Use Cases

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Introduction

Energy@home is a collaborative project between Electrolux, Enel, Indesit and Telecom Italia.

The aim of the project is to develop a communication infrastructure that enables provision of Value Added Services based upon information exchange related to energy usage, energy consumption and energy tariffs in the Home Area Network (HAN). The project envisions a protocol that shall be used to build an integrated platform to allow cooperation between the main devices involved in residential energy management:

- The **Electronic Meter**, responsible for providing certified metering data. The meter shall be interfaced via a new-generation device called Smart Info to enable communication with the telco infrastructure and the household appliances;
- The **Smart Appliances**, able to cooperate in order to adjust power consumption by modifying their behavior, while preserving the quality of service and user experience;
- The **Smart Plugs,** able to collect metering data and to implement a simple on/off control on the plugged energy loads other than Smart Appliances;
- The **Home Residential Gateway**, which acts as the central coordinator of the entire home. It allows data exchange between the devices operating in the Home Network, in the Home Area Network, and in the Internet;
- The **Customer Interfaces**, i.e. all the devices used by the customer to monitor and configure his/her energy behavior.

These actors identify the main categories of devices in the Home Domain, without any limitation to the possibility for a device to implement functionalities from more than a category. As an example, an advanced Smart Appliance, provided with a rich user interface, could also implement functionalities typical of a Customer Interface. In the same way, a personal computer might be considered a Smart Appliance from the protocol point of view if it was able to behave like a white good within the HAN.

From a **functional point of view**, Energy@Home envisions a system that can provide users with information on their household consumption directly on the display of the appliance itself, on the smart phone or on their computer. It is expected that, through easy access to information on consumption and through the possibility of downloading custom applications, consumers will be able to use their appliances in a “smart” way by enhancing the energy efficiency of the entire house system. For instance, Smart Appliances can start functioning at non-peak (and therefore less expensive) times of day as well as they can cooperate to avoid overloads by automatically balancing consumption without jeopardizing the proper execution of cycles.

The project is a further step towards the development of the so-called "**smart grid**", that, in the future, will allow continuous real-time two-way information exchange between utilities and appliances in the houses to enable each customer to “self-manage” his/her energy behaviors depending on power supply and prices.

Energy@home aims to **leverage existing standards**, in particular the Zigbee wireless technology, the Smart Energy and Home Automation ZigBee Application Profiles. If and where needed, these profiles will be extended and customized in order to fulfill the requirements of the project. The resulting protocol will be open to any stakeholder that will be free to define its own services and supporting business models, while being assured that the common communication platform will be able to ensure interoperability among platform of different vendors. Although the definition of services and business models is explicitly outside the scope of the project, partners have decided to perform a first assessment of the different categories of services that should be supported by the communication platform in order to ensure full support for a wide range of energy applications.
For this reason, this first deliverable of the project is the "Energy@home Use Cases" document, where the system architecture is presented together with reference application scenarios. In the document, different type of services are defined, taking into account incremental levels of interoperability in order to provide clients with different levels of service, starting from simple awareness, until the achievement of a fully integrated Energy Management system. The first release of the Use Cases has been identified taking into account the experience of the partners involved in the project and constitutes the initial set of functionalities that shall be addresses by Energy@home. Further versions of the document are envisaged during the development of the project, whenever partners shall identify the chance to implement supplementary categories of services for clients also taking into account additional experiences and points of view.

The project goal will be pursued through the following plan of milestones:

M1. identification of use cases relevant to the protocol and definition of the system architecture;
M2. definition of the protocol by leveraging existing standards and integration of partner's devices to implement a system prototype;
M3. assessment of the protocol and of the prototypes interoperability
M4. proposal of a pilot market test which will involve selected customers throughout Italy.

Companies' Profiles

Enel is Italy's largest power company, and Europe's second listed utility by installed capacity. It is an integrated player which produces, distributes and sells electricity and gas. Further to the acquisition of the Spanish utility Endesa, Enel has now a presence in 23 countries with over 95,000 MW of net installed capacity and sells power and gas to around 61 million customers. Enel was the first utility in the world to replace its 32 million Italian customers' traditional electromechanical meters with modern electronic devices that make it possible to take meter readings in real time and manage contractual relationships remotely. This innovation has enabled Enel to implement time-of-use electricity charges, which offer customer savings for evening and weekend electricity use, an initiative that has attracted interest from many utilities around the world, especially in Spain where Enel's subsidiary Endesa is about to install 13 million electronic meters to its customers.

Electrolux is a global leader in household appliances and appliances for professional use, selling more than 40 million products to customers in more than 150 markets every year. With a culture of passion for innovation, customer obsession and drive for results, the company uses thoughtful

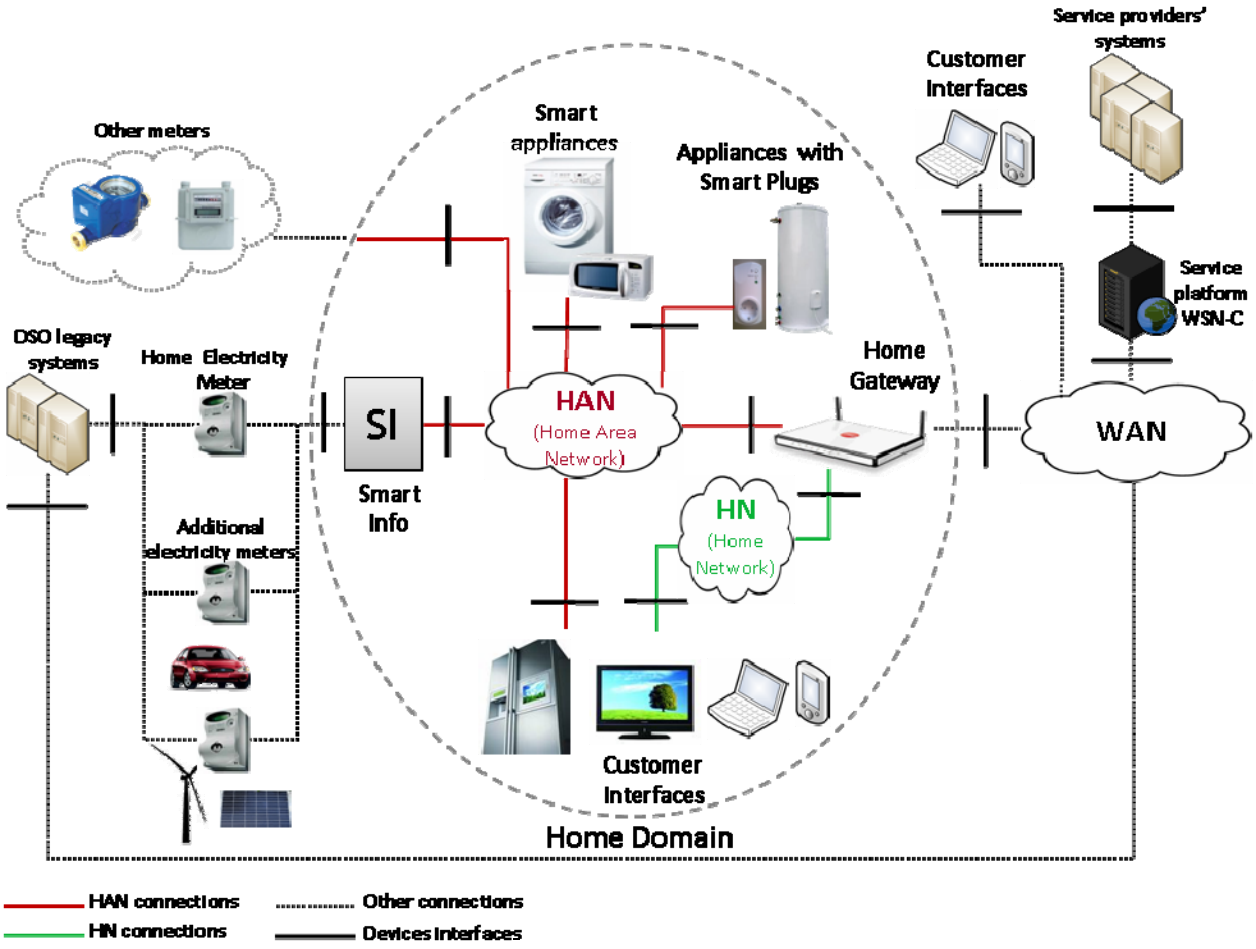
design and extensive consumer insight to meet the real needs of consumers and professionals. Electrolux products include refrigerators, dishwashers, washing machines, vacuum cleaners and cookers sold under esteemed brands such as Electrolux, AEG-Electrolux, Eureka and Frigidaire.

Indesit Company is one of the European leading manufacturers and distributors of major domestic appliances (washing machines, dryers, dishwashers, fridges, freezers, cookers, hoods, ovens and hobs). It is the undisputed leader in major markets such as Italy, the UK and Russia. Founded in 1975 and listed on the Milan stock exchange since 1987, the Group posted sales of €2.6 billion in 2009. Indesit Company has 16 production facilities (in Italy, Poland, the UK, Russia and Turkey) and 16,000 employees. The Group's main brands are Indesit, Hotpoint-Ariston and Scholtès.

Telecom Italia is an integrated telecommunications company that operates mainly in Europe, the Mediterranean basin and South America. It is a major Italian enterprise and a key European strategic ICT player. Driven by technological innovation and a commitment to service excellence, Group companies operate in fixed-line and mobile telecommunications, Internet & Media, Information Technologies.

1 System architecture

In the following picture, the overall system architecture is presented.



The part inside the dotted area (that includes both the HAN and the HN) is user's Home Domain, where all the actors (Smart Appliances, Home Gateway, Smart Info and Customer Interfaces) can cooperate through some communication mechanism. All the depicted interfaces are logical ones and could be implemented through one or more communication technologies.
The aim of this document is to identify and describe the requirements of the Energy@Home indoor platform; it is expressly out of the scope of this project the definition of the other interfaces and services provided through them outside the Home Domain.

Main actors in the Home Domain are (for the exact definition see Glossary.doc):

- **Smart Appliances:** an evolution of the actual and standard white goods; see hereunder some of their possible new functionalities:
  - Display to the customer information on their energy consumptions (e.g. used energy ,instant power,…)
  - Dispatch in the HAN information on their energy consumptions (e.g. used energy , instant power,…)
  - Autonomously adapt their behavior according to information on energy consumptions coming from the house. (e.g. reduce their load when global house consumptions goes beyond a threshold,…)
  - Cooperatively operate with other entities in order to optimize the energy usage through load shifting and load shedding.

  In any case, the load control operations, either performed autonomously or under an external supervision, shall be performed under the complete control of the appliance, which assures the correct execution of its working procedure and its results and performances. For example, a smart washing machine, when requested to modify its consumption behavior, shall assure the result of the washing cycle.
  Smart plugs (able to provide remote metering and to be remotely controlled) could be somehow included in the Smart Appliances category although they can provide no direct control over the effect of remote control activities; Smart Appliances will not be controlled by Smart Plugs

- **Customer Interfaces:** see hereunder some of their possible functionalities:
  - Display information on energy usage like instant power, historical data, contractual information and similar, from the whole house (coming from the Smart Info) and from every single smart appliance. The level of details and graphical layout of their user interface is freely defined by every device.
  - Transmit control message to Smart Appliances to request a modification of their behavior
  - Configure Smart Appliances to modify their power consumption profile (e.g. a personal computer used to configure a thermostat to activate the controlled load only in certain time slots).

  The Customer Interface, from this perspective, is connected in the HN/HAN; it is foreseen the possibility to have Customer Interfaces accessing the house from the WAN through a specific interface, but the definition of this interface is out of the scope of the Energy@Home project as previously stated.
  Typical Customer Interfaces are personal computers, Smart Phones, PDAs, ad hoc displays, entertainment systems, in-house monitor and similar. The software application, which implements the user interface, could be local in the device or remotely hosted in another device (e.g. the Home Gateway) and accessed through web-services.

- **Home Gateway:** it is the gateway between the HAN, the HN and the WAN (e.g. internet). It is able to interface Smart Appliances and other user's devices (e.g. PC) through the communication protocol(s) used in the HAN (e.g. ZigBee) and in the HN (e.g. IP/http) and to provide a broadband connection to internet (usually via a standard ADSL connection). Moreover, the Gateway is able to collect energy data from the Smart Info and additional

information from Smart Appliances, publish them in the HAN and in the HN and use all collected data to control Smart Appliances and optimize their behavior. Finally, the gateway can offer a web user interface and provide an Execution Environment (e.g. OSGi framework for Java) to host third-party application (e.g. a SW component implementing the algorithm to calculate the energy price at a given time, provided by the Energy Retailer).

Smart Info: it is the element, provided by the DSO, which dispatches energy related information into the HAN. Published data are a sub-set of those already available inside the Home Electricity Meter, hence the Smart Info acts like a proxy of the meter. Additional data could be possibly generated by the Smart Info itself. Noticeably, near real-time instant power (sampled at of about 1 Hertz frequency or higher) should be acquired by another metering device, likely embedded inside the Smart Info. Additional elements (SI') can also be provided by third parties and used to dispatch data generated by other meters into the HAN.

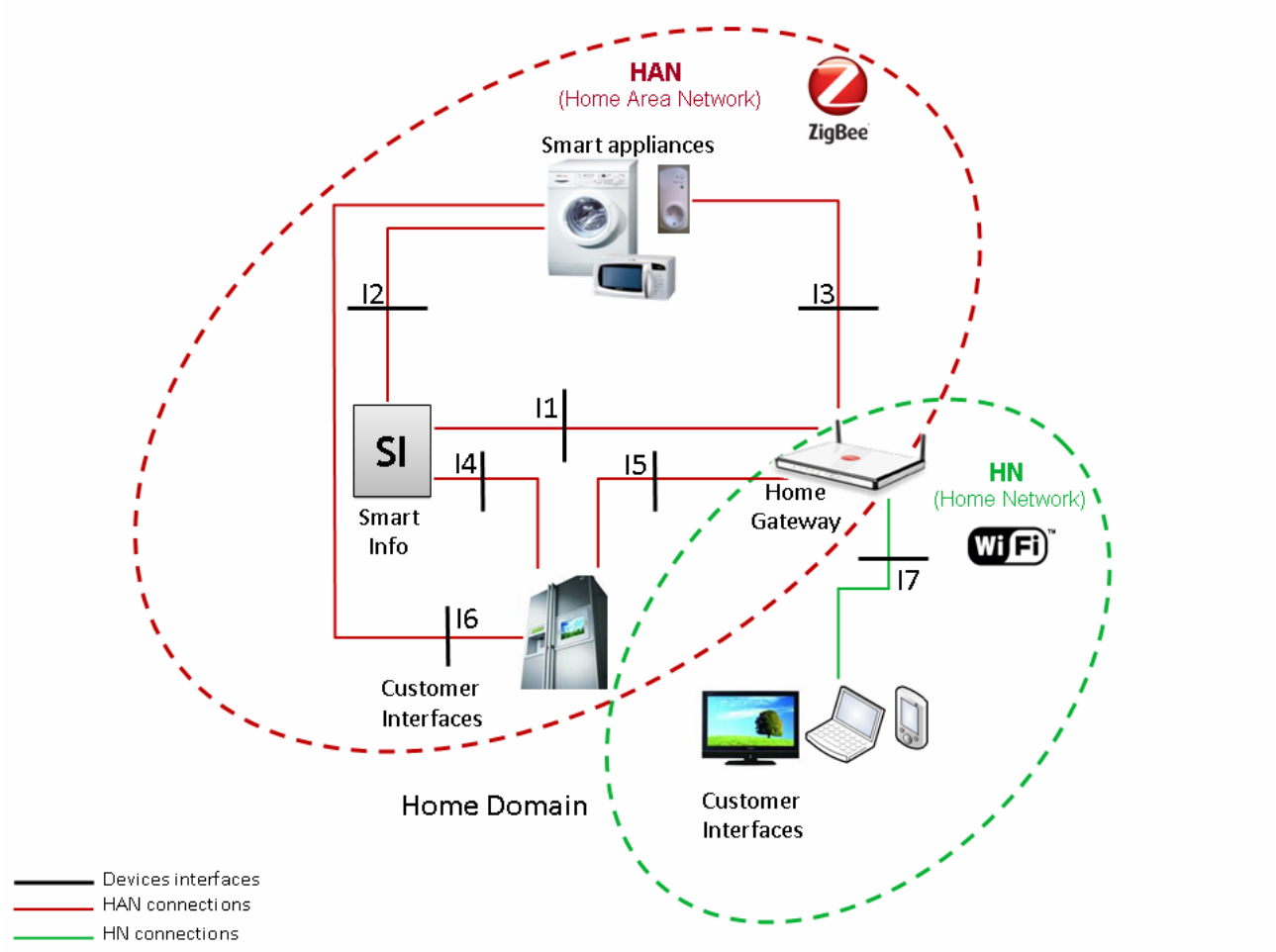
Outstanding components outside the Home Domain are:

- **WSN-C:** Wireless Sensor Network Center: it manages, together with the Home Gateway, the HAN devices and provides service oriented interfaces for the development of third-party applications.

- **Home Electricity Meter:** An electric meter, able to measure and record usage data in time differentiated registers, and capable of transmitting such data to central utilities system. Moreover, the meter should provide bi-direction communication to allow remote management of the meter.

Note: the proposed classification is mainly intended to identify the main categories of devices in the Home Domain, without any limitation to the possibility for a device to implement functionalities from more than a category. As an example, an advanced Smart Appliance, provided with a rich user interface, could also implement functionalities typical of a Customer Interface. In the same way, while typical smart appliances are smart white goods, also a personal computer, able to perform such operations, should be considered an appliance from this perspective.

In the following picture the in-home domain and related logical interfaces are presented in more details, together with two network levels: HAN and HN (ZigBee and Wi-Fi are mentioned just as an example of two possible communication technologies).


HAN
(Home Area Network)
ZigBee
Smart appliances
I2
I3
I1
SI
Smart
Info
I4
I5
Home
Gateway
HN
(Home Network)
Wi Fi
I7
I6
Customer
Interfaces
Home Domain
Customer
Interfaces
Devices interfaces
HAN connections
HN connections

2 Use cases

Use cases have been organized into clusters of scenarios and they maintain a unique incremental number in order to make them easily identifiable.
We define different incremental levels of functionalities of the Energy@Home System:

- Customer Awareness
- Appliance Regulation

Moreover it will be important to define some auxiliary use cases related to the set up and maintenance of the Network itself, not strictly related to the Energy Management of the house.
Let's describe all of them in detail:

2.1 Customer awareness

The goal of this first level of functionalities is to enhance customer awareness about her/his energy consumption by displaying some useful energy related data. The appliance will not suggest directly to the customer any related action.

2.1.1 Scenario 1: Visualization of current energy and power data

The aim of following use cases is to provide customer with information on the current situation of her/his consumptions.

Title	1.1 Visualization of global current metering data from Smart Meter and DSO	
Description	The customer is presented with information about the global current energy consumption of his/her house. Data are provided by the Smart Info, which retrieved them from the Meter and, possibly, integrates those data with near real-time power, measured by an extra module. Among the data coming form the Meter no information about costs are provided, hence any reference to the current tariff shows just which is the active tariff at the moment, but not the pricing. In this context "current" means near real time data and the consumptions of last few hours or days. Data can be presented in different formats (plain numbers, graphics, tables, etc.) in the Smart Appliance or in the Customer Interface. In this Use Case the Gateway is not strictly necessary; its presence would allow a number of extra functionalities described in the Gateway column.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Provides a sub-set of data contained in the Smart Meter and, eventually, instant power, calculated by the SI itself or another device connected to it.	Hosts a Web application that collects data from HAN devices and organizes them for a user-friendly presentation.	Receive over the HAN (from Smart Info) global current metering data and total in-house energy consumption. Display a sub-set of available

Data are dispatched upon request and in case of transition (only for slowly changing data). The Smart Info performs no elaboration over the data retrieved by the Meter, except the basic processing required to retrieve, validate, memorize and dispatch them. For example, load profile shall be dispatched with the same level of resolution available in the meter (e.g. 15 minutes). Any operation needed to change Meter data resolution or to integrate them with instant power, shall be performed by the device which displays data to the customer.	Exposes a web-based API over IP HN that can be used by 3rd party applications that wishes to elaborate current data and provides a different visualization. Implements an Execution Environment (e.g. OSGi framework for Java) to host 3rd party applications that wishes to elaborate current data and provides a different visualization. Implements a Trust Agent to manage all security keys of the HAN; this functionality can be implemented via collaboration with the WSN-C Service Platform Implements the communication with the WSN-C Service Platform and provides APIs to mediate communication between local bundles and WSN-C Service Platform.	data, depending on the richness of its user interface

Title	1.2 Visualization of global current metering data + cost information	
Description	This Use Case extends UC 1.1 adding also information about the cost of the used energy. According to rules imposed by the Authority, the DSO could not be allowed to provide such information, being the Energy Retailer the only subject entitled to define final rates for clients. (see notes below).	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
At least the same as UC 1.1 In addition, in case of time-of-use (TOU) pricing, the Smart Info can emit signal in the HAN, whenever a tariff change is taking place. (see notes below).	Same as UC 1.1 The Home Gateway hosts a dedicated algorithm, the *Energy Cost Algorithm*, to evaluate energy costs obtaining (either via a proper code or a proper form to be filled by user or a remote web site to gather the information) the cost information. Moreover, implements a proper web application to display both cost and energy consumption. In addition, this interface shall also provide a way to obtain the cost per kWh. The exact moment when a	Same as UC 1.1 + cost information if this last info is available (see notes below)

	tariff change occurs can be obtained by the Smart Info (this operation could also require to evaluate the possible difference between Gateway and Meter real-time clocks) Distributes over the HAN network the cost information to interested devices.	

Title	1.3 Visualization of current energy consumptions and power of Smart Appliances+ global current metering data	
Description	In this Use Case, the customer is also informed on the current energy consumptions of the single appliance. The level of detail, frequency and quality of data could be different among different devices. It should be possible for clients to display such disaggregated data together with total house consumptions; such functionality shall be performed by Customer Interfaces.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
At least the same as UC 1.1 In addition, near real time instant power information is to be provided in order to allow Smart Appliances to calibrate its energy consumptions.	Same as UC 1.1 Provides to user appliances a single point of contact to publish their respective current energy consumption information.	Each appliance ▪ displays its own energy consumption/power drawn data ▪ dispatches it own energy consumption data over HAN ▪ receives over HAN (from Smart Info) the total house energy consumption ▪ displays the total house energy consumption

Title	1.4 Visualization of current energy consumptions and power of Smart Appliances + global metering data + cost information	
Description	Similar to UC 1.3 with information on costs	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 1.2 plus UC 1.3	Same as UC 1.2 Same as UC 1.3	Same as UC 1.3 + cost information if this last info is available (see note below)

Title	1.5 Visualization of estimated energy consumption of Smart Appliances and its cost before starting to run
Description	One of the most important goals of this use case is to educate the consumer in selecting the parameters of the cycles feedbacking her/him their costs and energy consumption, before the start button will be pressed. Many studies show that, only by displaying this

	information, a energy consumption saving of 10-15 % could be achieved on the single appliance. The Smart Appliances estimate the energy that will be consumed during its next operation (ex: cycle). If possible, they give information also about the energy cost and the next operation cost by requiring to the Gateway to perform energy cost evaluation.. Moreover, in case of time-of-use (TOU) pricing, the appliance receives information about which tariff is currently in use.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 1.3	Provide the HAN with information about energy tariff profiles, energy costs and clock time.	The Smart Appliances: ▪ estimate the energy to be consumed to perform the next operation ▪ display the estimated energy value ▪ receives the information of energy cost through HAN ▪ display this cost

Title	1.6 Visualization of a warning if available total power (in the home) is not sufficient to run a Smart Appliance	
Description	The Smart Appliance estimates the maximum power that will be consumed during its next operation (ex: cycle). If the total available power in the home is not sufficient to run, the Smart Appliance notifies the user	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 1.3		The Smart Appliances: ▪ estimate the maximum power to be consumed to perform the next operation ▪ receive the information of total available power in the home through HAN ▪ display a warning to the user if it is not possible to run ▪ eventually send the information that it is not possible to run through the HAN

Notes:
In a fully "unbundled" framework, the DSO (owner of the SI) is not in charge of defining energy rates and to bill final customers. Nevertheless, the DSO, being the subject entitled to perform metering activity, knows all the metering data needed for billing, being the final price evaluated by the Energy Retailer on the basis of these metering data sent by the DSO. For example, in Italy, TOU schedule (number of tariff and start and stop time) is pre-configured into the Meter according to the requirement set out by the AEEG. In this way, the AEEG has frozen the timetable for electric offers, being each energy retailer free to decide the price for energy in tariff (i.e. each time slot).

Usually energy is priced higher during peak time and lower in off-peak; however it is also possible for the energy provider to charge every tariff the same, or even offer a flat rates for energy (already available in the market) similar to telecommunication rates (note that in case of flat rates the concept itself of euro-per-kWh itself is meaningless). The price could also depend on previous consumptions, for example in case the rate changes according to the overall consumptions in a given billing time (e.g. a year). Moreover, the price could increase given the maximum peak of power in a given period (e.g. a day). Whichever the conditions, the Energy Retailer shall rely on the metering data provided by the DSO.

To evaluate the price of used energy, the Smart Info shall provide the metering information to another device, which shall implement a dedicated algorithm, the ***Energy Cost Algorithm***. The *Energy Cost Algorithm* calculates the price of energy at a given time (e.g. € per kWh from 08:00 to 19:00) replicating the conditions applied by the Energy Retailer. The *Energy Cost Algorithm* to get the price could be quite complex, and, in any case, defined by each Energy Retailer. The *Energy Cost Algorithm* shall be hosted on the Home Gateway and should be ideally provided by the Energy retailer as a "plug-in" dedicated to price evaluation. In the scope of Energy@Home, the interfaces of the *Energy Cost Algorithm* shall be defined by detailing the input and output parameters. For example, to estimate the price of a forecasted consumption, possible input parameters are:

- The content of all metering registers from the Smart Meter
- The time boundaries of the different TOU tariffs
- The time in which the energy consumptions is going to take place, possibly with separate indication of the different TOU tariffs
- Other additional data should be collected by the *Energy Cost Algorithm* itself possibly via a direct machine-to-machine connection to the Energy Retailer server.

The output of the *Energy Cost Algorithm* could be a pair, including:

- The estimated price in euros
- An estimation error (percentage of estimated price)

.
Every actor in the HAN shall have access to the *Energy Cost Algorithm* via a dedicated service offered by the Home Gateway.

A simplified mechanism, without a Home Gateway, could be envisaged defining a ***Simplified Tariff Profile*** to be exchanged in the HAN. The *Simplified Tariff Profile* shall be standardized

and shall provide enough flexibility in order to evaluate, with sufficient accuracy, most common tariff offers. A possible content of the *Simplified Tariff Profile* is a sequence of time slots and the correspondent price (in euros per kWh) for each time slot. The actor that provides the Simplified Tariff Profile shall autonomously take into account all the relevant factors that influence the tariff, such as current time or differences between working and holiday days. The *Simplified Tariff Profile* could be provided by an actor present in the HAN and used by any other actor to perform approximated evaluations of the energy cost.
It should be noted that this solution should be considered as a sub-optimal one, to be used in case no actor in the HAN is able to offer the *Energy Cost Algorithm*.

A common requirement, for both cost evaluation mechanism, is that the evaluation process is completed within a time compatible with the proposed services. In particular, it shall comply with typical man-to-machine interface response.

2.1.2 Scenario 2: Visualization of historical data

The aim of the following use cases is to provide customers historical and statistical information on their energy consumption, disaggregating the global energy time variations with the one coming from the Smart Appliances.

Title	2.1 Visualization of historical data for the single customer (Global in-house and Smart Appliances)	
Description	The customer may access the historical data and verify how he used energy during time.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Retrieves, from the Meter, available historical data (i.e. the in-house power profile) and possibly internally generated instant power samples. Data resolution and number of samples could vary, according to meter configuration. The Smart Info itself does not perform operations to change time resolution of data coming from the Meter. Any needed operation, or integration with additional data, shall be performed by the Customer Interface device.	The access to the network platform, allows the storage of the total and single appliance's energy consumption. The Home Gateway can access and aggregate those data to present them to the user through a Browser. The Home Gateway allows external applications in the HN to retrieve the stored data	The Smart Appliances can display some specific data concerning their energy usage, considering the intrinsic limitations of their User Interface It will provide to the HAN its information on energy consumption.

Title	2.2 Visualization of historical data compared with a benchmark	
Description	The customers may compare their own energy consumptions with other customers to be able to check their behavior against virtuous references.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 2.1	Guarantee a simple access to the application in the network in order to enable comparison with other users.	None

Title	2.3 Visualization of historical data compared with a user community	
Description	The customers may compare their own energy consumptions with user communities	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 2.1	Guarantee a simple access to the application in the network to compare the energy usage with a community of users.	None

2.1.3 Scenario 3: Alarm

Title	3.1 Notification of Home Domain Overload	
Description	The customer is promptly informed when the overall power drawn exceeds the maximum available power, hence causing a Home Domain Overload. The notification shall be notified local alarms (e.g. acoustic). The customer can also access to an historical view of any alarm.	
Roles		
Smart Info	**Gateway**	**Smart Appliances**
The Smart Info receives from the Meter, or generates itself, a max-power-alarm, indicating that power is beyond a contractual threshold. The Smart Info, consequently, emits an alarm in the HAN to all the Customer Interfaces, Smart Appliances and to the Home Gateway, providing indication about the percentage of power beyond the threshold (if available). It should be defined whether the alarm is to be sent to all paired devices or only to those which have been previously registered for receiving the alarms. The alarm could be emitted more than once, before the Meter opens the breaker.	It can activate the local alarm through an in house TI terminal. It allows the user to set the priorities for the house device/appliance alarm activation (i.e. TI terminal, dishwasher machine, ect.)	The appliances can echo the general alarm

Title	3.2 Black out	
Description	In case of energy black out the Home Gateway, equipped with an UPS, is able to guarantee the correct activity for a minimum time (< 60 sec.). It can alert the customer about the event with an alarm (e.g SMS, phone call)	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
In case of black out the Smart Info will not be able to reach the Meter, hence it shall not emit any dedicated message toward the HAN.	Activate a SMS or a voice call alarm	None

2.1.4 Scenario 4: Other energy information

The Execution Environment, available in the Home Gateway, enables further applications dedicated to customer awareness. For example, the energy retailer could deploy an application able to provide clients with the **energy sources mix** used to supply his/her appliance, specifying the percentage of renewable sources, the CO2 footprint and similar information.

2.2 Appliance regulation

The appliance regulation can be performed according to 2 increasing levels of performance and system complexity: a coordinated regulation among the devices of the HAN or a self-regulation operated autonomously by the Smart Appliances. The goal of both approaches is to provide the customer automatically with suggestions and assistance on how to improve the energy management of the house.

2.2.1 Coordinated Management appliances regulation

In this configuration, all the Smart Appliances in the house cooperate together to regulate their behavior according to global energy information of the house, their current state and priority when the regulation is needed. The type of regulation performed by the appliance could vary according to the type of appliance. The regulation logic could be centralized or distributed but in any cases coordinated and harmonized. Only knowing the entire energy and power status of the Home Domain System, the full performances of the system could be guaranteed; on the other side, the involved algorithms will be the most complex, having to take into consideration the different and time variable energy states of the Smart Appliances and standard electrical loads in the house.

2.2.2 Self Management appliances regulation

In this configuration, the single Smart Appliance regulates its behavior according to global energy information of the house, such as current instant power and energy price. The type of regulation performed by the appliance could vary according to the type of appliance and its current state when the regulation is needed. No cooperation with other appliances is involved.
Since in this level there is no coordination with other Smart Appliances and thus knowledge of their power consumption (and of other independent electrical loads of the house), the full performances of the system could not be guaranteed; this is why the output of the use cases of this scenario should be considered as suggestions: the customer nevertheless will be in charge of coordinating the use of other Smart Appliances and independent electrical load of the house. She/he will always decide if accepting or not the suggestions from the system.

2.2.3 Scenario 5: Home Domain Overload management

In this scenario, the single appliance regulates its behavior upon home power availability. The aim of following use cases is to foster the use the appliances when there is enough power in order to avoid overloading. The power peak management can leverage both on coordinated and self-management regulation as indicated in the use cases.

Title	5.1 Home Domain Overload management in case of smart and non-smart appliances	
Description	The Energy@Home system can optimize the use of power in order to avoid Home Domain Overload. ***Coordinated management:*** The customer can define/modify the load shedding priorities and strategies in case of a Home Domain Overload, to be applied to smart and non-smart appliances (Smart Plugs could be used to manage power disconnection priorities for non-smart appliances). A central unit located inside the house will implement the coordination logic. An alarm (e.g. acoustic) can be generated to notify to the customer the critical condition. In order to simplify the process, default configurations could be considered. The Smart Appliances can activate enhanced features that guarantee to the whole set of devices a maximum energy consumption (peak limit). ***Self management:*** While working, the Smart Appliance can perform load shedding, modifying its behavior in order to reduce or adapt its power consumption to the overall status of the house.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 1.3 + UC 3.1	***Coordinated management*:** The Home Gateway hosts the application that allows the Home Domain Overload Management. The macro functionalities could be: • Allow the Customer to define its own overload rules (i.e. appliances priority) • Allow the Customer to associate to the Smart Plug a non-smart appliance (not yet connected to the HAN) • Receive from Smart Appliances info's about the estimated appliance power profile of the program activated by the	***Coordinated management*:** The Smart Appliance ▪ receives through HAN the coordination signals ▪ executes the relative actions, as a function of its status ▪ displays an information to the user ▪ before starting, informs the central unit about the appliance power profile ***Self management:*** The Smart Appliance receives from HAN the available power in the Home Domain. Using

	Customer • Coordinate the appliances in order to avoid the overload condition • Inform the Customer about any activated action (i.e. acoustic warning) • …. The Home Gateway also provides a web customer interface for these functionalities. ***Self management:*** The Home Gateway should be notified of the modified behavior (appliance power profile change) of the Smart Appliance.	this information, it adapts its behavior by some load shedding actions. In addition, it notifies its appliance power profile change in the HAN and, if possible, in its UI.

Title	5.2 Request of confirmation to start if available power (in the home) is not sufficient to run a Smart Appliance	
Description	The Energy@Home system may require explicit confirmation from the Customer if the use of a Smart Appliance may lead to power overload. ***Coordinated management:*** The Energy@Home system checks if the total available power in the home is not sufficient to run the Smart Appliance, depending on its power profile estimation, on other Smart Appliances estimated power profile and on the current total in house consumption. The Smart Appliance notifies the Customer and asks the confirmation to start. ***Self management:*** The Smart Appliance estimates the appliance power profile about its next operation (ex: cycle). If the total available power in the home is not sufficient to run, the Smart Appliance notifies the user and asks to the customer the confirmation to start	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 1.3	***Coordinated management:*** The Home Gateway hosts the application that allows the Customer to coordinate the Smart Appliances according to the available power and to knowledge of the potential activity schedules of other Smart Appliances in the HAN (e.g. due to pre-programmed schedules).	***Coordinated management*** The Smart Appliance: ▪ sends the estimated appliance power profile to the central unit and receives from it the information about the power overload risk ▪ interacts with the customer to avoid starting the cycle in case of potential overload by asking for confirmation

	Self management: The Home Gateway should be notified of the state of the Smart Appliance.	***Self management*** See UC1.6 Interacts with the customer to avoid starting the cycle in case of potential overload by asking for confirmation.

2.2.4 Scenario 6: Optimize energy cost in case of multi-tariff contract

In this scenario the E@H system performs actions in order to reduce and optimize the energy cost. The optimization of energy cost can leverage both on coordinated and self-management regulation as indicated in the use cases.

Title	6.1 Multi-tariff energy use optimization in case of smart and non-smart appliances	
Description	The Energy@Home system provides an optimization of appliances usage in order to optimize energy cost according to the variable energy tariffs. This Use Case is meaningful for all those appliances which are activated by the customer and perform a specific operating cycle, such as a washing machine, oven and dishwasher. The most important exception is the fridge, which operates continuously. ***Coordinated management:*** The customer can define/modify the house rules for the energy costs optimization in case of single or multiple appliances. For any appliances the customer can set parameters like the operational time interval allowed for the device (e.g. from 6:00 to 24:00). Smart Plugs could be used to manage operational time interval for a set of non-smart appliances (e.g. a boiler). In order to simplify the process, default configurations could be considered. The Smart Appliances can activate enhanced features that guarantee to the whole set of devices to minimize user cost according to the variable tariffs. ***Self management:*** The customer prepares the Smart Appliance for its operating cycle (i.e. a washing program) and sets the needed condition for activation, e.g. the lowest energy price time. The Smart Appliance automatically waits until the given condition is met.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Coordinated management and Self management: Same as UC 1.4	***Coordinated management:*** The Home Gateway hosts the application that allows the Customer to optimize the energy	***Coordinated regulation:*** The appliance before starting informs the central unit about its estimated power profile: the

	use. The macro functionalities could be: • Allow the Customer to define for each time interval the priority appliances list (i.e. from 19:00 to 23:00 priority to the washing machine) • Allow the user to associate to the Smart Plug a non-smart appliance (not yet connected to the HAN) • Receive from Smart Appliances info's about the estimated appliance power profile of the program activated by the Customer. • Control the appliances in order to optimize energy costs and life quality • …. The Home Gateway also provides a web customer interface for these functionalities. ***Self-regulation:*** Same as UC 1.5 As a function of the complexity of the optimization algorithm and of the Smart Appliance, some specific software in the gateway could help the determination of the optimal start time.	received appliance power profile data are used by the central unit to calculate the time when the appliance can start (according to the user desiderata, the total power availability and the tariff policy). ***Self-regulation:*** The Smart Appliance: ▪ Possibly performs the same activities as in UC 1.5. ▪ Implements or delegates to the gateway the implementation of the delay determination logic ▪ Offer to the customer the possibility to activate a delayed start. This operation can be performed in several ways and with different level of complexity according to the built-in User Interface capabilities. For example, a simple appliance can have just a button for starting when the lowest tariff is used. A more complex appliance can offer a rich interface showing the tariff profile in time and letting the customer to choose when to start. ▪ If the customer accepts the delayed start, the Smart Appliance waits until the required condition is met. ▪ Display the actual cost of the required cycle and the relevant "delayed start" economical saving (depending on the richness of its User Interface)

Title	6.2 Automatic time shifting of some phases or functions of the Smart Appliance for favorable economic conditions	
Description	This Use Case foresees Smart Appliances' capability to delay some of its specific functions (either activated by the customer or automatic inside the cycle) according to current tariff and energy cost. ***Coordinated management:*** The coordination between the different actors in the house and their needs in terms of power consumption will allow take into consideration the overall power consumption forecast and thus better optimize the energy costs and prevent overloads. ***Self management:*** The single Smart Appliances regulates time shifts its phase optimizing its own costs.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as UC 6.1	***Coordinated management:*** The Home Gateway hosts the application that allows the user to optimize the energy cost. ***Self management:*** Same as UC 1.5 As a function of the complexity of the optimization algorithm and of the Smart Appliance, some specific software in the gateway could help the determination of the optimal start time.	• Possibly performs the same activities as in UC 1.5. • The customer is warned about the appliance's choices. ***Coordinated management:*** The Smart Appliances coordinate together in order to find the best overall strategy in order to perform the shifting of the phase to optimize costs and to prevent overloads. ***Self management:*** The Smart Appliances decide autonomously the logic to time shift or adapt part of its cycle or some specific functionalities according to the energy cost.

2.2.5 Scenario 7: Demand response

This scenario takes into account possible requirements to be provided by different ongoing projects aimed to define the future interactions between clients and electricity market. In the scope of those projects, the clients shall be presented with daily (or even hourly) offers coming from other actors and aimed to modify clients' behavior. Offers shall be probably issued by a new player in the energy market called the **Aggregator**, which has the mission to aggregate many small clients and to operate into the energy market presenting them as a whole. The Aggregator shall reply to market needs offering services such as:

- Power limitation within a given geographical region and temporal slot
- Peak clipping
- Peak shifting

To assure clients' participation to the services, the Aggregator shall provide them with offers, for example providing them with a remuneration for power reduction within the required temporal slots. To achieve this goal there should be a mechanism to provide the clients with the offer details (temporal slot, needed reduction, remuneration mechanism, etc.), which are generally indicated as **price/volume signals**. For example the Aggregator could require its clients to limit the power below 2 kWh between 14.00 to 16.00, granting a remuneration for those who accept the offer. It is also possible that the same energy retailer could play the aggregation, hence offering discounts on energy price.

To guarantee a clients' acceptance of demand/response policies, price/volume signals have to contain information for the coming hours to allow the appliances' planning taking into account the clients needs and the appliances' cycles characteristics. This requirement could be satisfied if price/volume signals are linked to daily energy market results (in place in most European Countries), hence containing indication for the next day. Short term advices could be originated by intra-day markets, balancing activities and similar mechanisms. The planning activity shall receive short-term signals as well. Nevertheless, those signals make more complex the decision on the best time to run. Moreover, very short-term signal (few minutes of notice) shall have bigger impact on clients needs and should be limited to unexpected conditions like critical grid Peak Demand conditions for an immediate reaction of the appliances.
From the Energy@Home point of view, price/volume signals shall be collected by the Home Gateway and used as inputs for the cost-evaluation algorithms. Hence this scenario is an extension of scenario 6 (Optimize energy cost in case of multi-tariff contract).

Title	7.1 Demand response management	
Description	The Aggregator, in order to perform power limitation within a given geographical region and temporal slot, peak clipping or peak shifting, provides the devices within the HAN with the price/volume signals by means of the Home Gateway.	
Roles		
Smart Info	**Home Gateway**	**Smart Appliances**
Same as Scenario 6	The Home Gateway hosts the application that allows the Aggregator to provide price/volume signals to the devices within the HAN	The Smart appliance may react to price/volume signals as indicated in Scenario 6.

2.3 Energy@Home provisioning and maintenance

In order to enable the scenarios above described it is required to ACTIVATE, REMOVE and MAINTAIN the appliances in the HAN. Access to those three functionalities is required to guarantee the customer the desired level of security in order to prevent unauthorized control of the devices connected to the HAN.

In case of a ZigBee network, the admission of any new device into the HAN is charged to the coordinator of this network. It is assumed that the Home Gateway could play the coordinator role. In case of unavailability of the Home Gateway, another device in the HAN should provide a subset of its capabilities including the connection to the Internet. This device shall be, by instance, a smart meter, which provides the Smart Info data and some of the Home Gateway functionalities.

2.3.1 Add a new device

The user buys a Smart Appliance and would like to start it up in the Energy@Home HAN with the simplest human interaction possible. The admission procedure is required to guarantee the interconnection of the Smart Info, Smart Appliances and Home Gateway owned by the same customer.
If the HAN was previously activated by the Home Gateway, through a web interface, the user starts the admission procedure, identifies the new ZigBee device checking manufacturer and model and allows the new Smart Appliance to join the Energy@Home solution. The same procedure could be activated for the Smart Info.
In case the Home Gateway is not available, the admission procedure should be managed by another device, which shall provide user with a user-friendly interface.

2.3.2 Remove a device

In case of both joining of not desired device to the HAN and replacement of broken ones, the customer is provided with this procedure. The user experience could be similar to ADD one.

2.3.3 Maintenance

If the customer experienced some problems with Energy@Home a Web application on the Home Gateway could present the status of the HAN including the devices list, the devices status (i.e. joined to the HAN but not responding), etc. Also Warning and Alarm could be activated in case of communication problems.
If the Home Gateway is not available, this functionality is critical to be provided.

3 Glossary

Term	Description
AG	See HG
Appliance Power Profile	The Appliance Power Profile is a data structure containing information about the energy consumption of an appliance (load profile related to its cycles) and some other useful information for load shifting or load shedding its usage.
CEMS	Community Energy Management System: aggregator
Customer Interfaces	An appliance or Smart Info User Interface extension. Its goal is having a remote, more verbose, portable, remote, user friendly, configurable device. It could be a physical device or, more commonly, it is only a logical component, which can be visualized by a PDA, a pc or a Smart Phone (connected in the HAN or HN). Typical implementations are through Web pages or custom software written for each of these devices.
Demand Side Management	Demand side management (DSM) entails actions that influence the quantity or patterns (load profile) of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. Noticeably techniques are load shifting and load shedding.
DSO	In electrical power business a Distribution System Operator is an operator that carries and delivers electricity to the consumer from the TSO's distribution lines.
Energy Cost Algorithm	Algorithm, to obtain the price of energy at a given time (e.g. € per kWh from 08:00 to 19:00) replicating the conditions applied by the Energy Retailer. The Energy Cost Algorithm to get the price could be quite complex, and, in

	any case, defined by each Energy Retailer. The Energy Cost Algorithm shall receive as inputs a Power Profile, either actual or estimated, and all the needed metering data.
Energy Regulation Algorithm	Energy Regulation algorithm is any procedure which defines the strategy for coordinating Smart Appliances behavior, in order to reach energy consumption or cost optimization and to guarantee the overall performance of the system, using as inputs the global energy consumption, its cost, Appliances Power Profile and their status. Main control techniques involved in the Energy Regulation algorithm are load shifting and shedding .
Energy Retailer	Companies that participate in the retail energy market providing a service (energy) to the end user.
HAN	A home area/automation network is a residential local area network, usually characterized by low throughput. It is typically used for communication between devices within the home such as sensors, smart plugs, smart thermostats and household appliances. It can be a Wireless network (e.g. ZigBee) or wired (e.g. Power Line Communication). This is often referred to as PAN (Personal area network)
HG	Home Gateway: it is the gateway between the HAN, the HN and the WAN (e.g. internet). It is able to interface Smart Appliances and Customer Interfaces through the communication protocol(s) used in the HAN and HN (ZigBee, WiFi, etc.) and to provide a broadband connection to internet (usually via a standard ADSL connection). Moreover, the Gateway is able to collect energy data, from the Smart Info and from the user's appliances, and publish them in the HN and WAN.
Home Domain	It identifies a boundary of the wired/wireless communication system (HAN and HN), covering Smart Appliances, Customer Interfaces, Smart Info and Home Gateway. This boundary is usually the customer's House.

Home Domain Overload	Condition which takes place when aggregated home load exceeds a given power limitation. Power limitation can be determined by different causes according to the regulation in place. For example, in South Europe countries, domestic connections are subject to a maximum contractual power (eg. 3kW). Note that maximum contractual power limitation process is managed by the Meter, which is the only actor entitled to sense threshold exceeding and to perform needed action. In some circumstances, the Meter will open the breaker immediately, without emitting any alarm. In other countries, the limitation is imposed by physical limitation of the home equipment and apposite safety devices are installed to prevent the overload.
Home Energy Monitor	A Home Energy Monitor is a device providing the consumer a prompt and convenient feedback on electrical (or other) energy use. These devices may also display cost of energy, estimates of greenhouse gas emissions, near real time consumption of some electrical loads inside the house. Usually its display is remote from the measurement point and portable inside the house, communicating with the sensor/Home Electricity Meter using a wired (e.g. power line communications) or wireless methodology.
HN	A home network is a residential local area network, typically characterized by high throughput. It is used for communication between digital devices typically deployed in the home, usually personal computers, printers, gateways. The home network can be wireless (e.g.Wi-Fi) or wired (e.g. Ethernet).
Load Profile	Load profile is the variation in the electrical load versus time. A more specific definition is the Power Profile, which takes into account the power used by the load.

Load Shedding	Energy utilities' method of reducing demand on the energy generation system by temporarily rationing distribution of energy to different geographical areas; this can be done by forcing the switch off of some electric loads in the grid or by reducing the power consumption of some of those (thus altering their load profile). The most drastic kind of load shedding are rolling blackouts, the last resort measure used by an electric utility company in order to avoid a total blackout of the power system. Smart Appliances could significantly help to avoid these last resort measures, reducing temporarily their power consumptions: load shedding could be performed by the appliance control logic itself changing its power consumption profile (load profile) during its working operations . This action implies an information coming from the Utility through the Smart Grid to the Smart Appliance in order to to signal the need, carrying usually also a severity level. Their performances should not be greatly or noticeably affected by the load shedding operation. It belongs to the Demand Side Management techniques.
Load Shifting	Load Shifting is an electric load management technique that aims to shift the pattern of energy use of a device (load profile), moving demand from the peak hours to off-peak hours of the day. It belongs to the Demand Side Management techniques. In the Smart Appliance context, the load could be each single electric load of the appliance or, more generally and commonly, the overall working cycle of the appliance (which consists of a complex sequence of activation of those

	single loads, in order to achieve the needed performance of the machine).
Peak Demand or Peak Load	Peak demand or peak load are terms used in Demand Side Management describing a period in which electrical power is expected to be provided for a sustained period at a significantly higher than average supply level. Peak demand fluctuations may occur on daily, monthly, seasonal and yearly cycles.
Power Profile	Power profile is the variation of power consumption of an electrical load versus time, thus specifying the [[Load Profile]] concept. It will vary according to customer type (typical examples include residential, commercial and industrial), temperature and holiday seasons. In the Smart Appliances context, the more specific concept of Appliance Power Profile is used.
SI	Smart Info: is the element, provided by the DSO, which provides energy information into the HAN. Published data are a sub-set of those already available inside the Home Electricity Meter, hence the Smart Info acts like a proxy of the meter
Simplified Tariff Profile	It is a simplified structure of the energy tariff offered to the client by the Energy Retailer. The content of the Simplified Tariff Profile is a sequence of time slots for a configurable amount of time (e.g. the next 24 hours) and the correspondent price (in euros per kWh) for each time slot. The actor that provides the Simplified Tariff Profile shall autonomously take into account all the relevant factors that influence the tariff, such as current time or differences between working and holiday days.
Smart Appliance	It is an appliance connected in the HAN and equipped with some intelligence to cooperate with the other home actors in order to provide new services to the consumer, like for instance

	energy consumption awareness, demand response,.... The Smart Appliance plays an active role in the home system complying with the system policies, satisfying the user whishes and always assuring its best performance. Most of these technologies imply some information transfer from the Smart Grids to the Smart Appliance (thus a communication channel within the HAN and outside the Home Domain) and an additional control and supervision logic (inside and/or outside the appliance).
Smart Plug	Device provided with a HAN interface (e.g. ZigBee) that typically has a power meter able to calculate the power/Energy consumption of the connected load and is typically provided with a Relay that can be used to remotely power on/off the load.
TSO	Transmission System Operator. In electrical power business, a transmission system operator (TSO) is an operator that transmits electrical power from generation plants to regional or local electricity distribution operators (DSO).
WAN	Wide area Network: it is a computer network that covers a broad area (i.e., any network whose communications links cross metropolitan boundaries) This is different than personal area network (PANs), Local area network (LANs) which are usually limited to a room, building, campus respectively.