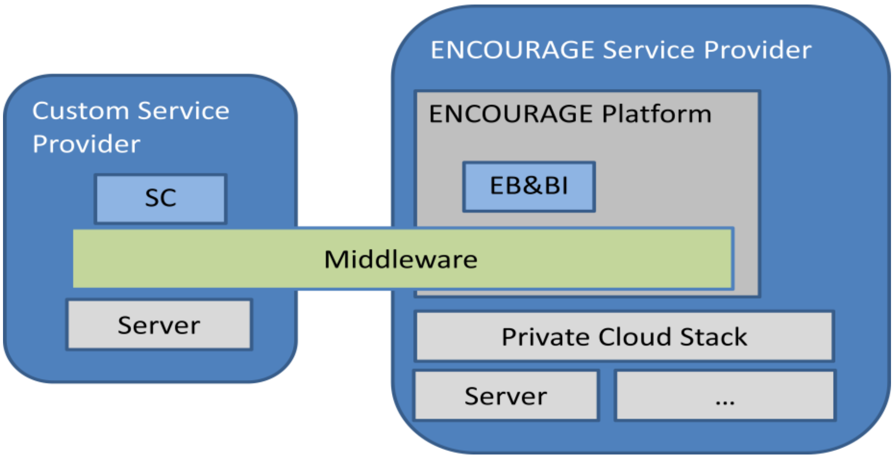


Figure 21 – ENCOURAGE Extension to Private Servers

The different actors interfacing with ENCOURAGE connect through an IP-based VPN infrastructure, made available by the ENCOURAGE service provider (Figure ***22***).

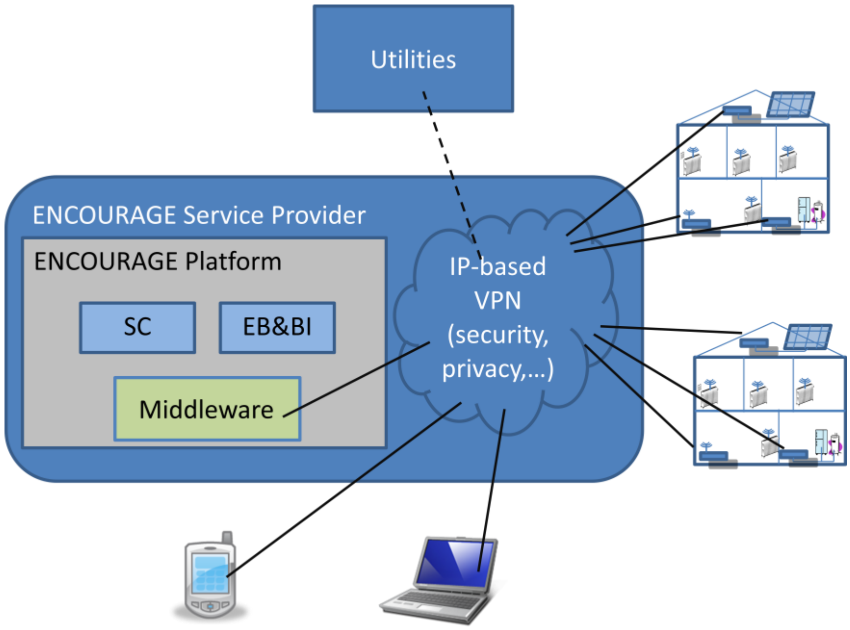


Figure 22 – ENCOURAGE IP-based connection

5. Devices Management

5.1. Introduction

As presented in Figure ***19***, the ENCOURAGE platform comprises a Middleware that is used to transport data between the different components of the scenario. In particular, the Middleware will act as a communication bus between the gateways that orchestrate the functioning of the devices located in the houses/buildings, and the applications deployed in a cloud environment that constitute the ENCOURAGE Service Provider. With respect to the gateway, ENCOURAGE separates the Home Area Network (HAN) side, and the Middleware (bus) side, with the gateway located in the middle and acting as a separator between the world of custom/standard technologies (HAN side), and the standards-based ENCOURAGE system (bus side).

This section briefly discusses the ENCOURAGE architecture devoted to the management of the devices located on the HAN side. In particular, this section discusses the bus end-points that connect the HAN Gateways to the Messaging Infrastructure, the architectural functionalities that must be present on the HAN Gateway, and the data storage subsystem that is deployed on the ENCOURAGE Service Provider to support device management.

In order to shield the ENCOURAGE architecture from specific and custom/proprietary implementations in the home networks, and also to support the easy adaptation of existent solutions, ENCOURAGE only specifies, at the HAN side, the required interface and services available. Therefore, existent systems can interoperate with ENCOURAGE, by simply incorporating the ENCOURAGE gateway services (Figure ***23***). Nevertheless, ENCOURAGE also supports interoperation with other applications or closed systems, at the Middleware level, by the addition of appropriate Middleware Plug-ins (Section 6.8), connecting to these applications or systems.

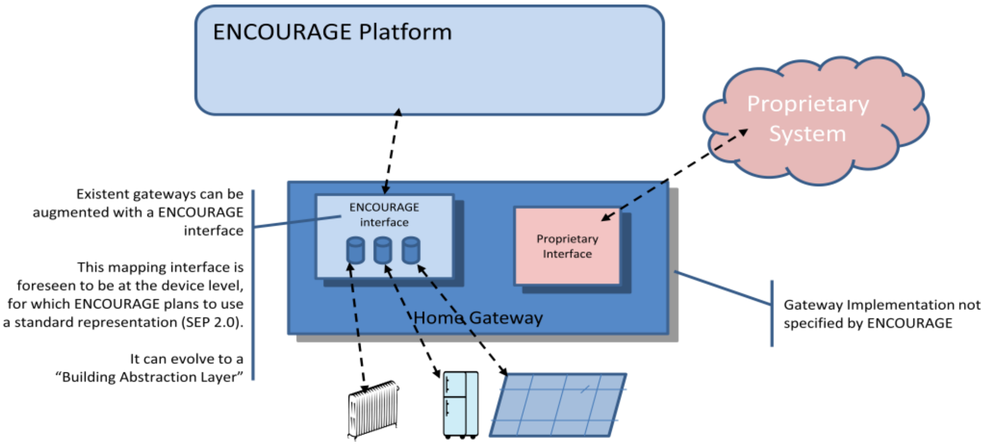


Figure 23 – HAN Gateways to ENCOURAGE

5.2. Communication technologies for the devices in the HAN

As previously presented, to provide a maximum level of generality and interoperability, it has been decided that ENCOURAGE does not address the internals of gateways. In fact, the system must be able to provide support to gateways produced and deployed by a potentially large number of providers, hence it is better for ENCOURAGE to specify the interface that must be implemented by the gateway to interoperate with ENCOURAGE, and then let the gateway producers to work towards implementing an adapter.

Regarding the message transport paradigm between the gateways and the ENCOURAGE Service Provider, we must take into account that standard protocols go in two different directions of mediating communication via Request/Response or Publish/Subscribe paradigms, hence it is necessary that ENCOURAGE provides two different ways of interacting, one for each communication paradigm. With this goal in mind, ENCOURAGE will base its communication on Publish/Subscribe in the Messaging Infrastructure and on an adaptation of SEP 2.0 to connect to the HAN Gateways. The adapter (the SEP Plug-in) will be part of the Messaging Infrastructure, and it will communicate via Publish/Subscribe with the rest of the ENCOURAGE system.

Regarding the encoding of the messages between the gateway and the rest of the ENCOURAGE applications, the commitment to adhere to international standards is not an easy task, since it is not yet clear which standard will be the de-facto one in the future. Possible candidates are SEP2.0/M2M/IEC 62056/IEC 61968-9 or IEC 61968-8. This initial definition specifies the encoding based on SEP2.0, but it is possible that this decision is revised during the initial implementation phase of the project, considering the current standardization processes.

The architectural element provided for the configuration of HAN devices, is the design of the interface between the HAN Gateway and the ENCOURAGE message bus, both in terms of message encoding, and of communication paradigm.

Functionalities

- Each HAN Gateway adopts the data format decided by ENCOURAGE to communicate to the home network of the HAN Gateway. The HAN Gateway communicates either via Request/Response or via Publish/Subscribe, with the Middleware.
- The ENCOURAGE Middleware implements a Middleware Plug-in component to communicate with the HAN Gateway, which makes the necessary translations to the format used inside the Publish/Subscribe Messaging Infrastructure.

The communication technologies related to the devices in the HAN are further detailed in Deliverable 3.1 [36].

5.3. Gateway services

A database with the device configuration data will be deployed on the Middleware. The data used to configure the devices will be stored in a safe place, with all the redundancy and security features needed to ensure a reliable configuration of the devices. The mechanism devoted to this operation is based on the communication of the HAN Gateways with a storage system (e.g.: a database in the Middleware) that contains the data to perform the configuration of the devices. In particular, by interacting with HAN Gateway vendors, we will design a set of HAN Gateway profiles, to be used to create ontology, and a standardized view, on the HAN Gateway functionalities, to ease their configuration.

The HAN Gateways can support a vast set of functionalities which range from providing only consumption data, driving the generation and storage of energy in the HAN, to providing information on metering of individual sockets (even when not co-located with the meter). Depending on the architecture of the HAN Gateway, it can support different levels of intelligence and programmability, featuring computational power and data storage capabilities. Further definition of the HAN Gateways functionalities will be detailed in Deliverable D6.1 [37], but include:

- The configuration of the devices in a HAN is distributed to them by the HAN Gateway. The configuration is stored on the ENCOURAGE Middleware Database, to ease the setup of the HAN Gateway.
- ENCOURAGE will design a set of HAN Gateway profiles, to provide a standard view of the HAN Gateway functionalities and to ease their configuration.

5.3.1. Exposed services

- Access the monitoring devices (sensors that collect information regarding the energy consumption patterns) and the control devices (actuators that receive messages to implement energy efficient changes in the system).
- Configure both the devices in the HAN, and the HAN gateway itself.
- Expansion of the HAN, by adding new devices in a seamless way.
- Upgrading of the HAN by updating drivers on already deployed devices, and by re-configurating them.
- Providing status of individual sensors/actuators; sending events on failures.

5.4. Virtual metering

The non-intrusive load metering of ENCOURAGE is based on the novel technique of virtual metering. Using signal processing techniques, ENCOURAGE will perform pattern matching between the power consumption of a set of devices, and a number of profiles corresponding to known consumption patterns. This operation needs a computational power that would be a too large burden for the HAN Gateway, and the comparison with a potentially large quantity of data (the consumption profiles), hence the techniques is based on transporting the data series related to the power consumption in the HAN to the ENCOURAGE Service Provider, and to the pattern matching performed there.

The architecture of ENCOURAGE for virtual metering will be invisible to the general user, since it will be made by a data collecting system, which transports log information on the energy consumption of the power socket, and a processing system, in the Middleware, that will compute individual consumptions by leveraging of known consumption profiles.

5.4.1. Functionalities

- HAN Gateways will send data regarding energy work load to the ENCOURAGE Service Provider, for storage and analysis on the cloud.
- ENCOURAGE will create profiles of consumption for common devices, to be used to infer the energy load of devices in use.

6. Middleware

6.1. Overview

The ENCOURAGE Middleware constitutes the infrastructure which provides the core of the platform. The technologies to be used in this Middleware will be defined and implemented in Deliverables D4.1 [38], D4.2 [39] and D4.3 [40]. Its main components are described in the next subsections.

6.2. Messaging Infrastructure

The Messaging Infrastructure links all higher level ENCOURAGE modules, in EB&BI and SC, between them, connects those applications with HAN gateways and with the other modules of the Middleware layer. This solution allows reducing the complexity of inter-application communications since it works as a message bus, thus applications use only one communication protocol and are only required to maintain one connection with the message bus. This Infrastructure should be capable of supporting different types of communication paradigms: publish/subscribe and also request/response.

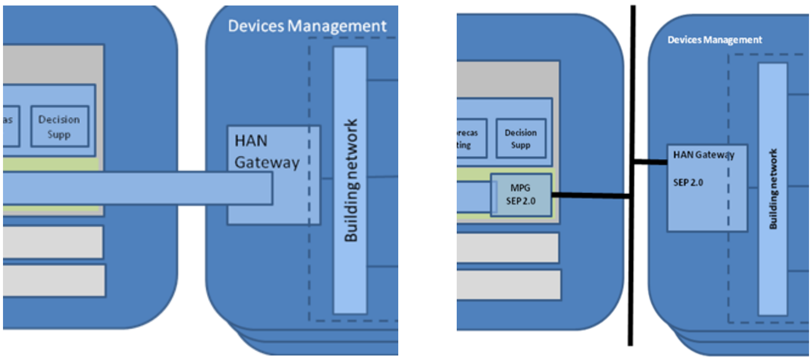
The publish/subscribe model [41] allows subscriber applications that want to receive messages from a publisher to inform the Messaging Infrastructure about those intentions, leaving the distribution of messages to the Messaging Infrastructure. In this way publisher and subscriber do not need to know each other, thus effectively decoupling both applications, in time, space and synchronization. Additionally, this module also increases the scalability of the overall system since it allows for parallel operation, message caching and improved message routing. If required by the applications the request/response communication paradigm [42] can be implemented over a publish/subscribe infrastructure.

In a publish/subscribe system, publishers define the availability of information by defining an event on the Messaging Infrastructure, after which they can start sending messages related to this event, addressed to the Messaging Infrastructure. When a receiver wishes to receive information related to an event it simply subscribes to a particular event. Then, it is the responsibility of the Messaging Infrastructure to send notifications, related to the event. The information can be cached on the information infrastructure, thus the subscriber has the possibility of receiving messages exchanged prior to its subscription. It is also possible to define several Quality of Service (QoS) policies for the reception of these events, e.g. guaranteed delivery and delay. The ENCOURAGE Messaging Infrastructure will not filter data/events.

The Middleware will also contain a Configuration and Diagnostic module which will be responsible for the configuration of the overall ENCOURAGE platform, including the middleware itself, the gateways (Middleware and HAN Gateways) and the devices. The extent of this module functionalities' depends heavily on the extent of services exposed by the HAN Gateways. It also interacts with the database module to store configuration data. The diagnostic functionality will allow to monitor the status of the different pieces of the ENCOURAGE platform.

The Messaging Infrastructure connects to the HAN by a SEP plug-in which converts from SEP 2.0 to the internal protocol used within the Messaging Infrastructure (Figure ***24*** b)). It is also possible to extend the Messaging Infrastructure to the HAN Gateway, as depicted in Figure ***24*** a), but that solution will not be implemented in this project, as it is less interoperable, and also ***24*** b) provides faster market acceptance.

It is also important to note that this model is usually agnostic in relation to the content of messages. Consequently, it is the responsibility of the applications to interpret the content of messages. The ontologies defined adhere to SEP 2.0 and IEC 61968 standards. This will be further defined in Deliverable D4.2 [39].



a) **b)**

Figure 24 – Different ways to connect a HAN Gateway to the ENCOURAGE infrastructure.

6.2.1. Functionalities

- Publish/subscribe communications:
  - Configure events and notifications on the Messaging Infrastructure.
  - Sending and receiving notification of events;
- Client/Server communications:
  - Send/receive messages.

6.3. Data and Virtual Devices Representation

The content of messages exchanged through the Messaging Infrastructure (MI) is not parsed or by any means interpreted by it. Therefore, the messages are only parsed by the applications when received.

It was one of the requirements of the ENCOURAGE project to specify the messages exchanged based on an international standard. The CIM standard IEC 61968 is a standard which defines the format of data for information/commands exchange in an electrical system. Of particular interest is the IEC 61968-9 standard which is a specialization of the CIM model for meter reading and control, whose functionalities can be used and extended by ENCOURAGE, encompassing its requirements.

As presented in Figure ***24*** b) a specific protocol interconnects the HAN Gateway and the middleware (SEP 2.0), which needs to be translated to the Middleware representation. The data encoding formats defined by IEC 61968-9 are structured upon complex and perhaps large XML messages. The coding and decoding operation of XML messages have high processing requirements and a large bandwidth is required for its transmission. The solution is to use binary XML formats (e.g. EXI), which are able to compress the XML payload and at the same time have more reduced processing requirements. This can be provided with efficient methods [43].

For higher performance, building devices will also have a virtual representation on the Middleware; this representation allows the devices to expose their internal status and to send data and receive commands. Furthermore, the VD module provides to the ENCOURAGE applications the abstract representation of Cells and MacroCells, allowing these applications to abstract from the individual device representation.

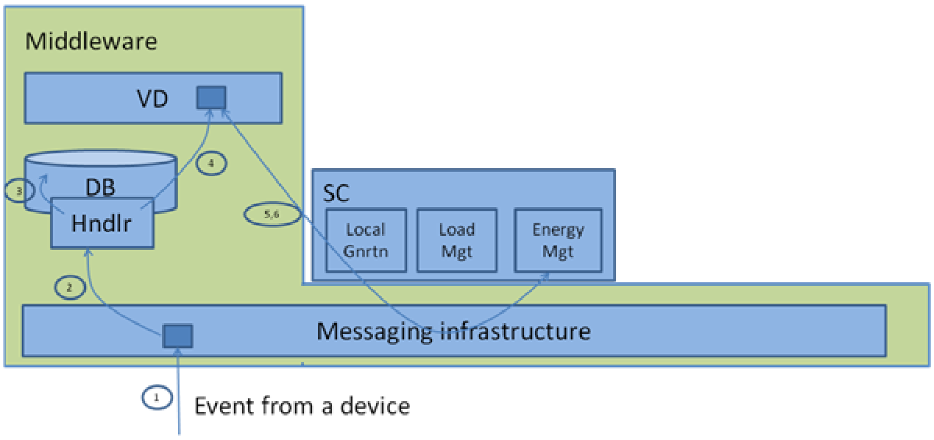


Figure 25 – Internal data conversion

The Virtual Devices (VD component in Figure ***25***) is updated through the messages received through the Messaging Infrastructure and then converted to a new representation, which allows for a fast (and abstract) access from the ENCOURAGE applications. Figure ***25*** illustrates that process;

at instant 1 an event is received from a device (e.g. a sensor reading), then (2) the message is passed to a Database handler, a subscriber of the event, which might store the event on the database (3) and convert it to the VD representation (4). Alternatively, the VD component can subscribe directly he messages in the system.

The Virtual Representation of the device can be accessed through read/write operations by other modules (5/6). If the operation is a write on this device then it should be propagated to the device.

6.3.1. Functionalities

- Filter and Virtual Devices configuration.
- Access to Virtual Devices data through read/write operations.
- Providing Cell and MacroCell abstract interfaces.
- All other data conversion operation are embedded on the ENCOURAGE applications.

6.4. Database

The Database module (Figure 26) is used to permanently store ENCOURAGE system information, it may contain historical data for every variable/device subscribed, which can after be used for consumption prediction.

The Database is responsible for storing data both historical and current within the ENCOURAGE platform. This data can be retrieved by calls made to the Middleware for the purposes of historical analysis, and consumption or production prediction. Apart from the actual database(s), the module provides several components for data handling.

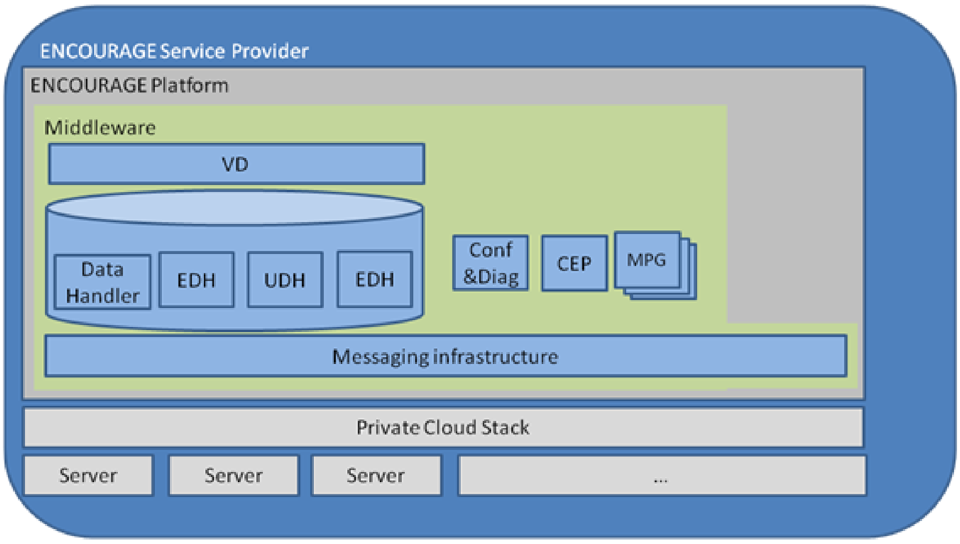


Figure 26 – Database logical subdivision

All connections to the Database should come through a request from the **Data Handler**. This component is responsible for opening and closing secure connections to the database. Once a connection is successful, the underlying sub-data handlers will serve the relevant data to the consumer. This will facilitate calls from the EB&BI and the SC logical blocks.

Varying forms of information regarding the ENCOURAGE platform may be stored in the database. Each of these forms of information will have their own database connector which will be responsible for serving that information set. These different kinds of data can even reside in different physical databases, for more adequate handling by modules. More specific applications can even implement their own plug-ins to make the necessary conversions and adaptations on data.

Data regarding device readings and device events taken at a period in time along with device thresholds and other configuration data will also be stored in the database. This data may be accessed through an **Event Data Handler** (EDH) component.

Data regarding device configuration and thresholds may be stored/retrieved to/from the database. This information will aid the EB&BI and SC logical blocks in any decision making that must be carried out. This data may be accessed through a **Device Data Handler** (DDH) component.

Data regarding user profiles and login credentials may also be stored and manipulated within the system. Login information may also be warehoused, which would provide an audit log feature showing user access to the system. This data may be accessed through a **User Data Handler** (UDH) component.

Using this approach will not only provide a security mechanism for access to the ENCOURAGE database, but will also maintain the integrity of the data by mutual exclusion. This means that only one transaction on a particular piece of information may occur at one time. Using this approach will ensure that when a request for data is made, the most up-to-date information is returned. Bottlenecks normally associated with this approach will be approached by use of a queuing system. As soon as the data lock is released form an information block the next request/change for that same block will then be carried out.

6.4.1. Functionalities

- Store and handle data.
- Access the virtual representation of a device
  - Convert between the Middleware representation and the Virtual Device representation.
  - Read/write access to virtual devices representation.

6.5. Complex Event Processor

The Complex Event Processor (CEP) is an engine that is capable of detecting real-time, asynchronous, independent incoming events of different types, and correlating them into outgoing events, called "complex events" [44]. The key difference with other concepts such as Business Rules and Event Stream Processing is that the incoming events can be asynchronous and of different types. Another difference is that the CEP has temporal awareness. Figure ***27*** presents a high-level overview of a CEP system.

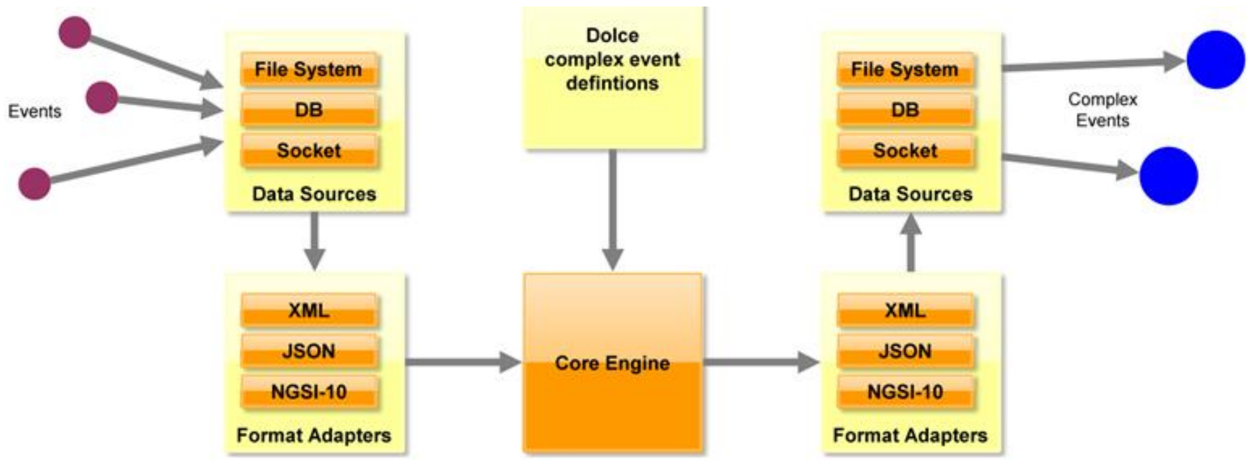


Figure 27 – Example of a CEP High Level Architecture

The CEP Engine reads events from and writes Complex Events to a Data Source and passes them through Format Adapters. It processes them based on a complex event specification provided in the Dolce language. A Data Source can be an Internet socket, a file system, database or RESTful interface, or any other future type of source. The Format Adapter adapts the incoming event to the internal formats and converts Complex Events from these internal formats to a desired output format.

As an example, assume two events: i) Sensor 1 detects a raise in temperature in Room 1; ii) Sensor 2 detects smoke in Room 2. If we are trying to determine if there is a fire then two isolated events might not necessarily be related to a fire, both events might occur, but separated by 1 hour. The key here is the fact that the two events must occur within 5 minutes from each other. Also, to be more accurate, the following event should happen as well: iii) Sensor 3 detects smoke in Room 1; iv) Sensor 4 detects a raise in temperature in Room 2.

The complex event processor to be used can be configure by any ENCOURAGE application in order to be able to rapidly detect and react to multiple events. After detection it creates one or more new events which, as an example, can be delivered to the applications that configured this specific complex event or has commands to multiple devices.

Therefore, CEP is a filter, configured by EB&BI and SC modules, in order that these two modules do not have to directly subscribe to events, and just react to CEP conclusions. The CEP should have capabilities to be executed in a massive parallel and distributed environments, since, as an example, it might be configured to react to events in 1000 houses to switch off the heating if the energy price are too high.

6.5.1. Functionalities

- Configure a complex event: this functionality also requires the interaction of this module with the Messaging Infrastructure to configure to which event it subscribes.
- Start, stop commands to activate, deactivate certain rules.

6.6. Configuration and Diagnostics Module

This module will manage the configuration of the Middleware, HAN and Devices, whose configuration data will be stored in the database. At system start-up this module is responsible for the initialization of all ENCOURAGE modules as well as for the setting of specific parameters on the HAN Gateways.

For scalability and operational issues, special care must be taken for the set-up of new devices and new HAN Gateway modules. The addition of new devices will in some cases imply changes on the control strategies currently being used (e.g. the CEP rules might have to be changed to cope with the new device), consequently the ENCOURAGE platform must be informed and propagate the information to all relevant modules. This is more relevant, if a new gateway is incorporated. The addition of new customers to the system should be as automatic and intelligent as possible. With the configuration of the Cell and MacroCell, all HAN devices should be recognized by the system, but it is expected that the ENCOURAGE service provider may be required to update some of the system configurations.

The module will also provide a diagnosis infrastructure which will be able to detect system-wide status, aggregating diagnosis information from the individual components, such as being able to detect if a gateway connection failure is specific to the gateway or due to site failure (multiple gateways failed at the same site).

6.6.1. Functionalities

- Load of system configuration.
- Update of system configuration.
- Set middleware parameter.
- Set gateway parameter.
- Set device parameter.
- Send events related to the addition of new devices or HAN Gateways.
- Diagnosing system state.

6.7. Security

Security is an important concern for the choice of the Messaging Infrastructure, which must support authentication, integrity and privacy mechanisms. This is an identified requirement, which will be detailed in Deliverable D4.1 [38].

Another concern is related to the security of communications between the HAN Gateways and the Middleware. To that purpose the SEP 2.0 uses the Transport Layer Security (TLS) protocol, thus ensuring the protection of sensitive consumer information and to ensure integrity of Smart Grid transactions. It is also possible to further enhance security by using Virtual Private Network (VPN) technologies on this connection.

The ENCOURAGE Middleware is supported over a cloud infrastructure, which is required to provide the necessary security mechanisms.

6.8. Middleware Plug-ins

It is expected that the ENCOURAGE platform will have to interface with other external entities, applications or systems, using completely different protocols. Middleware Plug-ins can be used to provide these interfaces, interacting with the external sources, and, if needed, translate the data to the formats used inside the Middleware.

Generally, most of the implementations which can suit the requirements for the Messaging Infrastructure already provide the necessary functionalities to integrate plug-ins, whose capabilities are similar to the objective of the ENCOURAGE ones. Figure ***28*** illustrates the concept, where the *Web Info* plug-in (a data retriever plug-in) is capable of use published data results to be used by web application on a browser, and the Utilities plug-in is capable of converting pricing signals to the internal representation on the Messaging Infrastructure.

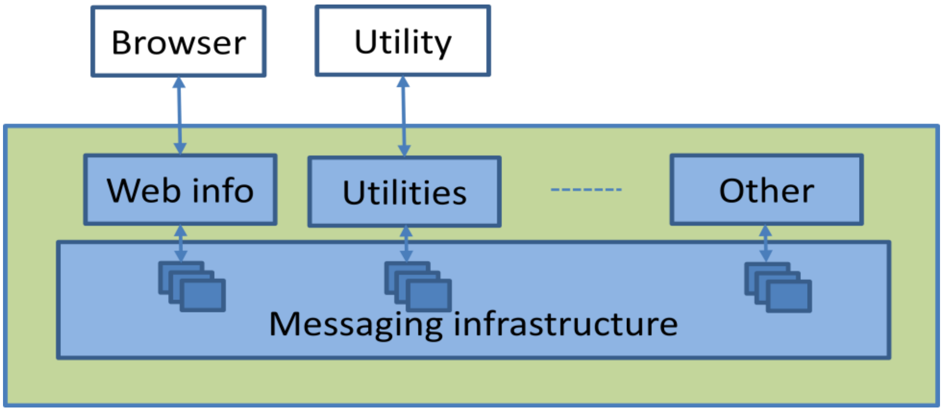


Figure 28 – Plug-in components

In the context of the ENCOURAGE demonstrators, we are envisaging the need for Middleware Plug-ins for data retrieving to be used for the web interfacing, to obtain pricing data from the utilities and to connect to weather prediction services. Specific plug-ins may be required to interface with pre-existent proprietary systems at the demonstrators' sites.

6.8.1. Functionalities

- Install plug-in: runs the necessary installation and setup routines in a plug-in component.
- Monitor plug-in component: enables to determine the status of a plug-in.

6.9. Cloud Infrastructure

The Cloud Infrastructure will provide a flexible and extensible platform for the deployment of ENCOURAGE services and applications. This infrastructure will be built on top of existing open source Cloud infrastructures such as OpenStack or Eucalyptus. Technical integration/interoperability could be addressed through the use of Open Cloud Computing Interface and Open Virtualisation Format standards. This section provides an overview which will be further detailed within Deliverable D4.3 [40].

A cloud service is composed by a set of Virtual Machines (VM) and a descriptor in Open Virtualization Format (OVF). This descriptor is a detailed description of all the aspects of the virtual images, from the amount of memory or the CPU characteristics to the network interfaces. The OVF also contains the Key Performance Indicators (KPIs), which are used for the elasticity of the service and they will be monitored and controlled by the monitoring infrastructure and the elasticity engine (see Figure ***29***).

The software needed to manage the cloud infrastructure can be split in three layers: the Physical Infrastructure Layer, the Service Management Layer and the Cloud Infrastructure Management Layer.

The Physical infrastructure layer will host all the cloud services required by ENCOURAGE

- A set of Servers, which can scale for performance considerations.
- Firewall services.
- Routers.

The **Service Management Layer** includes all the software managing the service lifecycle. It is in charge of deploying, un-deploying and optimizing a service during runtime. It contains two other modules. The Service Lifecycle Manager (SLM), which is the main brain and knows in every moment the status of the service, communicating directly with the virtual machine manager (OpenNebula) sending the correct signals to deploy, spin up or down VMs and, when it is time, un-deploy the service. The Elasticity Engine (EE) controls the KPIs of the service using the monitoring information system and informs the SLM when a violation has been produced and a reaction is needed. The Service Lifecycle Manager will be also in charge of providing authentication and authorization services for users to access to all the functionalities of the cloud infrastructure through secure standards protocols, employing a Single Point of Access. Different roles will be created for service deploy, those roles will grant the appropriate access to the required resources provided by the SML. Those functionalities will be provided mainly by JOSSO and OpenLDAP embedded within the SML.

The **Cloud Infrastructure Management Layer** is the closest one to the hardware and it is the one in charge of providing the monitoring of the physical infrastructure and VMs as well as the virtual manager, which is in charge of doing the provisioning management of the VMs. It also contains two additional modules: the Monitoring infrastructure (MI), which provides monitoring of the physical and virtual infrastructure, and the Virtual Manager, who is in charge of provision, schedule, starting and stopping physically the virtual images in the worker hosts. The initial foreseen infrastructure is:

- Virtual Manager: OpenNebula.
- Monitoring: Zabbix.
- VM image repository
  - Database: MySQL, postgreSQL.
  - Message broker: RabitMQ.
  - Configuration and Diagnostic module.

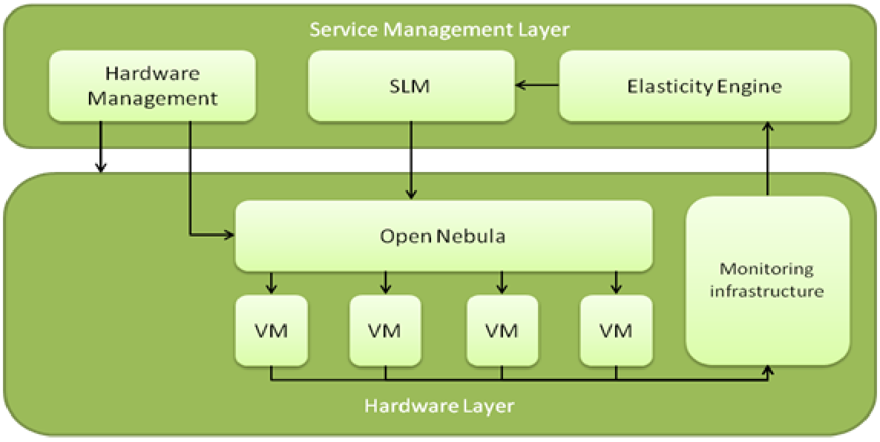


Figure 29 – Cloud Infrastructure building blocks

6.9.1. Functionalities

- Install, uninstall, run an application.
- Set/change parameters.
- Provide a suitable messaging system.

7. Supervisory Control

7.1. Introduction

The Supervisory Control block coordinates the local generation, storage and consumption of energy. The purpose is to achieve an optimal use of local energy production and consumption. This is achieved by monitoring and controlling the local generation elements (including local storage) and implementing adequate control strategies for management of internal loads in the building.

A way to optimize energy usage is to minimize the mismatch between the locally produced energy and the locally consumed energy e.g. by controlling the heating in the houses through controlling heat pumps and/or setting the set points for room temperature in the individual houses. The local production and consumption shall be monitored and logged in real time.

A significant portion of the optimized variables will be indicators whether a specific piece of equipment should be running or not ("on/off"), such as heat pumps, whereas others will allow adjustment of set points, typically for heating and air conditioning (temperature), ventilation (fan speed) and lighting systems (illumination level).

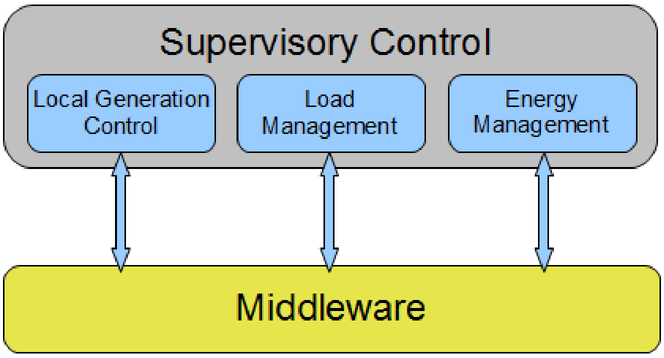


Figure 30: The links between the Supervisory Control block and the Middleware.

The Supervisory Control block (Figure ***30***) is divided into the **Local Generation Control**, the **Load Management** and the **Energy Management** modules. The block relies on the functionalities provided by the Middleware to obtain information about the devices' state and their capabilities within a house. It also relies on orders sent from the Energy Brokerage and Business Intelligence block modules to act upon devices within a house in order to fulfil a specific objective (e.g. to reduce the house consumption by 5%).

The Supervisory Control block will handle data and event from the middleware in a secure manner. This means that all data transmission will be carried out over a secure connection so that no information can be attained by unauthorized parties. The Supervisory Control block will also, through the Middleware, send the necessary events and data to the EB&BI modules and make available the required data for the interface with the user.

The next sections present the details and functionalities of each one of these modules (Figure ***31***).

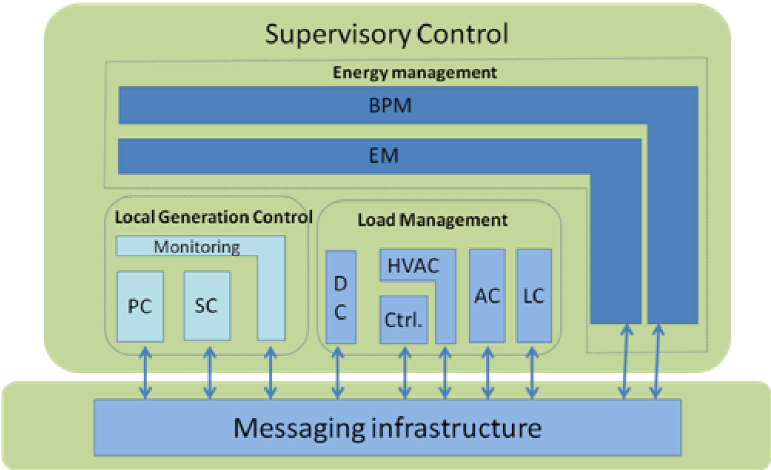


Figure 31 - Internal structure of Supervisory Control

7.2. Local Generation Control

The **Local Generation Control** module (Figure ***32***) manages the control of local energy generation sources (with a special emphasis on renewables) and local storage devices. It consists of Production Controller (PC), Storage Controller (SC) and Monitoring components.

The control of local energy generation encompasses algorithms that will reflect the expected operation (Deliverable D5.2 [45]) – i.e. if the generation source can be shared by multiple consumers, or if it will have just one owner who will determine the preferred mode of operation. Critical decisions will be made on the required level of intelligence. Among the controlled local storage devices are batteries and hydrogen based storage.

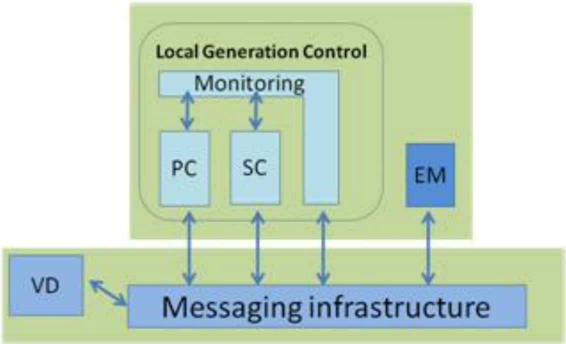


Figure 32 – Local Generation Control module flows

7.2.1. Functionalities

The functionalities can be divided in to these components:

- The monitoring component will collect all the necessary data and make it available for the rest of the ENCOURAGE system. The data is mainly the actual production data but it can also be data specifying the ability to increase/reduce the production and error/alarm signals that have an influence on other parts of the system.
- The Production Control takes care of the local production control. This component will mainly be based on the information and actuation of devices accessed through the Virtual Devices component of the Middleware, but it will also use production requirement information (e.g. from Energy Management).
- The Storage Controller is both a producer and a consumer of energy. Its task is mainly to handle the local control of these devices based on information coming from the Energy Management module, e.g. instructions to store or to produce energy.

7.3. Load Management

The **Load Management** module (Figure ***33***) is responsible for controlling the individual loads in such a way that the end user comfort is not affected, and if possible even increased. Besides that, this module will provide the Energy Management module with the necessary interaction possibility for optimizing the power consumption with respect to minimizing the power used and maximizing the consumption flexibility.

The module implements the specific control rules handling the loads in the buildings (which will be defined in Deliverable D5.3 [46]). Some of these rules can be implemented in this layer, but for others it can configure the Complex Event Processing module in the Middleware. These load control strategies assume the classification of the type of load (as critical, curtailable or reschedulable) and the execution of adequate control rules for each kind of load.

Load management consists of five components: the Dynamic Calculator (DC), the necessary feedback controllers (Ctrl.), the Heat, Ventilation and Air Conditioning (HVAC), the Appliance Controller (AC) and the Light Controller (LC).

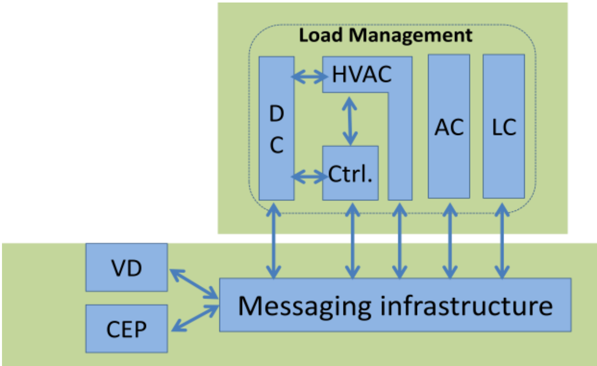


Figure 33 - Load Management module flows

7.3.1. Functionalities

- The Light Controller will take care of optimizing the power used for light. This will be done by using information from local sensors and by that means, dimming or switching off the light when possible, e.g. when there are no people in the house or in a specific room.
- The heating, ventilating and air conditioning system (HVAC) is the most energy consuming components in a house, but also can be the most cost-effective way to improve energy efficiency (when its use is optimized). The HVAC control systems task is to minimize the power consumption by using all the knowledge from sensors and information about user behaviour and user preferences, to lower the energy consumption without affecting the living comfort in the building.
- For that purpose the HVAC makes use of feedback controllers (Ctrl.) manly for controlling the temperature in the rooms. These controllers can be placed outside of the ENCOURAGE platform, in dedicated systems that will be represented as a VD in the middleware. In this case, the HVAC will control the set points of the control loops. The HVAC component also makes use of the Dynamic Calculator (DC) to analyse the dynamic of the house in order to allow prediction of the consequences of the control actions.
- In general, appliances such as the coffee maker, television or electrical tooth brushes cannot be controlled from an external computer. They do not have the necessary interface or they cannot be switched on or off without human interaction. The Appliances Controller (AC) will make available information for the user of the appliance. This information will typically be an advice providing guidance about when it will be preferable to use the appliance, based on a calculated rescheduling of the loads.

7.4. Energy Management

The **Energy Management** module (Figure ***34***) is responsible for the actual energy optimization in such a way that as much as possible of the surplus of local produced energy is used locally. It makes use of the functionality provided by the Local Generation Control and the Load Management modules and coordinates and dispatches the multiple generation, consumption, and storage devices connected to the local microgrid or to the building network.

One of the main innovations of ENCOURAGE is the possibility of running the energy management algorithms on the ENCOURAGE platform (on the cloud), and, at the same time, being able to use the related functionalities which usually run on the HAN gateways. In this way ENCOURAGE will provide hierarchical control functionalities (Deliverable D5.4 [47]) where the HAN gateway functionalities are controlled by the energy management algorithms on the ENCOURAGE platform.

Energy Management consists of two components: the Energy Manager (EM) and the Behaviour/Profiling Manager (BPM).

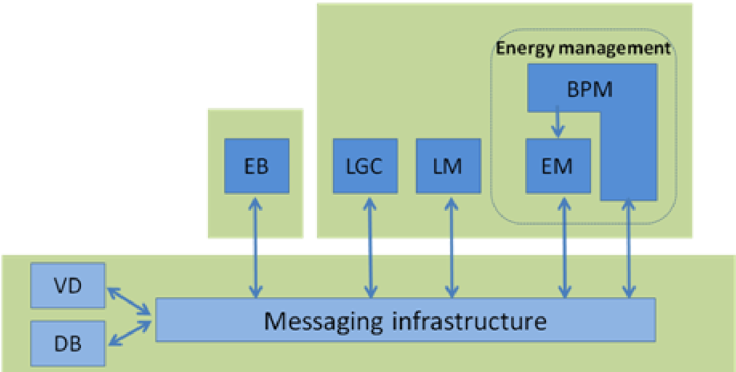


Figure 34 - Energy Management module flows

7.4.1. Functionalities

The functionalities will be to coordinate the operation of the Local Generation Control and the Load Management modules, based on the information provided by these modules, such as the ability to increase or decrease the production/consumption.

- The EM module optimizes the production and consumption of energy based on all relevant knowledge. This knowledge is derived from sensor readings, input from the Decision Support for Energy Brokerage (EB) module, user behaviour and more.
- The Energy Manager also sends requests to the modules, for example to increase or decrease production/consumption.

- The BPM component estimates the behaviour of the users in the house or building. This is done by analysing the readings from relevant VD’s and data from the database. Other sources of information, for defining the behaviour, can be e.g. temperature profiles from user inputs.
- The BPM sub-module supply’s the EM sub-module with relevant information about user behaviour.

8. Energy Brokerage and Business Intelligence

8.1. Introduction

The Energy Brokerage & Business Intelligence (EB&BI) block consists of three modules, namely, **Forecasting** (FC), **Decision Support for Energy Brokerage** (EB) and **Business Intelligence** (BI). The modules also interact with external entities using specific Middleware Plug-ins. The concept of Middleware Plug-ins is described in Section 6.8.

The main objective of EB&BI is to enable buildings to coordinate with other participants in the electricity market and exchange electricity at the local level. Any time when a building requires more electrical energy, it will have the capability to communicate directly with neighbouring buildings or local producers and negotiate with them possible use of the electricity produced locally in their premises.

The following diagram depicts the logical composition of the block.

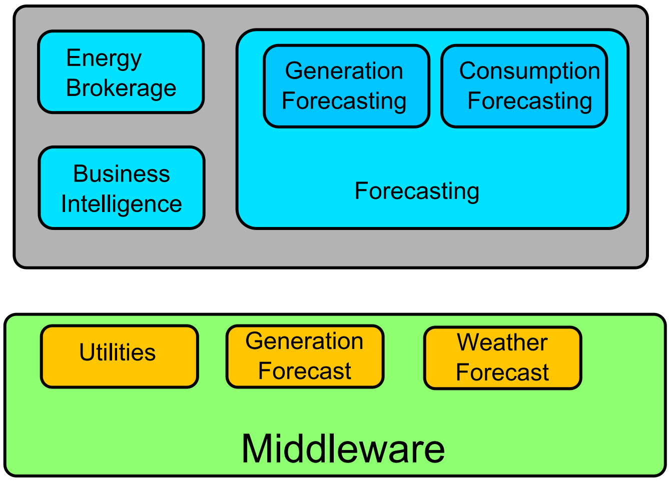


Figure 35 - Energy Brokerage & Business Intelligence Logical Block

8.2. Forecasting (FC)

This module will be capable of producing forecast files for a certain period and interval, usually configured to be for the next 24 hours, with an interval of 15 minutes.

The module consists of two components: Generation Forecasting (GFC) and Consumption Forecasting (CFC). Both components functionality is to deliver forecast information which can be used by the Energy Brokerage module and the Supervisory Control modules (possibly configuring the Complex Event Processor to handle it).

The **Generation forecast** component delivers a forecast of energy generation (for the next 24h, with 15 min precision). It takes the following inputs:

- Historical energy generation information, obtained from the Middleware Database.
- Meteorological data, obtained from an external provider, through the Weather Forecast Middleware Plug-in.
- Master information with data about generation plants, like location, technology, power.

A generation forecast can be provided for each production facility of the Cell/MacroCell. For example, in the Jadevej case (Deliverable D2.1 [35]), which consists of 8 houses with one solar panel each, a forecast for each of the panels (and/or a forecast for the whole 8 panels) can be provided.

The **Consumption forecast** component will deliver a prediction of the future amount of energy that will be consumed (for the next 24h, with 15 min precision). The module takes the following inputs:

- Meteorological information, obtained from an external provider, through the Weather Forecast Middleware Plug-in.
- Historical disaggregated quarter-hour consumption.
- Master information with data about consumption points such as user profile, installed consumption power (disaggregated or not, washing machines, fridges…), and contracted power.

Figure 36 describes the information flows within the module and identifies the main inputs required (these inputs will be further detailed within Deliverable D6.2 [48]). In order to run the internal algorithms, the computational element needs to get information:

- Operational information: current consumption of each device or current production of the renewable energy plant.
- Structural information: data about the energy configuration of Cells and MacroCells.
- External information: A weather forecast provider will be required to provide the needed weather forecasts variables. These variables will be defined in detail in the Deliverable D6.2, but as a first approach we can identify: external temperature, radiation or rain.

All inputs arrive to the module itself through the Middleware.

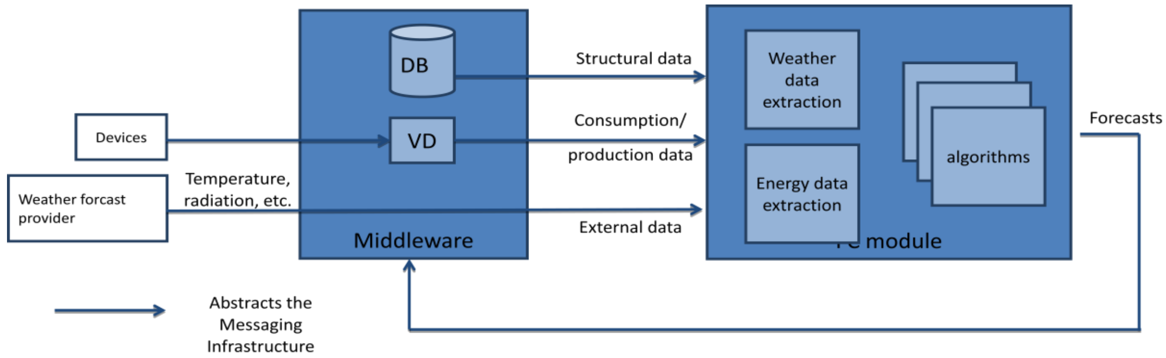


Figure 36 - Information flows involved in the forecasting module.

It is also possible to receive generation information from an external provider instead of providing ENCOURAGE-specific algorithms. In this case, the following inputs will have to be delivered to the provider:

- Energy Generation historical data (from the Middleware Database).
- Master information with data about generation plants like location, technology, power.

In this case, a middleware plug-in is responsible for the interface with the external provider.

8.2.1. Functionalities

The module has the following functionalities:

- Obtain, from the Middleware, data about the energy configuration of Cells and MacroCells: user profile, installed consumption power (disaggregated or not, washing machines, fridges…), contract power, historical quarter-hour consumption.
- Obtain, from the Middleware, data about the configuration of production plants within MacroCells: installed capacity, technology, historical quarter-hour production.
- Interact with external providers through the necessary Middleware Plug-ins to get or publish data.
- Publish, in the Middleware, forecasts on the generation capacity of installations and to generate consumption estimates for the next 24 hours with a quarter of an hour precision. This data can be published as a topic on the Messaging Infrastructure or on the Database.

8.3. Decision Support for Energy Brokerage (EB)

This module is connected to the Forecasting module through the Messaging Infrastructure; it receives as input data the generation forecast files generated in the Forecasting module, as well as utilities offers and market prices, through the adequate Middleware Plug-ins, which connect to utilities and market.

It will also have as its inputs the real-time consumption data and the storage state levels, which is made available by the Middleware. Additionally, the module also needs information about current and future generation capacity, current status of the local electricity market and will also be the receiver of offers or requests coming from other buildings.

With all this information, this module will either manage or present to the user the strategies to be adopted: buy (from its neighbour, from the market), sell, store, activate consumption, stop consumption, etc. The specific brokerage strategies will be further detailed in Deliverable D6.3 [49].

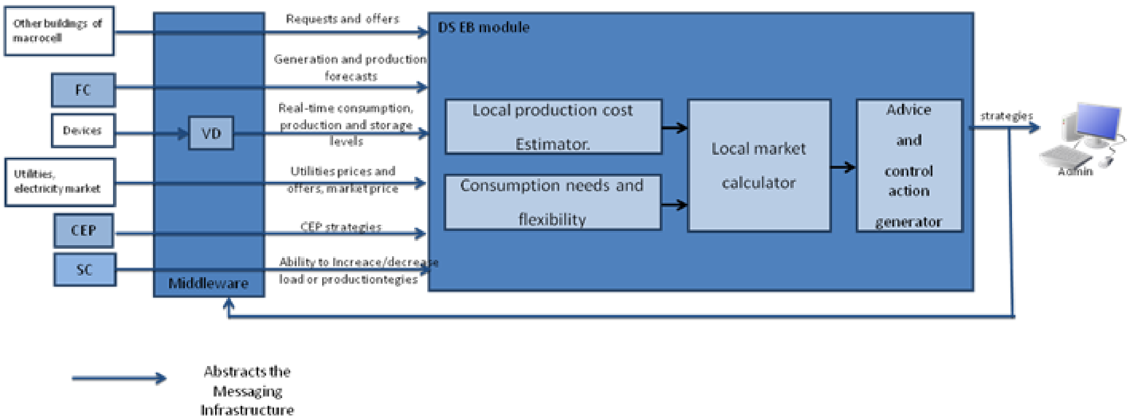


Figure 37 - Information flows involved in the decision support for energy brokerage module.

Figure 37 shows the internal structure and information flows of the EB module. It consists of:

- Local production cost estimator. This component estimates the production cost of the local produced energy. This will be done based on input from the owners of the energy sources. This cost price will be used as input to the local market calculator.
- Consumption needs and flexibility. This component will be based on production and consumption forecasts and the flexibility inputs from SC to calculate the future needs and flexibility. This information and the future production from the FC module will be used as input to the local market calculator.
- Local market calculator. This component will be based on the local production cost, future needs and flexibility, future production, utility market prices, request and offers from other

buildings, calculate the best actions to carry out. This best action will be based on a local market strategy.

- Advice and control action generator. This component will be based on the output from the local market calculator to transform these actions to advices to the users and, if feasible, direct control actions to the SC module.

8.3.1. Functionalities

- Get internal data about:
  - Generation forecast files from the Forecasting module.
  - Consumption forecast files from the Forecasting module.
  - Real-time consumption data from the Middleware.
  - Real-time production data from the Middleware.
  - Real-time storage levels from the Middleware.
- Get external data (through Middleware Plug-ins) about:
  - Utilities prices and offers.
  - Market prices.
- Receive requests and offers from other buildings through the Middleware.

8.4. Business Intelligence

The ENCOURAGE Business Intelligence module is a non-real time application that is able to use the raw data produced by the rest of the modules and, through a set of transformations and analysis tools, convert them into information and knowledge.

The final results offered will allow to understand how the platform is working, the energy behaviour patterns of the users, provide alerts on unusual behaviours or issues of concern, identify possible problems and opportunities for improvement, etc.

This module will use a dedicated database (data warehouse) which will contain aggregated data useful for BI analysis. The module will receive from this dedicated database information regarding historical consumption data files, consumption breakdown data files, real-time consumption data, historical production data file, current production data, utilities/market prices, generation and consumption forecasting data, and data from Supervisory Control.

The module will generate reports, KPIs and alerts addressed to the user or the energy manager of the Cells/MacroCells. These outputs will help the energy manager/user to analyse the energy behaviour of each device, Cell and MacroCell and determine:

- If the energy behaviour stays on established limits.
- If the decision support for energy brokerage is working properly.
- What are the main tendencies of consumption, production, processing events, etc.

There will be economic reports, Supervisory Control actions and alarm reports, energy efficiency objectives performance and consumption reports. All analyses will be performed at non-real time level (short, mid or long term analyses). The innovative aspect of this module is the set of rules and specifications to adapt to a smart-grid environment, and the design of an integrated management environment, which allows the control of all smart-grid platform key issues.

Some of the requirements for this platform are intuitive navigation, specifically designed for the smart-grid concept, graphic environment which allows drawing quick conclusions, access to aggregated and disaggregated information, visualisation of key aspects in terms of KPI, managerial reporting on how the platform is running.

ENCOURAGE foresees the integration of a standard available BI platform (this will be detailed in Deliverable D6.4 [50]), interacting with the ENCOURAGE middleware. Figure 38 summarizes these information flows and data sources within the Encourage BI module.

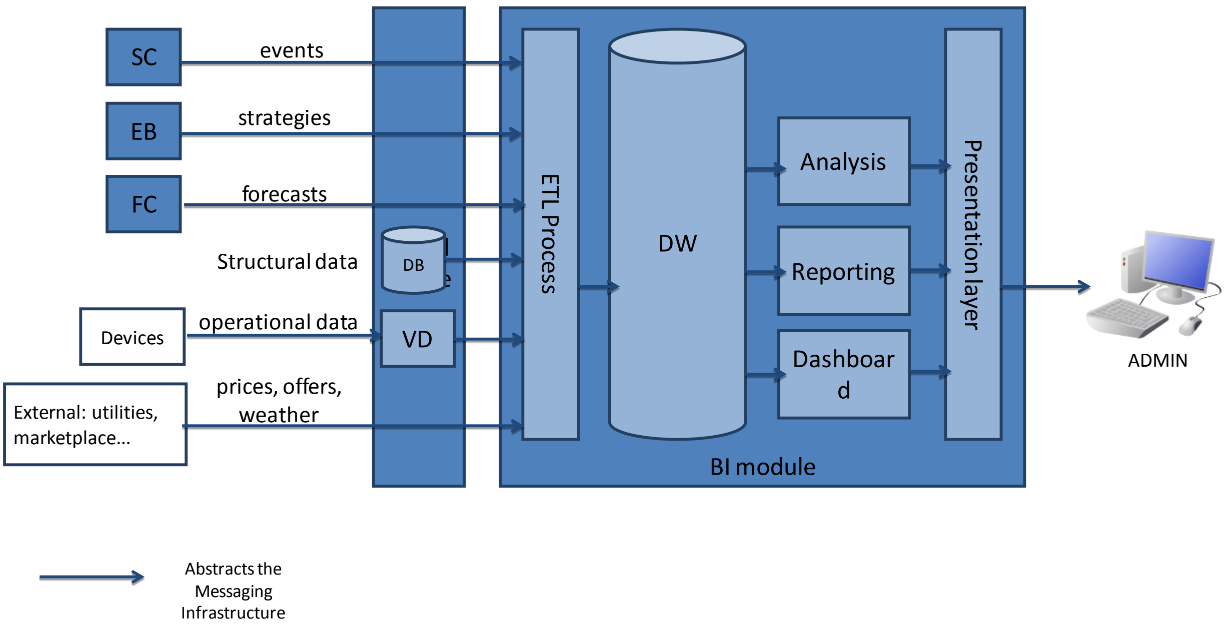


Figure 38 - Information flows involved in the business intelligence module.

The Extraction, Transformation and Load (ETL) and Integration components of the BI module will take the data from all the different data sources through the Middleware, filter them and aggregate them and load them to the Data Warehouse.

8.4.1. Database (data warehouse)

A Business Intelligence platform requires a dedicated database (Data Warehouse), where a high volume of data coming from completely different sources can be stored and organized in an integrated way. Using such an integrated database avoids common problems such as low speed access, data inconsistencies, lack of data reliability or filling the operational database with unnecessary data.

The Encourage Middleware Database ("fast" database) is designed in order to have an optimised, high speed information flow between all components. A dedicated Data Warehouse is therefore needed for the BI module to contain data that will be used to draw historical tendencies and analysis.

Moreover, the Data Warehouse only stores data that will be relevant for subsequent analysis, and ignores all other operational data. Therefore, this database focuses on the user information needs and not in the internal application and components processes.

A Data Warehouse allows as well a first level of aggregation according to the business needs. Data are already filtered, cleaned and integrated, to make sure that the same codification, units and conventions are used. Otherwise the data could be inconsistent and fine analysis would be impossible.

The following table summarises the main differences between the operational Middleware Database and the Business Intelligence Database.

Table 1 – Database main differences

Middleware Database (Operational DB)	Data Warehouse (BI dedicated Database)
All operational data	Only relevant data for analysis
Application oriented	User oriented
Detailed	Detailed and already aggregated
Continuously evolving	Stable (with daily actualizations)
No redundancy. Normalised schemes	High redundancy levels
High process speed	High queries speed, low response times

8.4.2. Data sources

As stated, the Data Warehouse will only contain data relevant for subsequent analysis in the BI Platform. Four different data sources are considered (further refinement will be done in Deliverable D6.4 [50]): structural data (from the Middleware Database), operational data (15 minutes snapshots), data or information generated by other ENCOURAGE modules and external data coming from other providers.

- Structural data (intrinsic devices properties that will allow information segmentation through some criteria for easy conclusions drawing)
    - Devices main characteristics (intensity, Cell/MacroCell, etc.).
    - Energy generation facilities characteristics (power, technology…).
    - Storage energy systems characteristics.
- Operational data
    - Energy generated and consumed, from different devices and facilities.
    - Storage levels.
    - Energy exchanges: energy sold to the market or bought to the utilities.
- Data from Encourage components
    - Supervisory Control operation.
    - Decision Support proposed strategies.
    - Generation and consumption forecasts.

- External data
  - Prices, offers and renewable electricity share from utilities.
  - Electricity marketplace prices (for selling produced energy, if applicable).
  - Weather information (forecasts or actual).
  - Energy/CO2 conversion data and other energy efficiency conversion data.
  - Consumption profiles.
  - User profiles.

8.4.3. Functionalities

- Data integration:
  - Extraction, Transformation and Load (ETL) process: it extracts the required data from different sources (internal, operational and external), transforms and cleans the data (to harmonise formats, calculations, dimensions, etc.), validates, combines and loads the data into the required format.
- Information delivery: Elaborate reports, KPIs and non-real time alerts enabling complex analyses
  - Standard and ad-hoc reporting.
  - Dashboards.
- Analysis
  - Online analytical processing (OLAP) or data mining to allow intelligent data analysis and provide knowledge to the user.

8.5. Middleware Plug-ins

The BI module makes extensive use of the ENCOURAGE Middleware Plug-ins, for the interfaces with external entities which are capable of furnishing the interaction services required by the EB&BI block.

The communication with these external services will be based on standards. The Global Forecast System (GFS) provides a numerical weather prediction model using a NOAA standard [51] and the European Centre for Medium-Range Weather Forecasts (ECMWF) [52] also provides weather forecast standard. Both can be used to interconnect with weather forecast providers. For this purpose, three different plug-ins are already identified:

- Utilities Plug-in. This plug-in will be responsible for contacting the utilities and making available several energy spot prices.

- Generation Forecast Plug-in. This plug-in allows the connection of the generation forecast external provider who will publish the forecast data.
- Weather Forecast Plug-in. This plug-in is responsible from obtaining, from an external provider, the weather forecast.

9. Conclusions

The definition of the ENCOURAGE reference platform, as well as the structure, functionalities and interfaces of its components is a fundamental task in the project, which is reflected in this document, and sets the necessary reference for the detailed specification of WP3-WP6.

ENCOURAGE provides an innovative platform allowing for its modularity, scalability and interoperability of both new and legacy systems. It provides an abstraction from the technologies within the buildings and supporting multiple independent gateways, creating the notion of a single abstract interface.

The main modules of this platform are here described, together with their structure and functionalities. Furthermore, the document defines the main interface standards to be used for interoperability. Finally, the document provides the mapping of the requirements identified in Task 2.2, identifying which modules must implement the underlying functionality.

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Appendix A. Mapping of requirements

The following table presents the mapping of the ENCOURAGE requirements, as specified in Deliverable 2.2 [1], to the ENCOURAGE architecture modules which will handle the requirement, as presented in this document.

Table 2 – Modules and components legend

Logical Block	**MW Middleware**	**EBBI Energy Brokerage and Business Intelligence**	**SC Supervisory Control**	**DM Devices Management**
Modules	MI: Messaging Infrastructure	CFC: Consumption Forecasting Submodule	LGC: Local Generation & Control	DC: Device control
	VD: Data and Virtual Device Representation	GFC: Generation Forecasting Submodule	LM: Load Management	HC: HAN Configuration
	DB: Database	EB: Decision Support for Energy Brokerage module	EM: Energy Management	VM: Virtual Metering
	CEP: Complex Event Processor	BI: Business Intelligence Module		CT: Communication Technologies for devices
	ConfDiag: Configuration and Diagnosis			
	MPG Middleware Plug-ins			

Table 3 – Requirements Mapping

ID	Rationale (The reason)	Actor	Action	Module
ENEL.1.1.40	Consumers can be represented also by associations and municipalities.		Encourage architecture must provide different level of aggregation (hierarchy) in order to allow associations of users or municipalities to assume the role of energy manager of groups of buildings and/or users	MW:VD
ENEL1.1.6	Involve users in efficiency targets	Data manager	The Encourage system should improve the energy efficiency of the building	EBBI:EB
EZM.1.1.3 + EZM.1.1.41	Well recognised industry standards and protocols should be used throughout.	Energy manager	Identified what defines types and common protocol	MW:MI MW:MPG DM:Interface
ESV.1.1.10	Construction companies and engineering service companies need to be more efficient	Data manager	To inform to construction companies and engineering services companies which investments can be done in order to move them to the energy efficiency field.	EBBI:BI
ATOS1.1.1	Improvement of consume of energy is a must	energy manager	Improve the consumption using the platform in buildings	SC:EM
ENO1.1.32	To give consumers ideas how to save energy	energy manager	Post ideas with how to save energy regarding the consumption	SC:EM, EBBI:EB
ENO1.1.28	To give prosumers opportunity to buy external supervision of solar panels and/or heat pumps	Energy manager	Sending status data from heat pump and solar panels to service provider	SC:LGC

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.19a + ESV 1.1.1 + EZM 1.1.44	The system shall monitor real-time disaggregated consumption	Energy manager	Real-time data plus recorded data	SC;EM
ADV.1.1.6	System should provide basic control (ON/OFF) for individual appliances	Energy manager	switch on/off	SC:LM
ADV.1.1.9	System has to react to events sent from the middleware (configurable alarms)	Energy manager	React according rules, e.g. send an alarm to BI & EB or a message to a user	MW:CEP
EZM.1.1.30 +EZM.1.1.5 + ENO 1.1.33 + ENO 1.1.34	Supervisory control will define algorithms to control in house devices (example increase/decrease temperature, floor heating, water tank temp, home appliances, UPS etc.... send notification)	Energy manager	Control Action	SC:LM
EZM.1.1.41	All data and user information gathered should be protected with reference to Data Information Directives / Regulations. It is important that no information can be attained by unauthorized parties.	Energy manager	Arch requirement	MW:MI
EZM.1.1.42	All data transmission must be carried out over a secure connection	Energy manager	Arch requirement	MW:MI
ENO1.1.34	To make sure the local surplus is used locally	Energy manager	By communication between the local house controls, a program makes sure that the local surplus is used local	SC:EM

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.36	To find out if the households are using more or less energy than other similar households	Data manager	Make a formular that the residence can fill out, with following questions: Size of the residence Number of inhabitants Construction year Heating system	EBBI:BI
EZM.1.1.34	The system shall monitor real-time multiple generation (co-generation, wind, solar, grid) in order to create predictive forecast	Energy manager	Real-time data recorded	SC:LGC, EBBI:GFC
EZM.1.1.45	The system should allow for certain devices to define their own constraints / critical set points	Energy manager	Apply a rule relating to critical devices	MW:ConfDiag
ENEL.1.1.36	To control customers' inertial loads to achieve peak shifting.	Energy manager	Transform high level decision into device orders (e.g. swithc on/off devices)	SC:EM, SC:LM, EBBI:CFC
ENO1.1.1	To raise the temperature in the house in case of surplus production or financial advantage. Otherwise and in case that solar cells are not producing electricity, the temperature can be lowered.	energy manager	If surplus or financial advantage the house control should raise the temperature in the house	SC:LM
ENO1.1.37	To store energy in the heat pump	energy manager + device manager (monitoring)	When there is surplus in the grid or financial advantage for the residents, the house control should tell the heat pump to raise the temperature in the water storage.	SC:EM

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.11	Decisions must be performed by a rule-based engine, e.g:To Avoid bacterial growth, the temperature in the hot water tank has to be raised to over 80°C once a week	energy manager	Execute control law: Wireless regulator and wireless communication to existing regulator to the hot water tank to raise the water temperature	SC:LM, MW:DB
ENO1.1.38	To store energy in building materials	energy manager + device manager (mgmt)	Look at possibilities to use new kind of building materials where it is possible to store energy.	SC:EM
ENO1.1.39	To store energy in geothermal pipes	energy manager + device manager (control)	Look at possibilities to store energy in the geothermal pipes.	SC:EM
ENO1.1.4	Energy Manager has to control the heating of the house	energy manager + device manager (monitoring)	Wireless temperature transmitters sending room temperature to the house control	SC:LM
ENO1.1.40	To use surplus energy to recharge an UPS system	energy manager + device manager (control)	To recharge an UPS system	SC:EM
ENO1.1.41	To save energy when the residence is empty or asleep	energy manager + device manager (monitoring)	Lover the temperature in the house when the house is stand by for a longer period like during nights, holidays etc.	SC:LM

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.5	Energy Manager has to control the set point of heating in the house	energy manager + device manager (control)	Connection to the heating system with information about raising or lowering the temperature.	SC:LM
ENO1.1.7	To use the washer and dryer when the electricity is produced.	energy manager + device manager (control)	Wireless relay on wire to the washer	SC:EM, SC:LM
ENO1.1.8	To lower the temperature of fridge and freezer when surplus production	energy manager + device manager (control)	Wireless regulator to control the temperature in the fridge and freezer	SC:EM, SC:LM
ENO1.1.9	To raise the temperature of the hot water tank when electricity is produced	energy manager + device manager (control)	Wireless regulator and wireless communication to existing regulator to the hot water tank to raise the water temperature	SC:EM, SC:LM
ENO.1.15	To turn off lights using motion sensors and/or sound detectors to make sure the consumers do not use unnecessary energy.	device manager (control)	Shut down the light in the room.	SC:LM
EZM.1.1.36 + ENO1.1.6	System needs to monitor external influences (external climate)	Energy manager	External sensors active	EBBI:GFC, SC:LGC
ENO1.1.24 + EZM 1.1.15	The system should be capable of sending event / rules driven emails, Text message. Private twitter feeds or IM should also be considered. E.g. Triggered when consumption is over budget	Energy manager	Notification Sent	EBBI:BI, MW:MI

ID	Rationale (The reason)	Actor	Action	Module
ENEL.1.1.2	Improve participation of users to network operation	Energy Manager	The system must have intelligence on board. The control logic has to be embedded in the system rather than centralized	EBBI:EB
ENEL.1.1.27	Utility companies need to increase customers' fidelization and reduce churn rates	Brokerage Manager	Encourage system must provide energy management strategies which enable the customer to comply with utility's tariffs schemes	EBBI:EB
ENEL.1.1.3	Improve participation of users to network operation	Brokerage Manager	Define a remuneration framework	EBBI:EB
ENEL.1.1.32	Utility companies need to find out a business model for the integration and management of distributed generation and storage at customers' premises.	Brokerage Manager	Encourage business intelligence and energy brokerage strategies must take into account the presence of generation and storage at customers' premises	EBBI:EB
EZM.1.1.46	The system shall allow the users to make localised decision on energy brokerage	Energy Manager	Accept or reject offer	EBBI:EB
ENO1.1.45	To make it possible to cope with ordinary electrical retailer business such as annual reading of the electricity meter, see the bill and give notice of relocation.	Brokerage Manager	To make a website with access to the utility company	EBBI:EB EBBI:BI
ENO1.1.47	Send information about the current electricity prices to the consumers to make the consumers aware about the advantage of changing prices.	Brokerage Manager	To send information about the prices	EBBI:EB

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.47	The system shall display all collected data, allowing for efficient analysis of metrics, reports and summaries	Energy Manager	Report provided	EBBI:BI
ISE.1.1.4	Owners of micro-generation and producers buy and sell electricity between them	Energy Manager	Receives prices, send buy others. All synchronized and with deadlines	EBBI:EB
EZM.1.1.27	The system should manage local tariff	Brokerage Manager	System alters tariff	EBBI:EB
EZM.1.1.37	The system should broker energy distribution between building	Brokerage Manager	Energy sharing with local	EBBI:EB
ENO1.1.43	To change the settlement rules, so it gets advantageous to use surplus energy	Brokerage Manager	Make business cases and user cases that shows that if we changes the settlement rules we can get residential to use surplus energy when it is available	EBBI:EB
ENO1.1.44	To trade renewable surplus energy between residential buildings in the local area	Brokerage Manager	Make business cases and user cases that shows that if we changes the settlement rules we can get residential to use surplus energy in the local area when it is available	EBBI:EB
ENO1.1.46	To buy energy to hourly variable prices for consumers with energy use under 100.000 kWh/year	Brokerage Manager	Make business cases and user cases that shows that if we changes the settlement rules we can get residential to use energy when it is cheap (out of the peak time)	EBBI:EB
ESV.1.1.11	Possibility to receive energy from surrounding energy producers	Energy Manager	To communicate energy needs directly with surrounding energy producers.	EBBI:EB

ID	Rationale (The reason)	Actor	Action	Module
ISE.1.1.11	In case of renewable surplus energy in the grid start storing energy using the heat pump or other storage mean.	Energy Manager	Store energy where it is possible	EBBI:BI SC:LGC
ENEL.1.1.28	Utility companies need to increase customers' fidelization and reduce churn rates	Brokerage Manager	Encourage system must provide alarms and suggestions to the customer to support him in respecting his tariff constraints	EBBI:BI
EZM.1.1.33	The system should be capable of monitoring multiple industry sources (Utilities) in a changing energy context	Brokerage Manager	All utilities recorded	EBBI:BI
EZM.1.1.34	The system shall monitor real-time multiple generation (co-generation, wind, solar, grid) in order to create predictive forecast	Brokerage Manager	Real-time data recorded	EBBI:BI MW:DB
ENEL.1.1.36	To control customers' inertial loads to achieve peak shifting.	Energy manager	Take high level decisions related to peak shifting	EBBI:BI
ENEL.1.1.18	Customers' profiles show load shifting capability to accomplish distribution network operation support services.	Energy Manager	Load Control strategies must include as objectives the respect of day-ahead requirements related to consumption profile	EBBI:BI
ENO1.1.42	To make it easy for the consumer to enter new price agreements with the retailer	Energy manager	To make a website where it is possible to enter new price agreements.	EBBI:BI
ISE.1.1.1	Smaller customers (yearly consumption under 100.00 kWh) can act according to spot prices.	Brokerage Manager	Apply an algorithm for energy retail/consumption, within a deadline	EBBI:BI

ID	Rationale (The reason)	Actor	Action	Module
ISE.1.1.5	Cogeneration companies monitor the evolution of electricity market prices in order to better adjust their load factor.	Brokerage Manager	Obtain market prices within a deadline	EBBI:BI
ENO1.1.19b	Predict the consumption of a house	Energy manager	Predict consumption	EBBI:CFC
ENO1.1.28	To give prosumers opportunity to buy external supervision of solar panels and/or heat pumps	Energy manager	Sending status data from heat pump and solar panels to service provider	EBBI:EB
ENO1.1.36	To find out if the households are using more or less energy than other similar households	Data manager	Make a formular that the residence can fill out, with following questions: Size of the residence Number of inhabitants Construction year Heating system	EBBI:BI
ESV.1.1.7	Investment costs are too high and energy saving too low in the residential sector		To suggest measures to reduce investment costs and increase energy savings, especially within the residential sector	EBBI:BI
ENEL.1.1.11	Improve efficiency of HVAC	Energy manager	Ambient temperature monitoring. Use temperature inertia of the building	SC:LGC
ENEL.1.1.21	It is necessary to develop a platform to manage large data volume together with data synchronization in a central repository	Data manager	Middleware has to provide HW and SW tools to store and manage large amount of data related to environmental, consumption and device data	MW:MI, MW:DB
ESV.1.1.6	Building users need to know how energy is consumed in the building and which is the carbon footprint of their daily activities in the campus.	Energy manager	To give each user a feedback of energy consumption of their daily activities in the campus.	MW:VD

ID	Rationale (The reason)	Actor	Action	Module
ESV.1.1.8	Building users being comfortable in the building	Energy manager	To preserve comfort in buildings' spaces	SCS:LM
ESV.1.1.9	Energy consumption is too high and energy manager needs to lower it	Energy manager	To inform about the high levels of energy consumption	MW:MI, MW:CEP
ATOS1.1.2	Existing energy management systems have to be compatible with encourage platform	Data manager	Take into account existing energy management systems in the design of the platform to ensure the interoperability of them with the platform	MW:MI MW:MPG
EZM.1.1.10	The system shall allow an administrator to add, remove, modify and view all event on the system	Energy manager	Administrator Action	MW:ConfDiag
EZM.1.1.13	The system shall allow an administrator configure the end-users information collected by the system	Energy manager	Administrator Action	MW:ConfDiag
EZM.1.1.16	User has the ability to override an automated threshold set by the system upon notification, example "we have set your heating up by 2 degrees" To accept do nothing, to override reply "stop"	Device manager	User cancelled suggested action	DM:DC
EZM.1.1.31	The UI may include energy efficient tips increasing awareness of energy consumption	Data manager	System provides tips	EBBI:BI, MW:CEP

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.38	Diagnostic analysis of connected peripheral devices in order to ensure efficiencies . The frequency of analysis of the devices must be prioritized according to the importance of the devices.	Data manager	Device degradation detected, send notification	MW:ConfDiag
EZM.1.1.7	The system shall support user interaction to set thresholds	Energy manager	User sets a threshold on Web UI	MW:VD
EZM.1.1.8	A User Interface is used to publish information on events and to allow home users to access their localised system.	Data manager	User Requests	MW:VD
EZM.1.1.9	The system will allow multiple UI's to communicate and distribute the information (mobile devices, web-enabled devices) To improve user awareness of energy consumption, by visualizing consumers' behaviour, comparison of costs -with/without smart mode-, yearly overview of consumption and saved money and emissions, and guidance on energy savings, through an intuitive user interface (accessible from PCs, tablets and smartphones).	Data manager	User Requests	MW:MI

ID	Rationale (The reason)	Actor	Action	Module
ENEL.1.1.24	Utility companies need to fulfil European objectives 20-20-20 and improve their image and their environmental position	Energy manager	Encourage system must include functionalities for the measurement and presentation of energy savings and reduction obtained from the application of energy management strategies. Users needs to see the amount of energy saving compared with an energy consumption profile benchmark.	MW:VD
ENEL.1.1.25	Utility companies need to fulfil European objectives 20-20-20 and improve their image and their environmental position	Energy manager	Obtained results must be publishable at utility level and usable as green certificates	MW:VD
ENEL.1.1.28	Utility companies need to better understand, through customers' behaviour, how to develop more fitting tariffs and services to be delivered	Brokerage manager	Encourage system must allow, when agreed with the retailer, the transfer of a subset if customer's data to the retailer.	MW:MI
ENEL.1.1.39	All possible stakeholders have to be involved during the project development in order to take into account their needs and verify if the project results are adequate to their expectations	Energy manager	User's interfaces design has to be submitted to final users in order to verify if it fulfils its objectives	MW:VD, EBBI:BI

ID	Rationale (The reason)	Actor	Action	Module
ENEL.1.1.4	The technology can´t stand alone therefore it is important to involve the users in the efficiency targets	Energy manager	The system shall of course be at the user oriented language, and according to the observed behaviour it make suggestions to the user about behaviour. The communication with the user should be notifications in a inbox or a web place	MW:VD, EBBI:BI
ENEL.1.1.47	The promotion of smart appliances should be supported by independent institutions, like governmental institutions on national and European level and by consumer organizations.	Energy manager	Web site links to institutions and government agencies, independent consumers organizations should be included in web applications oriented to guide customers' energy behaviour	MW:VD
ENEL.1.1.7	Involve users in efficiency targets	Energy manager	A User Interface should show abnormal consumption of monitored devices	MW:CEP, MW:VD
ENEL.1.1.8	User needs to be aware of their consumption profile	Energy manager	An analogic indicator (for power consumption or total daily energy) may be implemented in the user interface. Analogic indicator like the speedometer of a car dashboard could be a common and easy to understand indicator.	MW:VD
ENEL.1.1.9	User interface has to be simple and clear	Data manager Device manager	Show consumptions and energy saving not in kWh or CO2 tons but in monetary units or equivalents (like "saved trees")	MW:VD, EBBI:EB, MW:ConfDiag
EZM.1.1.1	The system should be scalable and modular	Data manager Device manager	Ensure System design meets requirement	N/A

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.18	The system should allow an administrator to configure user ID and passwords for the system	Energy manager	Administrator Action	MW:ConfDiag
EZM.1.1.19	Users shall be able to self-register on the system using web client with email authentification	Energy manager	User registers via web	MW:ConfDiag
EZM.1.1.20	The system shall allow the administrator to configure the cost scale for thresholds in both monetary and unit measurement	Energy manager	Administrator alter cost scale	MW:ConfDiag
EZM.1.1.21	The system shall output information in Text, Xml or CSV file format capable of been imported into existing Utility billing platforms. It is up to the Utility to develop a way of integrating this information into their billing system	Data manager	System allows request	MW:ConfDiag, EBBI:BI
EZM.1.1.22	The system shall allow end-users to give feedback on the solution via social networking	Energy manager	User sends feedback	N/A
EZM.1.1.24	The system shall allow reports to be gene-rated. The reports shall be possible to filter using the key capture metrics	Data manager	System generates report	MW:MPG, EBBI:BI
EZM.1.1.25	The system shall allow end-users to download usage metric	Energy manager	Usage metric provided	MW:MPG, EBBI:BI
EZM.1.1.26	The system shall produce graphs and statistics of current and historic energy usage and any savings based on intelligent use	Data manager	Graph provided	MW:MPG, EBBI:BI

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.32	The system integration model should be dynamic to cater for new and legacy buildings and systems	Data manager Device manager	New devices added for building	MW:VD MW:DB
EZM.1.1.35	Energy Storage commences based on surplus, availability or tariff	Energy manager	Energy storage commences	SC:EM
EZM.1.1.39	The Encourage Platform should make available API's allowing third party interfaces. The availability must be based on a given standard.	Data manager	API published to third party	MW:MPG
EZM.1.1.40	The system shall allow the manipulation of data for comparison purposes (Compare similar households)	Data manager	Comparison drawn between 2 households	MW:MPG
ADV.1.1.10	System should support rules definition (by user/admin)	Energy manager	set alarms/thresholds	MW:VD
ADV.1.1.12	System should provide capability to configure/reconfigure monitoring devices	Device manager	set config. param	MW:ConfDiag
ADV.1.1.4	System should provide individual appliances energy consumption monitoring, where it is possible and makes sense.	Device manager	individual monitoring	MW:VD, DM:VM
ADV.1.1.5	System should provide branch-level energy consumption monitoring	Data manager	branch-level monitoring	MW:MPG
EZM.1.1.11	The system shall allow an administrator to list a summary of all events on the system	Energy manager	Administrator Action	MW:MPG

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.14	The system shall allow the administrator to override any data set by end-user that has access to the system (emergency uses ++	Energy manager	Administrator Action	MW:ConfDiag
ISE.1.1.12	Consumers may follow their current energy consumption in real-time through speedometer display or similar.	Energy manager	Periodically send info about consumption	MW:MPG
ISE.1.1.2	Utility companies can disconnect selected household items during peak demands, if the customers has signed a contract with the grid manager.	Brokerage manager	Connect or disconnect household items, within a deadline	DM:DC, MW:VD
ISE.1.1.3	Utility companies need to know the load state and the surplus production of the grid in real time.	Brokerage manager	Obtain synchronized load readings, within a deadline, and share the information with the local building to act on	SC:LGC
ESV.1.1.3	Building users need to be motivated to reduce energy consumption and achieve energy savings	Energy manager	To suggest measures to motivate building users.	EBBI:EB
EZM.1.1.4	The system should support threshold rules and values, which can be set on over-ridden by the users / administrator	Energy manager	User sets a threshold on Web UI	MW:ConfDiag DM:DC
ENO1.1.31	To reward consumers who are good at using renewable energy	Energy manager	To store information the residential uses the energy	EBBI:EB
ENO1.1.29	To be able to follow current and historical energy consumption	Energy manager	To show the monitoring data on a website	MW:DB, MW:MPG
EZM.1.1.17	The system shall allow information to be sent to all registered users	Data manager	Information sent to user	MW:MPG

ID	Rationale (The reason)	Actor	Action	Module
EZM.1.1.2	All kinds of common household devices, conformant with the Encourage implemented standards, can be added to the system.	Device manager	Identified what defines types and common protocol	MW:VD, MW:ConfDiag MW:MPG
EZM.1.1.41	The system shall allow automatic detection of new and old devices and seamlessly interact with them. The design must include the possibility of being easily upgradeable, so that future devices will be capable of being adapted to the network without much trouble.	Device manager	Arch requirement	MW:ConfDiag, MW:VD MW:MPG
EZM.1.1.29	The system shall monitor real-time Utility tariffs where possible	Energy manager	System alter Utility prices	MW:MI, MW:VD
ENO1.1.31	To reward consumers who are good at using renewable energy	energy manager	To store information the residential uses the energy	EBBI:EB
ENO1.1.29	To be able to follow current and historical energy consumption	data manager	To show the monitoring data on a website	MW:DB, MW:MPG
ATOS.1.1.1	Improvement of consume of energy is a must	energy manager	Improve the consumption using the platform in buildings	N/A
ENO.1.1.4	House control has to control the heating of the house	energy manager + device manager (monitoring)	Wireless temperature transmitters sending room temperature to the house control	SC:LM, DM:CT
ENO.1.1.3	Sub metering of local energy production	energy manager + device manager (monitoring)	Sub meter sending information about production to the house control.	DM:VM, DM:CT

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.5	House control has to control the set point of heating in the house	energy manager + device manager (control)	Connection to the heating system with information about raising or lowering the temperature.	DM:VM, DM:CT
ENO.1.1.25	To make it possible to monitor water and heat consumption	device manager (monitoring)	Make a wireless device to get data from meters	DM:CT
ENO.1.1.3	Sub metering of local energy production	device manager (monitoring)	Sub meter sending information about production to the house control.	DM:CT
ENO.1.1.14	To detect motion in rooms	device manager (monitoring)	Wireless motion detector which can detect activity and send the information to the house control	DM:CT
ENO1.1.20	To make outdoor temperature compensation	energy manager + device manager (monitoring)	To send information to the heating control system about raising or lowering the flow temperature	DM:CT, SC:EM
ENEL.1.1.17	Energy strategies development can take into account the accomplishment of demand side service.	brokerage manager	Smart metering features must include capability of measuring on a quarter of an hour basis in order to be complaint with demand side services	SC:EM, DM:CT EBBI:GFC EBBI:CFC
ENO.1.1.41	To save energy when the residence is empty or asleep	energy manager + device manager (monitoring)	Lover the temperature in the house when the house is stand by for a longer period like during nights, holidays etc.	DM:CT, SC:LM
ENO1.1.6	House control has to measure the outside temperature to decide if heating is needed.	energy manager + device manager (monitoring)	Wireless temperature transmitters sending the outside temperature to the house control	DM:CT, SC:LM

ID	Rationale (The reason)	Actor	Action	Module
ENO1.1.7	To use the washer and dryer when the electricity is produced.	energy manager + device manager (control)	Wireless relay on wire to the washer	DM:CT, SC:LM
ENO.1.1.8	To lower the temperature of fridge and freezer when surplus production or financial advantage	energy manager + device manager (control)	Wireless regulator to control the temperature in the fridge and freezer	DM:CT, SC:LM
ENO.1.1.9	To raise the temperature of the hot water tank when electricity is produced	energy manager + device manager (control)	Wireless regulator and wireless communication to existing regulator to the hot water tank to raise the water temperature	DM:CT, SC:LM
ENO.1.15	To turn off lights using motion sensors and/or sound detectors to make sure the consumers do not use unnecessary energy.	device manager (control)	Shut down the light in the room.	DM:CT, SC:LM