AN APPROACH TO ASSESSING DIVERSE ACTIVE DEMAND PROGRAMS DEVELOPED IN THE ADVANCED PROJECT

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ABSTRACT

ADVANCED (Active Demand Value ANd Consumers Experiences Discovery) is a research project co-funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 308923, that aims to shed light on ways to overcome the barriers hindering the mass deployment of Active Demand (AD) in Europe. It is promoted by a consortium of some of the major European energy utilities, universities, research centres and consulting firms in the energy sector, one of the European leading agencies specializing in market research and one of the leading energy management solution provider for decentralized energy resources in the industrial, commercial and institutional sectors.

The project is developing actionable frameworks enabling residential, commercial and industrial consumers to participate in AD initiatives, thus contributing to the mass deployment of AD in Europe.

The basis for this result is a unique empirical knowledge base including data generated within four different real life AD demonstration projects and a database containing a meta-analyses of over 110 AD pilots, involving 450,000 residential consumers. Moreover a on-line quantitative survey and some in-depth qualitative interviews with some consumers are being carried out and their outputs will enrich the study with insights into socio-economic drivers of consumers' behaviour.

The above described knowledge base was organized in the form of a "Target matrix" of variables, in such a manner that data from a wide range of pilots (in terms of recruitment strategies, incentives, communication strategies, applied technologies etc) and consumer segments can be compared in a logical, comparable manner.

The investigations in ADVANCED rely on the definition of a conceptual model, in which all the relevant factors influencing the participation of consumers in AD programmes have been included and their relationships described. It is built around active customer participation taking into account the target behaviour, the customer and his context and the intervention and its implementation. The hypotheses formulated within the model provide insight in the mechanisms behind user behaviour and the way interventions for behavioural change can work. These hypotheses are validated during the project both using the data from the target matrix (quantitative analysis) and exploiting the lessons learned in the different pilots (qualitative analysis). Once tested, the conclusions will provide all the stakeholders in AD initiatives with a solid framework to base their pilots or roll-out programs design.

By applying appropriate Key Performance Indicators (KPIs), that were developed and validated within the project, the hypotheses of the conceptual model are tested and so the relative success of the different AD strategies can be determined. The KPIs list covers the different aspects of AD taking into account the perspectives of the key AD stakeholders. Among those, the evaluation of the "increasing demand flexibility" and "change in overall electricity consumption" are of outmost importance for assessing active participation.

The successful application of the above mentioned approach required the collection and management of a large amount of heterogeneous data, differing in terms of units of measure, granularity and subject to privacy restrictions.

INTRODUCTION

In the energy industry, given that the cost and environmental impacts of electricity consumption vary over time, a more efficient use means not only reducing consumption, but also managing this consumption in time. AD has the potential to contribute to solving some of electricity systems current and future challenges while offering significant benefits to consumers.

At the moment, only few "real" AD programmes (not being field tests or pilots) are implemented in Europe. The majority of them offering services only to industrial consumers since shifting and/or lowering the load of this group is seen as the most promising in terms of cost/benefit while the AD potential of residential consumers remains largely invisible and inaccessible.

AD is often seen as one of the largest untapped energy resources and the main reason behind this is insufficient consumer awareness of their own energy consumption and of the benefits of altering it in line with network constraints but also due to the lack of tools and incentives to do so. This is aligned with the lack of insight into the behavioural barriers to AD and

unavailability of best practices for AD program design. To identify best practices a sufficiently large set of comparable empirical data is required but not available so far. Furthermore the verification of the best practices should be based on a set of commonly accepted Key Performance Indicators (KPIs) making the AD programmes measurable and transparent, that are still missing as well.
Another crucial barrier to AD deployment is that there is still only cloudy information available on the benefits AD bears for further – apart from consumers – key stakeholders of the electricity system. In particular, network operators miss quantified data on the flexibilities AD programmes might offer to them and which AD based system services are feasible.
Also the existing regulatory framework does not properly reflect the specifics of AD and in particular a redefinition of the roles and responsibilities of the existing and emerging players of the electricity system could trigger wider AD uptake.
Finally, as AD involves processing of very sensitive consumer data, and there have been already concerns arising with respect to the intrusiveness of technologies, it is necessary to carefully map the key privacy and security related risks and elaborate strategies to mitigate them, thus promoting a "privacy by design" approach for AD programmes.

ADVANCED

ADVANCED (Active Demand Value ANd Consumers Experiences Discovery) is a research project co-funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 308923.
It is promoted by a consortium of some of the major European energy utilities (Enel Distribuzione, ERDF, Iberdrola Distribución, RWE Deutschland), universities, research centers and consulting firms in the energy sector (Comillas, Universidad Pontificia, Fondazione Eni Enrico Mattei (FEEM), TNO, VaasaETT), one of the European leading agencies specializing in market research (TNS) and a leading provider of Demand Response solutions for commercial and industrial consumers (Entelios). The consortium is supported by a Stakeholder Advisory Board composed of the main AD target groups.
The members of the ADVANCED consortium define AD as "*providing electricity consumers with information on their consumption and the ability to respond to time-based prices (either manually or automatically) as well as with other types of incentives, thus motivating them to actively manage their consumption by altering usage in line with the network conditions, such that modifications in consumer demand become a viable option for addressing challenges of electricity systems*". Accordingly, the research focuses on energy efficiency (EE) and demand response (DR) programmes.
EE programmes offer consumers more direct, detailed, comparable and comprehensive information about their household's energy consumption patterns. This type of information has been shown to influence the behaviour of residential consumers and lead to a conserving behavioural effect. [1]
DR programs are a way to meet the need for flexibility as a product to energy markets. Flexibility is key to building a clean and secure European energy system. Some DR programs can also contribute in mitigating the inefficiencies caused by the fact that although the cost of supplying power to consumers can vary by an order of magnitude within the same day, the price paid by most end-users remains flat all year round in many countries.
The ADVANCED project aims at developing actionable frameworks enabling residential, commercial and industrial consumers to participate in AD, thus contributing to AD mass deployment in Europe. The project will also quantify the benefits of AD for key stakeholders and the inherent impacts on the electricity systems considering its potential contribution to system stability and efficiency, according to different scenarios (in terms of status of electricity market, energy policies, market regulations, technology, etc.. in the time horizon of 2020).
In order to reach the project objectives, data and lessons learned made available by the four utilities participating in the consortium and collected through four major EE and DR pilot projects currently running or finished shortly in Europe (the so called "ADVANCED" sites) are analysed: two ADDRESS pilots (Spain and France), E-DeMa pilot (Germany) and Enel Info+ pilot (Italy). Furthermore, data collected in VaasaETT's database (from over 110 European Active Demand projects with the participation of around 450,000 residential consumers) will be exploited.
In-depth qualitative interviews with approximately 20 residential or small commercial consumers per ADVANCED site and with some industrial consumers (recruited in Germany with the support of Entelios) have been carried out and their outputs will enrich the study with insights into socio-economic drivers of consumers' behaviour.
Some additional data will be gathered through quantitative online surveys within a representative sample of residential consumers in eight European countries with the aim of providing statistically robust indications of awareness, understanding and attitudes towards AD revealing in particular the degree of knowledge and understanding of AD and consumers' stated flexibility when it comes to their energy consumption.

THE ADVANCED SITES

ADRESS pilot sites

ADDRESS ("Active Distribution network with full integration of Demand and Distributed energy RESourceS") is a five-year large-scale R&D European project launched in June 2008 and co-funded by the European Community's 7th Framework program (FP7/2007-2013). The aim of the project is to study, develop and validate solutions to enable AD and exploit its benefits. Thus it has developed a comprehensive commercial and technical framework for the development of AD in the smart grids of the future.

At the consumers' premises electrical appliances, distributed generation and thermal or electrical energy storage systems could be controlled and optimized by an Energy Box, which was the interface with the external world and with the consumer. The Aggregators, through an Aggregator Toolbox, were the mediators between the consumers and the markets, allowing power system participants to explore the flexibilities of the aggregated customers. DSOs could interact with the other power system participants via the markets. Three pilot field test were located in three European countries (Spain, France and Italy) with different network topologies, climate conditions and social acceptance which, taken together, provided a validation of the entire concept. The Spanish and the French sites are analysed within the scope of ADVANCED.

The Spanish field test was located in the city of Castellón (Mediterranean Coast), where around 265 consumers were recruited. The pilot was mainly aimed at analysing the relationship between the Aggregator Toolbox and the consumers through the Energy Box in order to be able to manage the demand and individual loads.

The aim of the French field tests carried out in the Brittany Islands of Houat and Hoëdic was to test the whole ADDRESS chain, i.e. from the needs of the electricity system players to the controlled appliances in the consumers' premises, including also consumers' acceptance studies. Around 30 residential customers and a few small commercial customers were involved in the project.

E-DeMa pilot site

The publicly funded E-Energy project E-DeMa targeted an increased mobilization of flexibilities in electricity usage at the household level for the energy system of the future. In order to achieve this goal a regional energy market place, i.e. the "E-DeMa marketplace", connecting the approximately 700 households that have been participating was developed. This market place was an innovative ICT platform that enables current market roles (supply companies) as well as new ones (Aggregators) to offer new and innovative products which in turn help to "harvest" flexibilities from the customers. The project started in 2008 as part of the E-Energy Programme of the Economics and Technology Ministry (BMWi) and Environment Ministry (BMU) and it was completed in May 2013. The field test comprised households in the Mülheim and Krefeld area in Germany.

Two types of interventions were used influence the participants' energy consumption: Energy Awareness / Efficiency and Demand Response. On the one hand, Energy Awareness / Efficiency was enhanced by providing feedback of the energy consumption to the consumer via a display and in addition via E-DeMa marketplace, i.e. using a website. On the other hand, home appliances like washing machines, dryers and dish washers as well as decentralized generation devices like micro CHP's were used as flexibilities to manage the energy system, i.e. demand response was realized with time of use tariffs which motivated the consumers to shift energy consumption from times with high prices to low price zones. The actual time of power usage was managed via price signals which were distributed via the E-Energy market place. The control of the home appliances was achieved either manually by the consumer using the energy display or automatically controlled by the home energy gateway. Alternatively the consumer could leave the flexibility of an appliance to an Aggregator.

Enel Info+ pilot site

Enel Info+ is a large scale trial of Enel smart info, a device designed by Enel Distribuzione to allow end users to have the certified information on electricity data managed by the electronic smart meter at their fingertips. The Trial is part of the "Isernia Project", a project financed by the AEEG ("Autorità per l'Energia Elettrica e il Gas") that foresees the installation of a model of smart grid connected to the Primary substation of Carpinone (a little town in the Isernia district). Enel Info+ involves a representative sample of low voltage households and small commercial consumers served by the Carpinone primary sub-station in some municipalities in the area of Isernia with the aim of demonstrating whether giving to end users a feedback on their energy consumption can address more efficient energy behaviours. The consumers participating to the project thus receive an energy monitoring kit including Enel smart info and dedicated interfaces they use for one year to view how much electricity is currently being used in their household and to process their historical consumption data. "Prosumers", consumers who are also producers of renewable energy (by photovoltaic or mini-eolic plants), receive an additional Enel smart info in order to manage both production and consumption metering data. The Enel Info+ kit and the related monitoring solutions are modular and foresee three levels of analysis. The first one is based on the use of Smart Info Display, a full colour, touch screen in-house display, that lets the consumers keep an eye on their household energy consumption pattern easily. The second monitoring solution is based on Smart Info Manager, a software application that allows the consumers to examine their consumption data in detail on their personal computers and the energy prosumers to compare production and consumption data. The third monitoring solution is based on the smartphone App Smart Info Mobile that enables the consumers / prosumers remote access to their own energy data

VaasaETT database

VaasaETT keeps up-to-date a database which currently comprises over 110 feedback and dynamic pricing pilot programs from around the world. These pilots are selected from a larger pool which include pilots whose design or reporting of results were not sufficiently detailed or comparable with the others to be included. Final reports, presentations and academic papers analysing the selected pilots are collected from numerous sources. Papers published in academic journals are collected from academic databases. Public pilots' reports are collected directly from the organizer (often local regulators or public utilities). In addition, VaasaETT draws on its extensive network of practitioners around the world to collect pilots whose results were not made public usually from technology

providers or investor-owned Utilities. Analysing and comparing such a large number of pilots offers the possibility to spot consistent results and allows visualization of emerging pattern.

THE ADVANCED CONCEPTUAL MODEL

The investigations in ADVANCED rely on the definition of a conceptual model of active consumer participation in which all relevant factors influencing the participation of consumers in AD programmes are included and their relationships described.
AD programs aim at changing the energy use of the consumers either by reducing their total electricity consumption (EE programs) or by shifting load in time (DR programs).
Various factors (determinants) influence user behaviour: There are user characteristics: do they know they need to change their behaviour, do they know how to change it, are they motivated to change, and able, etc. Users always act in a user environment that will strongly influence their behaviour: both a physical environment (e.g. their home and appliances and the climate in their region) and a social environment (e.g. friends that act sustainable or not, government policy). This flow is depicted in Figure 1.

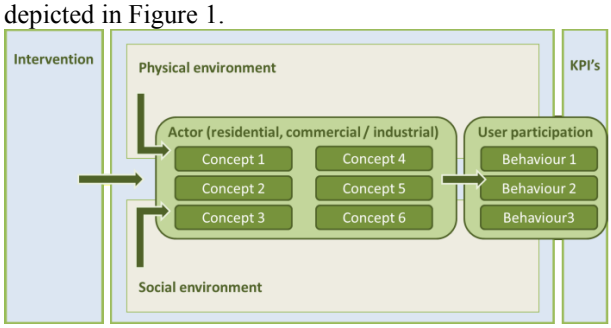

Figure 1 The conceptual model (residential consumers)

In order to stimulate active end-user participation and the desired behaviour, interventions are designed (e.g. providing feedback on energy consumption via an in-home display) and implemented in a pilot with certain characteristics (duration, number of participants, etc.)
Thus the building blocks of the conceptual framework proposed in the ADVANCED project are:

- the desired behavioural change of
- actors who live in,
- physical environments and
- social environments
- upon whom interventions are targeted
- of which the success will be measured by KPIs

By formulating generic concepts within these blocks (derived from both the scientific literature as the practical experience in real-life pilots), numerous context-specific conceptual models can be formulated and tested. Hypotheses are formulated as a causal association (i.e. testable correlations), between at least two concepts (e.g. household size is directly associated with total energy consumption) to provide insight in the mechanisms behind user behaviour and the way interventions for behavioural change can work. [2]

These hypotheses are validated in the project by using the data collected in the ADVANCED sites (at household level) to uncover what profiles of household consumers adjust their consumption the most or the least to certain interventions and to what extent and further explored through the analysis of each ADVANCED site results and lessons learned.
For this purpose, a large pool of comparable data is required within the ADVANCED knowledge base that has been organised in the form of a "target matrix" of variables.
Moreover a set of KPIs is needed to determine the success of the interventions and identify the best practices for active end-user participation under certain conditions.
Designers of new AD-pilots or roll-outs can benefit from this analysis which will identify and make explicit the psycho-social drivers of household behavioural change when it comes to energy consumption (and therefore increasing their chances to successfully change behaviour) and determining which data have to be collected.

THE TARGET MATRIX

In order to test the hypotheses in the ADVANCED conceptual model, a large pool of data is required within the ADVANCED knowledge base. This must be organised in such a manner that data from a wide range of pilots (differing in terms of recruitment strategies, incentives, communication strategies, functionalities and applied technologies etc.) and consumer segments can be compared in a logical, comparable manner.
The ADVANCED knowledge base is built on a "target matrix" that was designed following both a top-down and a bottom-up approach. As a basis an operationalization was made on the concepts identified in the conceptual model, turning them into variables (with corresponding units) that can be collected in the ADVANCED sites and the VaasaETT database or through the surveys of the project aimed at additional data collection (top-down). On top of this operationalized concepts an extended set of variables was identified that could be collected within the ADVANCED sites or gained from the VaasaETT database and that could be used for a bottom-up explorative analysis.
About 250 variables have been identified and included within the target matrix. They have been grouped into four main sections:

- "Generic variables"; that describe the main features of the pilots under analysis.
- "Pilot variables (subject to data privacy)"
- "Personal variables (subject to data privacy)" that are directly related to the customer's behavior, attitude and performance.
- "Other variables", including all the variables that cannot be collected from any of the ADVANCED information sources (neither from the Advanced sites nor from the VaasaETT database) but should be taken into consideration in designing other AD initiatives [2]

THE ADVANCED KPIS

AD has a broad range of potential benefits and AD initiatives can help meet EU's energy policy goals (affordable, sustainable and secure energy). The following main categories of KPIs were identified within the project taking into account the perspectives of the key AD stakeholders: improving energy sustainability, reducing system costs, maintaining electricity system reliability, improving affordability, and improving customer relationship.
Within the aforementioned categories, some KPIs have been identified measuring benefits that take place at the grid level, this is the case for:

- Net avoided CAPEX;
- Net reduction in OPEX;
- Maintained quality of voltage;
- Maintained continuity of supply;
- Reduced amount of balancing and reserve power required;
- Net reduction in systemic electricity costs.

Some other benefits take place at the household level, and the related KPIs identified within ADVANCED are:

- Reduction in CO2 emissions;
- Increased customer awareness;
- Increased proportion of consumed electricity produced from intermittent;
- Net reduction in power bills;
- Compensation for flexibility;
- Participant's satisfaction with AD programs;
- Improved participant's satisfaction with the energy industry.
- Increased demand flexibility (peak clipping and valley filling);
- Reduction in overall electricity consumption.

The "Increased demand flexibility" and "Change in overall electricity consumption" KPIs are extremely common for AD pilots but the success is always measured at an aggregated pilot or group level. ADVANCED is unique in defining, measuring and evaluating these KPIs on a household level. They were chosen for validating the hypotheses included in the conceptual model and a methodology to quantify these KPIs in a univocal manner has been developed.
They are of paramount importance as they are the measurements for the actual changes in consumption of the households.
Nevertheless the "Increased demand flexibility" KPI in fact doesn't measure behavioural change due to DR signals, therefore an additional indicator: "Signal Compliance: difference in consumption pattern" has been defined. The KPI is calculated comparing the consumption trend of each consumer after the DR signal comes into force with its habitual one. It is a unique ADVANCED KPI and can only be calculated using data at a household level. [3]

CONCLUSIONS

The ADVANCED FP7 project vision is to enable AD adoption at large scale in Europe.
One of the strength of the ADVANCED project is the access to extensive amounts of pilot data (coming from the ADVANCED sites and the VaasaETT database) on individual household behaviour in different countries as a response to AD interventions with different characteristics.
The investigations in ADVANCED rely on the definition of a conceptual model of active consumer participation in AD in which all relevant factors influencing the participation of consumers in AD programmes are included and their relationships described. These hypotheses are tested in the project by using the data collected in the ADVANCED sites (at household level) to uncover what profiles of household consumers adjust their consumption the most or the least to certain interventions and to what extent.
For this purpose the ADVANCED knowledge base has been organised in the form of a "target matrix" of variables organised in such a manner that data from a wide range of pilots (differing in terms of recruitment strategies, incentives, communication strategies, functionalities and applied technologies etc.) and consumer segments can be compared in a logical, comparable manner. As the pilots in the ADVANCED sites as well as in the VaasaETT database started before ADVANCED, data gathering could not be mutually tuned and the target matrix includes some variables which cannot be collected within the scope of ADVANCED. Other projects however can use this extensive list of variables when designing the data gathering and data analysis for their project.
A set of KPIs was defined to identify the best practices for active end-user participation under certain conditions. A methodology to quantify specifically the "Increased demand flexibility (peak clipping and valley filling)"and the "Change in overall electricity consumption" KPIs at a household in a univocal manner has been developed and a completely new KPI measuring the behavioural change due to DR i.e. the pattern change in response to a DR signal has been defined.
The conceptual framework will allow to go beyond the state of the art in the current pilot sites, enabling designers of new AD-pilots or roll-outs to include more relevant factors in their design and therefore increase their chances to successfully change behaviour. Furthermore, by using one generic framework, comparisons over situations and contexts becomes possible.

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