# Project Identity

ADDRESS is a large scale research project co-funded by the European Community's Seventh Framework Programme for the "Development of Interactive energy networks". It aimed at developing technical and commercial solutions for the active participation of domestic and small commercial consumers in energy markets, that is the so called active demand. The project started in June 2008 and lasted 5 years, during which 22 technical reports and 31 use cases have been delivered and validated in field, setting a solid basis for active demand realization.

More than 400 professionals have been working in the project, coming from 11 European countries and representing the entire electricity supply chain, qualified R&D bodies and manufacturers:

- **Research**: University of Manchester, Universidad Pontificia Comillas, Università di Siena, Università di Cassino, ENEL Produzione, VTT, VITO, Tecnalia, KEMA, Consentec
- **Distribution and transmission network operators**: ENEL Distribuzione, EDF Energy, Iberdrola Distribución Eléctrica, Vattenfall
- **Energy supply and retail**: ENEL Distributie Dobrogea
- **Energy producer, Balancing Responsible Party and Energy supplier**: EDF SA
- **Electric equipment manufacturers**: ABB, Landis+Gyr, ZIV
- **Home appliances manufacturers and consultants**: Philips, Electrolux, RLtec
- **ICT providers and Electric equipment manufacturers**: Ericsson Españа, Alcatel, CTI.

The total budget of the project was above 16 millions, 9 of them funded by the EC.

## 1.1. The ADDRESS vision

Reaching the objectives and exploiting the results of the ADDRESS project can help the European Smart Grids Technology Platform vision to become a reality: a network that is flexible, reliable, accessible and economic:

It is possible to  add flexibility:

- enhancing the flexibility and the adaptability of consumers by enabling Active Demand;

- providing real-time management of energy flows at local and global level.It is possible to add reliability:

- developing technologies for distributed control and real-time network management;

- exploiting load flexibility to achieve safer operation of the network and increase the power system efficiency.

It is possible to adda ccessibility:

- proposing solutions to remove commercial and regulatory barriers against Active Demand and the full integration of DG (Distributed Generation) and RES (Renewable Energy Resources).

Finally it is possible to add economy:

- enabling profitable energy services by all market players to provide local and global electricity system optimisation and increase the energy market competitiveness to reduce the energy bill;

- combining Active Demand with DG and RES to allow sustainable growth and energy consumption.

## 1.2. Objectives

In the smart grids, there is a growing need for a more active participation of consumers into the power system market and in the provision of services to the different electricity system participants (Active Demand – AD) and an increasing concern of consumers about environmental and energy efficiency issues.

In this context, ADDRESS aimed to develop a comprehensive technical and commercial architecture to enable AD at small commercial and domestic consumers, and to exploit the benefits of AD, with supporting activities.

To this end, the first objective of the project was to enable active demand which means that technical solutions at the consumer's premises and at the power system level have been developed and recommendations and solutions to remove possible barriers have been proposed. In particular, technologies for the control and the optimisation of home appliances, for the control and safe operation of power grid and for the communication were studied.

The second objective of the project was to exploit the benefits of active demand for the electricity stakeholders and all the players involved in the ADDRESS architecture. So the potential benefits for the different power system participants were identified and appropriate markets mechanisms and contractual structures were proposed to integrate the new scenarios.

Another objective was to study accompanying measures to deal with societal, cultural, behavioral aspects.

The proposed solutions were then implemented in technological prototypes that were first tested in laboratories and after installed in three complementary test sites (Italy, Spain and France) where the outcomes of the project have been validated.

Finally, during all the project dedicated dissemination activities for the stakeholders have been carried out.

# 2. Architecture and Main Concept

Figure1 represents a simplified version of the ADDRESS architecture in order to show the main players and the relationships among them.

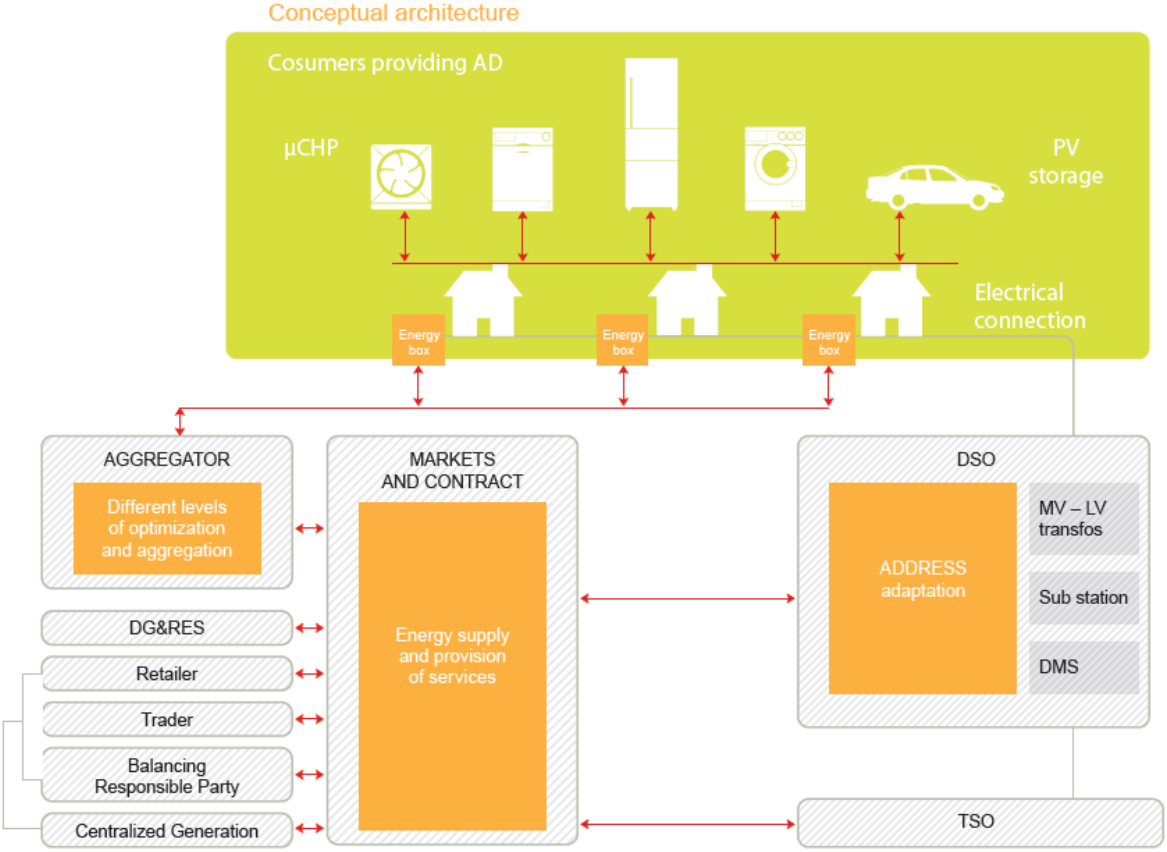



Figure 1. ADDRESS architecture

One of the central concepts of the project is the aggregation service.

The aggregators are the key mediators between the consumers on one side and the markets and the other power system participants on the other side, namely:

- The aggregators collect the requests for AD-based services coming from the markets and the different power system participants.

- They pool the “flexibilities” and the contributions provided by consumers to form AD-based products and they offer them to the different power system participants through various markets or bilateral relationships to meet their needs.

It should be emphasized that the flexibilities and contributions of consumers are provided in the form of modifications of their consumption profile. Therefore aggregators form their AD services and offers using consumers’ “demand modifications” and not consumers’ energy profile as such. Or in other words, the aggregators sell a deviation from the forecasted level of demand, and not a specific level of demand.

Other important players involved in the ADDRESS architecture are: consumers, Distribution System Operators (DSO), and markets and contracts. Consumers are the providers of the flexibility and therefore of active demand. They are mainly domestic and small commercial consumers directly connected with the low voltage network. The Energy Box is the interface between the consumers and the aggregator and it also carries out the optimization and the control of the appliances inside the houses. The aggregation of the flexibilities provided by domestic consumers is a fairly new function in the energy business.

The DSO (distribution System Operator) plays an important role because the consumers considered in ADDRESS are directly connected to the Distribution Network that means that the DSO has to enable active demand on the distribution grid by providing the appropriate services to market players and at the same time it has to ensure the secure and efficient operation of the network. The DSO interacts with the aggregator through the market to use active demand products for its own need. The DSO has a direct interaction with the TSO (Transmission System Operator) for system security aspect. Markets and Contracts mean all type of commercial relationships between players (organized markets, call for tenders, bilateral relationships). The type of services considered in ADDRESS are for instance:

- Energy supply;
- Relief of overload & network congestion;
- Balancing services (compensation of RES variability included);
- Ancillary services: steady state control, tertiary reserve;
- Load shaping services (e.g. peak shaving);

The electricity system players to which AD services could be provided are both Regulated players, namely DSOs and TSOs (7 AD services for regulated players), and Deregulated players (24 AD services) such as Producers, Intermediaries and Consumers as defined in figure 2.

| Player | Principal services | Type of AD Product |
|---|---|---|
| Retailer | Short-termi load shaping in order to Optimise Purchases and Sales. | SRP |
| | Management of Energy Imbalance in order to minimise deviations from declared consumption programme and reduce imbalance costs. | SRP |
| | Reserve capacity to manage short-term Risks. | CRP |
| Centralised Producer | Short-termi optimisation through load shaping in order to Optimise the Operation of its Generation Portfolio. | SRP |
| | Managementi of Energy Imbalance in ordet to reduce imbalance costs. | SRP |
| | Tertiary Reserve provision in order to meet obligation of tertiary reserve provision contracted with the TSO. | CRP |
| Decentralised electricity Producer or Production Aggregator | Short-terms Management of Energy Imbalance in order to minimise deviations from declared producion programme (low uncertainty). | SRP |
| | Load shaping in order to Optimise its Economic Profits. | SRP |
| | Tertiary reserve provision in order to meet contracted tertiary reserve programme. | SRP |
| | Reserve capacity to Short-term Manage Energy Imbalance in order to minimise deviations from declared production programme (high uncertainty). | CRP-2 |
| | Reserve capacity to manage provision of contracted Tertiary Reserve (medium uncertainty). | CRP |
| | Reserve capacity to manage provision of contracted Tertiary Reserve (medium uncertainty). | CRP |

| Player | Principal services | Type of AD Product |
|---|---|---|
| Producer with Regulated tariffs | Short-terms Local Load Increase in order to compensate the effect of network evacuation limitations and to be able to produce more. | SRP |
| | Short-term Load Increase in order to avoid being cut-off. | SRP |
| | Local Load Inrease reserve in order to compensate the effect of network evacuation limitations and to be able to produce more or to invest more in geration capacity. | CRP |
| | Loard Increase reserve in order to avoid being partially cut off, even to be authorized to invest more. | CRP |
| | Reserve capacity to Manage Energy Imbalance in order to minimise deviations from the production program previously decared and reduce the imbalance costs. | CRP-2 |
| Traders and brokers | Short-term Optimisation of Purchases and Sales by load shaping. | SRP |
| | Short-term Optimisation of Purchases and Sales through Reserve Capacity. | CRP |
| Balancing Responsible Parties | Managemet of Energy Imbalance (low uncertainty) | SRP |
| | Managemet of Energy Imbalance (medium uncertainty) | CRP |
| | Managemet of Energy Imbalance (high uncertainty) | CRP-2 |
| Large consumers | Minimisation of Energy procurement Costs | SRP |
| DSO/TSO | Scheduled Re-Profiling Load Reduction (slow) | SRP |
| | Scheduled Re-Profiling Load Reduction (fast) | SRP |
| | Scheduled Re-Profiling for Voltage Reguation and Power Flow control (slow) | |
| | Conditional Re-Profiling Load Reduction (fast) | |
| | Conditional Re-Profiling for Voltage Reguation and Power Flow control (fast) | CRP |
| TSO | Bi-directional Conditiona Re-Profiling for Tertiary Reserve (Fast). | CRP-2 |
| | Bi-directional Conditiona Re-Profiling for Tertiary Reserve (Slow). | CRP-2 |

Figure 2. AD services

Three main products provided by the aggregator can be able to provide all these services.

1. Scheduled re-profiling (SRP): the aggregator has the obligation to provide *a* specified demand modification (reduction or increase) at a given time to the product buyer.
2. Conditional re-profiling (CRP): the aggregator must have the capacity to provide *a* specified demand modification (reduction or increase) during a given period. The delivery is called upon by the buyer (similar to a reserve service).
3. Bi-directional conditioning re-profiling (CRP2): the aggregator must have the capacity to provide a

specified demand modification during a given period in a bi-directional range [ -y, x ] MW, including both demand increase and decrease. The delivery is called upon by the buyer of the AD product (similar to a reserve service).

Shortly, the provision of the AD services can be summarized as follows:

During their operational processes, the (archetypal) players or functions of the electricity system identify needs that can be met by AD. They formulate requests for AD services corresponding to these needs. Then, depending on the case, they submit or send these requests to the aggregator through different possible mechanisms, e.g. organized markets, contractual or direct bilateral relationships The aggregator optimises and gathers the “flexibilities” and contributions provided by its portfolio of consumers to form AD-based products that are then offered to the electricity system participants through the above-mentioned mechanisms to meet their needs.

Once the AD products are traded, the aggregator sends the appropriate information on the products to the DSO. The DSO checks the technical feasibility of the actions of the aggregator on the network. If the amount of active demand involved might have an impact on the transmission network, the DSO is going to aggregate the information at the point of connection with transmission system and it will send the required information to the TSO in order to check the technical feasibility of the aggregator actions on the transmission grid. Once the AD program is validated by the DSO, the aggregator generates and sends the appropriate combined price and volume signals to the Energy Boxes of its customers in order to implement the AD program. Finally the aggregator checks the consumers profiles for settlement and billing purposes on the basis of the measurements received by the metering operator.

## 2.1. The aggregator

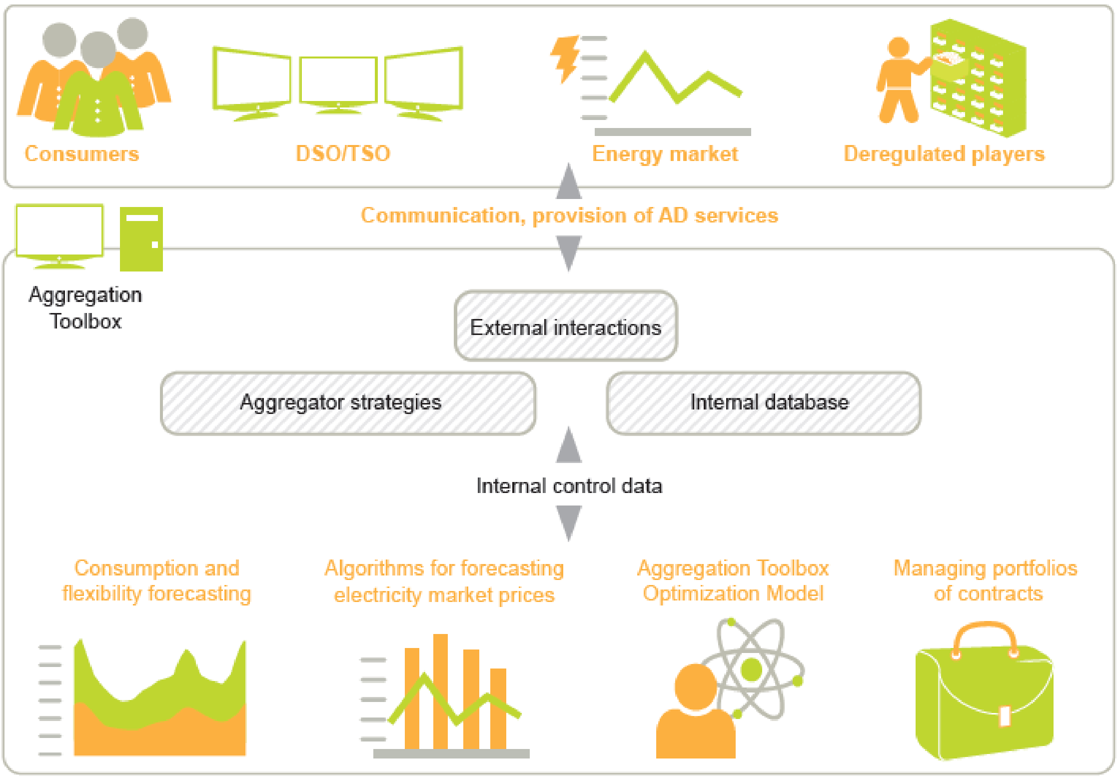



Figure 3. The Aggregator toolbox

The aggregator is the key mediator between the consumers and the markets and other power system participants. Its main functions are (i) to pool the flexibilities of consumers to "build" Active Demand (AD) products and offers them to the power system participants via the markets or bilateral relationship, (ii) to manage the risks associated with uncertainties in the markets and responsiveness of its consumer base (price and volume risks), (iii) to maximize the value of consumers' flexibility and interacts with them through price and volume signals, and (iv) assesses their response and behavior. The way to approach the aggregator within ADDRESS project was to split its main functions into core modules and then implement them, design the so-called Aggregator Toolbox (ATB) and test it during the field tests.

The Aggregator Toolbox implements several functionalities:

- consumers consumption and flexibility forecasting: to forecast in the short-term and long-term the behaviour of the aggregated consumption of the consumers in its portfolio;
- market forecasting: to provide the Aggregator with the prices that Active Demand buyers are expected to be willing to pay in the different Active Demand markets;
- market and consumer portfolio management: to define the Aggregator's long-term strategy having information from the long-term forecasting of consumer flexibility and market prices;
- operational optimization: to determine the bids to offer in short-term markets and create the price and volume signals to send to the EBox of the consumers in its portfolio. This process deals also with the payback effect management;

- settlement and billing: to pay incentives to the consumers in the Aggregator's portfolio according to the established contracts and to carry out the billing of the Active Demand buyers.

It works according to an aggregation objective function that is composed of three terms:

- the income from selling products to Active Demand buyers;
- the cost of paying the consumers for their participation in the flexibility provision;
- the estimated costs of the payback effect (with adjustable weight).

This function uses a mixed Linear Integer programming formulation to build an optimal set of:

- combined price and volume signals (reduction/increase requests) for the clusters on the consumer side (to be sent to the EBoxes);
- flexibility offers (bids) for the electricity market.

It also takes into account electricity market price and price forecasts, existing contracts, power constraints issued by the DSOs and TSOs (Flexibility Tables) and expected consumer clusters' responses.

There is a double interaction between the aggregator and the regulated players: on the one hand the regulated players can act as buyers of AD products to meet their own needs and on the other hand the aggregator interact with them for the technical validation of the AD products (flexibility).

With respect to the interaction between the aggregator and the consumers, the Energy Box (Ebox) is the gateway to consumers. It also receives 5 minutes aggregated measurement information either from the meter itself (where possible) or from an alternative metering device, and sends this information to the aggregator at the end of (or after) the AD action as a report on AD delivery (not for billing). Consumer assessment and settlement is done with the registered consumer profiles or consumption curves sent by the metering responsible (at least monthly) to the aggregator.

### 2.1.1. Price and Volume signals

In order to deliver the active demand products, the aggregator sends to the EBoxes of the consumers in its portfolio the price and volume signals that should produce the needed aggregated consumption modifications according to its forecast. These price and volume signals are based on incentives associated to volume (power) limits as shown in the figure below.

As an example, the incentives may be decreasing from the red band to the grey band in case a reduction of power is wanted, or increasing from the red band to the grey band in case an increase of power is wanted.

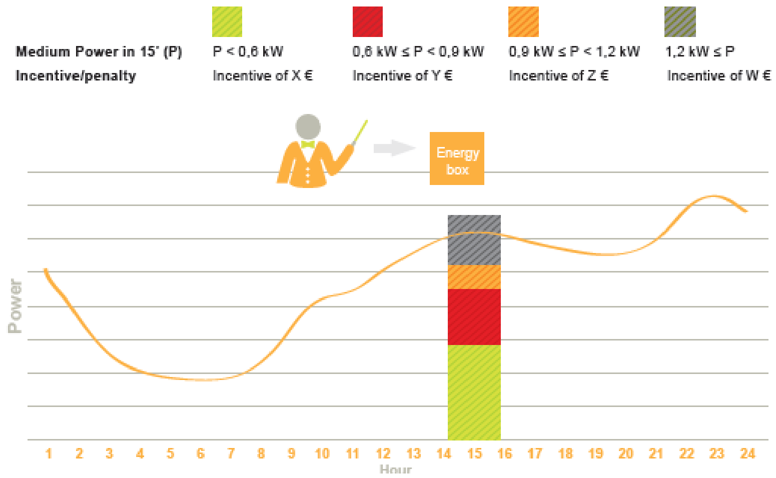



Figure 4. Price and volume signal

## 2.2. Home equipment

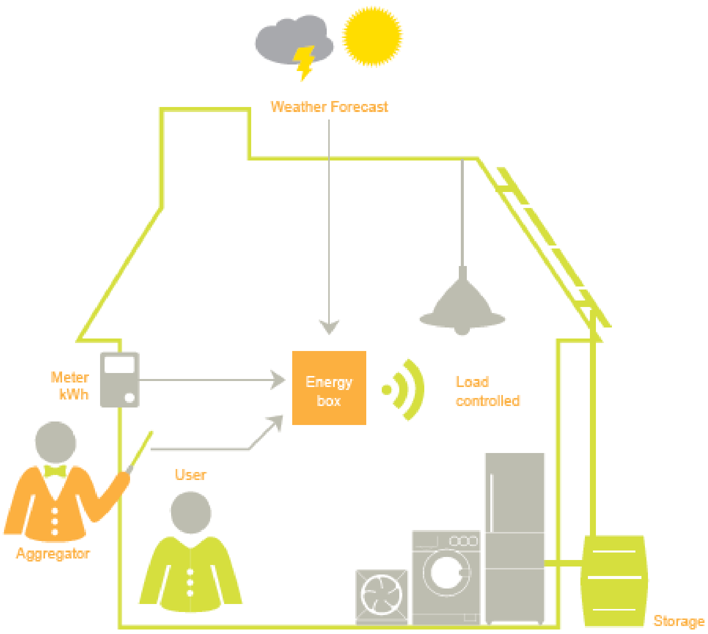



Figure 5: Home equipment

The EBox is a key component in the ADDRESS architecture: a smart energy management box which manages home loads based on the optimal combination of user preferences and reward-based requests to modify energy consumption. The EBox internal SW architecture has evolved through the project and has been divided into three main layers: application level, virtual hardware level and physical hardware level. Four main types of home loads where defined: Shiftable, Interruptible, Thermal and Non-controllable. Smart Plugs are used extensively to “convert” in some way non-Smart Appliances into Smart Appliances in the eyes of the Energy Box (for both Shiftable and Interruptible loads).

The EBox optimizes the operation of the electric appliances under its control. The optimization of the operation of the appliances is done on the basis of the consumers preferences in terms of savings and comfort. The consumer also has the possibility to override the whole operation of the EBox or of each single appliance.

The EBox shall have plug and play characteristics so that the installation of new devices is made easy. It shall also allow the user a friendly and easy configuration of its preferred comfort settings. The optimization processes coordinate the operation of the different devices according to the price and volume signals coming from the Aggregator, the user settings regarding the preferred comfort levels and the operational constraints coming from the devices themselves.

To execute the defined functions the EBox shall implement processes for:

- The definition of the comfort settings and the technical configuration of the loads;
- Plug and play capabilities, enabled by discovery registration functions;
- Data acquisition and storage;
- Planning and operation optimization of the loads;
- User interface.

The EBox shall exchange information with the appliances it coordinates, the meter and other external sensors:

- The EBox shall receive metering information from the official meter. In those cases where there is not such possibility, new measurement equipment are installed.
- The signals from the appliances to the EBox may include requests for starting operation together with the flexibility allowed by the specific appliance. Periodical retrieval of power consumption/production data and status information are also sent to the EBox.
- The EBox shall define when to operate and what operating settings to use for the devices according to the results of its optimization processes. Sending of prices to appliances is not considered.
- The software architecture in the EBox shall be flexible enough in order to be adaptable to different communication protocols.

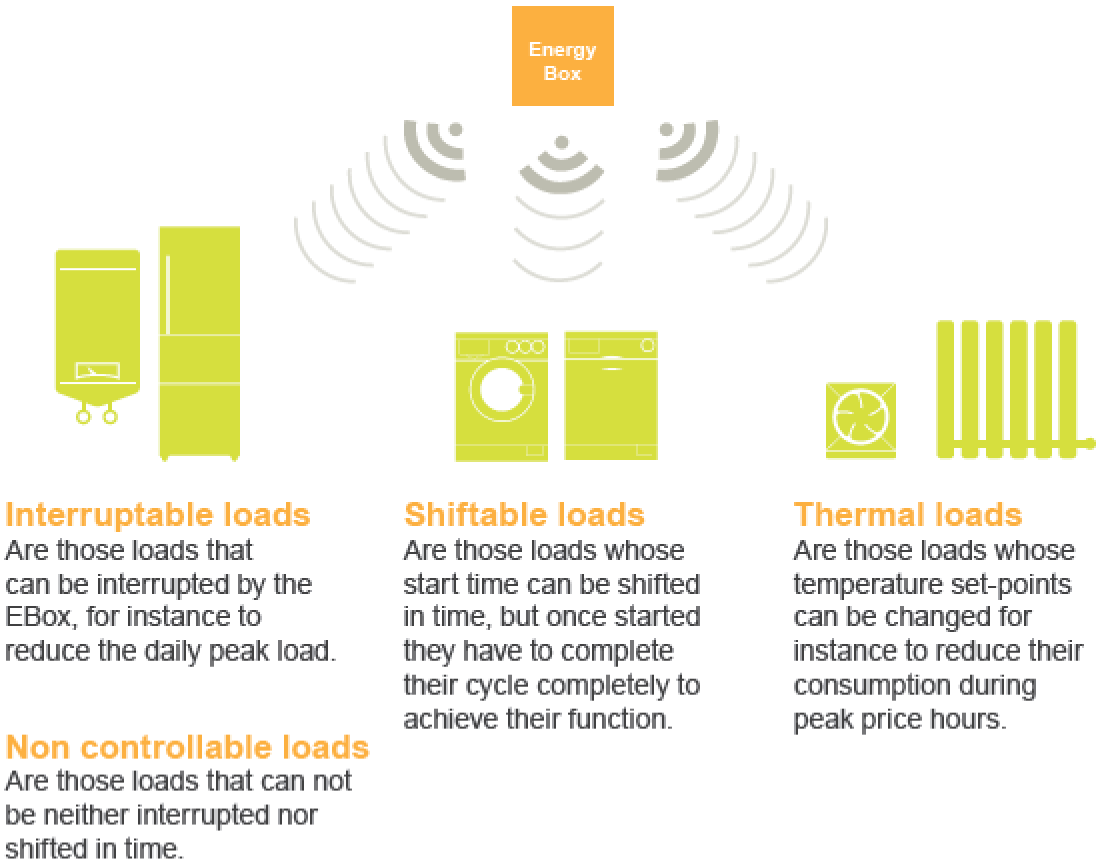



Figure 6:controllable-non controllable loads

## Smart Appliances in ADDRESS

Classical appliances are monitored and controlled by means of smart plugs but smart appliances have also been developed in the project. The main characteristics of the Smart Appliances in ADDRESS are that they are technologically advanced and able to operate in conjunction with the EBox in a more cost-effective and coordinated way through communications nodes.

These devices should have two main capabilities:

- **Timing Flexibility**: ability to move the start of running when requested so for instance when it is most cost effective (Load Shifting)
- **Power Level Flexibility**: ability to adapt the cycle to the available electrical resources at that time (Load Shedding)

The first characteristic was implemented in the prototypes developed in the project.

The information exchanged between the EBox and the smart appliances is mainly related to:

- Smart appliances registration with the EBox
- Polling, control and event based device monitoring (device status, start/finish times, power profile, power consumed, change of state as alarms)
- Operation requests from the EBox to appliances.

### 2.3. The DSO Medium Voltage Control Centre

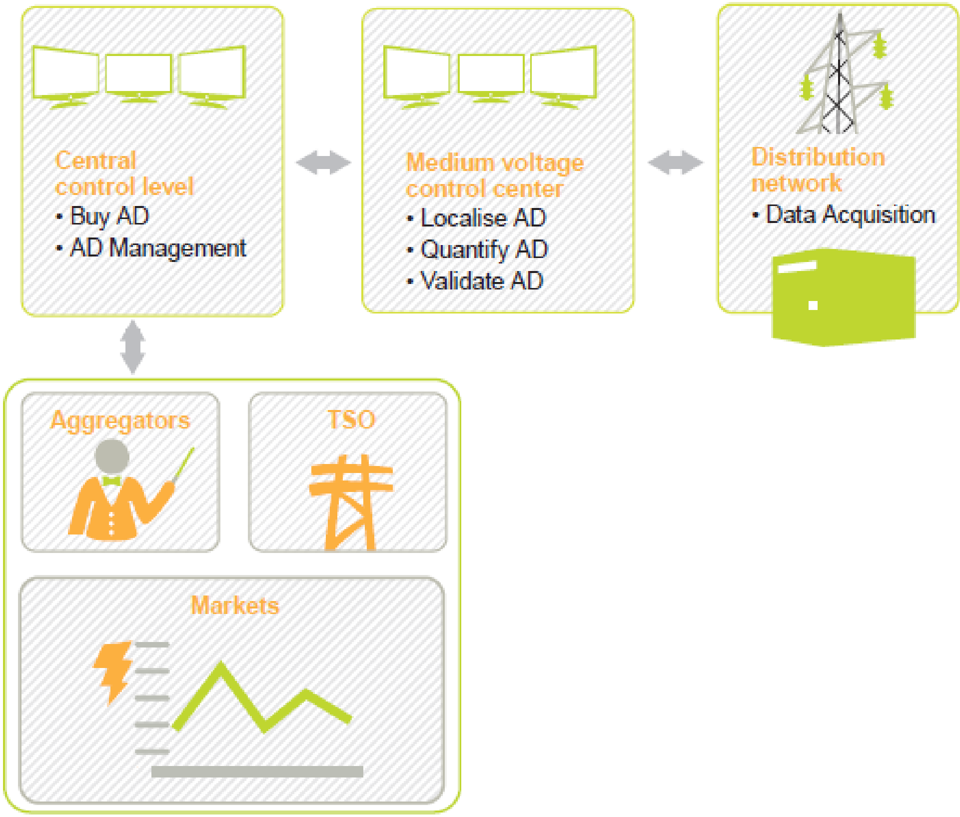



Figure 7: DSO Medium Voltage Control Centre

The DSO has (i) to operate the distribution network in a secure, reliable and efficient way, (ii) to maintain and develop the electricity distribution network, (iii) to provide transparent and non discriminatory access to all network users.

AD products can be procured by deregulated players to fulfill their operational needs and enhance their business optimisation processes. On the other hand, DSOs and TSOs can also procure AD products for real time network operation contingencies, long term operational planning and for network upgrading optimisation. So they can be AD buyers too.

The modification of the load profile stemming from the AD market may have a negative impact on network security and quality of supply, and players may perform contradictory actions. Therefore it is necessary to have coordination among the involved players. The system operator has to be informed about envisioned AD deployment and has to validate AD requests in its area of jurisdiction.

Therefore, the SOs play a double role in the ADDRESS architecture: the role of technical players (or *AD programs "validators")* and the role of commercial players (or *AD product buyers*):

The main functionalities of the SOs as technical players include:

- Enable AD on their network and ensure secure and efficient network operation
- Do the technical validation of AD programs
- Have a direct interaction with TSO (for the DSO) or DSO (for the TSO) for system security.

In such a context, DSOs and TSOs have to verify whether AD applications (e.g. increase/decrease of power demand at specific network location and at a specific time) are compatible with the secure and reliable network operation. This also implies that the System Operator has to provide to AD players location information, to localize the service on the network and to validate AD itself. For this purpose, consumers "equivalent" for the network operation are grouped in Load Areas (on distribution network) and Macro Load Areas (on transmission network), which are calculated, published and updated by DSOs in coordination with the relevant TSO.

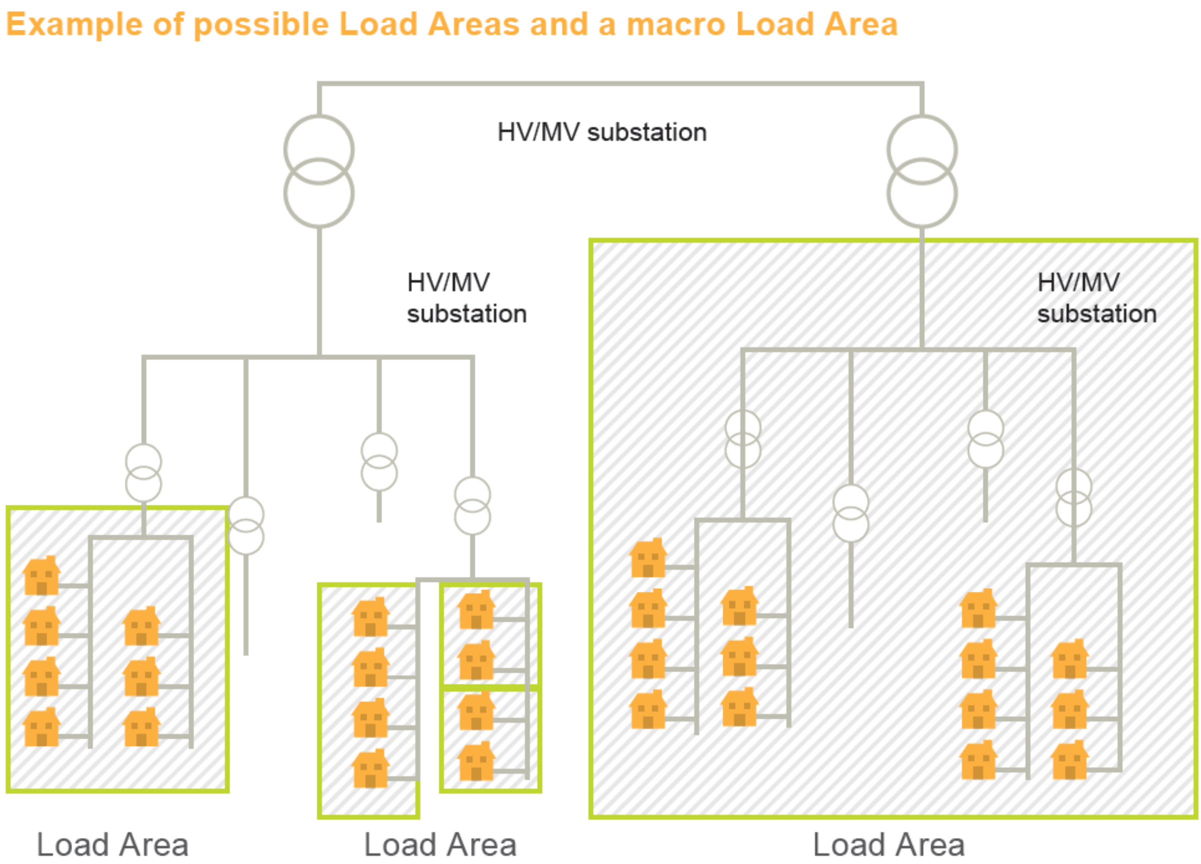



Figure 8. Load areas

To help aggregators to prepare their offers, the DSOs in coordination with TSOs also calculate, publish and update Flexibility Tables before market opening. These tables define the allowed flexibility per Load Areas and Macro Load Areas and are used as a guideline for aggregators. It is not a DSO/TSO commitment: the submission of requests within the limits does not guarantee that these requests will not be curtailed.

The DSO functional architecture encompasses three levels: the Central Control Level, the HV/MV substation level and the MV/LV substation level. Intelligence is distributed among the levels how and when needed. To carry out the double role of AD product "buyer" and AD programs "validator", the new functions of both the DSO Control Centre and the decentralised intelligence (e.g. local controllers at HV/MV and MV/LV substation levels) have to substantially improve the capability of DSOs (and TSOs) in terms of:

- Real-time monitoring and control over the whole Medium Voltage (MV) distribution network and over parts (or even the whole) of the Low Voltage (LV) network (for mature AD markets);
- Operational planning and decision-making process in order to determine the attractiveness of AD with respect to other alternative solutions;

- Evaluation of the feasibility of both AD products traded in the day-ahead, intra-day markets and the possible real-time validation of other types of AD products;
- Definition of load area and interaction with the TSO for the definition of the macro load areas (from the network topology/consistency point of view);
- Publication and updating of load area and macro load area (with the relevant consumers encompassed) with a well-established codification;
- Definition and publication of the Flexibility table;
- Procedure for the assessment/settlement, in case the DSO coincides with the metering company (as it happens most often); this may involve metering data provision, possible data storage and others;
- Interactions with other DSO and TSO intelligent systems, like Energy Management System (EMS), Geographical Information System (GIS) and Automated Metering Reading (AMR).

## 2.4. The Communication architecture

In the ADDRESS project, the goals of the communication tasks were to provide a guideline to design a communication architecture that enable active demand, together with a guide to test that the implemented communication system is sufficient to operate a smart grid with active demand.

The following communications requirement have been identified:

- Flexibility with respect to physical media;
- Full interoperability for all network elements to be guaranteed by XML based messaging and CIM standards;
- Secure remote access to all elements of the network;
- Implementation to be compatible with TCP/IP and Web Services;
- Communication performance should be independent of grid state;
- At Aggregator and E-Box level the network should be self-configuring;
- Network management: visualization and remote configuration.

A service oriented architecture based on web services and standardized XML messages forms the basis for ADDRESS communications. The Traffic matrix has been introduced as a tool for estimating and representing the overall performance requirements for a specific scenario.

On this basis the communication architecture has been designed. A specific methodology was adopted using UML:

Step 1: Textual Use Case Definition

The first step is to define textual Use Cases. In order to give guidelines it was promoted IEC Publicly Available Specification 62559. It is highly recommended to use this international standard and more specifically 62559-2 which defines the Use Case templates.

Step 2: UML Use Case Definition

The second step is to give a UML representation of the textual use cases defined into step 1. This graphical representation is complementary from the textual representation and facilitates the understanding and the design. Whatever the level of detail is for the UML representation, this step needs to highlight clearly sequence diagram focused on external interactions between actors (step 2b)

Step 3: CIM-ADDRESS UML Information Model Building

This step is focusing on building a common semantic on which all exchanges of data are based on. It enables to improve application interoperability and minimize the effort at the implementation side because all messages will share the same semantic. Once this step is completed, the result is an extended CIM information Model containing all required data for ADDRESS projects.

Step 4: Message Payload Definition

This step enables to define the structure of Message Payloads based on the previously defined CIM-ADDRESS information Model.

Step 5: IEC 61968-100 Web Service Definition embedding message payload

Once a XML schema is generated for each Message Payload, the resulting XSDs can be embedded and used for the implementation of an interface exchanging messages with external systems belonging to other Actors.

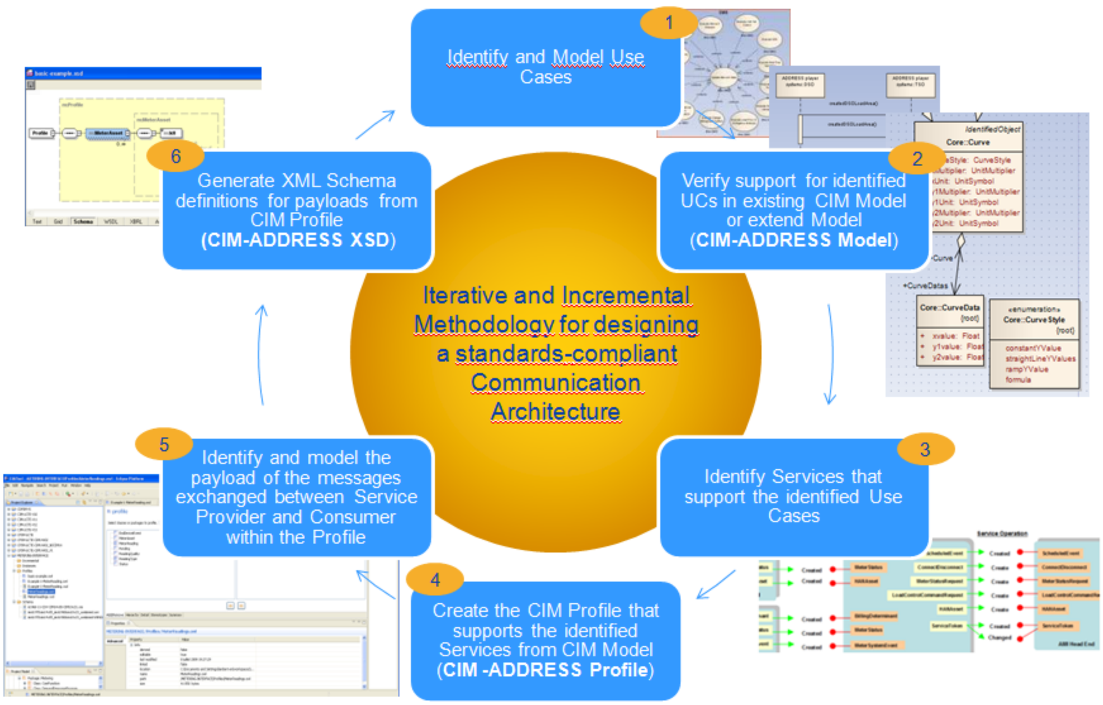



Figure 9. CIM Communicatiobn Architecture

# 3. Field test sites

The ADDRESS project had three test sites in three European countries with different network topologies and social and cultural backgrounds.

The combination of these three test sites (carefully selected) provides a validation of the entire concept. In Italy it was validated the “upstream part of the ADDRESS chain” (from Active Demand buyers to aggregation platform) with a focus on DSO algorithms and prototypes to enable and exploit Active Demand on a real and operating MV network and the effect of Active Demand visible at MV an HV level.

In Spain it was validated the downstream part of the ADDRESS chain, from aggregation platform to controllable appliances. Metering and appliances equipment have been installed at 263 customers to put under real conditions the concepts of ADDRESS at a scale in which tangible benefits can be studied.

In France it was validated the “whole ADDRESS chain”: from Active Demand buyers to controllable appliances but on a smaller scale, with around 30 consumers, one MV feeder and several LV networks and a relatively high penetration of Active Demand. In Spain and France different climate conditions (warm in Spain, cold in France) ensured different equipment (e.g. air conditioning in Spain and electric heating in France) and usage patterns.

The mixture of HV, MV, LV networks, hot and cold climates, as well as large and small networks provided a good basis from which to extrapolate to cover a good sample of European conditions.

## 3.1. Italy – Carpinone, Isernia

The objectives of the Italian field test were to make sure that the grid operator can maintain the normal grid operating conditions of an active grid and perform the technical validation of AD bids. Electrical distribution network management in presence of Active Demand was tested. Being not possible to involve too many Low Voltage consumers, AD products were emulated on the Medium Voltage network by means of a storage system and load/production variations of Medium Voltage customers/producers. Different degrees of AD products delivery (80%, 100%, 120%) were emulated in order to simulate the real Low Voltage consumers behavior. Tests performed were:

- Services provision by the DSO to enable AD business
- DSO operational algorithms to exploit AD services
- Interaction between DSO and Aggregators

The DSO algorithms used models of actual Medium Voltage and Low Voltage networks in operation.

The load/generation forecasting algorithms used the database of the real load/generation curves recorded by the electronic meters already in operation in the Enel Distribuzione networks.

The test was carried out in the distribution network supplied by one of the two HV/MV transformers of the Carpinone substation. The 340 km network under test includes 10 MV feeders, 157 MV/LV substations supplies more than 8000 LV customers.

## 3.2. Spain – Castellòn

In Spain the main objectives were to validate social acceptance and consumers commitment and to technically validate proposed solutions and prototypes for the Home Area Network.

The main functionalities tested refer to:

- HAN Communication;
- Validation of the EBox (remote user interface, optimization algorithm, interactions) and the rest of equipment (smart plugs, measuring device, smart washing machines, air conditioning management system);
- Validation of external communication EBox – Aggregator;
- Validation of consumers' experience.

The tests performed referred to:

- The functionalities of the Aggregator Toolbox
- The functionalities of the Ebox
- The functionalities of smart loads and smart plugs
- A global analysis of the whole system
- Consumers' behavior according to different incentives
- Consumers' behavior according to different duration of the signal

In particular social studies allowed to identify the reaction of residential consumers to AD helping for future research from different points of view: technical, societal and legal, concerning the definition of tariffs and contracts with the consumers. The consumers engagement policy was to offer a discount on the bill and incentive for the duration of the pilot.

## 3.3. France – Houat and Hoëdic

The main objective of the French field test was to demonstrate that the ADDRESS solution works from the beginning to the end of the ADDRESS chain. Tests performed covered the following aspects:

- The provision of services by AD to the electricity system players based either on requests of actual local players or requests resulting from the simulation of possible needs or problems, and in particular the use of AD for peak load reduction and combination with RES production
- The technical performance of the algorithms and strategies developed for the aggregation platform, the DSO (e.g for the technical validation of AD actions), the EBox, the control of the appliances and the exchanges of signals/data between the DSO, the aggregation platform, the Ebox and the appliances.
- Simulated market interaction by means of a market simulator and simplified modeling of players.
- Assess consumers' commitment in field tests and acceptability with respect to AD and project concepts

The test was performed in two small islands: Houat and Hoëdic.

Consumers engagement policy: incentive in the form of vouchers:

- a fixed amount of 50 € for the « participation » to the field tests
- a variable amount corresponding to the actual response of the consumers to "effective AD requests, namely 0,50 € each time the EBox modifies the consumption of at least 1 piece of equipment during the AD request (a minimum amount of 25 € equal to 50 requests received by the EBox is however guaranteed).

# 4. Results

In this chapter the main technical, societal, economic results are provided.

## 4.1. Technical

### 4.1.1. AD-market and the players of the electricity system

Different scenarios were tested with the market simulator to illustrate the potential impacts that Active Demand offers can have on the Energy Market. They replay actual past market situations that happened in the French Energy Market.

The real offer and demand bids were reproduced and the potential impact of Active Demand offers made by aggregation entities was studied, taking realistic hypotheses regarding their consumers' portfolio, the associated consumption flexibility and the market rules. In the case showed in the figure, an offer for a 250 MWh consumption decrease is proposed on the wholesale market.

The market has accepted all the volume of this offer and the resulting market price has decreased from 232 €/MWh without any Active Demand offer (Price 1) to 212 €/MWh with the Active Demand offer (Price 2).

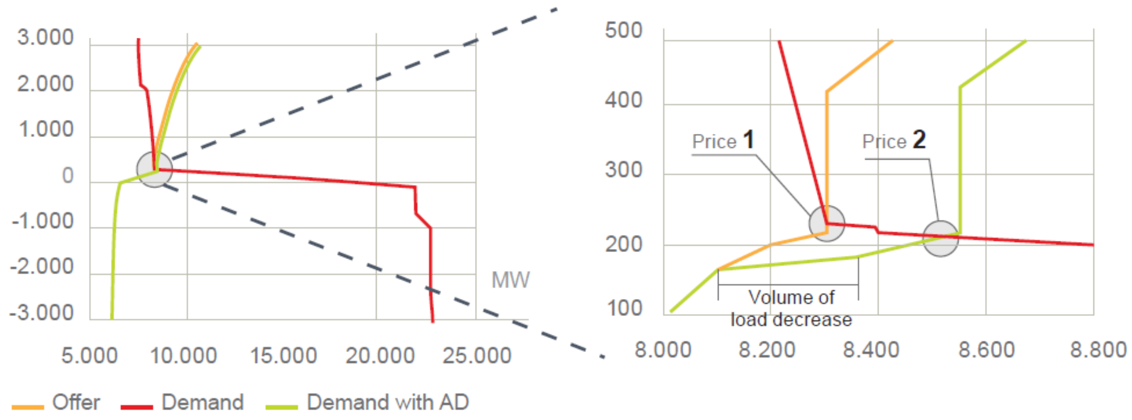



Figure 10. AD market and the players of the electricity system

### 4.1.2. The Home Area Network

The use of Active Demand at home is focused on the relationship between Aggregator-EBox – Smart Plugs/loads.

The equipment installed in all the houses allows the analysis of the technical solution implemented and of the acceptance or rejection of Active Demand by consumers.

The relationship between the players/components involved in the HAN is:

1. EBox receives the price volume signal the day ahead or in intra-day;
2. EBox runs the optimization algorithm in order to fulfill the Active Demand request with the manageable loads;
3. EBox sends the orders to the different Smart Plugs or smart appliances;
4. During the day, if consumers switch on a new manageable appliance, this one sends its requirement to the EBox;
5. EBox runs again its internal algorithms;
6. EBox sends activation signals to appliances again;
7. EBox records information received from the additional metering device during the day (5' slots);

8. EBox records information from smart plugs and smart loads during the day (5‘ slots);
9. EBox sends information concerning the measurements and status of all the appliances in the house at the end of the day to the Aggregator.

From Smart Plugs/loads’ point of view.

- The Ebox sends the orders to these devices in order to fulfill the Active Demand signal received from the Aggregation Toolbox.
- Figure 11 presents the behavior of the Smart Plugs when a signal is received. Depending on the target of the signal (increase or decrease of demand) the Smart plugs interrupt/schedule their loads to fulfill this Active Demand signal.

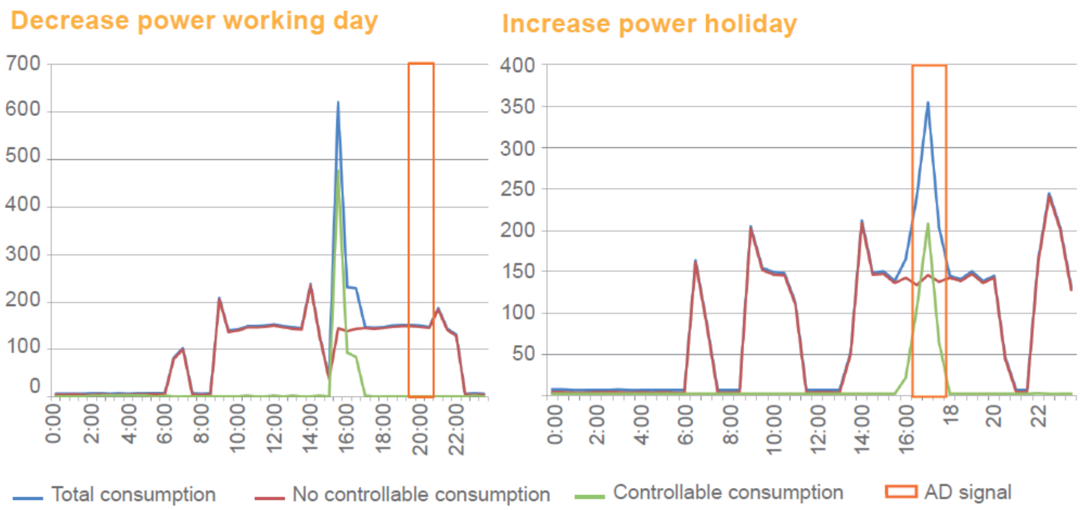



Figure 11. Behavior of the Smart Plugs

### 4.1.3. Requests from aggregation system and consumer response

The use of Active Demand to provide services to the Electricity System players was tested, namely:

- for DSO or TSO: voltage control, active power reserve, overload or network congestion relief, limitation of peak load on the grid;
- for deregulated players such as the BRP, the retailer or the PV producer: load shaping for peak load reduction, combination with PV production connected to LV level in order to shift consumption to periods when the PV plant is producing.

The corresponding requests were sent to the consumers’ EBox and the volume of the consumer response was assessed.

Figure 12 shows the average consumer response for a request to reduce consumption between 7h45 to 8h15 on March 14th in the French field test during the morning peak load period. An average reduction of more than 700 W per consumer is observed.

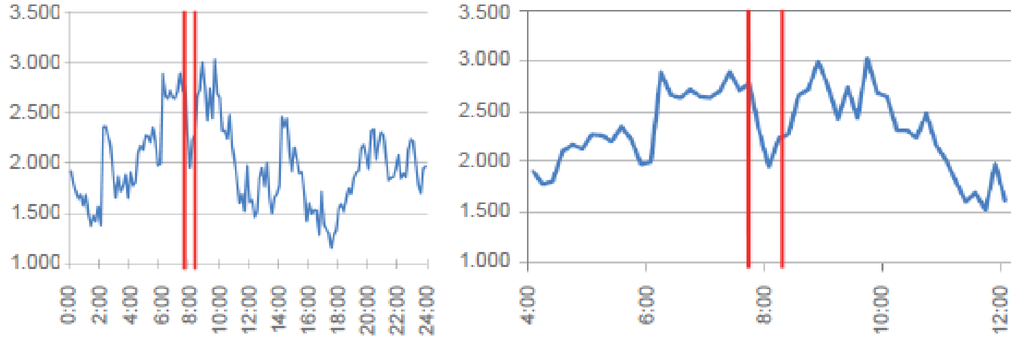



Figure 12 average consumer response

### 4.1.4. DSO systems

The tests performed in field have shown some important results:

- **DSO as an AD product validator: requests by deregulated players**

In this case, the DSO received bids (5,50 MW) for intraday and day-ahead Active Demand market to be validated.

In some cases a product curtailment was necessary to ensure a reliable network operation.

Validation algorithms fine tuned in order to validate properly Active Demand products both in intraday and day – ahead markets.

- **DSO as an AD product buyer: to solve its own network problems**

In this scenario, the DSO bought the Active Demand products (0,3 MW) in order to solve some expected network congestions (to avoid MV cable overloading).

Afterwards, thanks to Active Demand there was no network violation (the problem was solved).

Distribution State Estimation fine tuned in order to:

- Adapt it to the network under test and react well to the network configuration changes;
- Manage better the real measurements and other input data from the Load Forecast and Generation Forecast algorithms;
- Detect correctly network constraints violations, and the effectiveness of the countermeasures;

**- TSO as an Active Demand product buyer: to solve a transmission system problem**

In this case, the TSO in order to limit the existing power flow rising to the transmission network through the HV/MV substation, bought a 1,2 MW Active Demand product located in the MV network of Carpinone.

The Italian and French field tests validated the DSO algorithms to enable Active Demand and showed that Active Demand can be used to solve some DSO and TSO problems.

### 4.1.5. Interoperability and communication

DSO/TSO coordination is needed taking into account responsibilities and different needs and constraints of regional and local networks.

Suitable and “cheap” communication systems have to be envisaged to ensure the DSO role in the Active Demand market, taking care of the huge number of nodes and branches of distribution networks.

Similarly, the communication between the players should also involve a “cheap” and suitable communication system ensuring the interoperability of the different components of the Active Demand architecture, protecting the confidentiality of the exchanged data and sufficiently robust.

In the tests, the communication was implemented through:

- GPRS communication in Spain and internet in France, between the Aggregation Toolbox and the EBoxes;
- Zigbee Technology inside the dwellings between:
    - The EBox and the smart plugs and smart loads, both in Spain and France
    - The EBox and the additional metering device in Spain
- WMbus communication between the meter and the EBox in France.

Several communication issues were identified in the field tests showing that research work is still needed before achieving the required reliability, robustness and interoperability for an effective Active Demand deployment.

## 4.2. Societal

The ADDRESS field trials installed an innovative EBox to control appliances in consumers' homes. Before the trial, consumer expectations of living with the technology were positive.

In France, 64% thought that living with Active Demand would be fairly easy, and 21% believed it would be easy. In contrast, 33% of participants in Spain expected living with Active Demand to be fairly easy and 29% believed it would be easy. Many consumers expected programming the EBox to be straightforward; 64% of those in France expected that it would be easy or fairly easy, compared with 42% of those in Spain. There was a significant proportion (43%) of respondents in Spain, however, who did not know what to expect in relation to the EBox.

For some, however, experiences during the trial did not live up to the positive expectations; these consumers found using the EBox difficult and for many, the technology was invisible.

In the pre-trial questionnaire, respondents were asked how easy or difficult they expected living with ADDRESS to be, as well as how programming the EBox and using the different technologies of ADDRESS, such as the smart plugs, would be. For those respondents who had completed both (pre-trial and post-trial) questionnaires (37 in Spain and 9 in France) these results were then compared to their perceptions of the technology after they had lived with it for a period of time.

In Spain, in terms of living with ADDRESS, there was no significant change in perceptions, with respondents reporting similar levels of ease. 33% of respondents expected that it would be fairly easy and 28% expected it to be easy, which is comparable to 39% who found it fairly easy and 22% found it easy, registering a slight increase.

However, when it came to programming the EBox, whilst 39% expected it be easy, only 25% believed it to be so after trailing it. A smaller difference is observed in the case of the use of the smart plugs. This suggests connecting to the EBox and making sense of its sections or pages was more difficult than expected.

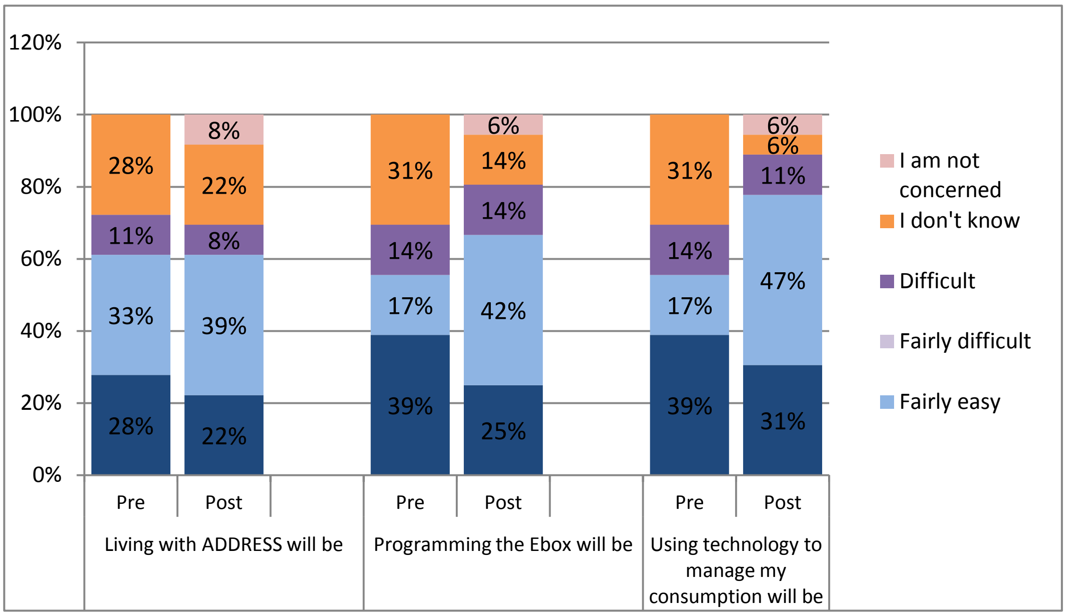



**Figure 13. Expectations of ADDRESS technology in Spain**

In France, all the respondents  have found living with ADDRESS installed in their homes easy and fairly easy. This is likely to reflect  the invisibility and unobtrusiveness of ADDRESS technology in the case of the French field test site, since the field trial focussed on interruptible appliances such as water heaters and the heating in rooms.

However, the experience of respondents differs considerably in relation to  programming the EBox, where mixed responses reflect the different experiences people had when using the EBox. Experiences regarding using the ADDRESS equipment to manage their household electricity consumption only slightly differed from expectations with a slightly higher percentages of respondents (44%) finding it easy, compared to 33% who expected it to be so.

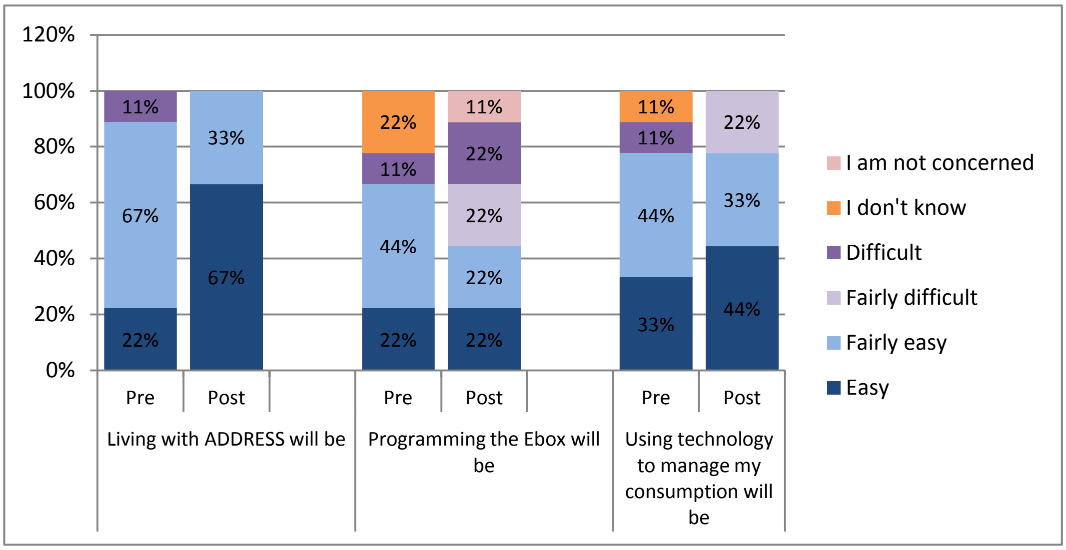
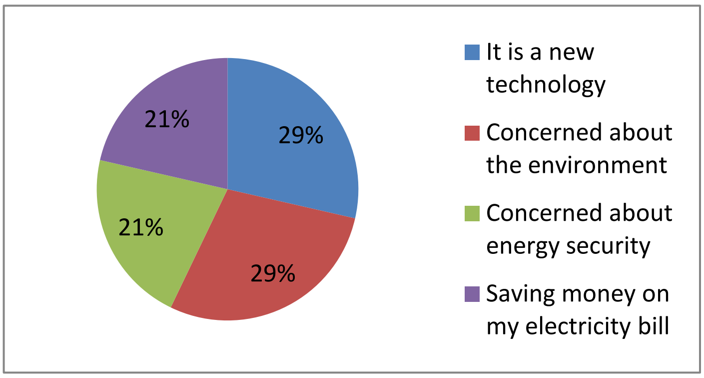



**Figure 14. Expectations of ADDRESS technology in France**

Motivations for adopting Active Demand go beyond financial incentives. Results suggest wider system benefits are important to people. Participants in the French field test were motivated because ADDRESS was a new technology (29%), and others were driven by more collective concerns about the environment

(29%) and improving energy security in the islands (21%), whilst only 21% were interested in saving money (Figure 3). Although in the Spanish field test the majority (68%) was interested in saving money, 11% expressed interest in ADDRESS as a new technology and 8% in protecting the environment and energy security (3%), whilst other reasons (7%) were a combination of the above factors, where interest in the technology and environmental concerns featured strongly.



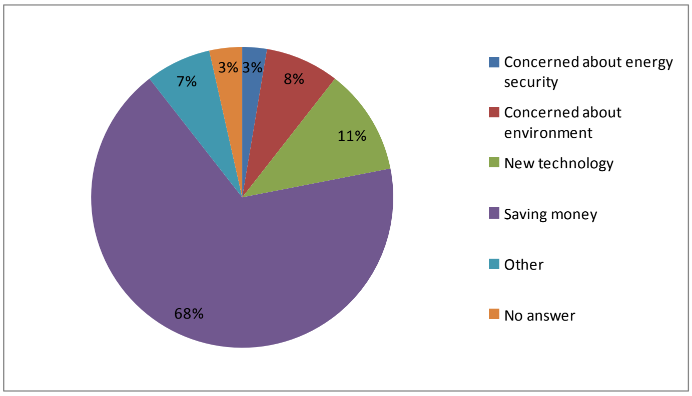




**Figure 15. Motivation for adopting Active Demand in France (1) and Spain (2)**

These motivations are mirrored by participants' rationales for saving energy. In the test site in France, 68% wished to save energy equally for money and environmental concerns, compared to 47% in the site in Spain. Similarly, 8% in the French field test wished to save money more than protecting the environment compared to 35% in the Spanish field test. Furthermore, there was considerable interest in other aspects of Active Demand, such as feedback on household energy consumption, evident through conversations with participants in France.

Figure 16 illustrates the age of children within the households. The presence of children may impact the household practices related to ADDRESS, such as the flexibility (and amount) of laundry and other related activity, the amount of time the household is occupied and the thermal comfort. An important point in relation to life on the isles is that from the age of 15, children will most likely be attending school on the mainland, returning to their home for weekends and holidays. This may change the nature and dynamics of households that have children in this age group.

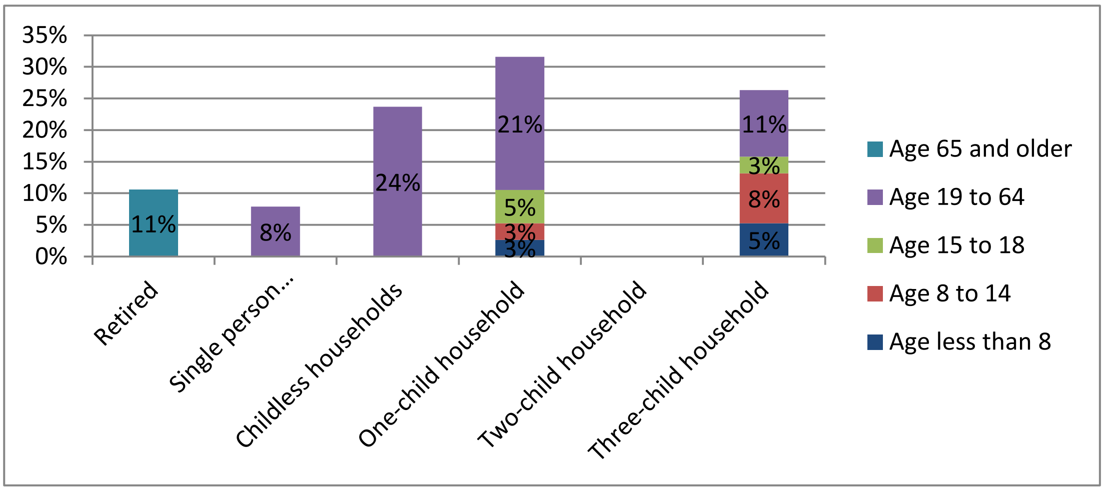



**Figure 16. Age of participants by type of household in the French field test site**

Regarding the Spanish participants, the age distribution by household type for the 114 households who completed the pre-trial questionnaire is showed in the figure below. Of the 114 households, 61 (52.4%) have children; 3 (2.6%) are retired couples with no children, 10 (9%) are single-person households and 40 (35%) are two person households without children. The majority of the respondents are adults (between 19 and 64 years old), whilst the majority of children involved in the ADDRESS trial are younger than 8.

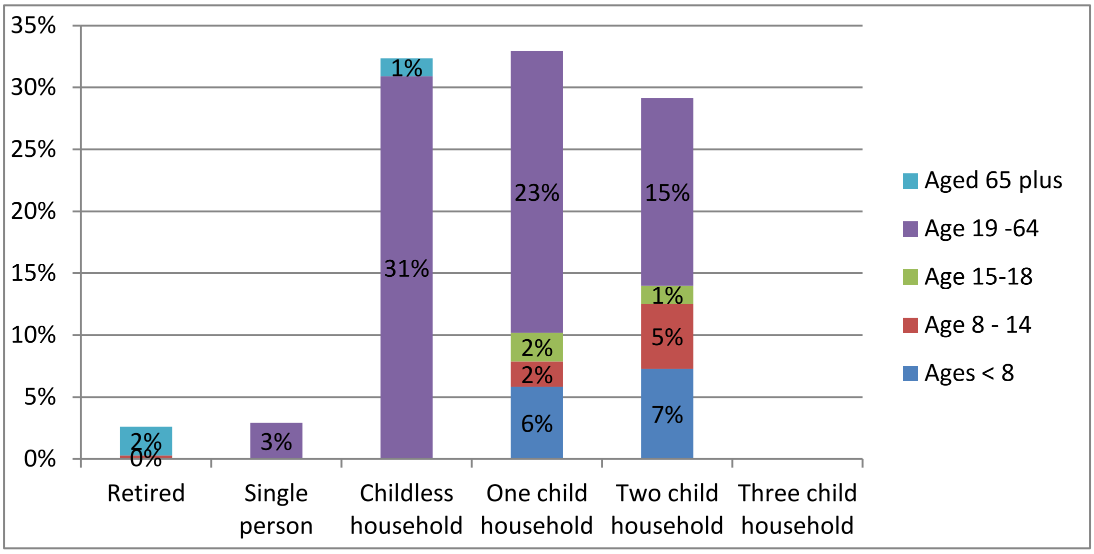



**Figure 17. Age of participants by type of household in the Spanish field test site**

In the ADDRESS system architecture, the EBox is the gateway to AD. As such, consumers can use the EBox to set the parameters for the control of their connected appliances, and monitor the consumption of connected appliances. The following figures illustrate participants' interactions with the EBox in the two field test sites.

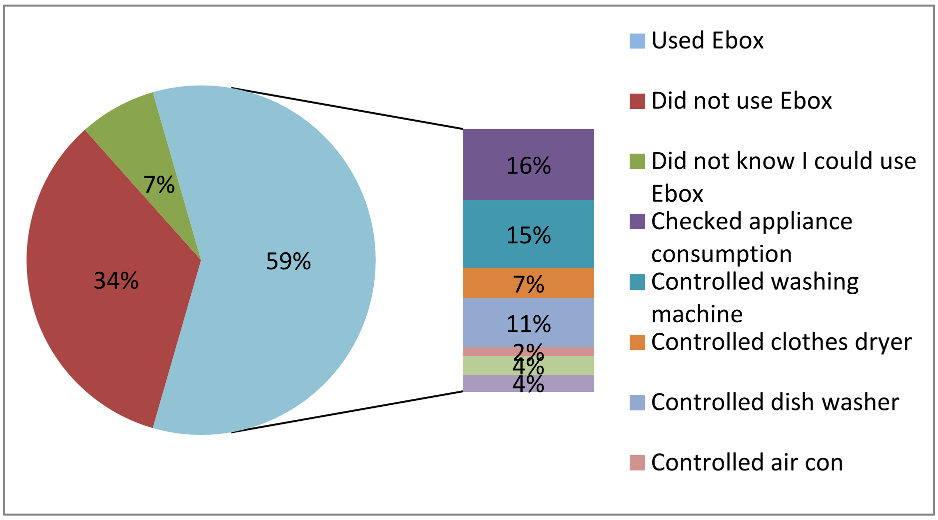



***Figure 18. Interactions with the EBox, Spanish field test site***

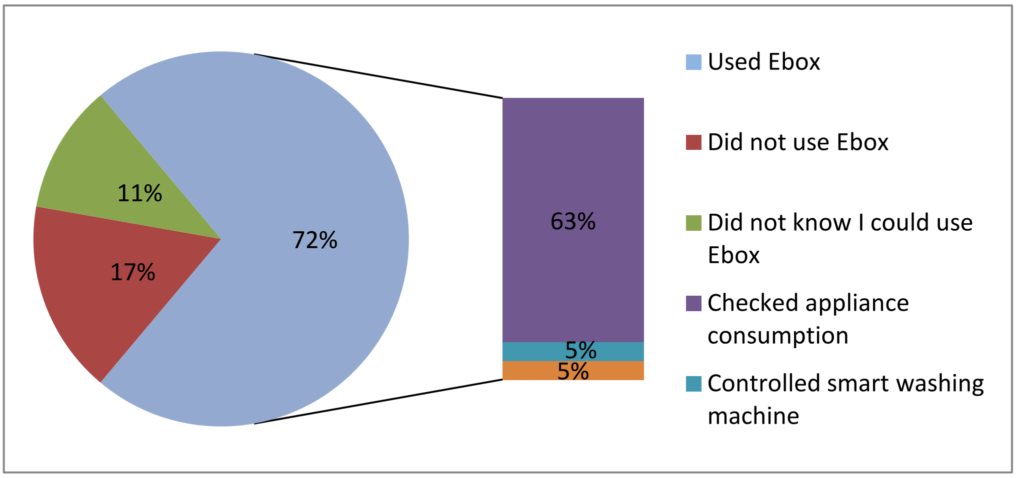



***Figure 19. Interactions with the EBox, French field test site***

In the figures above all those participants who used the EBox sought information about the consumption of their appliances, but control of appliances was limited. In both cases a significant number of respondents did not use the EBox, or did not know they could use it. The greater diversity of reasons for using the EBox in the Spanish field test reflects the increased functionality of the field test. For those appliances for which the parameters (time of operation, comfort and financial savings) were controlled by the EBox, respondents used the EBox to both change these parameters and override control. Similarly to the French field test site, participants in the Spanish field test were keen to learn about the consumption of their appliances.

Implicit in any AD system is the monitoring of a household's energy consumption and in the case of ADDRESS the communication of that data outside the home, both for reasons of monitoring the trial, but also to inform the operation of the aggregator. The following figures explore the extent to which issues of monitoring and recording of data, and the automation of control of domestic appliances was of concern to respondents. These results must be seen within the context of the different field trials, where consumers in Spain experienced a far greater element of AD than those in France, most notably over a greater range of domestic appliances. Thus the technology in the Spanish field test intruded far more on household life on a day to day basis.

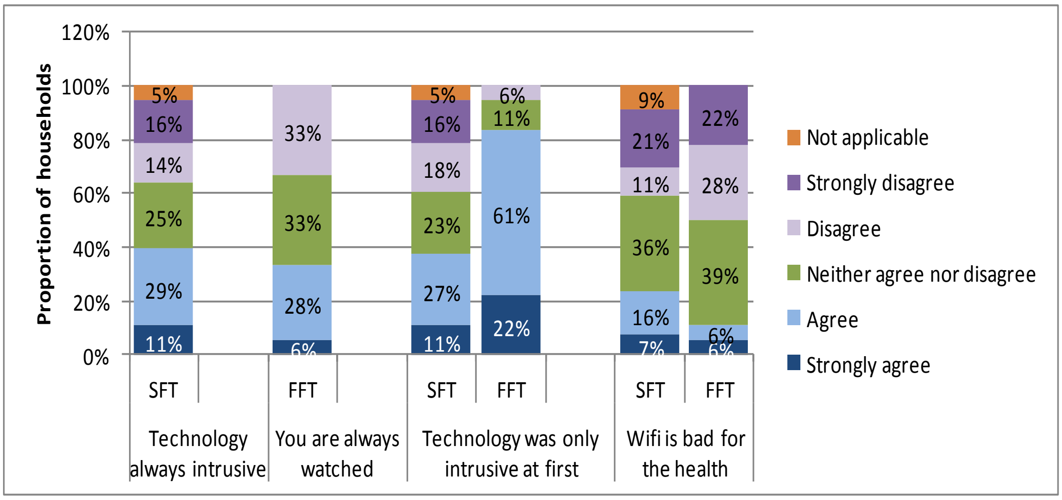



***Figure 20. General impressions of the technology***

Respondents were asked how they rated the trial overall, where 1 is very poor and 10 is very good. Figure below summarises the ratings for the trial. For participants in the French field trial, the mean score was 5.82, and the most commonly occurring score (mode) was 6. A majority of respondents had an above average experience. In the Spanish field trial, the mean score was 5.75, with 3 modes (3, 5 and 7). Experiences of the trial were more evenly distributed than in the French field trial. Overall, the mean scores reflect the issues experienced by those who had problems during the trial and who rated the trial poorly.

| | **Spanish field trial** | **French field trial** |
|---|---|---|
| Range | 1 - 10 | 1-9 |
| Mean | 5.75 | 5.82 |
| Median (middle) | 6 | 6 |
| Mode (most commonly occurring) | 3, 5, 7 | 6 |

***Figure 21. Overall trial performance***

30 of the 57 respondents from the Spanish field trial would consider adopting an ADDRESS style technology in the future, and 13 of the 17 respondents in the French field trial. In both field trials, reasons for adopting the technology highlighted its potential as a tool to manage electricity consumption in the home, with financial benefits for consumers, and electricity network benefits. The latter was particularly highlighted in the French field test.

Figure 21 summarizes the responses of the respondents from the Spanish field trial who would consider adopting an ADDRESS type technology in the future. In response to how important each of the above variables are for adopting the technology, the financial benefits and subsidies for smart appliances appear to be the most important for the majority of respondents. This is followed closely by clear information given in advance regarding financial penalties for overriding the shifting or interruption of loads, and information about how much savings are accrued by accepting an AD request. Less important were issues related to information about the environmental benefits and energy security gains resulting from the use of AD technology.

What is noticeable amongst this sample is that for those who would consider adopting AD technology in the future, minimal changes to their routines appears to be less important than the financial benefits, penalties or costs of replacing their appliances. This is also reflected in their concerns for the amount of effort required to install and set up the system in their homes. This suggests that for the AD to be made more attractive to consumers, improvements to the technology such that it can be more manageable according to people's lifestyles and routines would encourage those – who at this point in time – perceive the ADDRESS to be too disruptive. Examining closely the reasons people gave for not adopting the technology, out of the 23 who said they are not likely to adopt it, only 5 had cited technical issues with the system – including the inability to programme the system according to their daily needs, 9 gave the disruptions to their routines and household organization as an answer, whereas others were deterred by the technical problems that they faced (5), lack of information (4) or felt that the technology is not ready or not necessary.

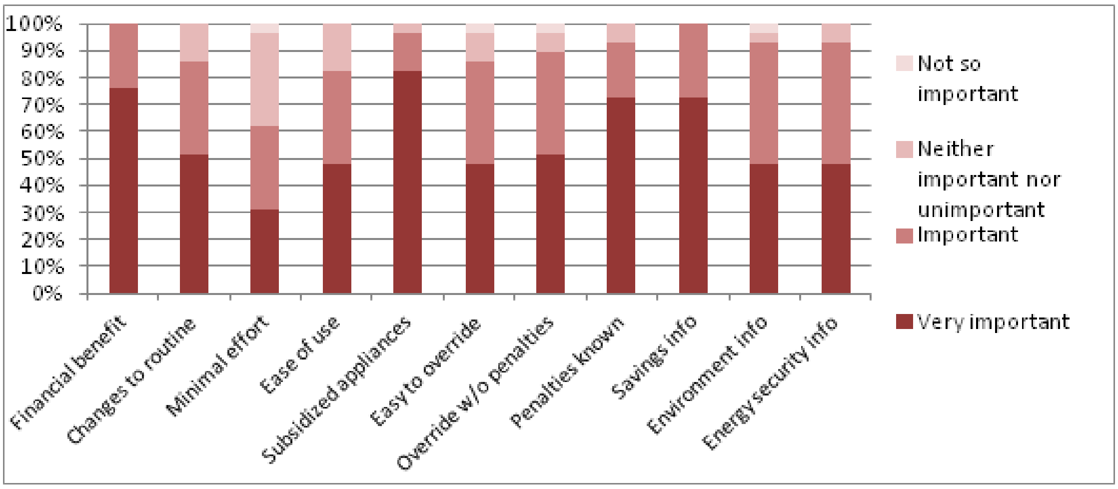



Figure 22. adopting an ADDRESS type technology in the future (Spain)

The relative influence of different factors over the adoption of AD in the future is summarised in the Figure 23 for the French field trial. As in the Spanish field trial financial savings are the most important factor in people's decision to adopt an AD technology in the future, and more important than the need to avoid changes to routine. Whilst the EBox must be easy to use, emphasising that some consumers found using the EBox more difficult than they expected, the time to set up the system is not an important factor for a majority of respondents. Clear information must be provided such that consumers know the benefits of AD, both to themselves in terms of financial benefits, but also wider benefits such as environmental benefits and impact on the security of supply. Of these, information about the impact on security of supply was the most important (92% or 12 people) compared to 85% (or 10 people) and 77% (or 8 people) for information about financial benefits and environmental benefits respectively.

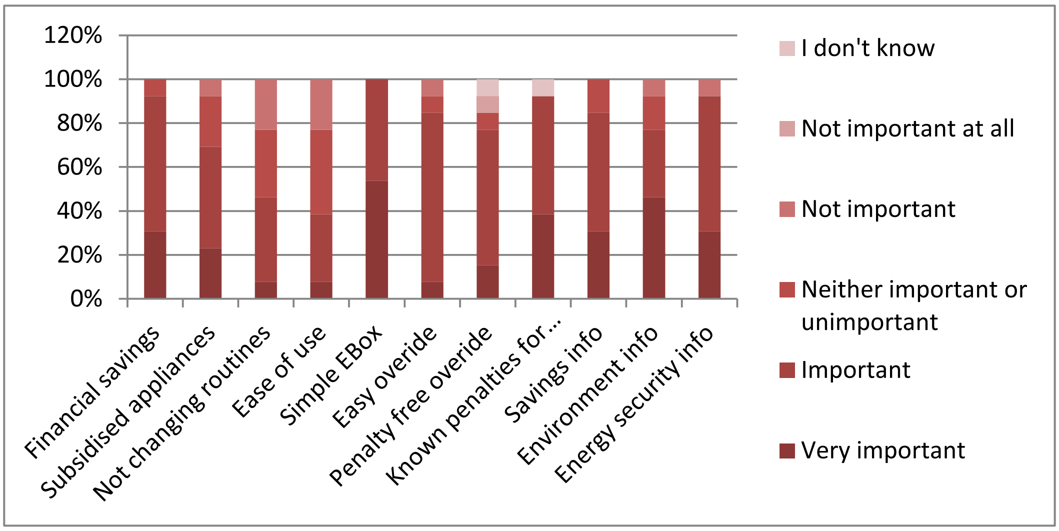



Figure 23. adopting an ADDRESS type technology in the future (Spain)

The ADDRESS trial has involved a diversity of households: single people, couples, families and older people. The field trials have taken place in two contrasting areas, the small islands of Houat and Hoëdic in France and the urban setting of Castellón in Southern Spain. The contexts for the field trials are very different as are household practices, thus for participants in the French field trial, thermal comfort is about keeping warm in winter, whereas for participants in the Spanish field trial it is about keeping cool. Similarly, different laundry practices were prevalent in the two field trial locations, with the use of delayed start common amongst participant household in Houat and Hoëdic, but not in Castellón. Living on an Island, which was only connected to the electricity network in the 1960's, concern over energy security and concern for the environment were a key motivator for participation of participants in the French field trial, in contrast financial motivations were most important to those took part in the Spanish field trial.

The interviews shed light on the everyday experiences of living with the technology and the impacts of the shifting and interruptions to electricity consumption. For field trial participants, the shifting and interruptions – central yet technical elements of the ADDRESS technology, translated into disruptions to household routines and rhythms. Thus, if the benefits, both societal and to individuals, that an innovation such as AD can bring are to be achieved, the complexities of everyday life have to be brought into the design and development of what is effectively an object of the future. This idea is further emphasized when considering the user interface and the usability of the system. The findings suggest people are willing to make changes and adapt, but these intentions corresponded to requirements for easier to use interfaces, accessible systems that need to be retrieved at short notice, and convenient programming that fits in better with normal family life.

The experiences of participants in the field trials have been strongly influenced by the performance of the technology and their understanding of the trial and the equipment installed in their homes. This was particularly the case for the shiftable loads where the control of conventional appliances with smart plugs was an imperfect technical solution. In these instances, instead of operating in the background as intended, the technology came to the fore as participants waited for their washing machine or clothes dryer to restart. In these instances, and also at times where events occurred outside the normal day-to-day of the household, stopping the EBox control of an appliance became a priority, and for many, unplugging the smart plug was the most expedient solution. Where a smart washing machine was installed, the framing of AD differed, in that a decision is made to hand control of the appliance to the EBox, and to allow AD on a case by case basis. In this sense, the control is with the consumer, whereas with the control of conventional appliances, a consumer has to take control back.

In contrast, for many the interruptible loads slotted more into household life. EBox control of hot water heaters across both field trials was, for most, effective and unobtrusive. Considering AD going forward, a significant number of participants who completed the post trial questionnaire would consider adopting an ADDRESS style technology in the future. Consumers would potentially be in interested in a number of AD interfaces, where they have the ability to enter a range of parameters, with financial savings being the most important of these. An override function is an essential component of an AD system, and any penalties for using this function must be made clear. Contracts which offer a combination of fixed and variable remuneration were preferred. In the context of these field trials, existing electricity suppliers are in a good position going forward as many of those who would consider AD would prefer this service to be offered by their existing electricity provider.

In terms of identifying a typical ADDRESS adopter, the results show that looking at demographics alone was not sufficient, as there was little variation in the type of households willing to consider ADDRESS in the future to those who are not willing to consider it. However, the time available to the householders to complete their household activities, which varies between households, was a strong predictor in accepting AD technology. Those who were home during the day, or between 2 and 4 during the day, had more time to complete and schedule their activities, allowing them the space to integrate ADDRESS into their routines and schedules. In contrast, those who had a relatively erratic schedule were unable to give the technology control over their household activities, preferring not to consider ADDRESS as a viable energy management system for the homes in the future.

## 4.3. Economic

The degree of adoption of Active Demand (AD) programs will be largely influenced by their costs and benefits, and more particularly, by the costs and benefits that accrue to each agent in the power system. For example, saving money is cited as the most important reason for engaging in AD programs in Spain (although in the Brittany Islands in France other reasons such as security of supply and protection of the environment appear to be as important as money savings due to the particular situation of the islands).

Regulators will (or should) be driven mostly by the results of social cost-benefit analyses. Here the key elements seem to be the long-term investments (of which the largest seem to be the communication costs) and benefits (regarding mostly avoided investments in networks and power plants).

Distribution System Operators (DSOs), as the parties typically responsible for deploying Medium and Low Voltage network infrastructure, will be mainly concerned by the costs, particularly by those that may be more difficult to transfer to consumers, that is, communication and control and network automation costs.

Aggregators, in turn, will be motivated by the business opportunity that appears whenever there are significant savings (benefits) to be shared with the consumer. In particular, given the structure of most electricity markets, the most relevant benefits here will be those related to the generation markets (daily, intradaily or balancing).

However, for all these costs and benefits to take place, the keystone is the consumer. What are the key economic factors that may influence the adoption of AD programs by consumers? Again, the consumers, if reasonably rational, will also conduct their own cost-benefit analysis (not precluding of course the inclusion of other non-economic factors, such as the desire to save energy or protect the climate, among others). The benefits will come basically from changes in the budget devoted to electricity consumption, that is, there will be benefits if the expense in electricity decreases. The cost, in turn, will have two parts. Firstly, the direct cost to be paid by the consumers (typically, the adaptation of appliances and plugs in their homes). Secondly, the cost that is passed-on by DSOs and aggregators in return for the infrastructure to be deployed (smart meters, telecommunication services, among others).

At the system level, the benefits assessed have been: reduced energy and pollution costs, reduced network investments, reduced network losses, and reduced costs of balancing. The total figures obtained per country range from 400 to 2,200 million Euros per year, which amount to 1.5 – 6.5% of each country's system typical costs. Of these savings, most correspond to a reduction in fuel and emission costs, and a much lower share belongs to network benefits and savings in balancing. The actual numbers vary based on the power system configuration in each country and on the scenario of penetration of AD. The four scenarios considered, originally proposed differ in the peak load reduction and total energy reduction. This is shown in the figure 24.

**Scenarios considered**

| | Peak load reduction | Payback effect | Energy reduction |
|---|---|---|---|
| Scenario 1 | 20% | 20% | 10% |
| Scenario 2 | 25% | 20% | 15% |
| Scenario 3 | 10% | 20% | 5% |
| Scenario 4 | 35% | 20% | 20% |

| | Country |
|---|---|
| Scenario 1 | Italy, Spain |
| Scenario 2 | Germany, Italy, Spain |
| Scenario 3 | Belgium, Germany, Spain |
| Scenario 4 | Belgium, Germany, Spain |

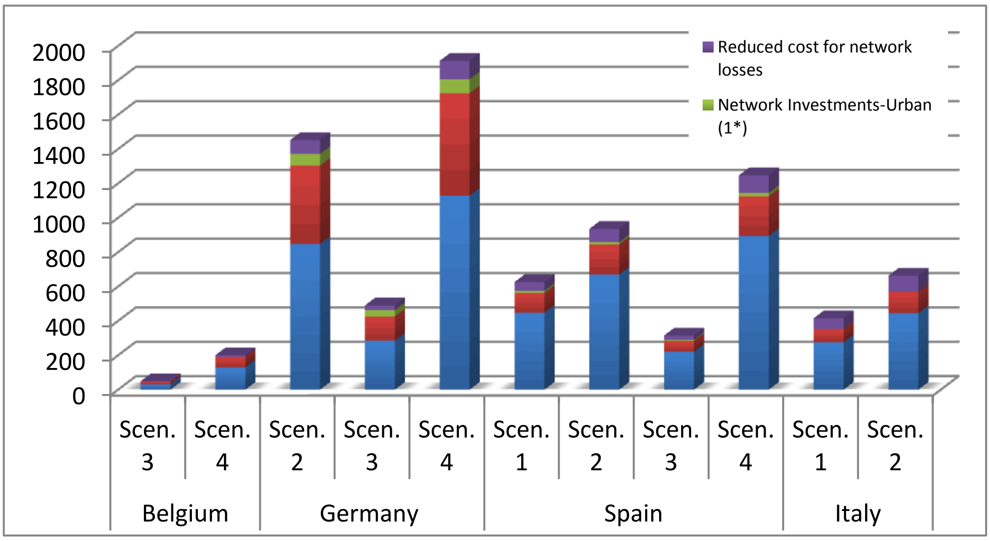



Figure 24. Annual savings in million Euros from different AD scenarios

These are not negligible benefits, although of course they should be compared against the costs of setting up the infrastructure required for AD programs to take place. Here the estimation is even more difficult, as there are few real cases in which all the infrastructure required for the ADDRESS architecture has been installed (it should be highlighted that this architecture is not only the deployment of smart meters), and even in these cases it is not clear whether the costs quoted are already commercial (the low level of penetration of these technologies suggests that current costs are much higher). In addition, given that this infrastructure can be used for other purposes, and not only AD, it is difficult to allocate the costs to AD programs in order to compare them with the benefits[1].

However, as mentioned before, these system-level benefits may be interesting as drivers for regulators' or policy-makers' decisions, but will not determine whether the rest of stakeholders will actually engage in AD programs. In this regard it would be more important to assess the individual benefits and costs for each stakeholder.

This presents an important difficulty: the attribution of the costs and benefits of AD programs will depend both on the regulatory context and market conditions. The regulatory context may determine for example to what extent the savings achieved by DSOs or TSOs (Transmission System Operators) through AD programs must be passed on to consumers. The market conditions can allow for example the sharing of benefits between aggregators and consumers.

Two different estimations are presented. A first one, in which the total social benefits are divided by the number of consumers affected. This should provide an indication of the benefits available for sharing between the agents. Depending on the country and on the scenario considered for the penetration of AD programs, we have estimated these total benefits to be between 6 and 48 Euros per consumer per year.

The potential for providing the selected AD services in the countries analyzed will strongly depend on the future evolution of electricity markets and regulation. This way, positive changes in market regulation, increased customers' environmental awareness, changes in tariff structures/design and higher cost of energy fuels, among others could create the conditions needed by aggregators to launch AD programs and by consumers to engage in those programs.

However, there are some other “capacity-related” services whose potential can be attractive today. In these services, AD helps grid operators, either by reducing the allocation of grid use, by providing additional resources for balancing the system, or by deferring/avoiding network investments.

In Spain, the use of AD to reduce the contracted power can save an active consumer about 29.5 €/year. If an interruptibility service were implemented for small consumers as there is for big ones, they could obtain additional 24.7 €/year.

In Belgium, there is no contracted power, but active consumers could still obtain about 18 €/year if they were allowed to participate in the market for the provision of reserve services for tertiary control to the TSO.

In Italy, aggregators may provide the following services:

- Smart load reduction service to the DSO, so that the latter can be involved in the mitigation service that is currently active in Italy. By taking into account that the TSO pays the DSO for mitigation services 10 €/kWh for the first 4 hours and 3 €/kWh for the following hours, and if the DSO shares 90% of this amount with the aggregator, each consumer can get about 26.1 €/year for providing 0.2 kWh per call in about 40 calls.
- Smart load reduction as an interruptible load service, whose total cost for the system and number of providers are a bit higher than in Spain, so that the potential for small consumers (if they are allowed to provide it) should be in the same range of about 25 €/year.

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[1] This of course brings the question of how to share the costs among the different applications of the smart grid.

- Voltage regulation and power flow control for the DSO, so that the annual investments of about 71 M€ in the LV networks could be significantly reduced. The amount that the DSO can actually save will strongly depend on the distribution grid conditions and on its own confidence towards AD. In the short-term, it is likely that DSOs still reinforce their networks, but, as AD markets evolve and DSOs gain confidence, they are expected to use AD to avoid reinforcements more frequently.

Annual electricity bill for Italian consumers is about 524 €, 95 € of which correspond to system costs that could be reduced by the provision of these services. Therefore, we could envisage that all domestic consumers could benefit from a reduction in their annual electricity bill, as long as AD markets are developed and, as expected, they are more cost efficient in providing these services.

There are several interesting possibilities for specific AD services in other countries than Spain, Italy, Finland and Belgium, but only the example of capacity related services in the UK is elaborated in deliverable 5.4. From the analysis, it can be concluded that:

- Although the minimization of DSO interconnection costs and investment deferral or avoidance is case sensitive (some applications would produce no value, whereas others can offer significant benefits), in cases with high capacity charges and fixed costs, or networks approaching their operational limits and subject to significant demand growth uncertainty, AD can provide around 237 and 4740 Euro per year for domestic and commercial customers, respectively. Another good point of the AD capacity services for DSOs is their low frequency, which in the base test case and with a 5% AD penetration was only 3.78h per year per customer (i.e. 8 HH calls per year in the UK). This service could be notably attractive for customers, as it could offer high gains for a service that would only be active a few hours during some years.
- The value for avoidance of transmission charges is less (£4.4 or about 5 € under ADDRESS consistent assumptions, £7.5 or about 9 € for domestic and £141-£145 or about 170 € for commercial) but still reasonably attractive, especially given the low number (around 15) of calls per year.

# 5. The potential impact of project ADDRESS

The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

The adoption of the ADDRESS architecture will impact the overall power system and its participants, particularly the aggregators, customers and system operators. In addition, the trade of AD products will affect the manner in which power system participants interact and energy services are valued, especially by customers who will be more actively involved in the management of the system and will accrue economic and social benefits.

## 5.1. Overall system

The ADDRESS architecture involves several costs in exchange for a broad range of potential benefits. The costs are mainly related to investments in Advanced Metering Infrastructure (AMI) and other bi-directional communication facilities, smart meters, and the adaptation of households. The benefits can include (i) reduced energy costs, (ii) improved market and system performance, (iii) lower network losses, (iv) reduced network investments, (v) emissions reductions, and (vi) the provision of capacity services.

### 5.1.1. Reduced energy costs

AD management can result in reductions in overall demand whenever the payback is lower than 100%. The latter effect is not a benefit, but merely a transfer from producers to consumers or from consumers paying AD measures to other free-riding consumers.

Apart from reducing total demand, AD services may reduce the need for reserves, ancillary services, or start-ups, by better adjusting in real time supply and demand. This in turn will reduce the aggregated cost of electricity production. In this case, although the final beneficiary may be the consumer, other players may share some of these benefits. These players can be compensated for mediating the participation of consumers, and for reducing uncertainty and risk by aggregating multiple consumers.

In the ADDRESS project the reduced energy costs were calculated based on fuel cost reductions, which results in overall cost reduction of 31M€ to 894M€. This translates to reducing the cost per consumer by €5.8/year to €32.3/year.

### 5.1.2. Improved market and system performance

AD may have an interesting contribution to the reduction of the balancing costs of the system, as AD products could be used instead of flexible but expensive generation. This can provide several market benefits such as reduced price volatility and higher use of intermittent generation, and even system benefits such as quality and security improvements.

The value of AD products for balancing according to the ADDRESS project is 19M€ to 104M€. This translates to reducing the cost per consumer by €0.7/year to €3.8/year.

### 5.1.3. Reduced network losses

By reducing congestion, and by adapting better to the network capacity, AD services may reduce network losses. This benefit is rather straightforward, as it may be calculated at the avoided cost of producing this electricity. The same issue about regulated services applies as before: this reduction in losses may be translated or not into tariffs for the end consumer, depending on the regulation of the system.

Network losses reductions in the different countries under study are estimated to produce savings of 10M€ to 103M€. This translates to reducing the cost per consumer by €0.5/year to €3.3/year.

### 5.1.4. Reduced network investments

Similarly, AD services for the reduction of peak loads may reduce network reinforcement investment needs. This benefit is measured as the reduction in investments required with and without AD services. Nevertheless, the issue of how to share the benefits among players will still arise. For example, if all benefits are transferred to consumers, with no share for the transmission or distribution system operators, operators will have no incentive to use AD as an alternative to network investments. Thus, the mechanism by which Distribution System Operators (DSOs) or Transmission System Operators (TSOs) are paid is critical for this issue.

Network investment reductions in the different countries under study are estimated to produce savings of 1.2M€ to 302M€. This translates to reducing the cost per consumer by €0.15/year to €9.4/year.

### 5.1.5. Reduction of emissions

Lower energy use and a modified demand profile may result in a reduction in pollutant emissions. If the social cost of these emissions is internalized, then the benefit will be seen directly by the players.

Within the context of ADDRESS, emission reductions result in savings of 15M€ to 595M€. This translates to reducing the cost per consumer by €2.7/year to €13.8/year.

### 5.1.6. Provision of capacity services

The ADDRESS project focused on a detailed assessment of the energy based AD services that were discussed in the previous subsections. In addition, the project comprises a high level assessment of capacity base AD products. Such products can offer high benefits compared to energy based services under the appropriate conditions. A brief description of several capacity base AD products is presented below.

The use of AD to reduce the contracted power of a consumer was assessed for Spain and Belgium. In Spain, the contracted power reduction service can save an active consumer about 29.5 €/year. In Belgium, there is no contracted power, but active consumers could still obtain about 18 €/year if they were allowed to participate in the market for the provision of reserve services for tertiary control to the TSO.

In Italy, three capacity based services for aggregators were assessed, namely smart load reduction for DSOs, smart load reduction as an interruptible load service, and voltage regulation and power flow control. These services could drastically reduce the annual electricity bill for Italian customers, which currently is about 524 € (95 € correspond to costs that could be reduced by the provision of these services).

In the UK, capacity services can be used to support DSOs and TSOs reduce capacity associated costs and charges. These services are particularly attractive for consumers because of their low activation time of 15 or less calls per year.

It is important to note that the value of capacity services is not included as part of the expected benefits for market participants described in the following sections. The value of these services cannot be included due to their case specific nature.

## 5.2. Aggregator

In the ADDRESS architecture, the main responsibility of enabling the trade of AD products lies with the aggregator, also called AD provider. The aggregator has many new obligations to enable AD products trading and the market and power system structures have to be upgraded to facilitate the aggregators' business.

### 5.2.1. New obligations of the aggregator

The aggregator is in charge of securing the different AD products and selling them to different players. For this purpose, the aggregator (i) possesses a portfolio of flexible consumers that can provide the AD products, (ii) interacts with different players that might request the products or facilitate their delivery, and (iii) ensures that the AD business is profitable.

The portfolio of flexible customers comprises many diversified residential and small commercial consumers connected to an Energy Box (EBox). The EBox has the ability to modify and coordinate the behaviour of the distributed resources via price and volume signals sent by the aggregator.

The operation of the aggregator relies on multiple interactions with other system participants that request AD products, DSOs and TSOs that besides requesting for services also assess the technical feasibility of AD transactions, and metering responsible parties that monitor the behaviour of different consumers, among others.

The AD business model of the aggregator must be profitable; otherwise AD would not be traded. The aggregator performs several tasks to ensure that AD services are profitable for customers, buyers, and the aggregator itself, namely energy consumption and demand flexibility forecasting, attractive pricing for AD products, managing the market and the portfolio of flexible consumers, optimising the value of the price and volume signals sent to each EB, and paying and billing actors that respectively provide and request AD services, respectively, among others.

### 5.2.2. Changes in the market environment to facilitate the Aggregator's business

Based on insights gained from the ADDRESS project, the success of AD services from the perspective of the aggregator can be facilitated by upgrading existing market structures and rules and implementing new AD service trading, provision and charging related standards.

New market structures and rules are needed for the trading of different AD products (e.g. energy, reserves and capacity), setting a regulatory regime to account for ownership issues regarding data and infrastructure, and determining the balancing responsibilities of the aggregator.

Current market mechanisms require minor changes and adaptation to handle the aggregators business. The major obstacle is the minimum size of the products required to participate in the market, which can be too large for the aggregators to provide. This obstacle could be circumvented with minor changes in the market organization such as by allowing AD products grouping or reducing the minimum requirements for AD based services to participate in the market. The latter may not present significant technical challenge; however, it would result in increased communications and data storage requirements.

Price controls, consumer protection, fair competition, balancing responsibilities, payback effect charges and payments, standardization, and other regulatory issues associated to AD management should be incorporated into the current regulations. Nevertheless, other topics such as data and infrastructure ownership and data exchange fees need to be addressed specifically.

Based on the assessments performed as part of the ADDRESS project, aggregators can accrue about €2.6/consumer/year to €6.0/consumer/year from the implementation of the ADDRESS architecture.

## 5.3. System operators

System Operators (SOs) play a double role in the ADDRESS architecture. Firstly, they must ensure that the provision of the AD services does not compromise the secure and efficient operation of the power network. Secondly, operators act as AD buyers by requesting products from the aggregator to solve network operation problems.

### 5.3.1. New obligations of the system operators

The control of the real modification of energy thanks to AD program has to be controlled by SOs. This is crucial for the security of the grid and for the balancing of the system.

AD products must be validated by both the TSO and the DSO, and AD actions requested by one of them must be validated by the other, to prevent problems in the grid. This validation will also avoid duplicities when one AD provider tries to sell the same product to both agents. For the technical validation of the aggregator's AD programme, whether the products are sold to regulated or unregulated players, grid operators need to define areas in the distribution (load area) and transmission networks (macro load areas). This validation will require fast, efficient and coordinated communications between TSOs and DSOs, which can be enabled via the standardization of both communications and network codes.

### 5.3.2. Benefits for system operators

AD products can be beneficial for the SOs as they can use AD as a tool for balancing the system in real time. The SOs can request the aggregator to provide an AD product as a "best effort" attempt to resolve network problems (e.g. in an emergency before shedding load). The SOs must be totally confident on the tools they use and should penalize aggregators if there is a deviation between the AD product delivered and sold.

## 5.4. Consumers

Customers have a central role in the ADDRESS architecture as they provide the demand variations requested by the aggregator. For this purpose, customers must possess the ability to respond to signals sent by the aggregator and must receive sufficient incentives to provide the services.

### 5.4.1. New abilities of consumers

Customers can provide AD via the use of an EB. The EBox controls demand response based on price and volume signals sent by aggregators and settings set by each customer. From an appliance perspective, the EBox can control flexible loads (e.g. washing machine, dish washer and clothes drier), interruptible loads (e.g. fridges, freezers and electric water heater) and thermal loads (e.g. air conditioning units and electric radiators).

The contract defining the relationships between an aggregator and flexible consumers must offer the best balance between transparency and clarity to guarantee the protection of the consumer, whilst having sufficient flexibility to permit the development of various business models by aggregators. Such contracts should provide clear descriptions regarding how customer benefits can be made or maximised and the implications of the different actions (e.g. using the override), as well as clauses for general legal obligations (e.g. administrative information, description of payment and duration of the contract) and ADDRESS essentials (e.g. definition of the payment for AD product provided, comfort settings, and ability to use the override mode), among others.

### 5.4.2. Consumer engagement

The customer acceptance of the ADDRESS architecture was assessed via field tests in two locations, namely France and Spain. The field tests were conceived differently in terms of engagement with the local communities and the manner in which the projects were framed.

The field test in France (Brittany Islands) was embedded deeply within the local community. In this field test local students used the ADDRESS technology, people were allowed to visit test houses and there was a press conference to disseminate the results of the project amongst the general public. These activities were aimed at fomenting the participation of local people, but also made locals feel that the project was beneficial for their community. As a result, AD is highly accepted and deemed a good option to manage consumption and improve the power supply in the region.

In the French field trial 76% of the participants who answered the post trial questionnaire (17 users) would consider or strongly consider adopting an ADDRESS style technology in the future. Popular loads in terms of potential future adoption were thermal loads such as electric heating and hot water heaters. Most of the households who answered the survey owned dishwashers and would consider a smart dishwasher. All those who would consider adopting an ADDRESS style technology in the future would accept a smart fridge. 70% would be interested in a smart washing machine, though the extent of EBox control may be limited for many of these. That is, a washing machine operating at night was acceptable, but many would not accept EBox with greater control, such as the control to decide the time and day of operation. Ownership of clothes driers is low amongst field trial participants and this is reflected in a low level of interest in smart clothes driers.

The Spanish field test took a more business orientated approach, driven by pragmatic concerns that local meetings and approaching community leaders would not secure the numbers of participants required. In this context, the sense of AD benefitting the region is not as strong. In this field test 68% of those who answered the questionnaire (53 people) would consider an ADDRESS style technology in the future. However, the problems with the technology have impacted on the engagement with some participants in the trial.

People in this field test did not have a wide understanding of the system and have different perceptions of the benefits. There is also a sense that AD can facilitate the automation of domestic chores, and has a role to play in a future electric city. On a day to day basis however, the technology has to fit within the patterns of daily life, particularly family life, where people wish for appliances to make chores easier and so want the appliance to fit with them, and not the other way round.

### 5.4.3. Consumer benefits

The implementation of the ADDRESS architecture is expected to result in benefits for consumers of around €1.2/year to €2./year. These economic benefits might not suffice to engage consumers on providing AD management. Thus, additional incentives should be provided to the consumers.

Capacity based AD services can provide additional economic incentives to engage consumers. Nevertheless, these services only provide high benefits in some cases, which will not suffice to engage all consumers.

Consumers are not only driven by economic incentives alone and might be willing to provide AD services if they perceive other benefits such as social value. For example, consumers might be willing to offer AD if it provides an environmental benefit (e.g. increased use of renewables), a service for the system (e.g. higher quality), or a social service (e.g. higher supply security for a hospital). Clear communications with consumers about the use of their AD and the implementation of test systems such as those described in the previous subsection might be a key aspect to engage consumers.

Finally, it is important to note that consumers may require a benefit in exchange of providing AD services because providing the service can cause them discomfort. This might not be the case in a future where consumers possess smart appliances that can modify their consumption without disrupting their operation. In such a scenario, consumers will only require little or no economic incentives to provide the service.

# 6. Main dissemination activities

The dissemination activities of the project ADDRESS have been intended to create awareness in the society at large of the work carried out and paving the way to participants acceptance of ADDRESS solutions. The dissemination activities have been organized so as to take care of the characteristics of the intended audience.

Diffusion to the stakeholders of the information about the ADDRESS project, its objectives and expected results has started from the very beginning of the project, and has become more and more intense as the project progressed. The first event where ADDRESS has been presented is dated June 2008, the first month of activity. Since then, about seventy events in Europe and abroad have seen the participation of ADDRESS representatives with presentations, posters, papers, exhibition, panels, and about twenty events specifically focused on ADDRESS have been organized in Europe (six regional workshops in Belgium (2), Finland, France, Italy, Spain, two international workshops (Clamart, Rome), presentations to utilities, workshops with regulators at Florence School of Regulation and system operators at ENTSO-E meeting, meetings with the project Group of Users and Stakeholders).

The project website has been set-up by the fourth month of activity, with a public section where all relevant information about the project is available, in particular the public deliverables. Eleven issues of ADDRESS Newsletters have been issued and can be downloaded from the public website, which also allows to subscribe/unsubscribe.

Twenty-one scientific (peer reviewed) publications have been produced, together with some technical publications.

An international student contest has been issued for producing a media on what the ADDRESS future might be, to which students of three Universities in the Consortium have participated. Nine theses have been written by students of Universities in the Consortium.

Visits at demo sites involving consumers (France and Spain) have also been organized. Project flyers and final brochure have been published, and distributed to many events.

An estimated 5.000 people had a direct contact with ADDRESS, not counting neither the web accesses nor the readers of papers.

# 7. Main exploitation of the results

Partners of the ADDRESS Consortium were able

- to create and gain relevant know how on AD, its possible business models and opportunities;
- to understand requirements and options of technical solutions aiming at exploiting the potentials of AD in the optimisation of the electricity supply;
- the roles and responsibilities of energy market players (significantly on aggregation and system operation) and their relationships
- customers' involvement and attitude towards electric energy utilization. In particular, the relationship between consumers and the other electricity system players which allow the utilities to reinforce their strategic line and go on developing new tests and initiatives with residential consumers.

The results obtained in ADDRESS include:

- prototype tools and business case evaluations for demand flexibility aggregation
- tentative concepts and experience from testing its real implementations
- lessons regarding possibilities, barriers, and what to do and what not to do
- identification of the required changes and adaptation for industrial and commercial AD viability, from prototyping and testing on field.

A new set of equipment suitable for AD applications at consumers' facilities were designed,:

- new metering device, featuring Zigbee wireless communications
- new smart plugs and key equipment for in-home AD and communication management (the Energy Box - EBox).

This made possible the acquisition of a new field of knowledge about the technical difficulties and solutions related to AD implementation, management and deployment of AD policies at customers' premises and an improved skill in wireless communication protocols, standards and technologies oriented to in-home energy management applications.

It was possible to extensively work on how to use metering data, to process them and to render them user-friendly and accessible to the consumers (through the EBox), how to transfer consumption data from the smart meter to the EBox. Finally it was also possible to design and test new technologies and algorithms for the network management in the smart grids context and acquire know how on network modeling using CIM.

Due to the wide-scope and cross-functional competences required, the ADDRESS Consortium embraces a well balanced set of partners, with a representation spanning the entire electricity supply chain, qualified R&D bodies and manufacturers.

The generated foreground is intended to be used by most of the partners in new projects, both in national and international (EU) projects in order to enable further developments in the field of smart grids and AD services.

The ADDRESS foreground on the AD business model and technologies and on consumers engagement in AD programs are exploited to design and develop new technologies, end users applications and programs for energy efficiency and AD.

The technology developed for the network management in presence of AD and the understanding of the implications of AD on the operation of medium-voltage network control centers and network management in general is exploited to go further to the prototype state and be used in the smart grids management.

Manufacturers express interest towards the industrial development of the new solutions and technologies that can be offered to consumers, adapting and enhancing the prototypes developed; proven results are brought into the companies' own product and solution development.

Consulting and solution providers intend to propose further developments in the field of smart grids and AD services, to support different stakeholders and decision makers on several policy levels, regulators, energy market players, with the aim of strengthening economic activities of different energy market stakeholders within Europe.

Finally the foreground coming out of the pilot tests in France and Spain is going to be disseminated and used in the newly launched EU project ADVANCED, where many ADDRESS partners, have become part of the Scientific and Advisory Board; the comparison with other similar experiences will allow the identification of best practices and how to improve the solutions developed to achieve large scale and replication. It is worth mentioning that ADDRESS concepts and vision inspired many new projects, demos and studies in the active demand field (Grid4Vehicle, Grid4EU, Green e-Motion, S3C, Think report).

# ANNEX I: ADDRESS LOGO

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# ANNEX II: VIDEOS AND EVENTS PICTURE

VIDEOS

http://www.addressfp7.org/index.html?topic=config/news_multimedia

http://www.addressfp7.org/index.html?topic=config/news_studentinvolv

http://www.addressfp7.org/ws2013/ENEL%20ADDRESS%20SPAIN.mp4

http://www.addressfp7.org/ws2013/ENEL%20ADDRESS%20ITALY.mp4

PICTURES:

http://www.addressfp7.org/index.html?topic=ws2010/workshop2010_pictures

http://www.addressfp7.org/index.html?topic=ws2013/workshop2013_pictures

http://www.addressfp7.org/index.html?topic=innconv2011/innconv2011_info

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