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DEMAND RESPONSE. BEHAVIORAL AND ENERGY ANALYSIS IN RESIDENTIAL ENVIRONMENTS

Executive summary

The energy system is undergoing a dramatic change, mainly driven by the diffusion of decentralized renewable generation, such as solar and wind. These sources are inherently less predictable, thus making it more difficult to guarantee a real-time balance between demand and supply on the grid.
Therefore, a higher degree of flexibility will be needed to facilitate the integration of intermittent green energy: the new paradigm will require demand to follow the electricity supply when available, with final customers playing an active role.
Demand Response (DR) refers to any change in end-use electricity consumption according to the needs of the grid: as for now, demand is not allowed to participate in the grid balancing in most of European countries, nevertheless, in Europe the majority of theoretical demand response potential lies with residential consumers, and this potential is still waiting to be exploited. The main barriers are related to a low consumer engagement with energy-related activities, and a lack of regulation specifically designed for this customer segment. Moreover, the level and the firmness of response that can be achieved is still uncertain.

The main goal of DR.BEAR project is to develop a Business Model to harness the potential flexibility coming from load shifting at household level, designing an appropriate customer engagement strategy and incentive scheme to involve them in such programs.
Our project will be particularly innovative for the italian case, as in this country few projects of the kind have been implemented so far; DR.BEAR framework can represent a good starting point for all those companies, including our main external partner Siemens, interested in developing a market for DR in Italy.
The innovation of our solution is in applying a behavioral approach to achieve demand side management, meaning that the focus will be on triggering a behavioral change in residential customers while involving them as active player of DR programs.

Key Words

Demand Response, Residential Customers, Customer Engagement, Behavioural Approach.

Project description written by the Principal Academic Tutor

Decarbonisation, decentralisation and digitalisation are considered the three big drivers of change of the power sector in the coming years. The decarbonisation agenda foresees a rising share of renewable energy sources on the production side, leading to a substantial decentralisation and to the phase out of high emission power plants. This might have, nevertheless, a drawback in terms of power grid management, since renewable energy supply is quite unstable and unpredictable. That is why the risk of blackouts or lack of energy might increase. In order to compensate unstable generation, storage systems are required; however, no technology is currently available and deployable to guarantee national grids balance. An alternative way to manage unstable generation is to provide flexibility on the demand side, for instance promoting demand-side response programs.

DR.BEAR, addressed the topic of energy transition, by investigating the potential of demand-side response programs for domestic buildings within the European energy market. The subject is highly multidisciplinary, and it requires knowledge, on building energy use, grid management, energy market, and occupant behaviour. In particular, no demand-side response program may be activated without a behavioural change of the final users. How to enable this behavioural change via the activation of a digital social market was the principal object of investigation of DR.BEAR. The project focused also on the industry point of view, studying potential business models to activate a flexibility market. A case study in Greenwich, UK, has been selected to provide a practical application of the research activities, which might lead to further actions in the coming years.

Team description by skill

- **Kareem Abo Ayanah:** Petroleum Engineering. Load Profiling, Stakeholder `analysis, and Economic assessment
- **Matteo Barsanti**: Energy Engineering. Load Profiling, Business Models development and techno-economic assessment
- **Letizia Garbolino**: Architecture for Sustainable Design. Communication coordinator. Questionnaire development and preferences assessment, App Interface design, and graphical representation
- **Benedetta Leway**: Architecture Construction City. Questionnaire development and behavioral analysis assessment, App Interface design, and graphical representation
- **Muhammad Mansoor:** Electrical Engineering. Load Profiling and Management, Analysis of Requirements, and Needs of Stakeholders
- **Giulia Realmonte:** Energy Engineering. Team Controller. Business Models development, and techno-economic assessment
- **Rita Zeinoun:** Sustainable Architecture. Questionnaire and analysis of the market, App Interface design, and graphical representation

Goal

The objective of DR.BEAR project is to develop a business model proposal to implement Behavioral Demand Response in the European market, harnessing the flexibility coming from residential consumers.

This project is based on a behavioral approach to achieve demand side management, that means the key focus will be on triggering a behavioral change in residential customers while involving them as active player of DR program.
In order to identify the most profitable Business Model, we have investigated both manual load shifting (Behavioral Demand Response *stricto sensu*) and the use of direct load controls with Smart Plugs (being an automated response, this pertain more to traditional DR programs). In both cases, a behavioral change is needed: in the former one, consumption patterns need to be changed manually by customers according to the DR signals received, in the latter one, the change is related to the attitude and the awareness of end-users towards energy consumption in order to increase their acceptance of digital technologies and automation, thus reducing override events.

Behavioral Demand Response requires a multidisciplinary approach, combining behavioral science and user experience, together with load management and multi-energy system optimization, therefore it results particularly suited for the diverse background of our team, combining Energy and Electric engineering skills, with data visualization and sustainable architecture knowledge.

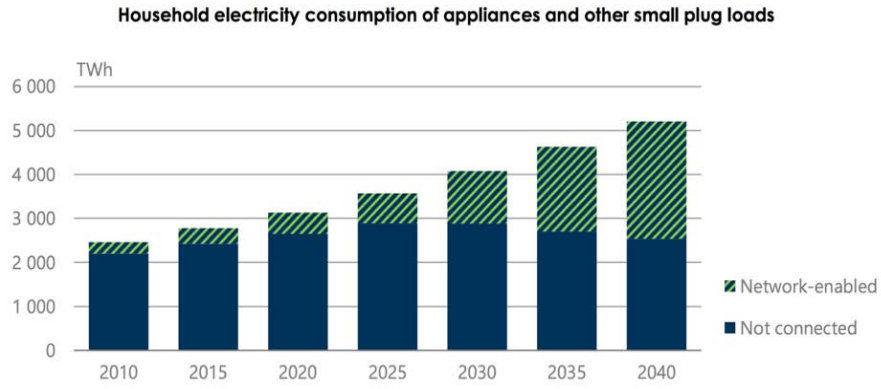

Figure 1: Role of digital technologies and IoT in the residential sector, source: IEA WEO 2017

Understanding the problem

The energy sector is undergoing a dramatic transition, that will change completely the way energy is produced and sold all around the globe. This is not only the result of stringent climate targets and global mitigation efforts, but it is also related to the rapid diffusion of low-carbon energy sources, given their cost-competitiveness with respect to traditional fossil-based generation. Therefore, three main trends are going to be the key driver for this transition: *decarbonisation, decentralization and digitalization*.

This transformation brings a number of challenges: the rapid retirement of fossil fuel-based generation together with the reduction in cost for wind and solar energy leads to a growth of non-dispatchable electricity generation that requires additional efforts to keep a real-time balance between demand and supply on the electric grid. Indeed, storage technologies are not yet cost-competitive to be deployed on a large scale, therefore a higher degree of flexibility is needed on the power network to face renewable intermittency, both from the electricity suppliers and from the demand side.

This implies a change in the paradigm of the power sector: from the traditional approach of supply following demand whenever it occurs, the future energy system will require demand to follow supply when available.

Demand Response (DR) actually refers to the changes in end-use electricity consumption according to the availability of generation and the needs of the grid, to guarantee a balance between demand and supply over time. In Europe most of theoretical Demand Response potential lies with residential consumers, and this capacity is still waiting to be exploited: currently, DR programs have been fully implemented in few European countries (UK, Germany and France are the main markets), focusing on industrial and commercial customers, as they are characterized by large loads, that can be scheduled and controlled in a reliable way.

The main barrier to access residential flexible potential are a low consumer engagement, combined with a general mistrust towards utilities, and the lack of regulation specifically designed for it (Parrish et al., 2016).

Exploring the opportunities

Electricity consumption in residential sector can be reduced by providing consumers with tailored information about their energy-related practices at home. When these techniques are coupled with demand response logics, the benefit of such programs may exceed greatly.

Considering the current market, a limited number of aggregators are already active in managing commercial and industrial loads to provide balancing services to the system operators in the UK, Germany and the US (e.g. KiWi Power, Flexitricity, and EnerNOC). However, for the residential sectors only some pilot projects have been done so far, in order to understand the technical and economic potential, assessing customers' response and its persistence in time.
At the same time, a number of solutions are already on the market to effectively engage customers, combining energy-related services (e.g. feedback on household consumption, energy efficiency advice, etc.) with gamification and social competition aspects (e.g. bonus collection, community-based rewards, etc.). The communication channels used range from mobile application to in-home displays and websites. Both of these aspects have been considered as a benchmark to develop our solution.

Given the uncertainties related to the residential segment, our case study will be represented by a pilot project currently carried out in the Royal Borough of Greenwich (London, UK) by KiWi Power, an existing aggregator active in commercial/industrial DR. The project will involve two social housing blocks (150 dwellings) recently retrofitted , in order to understand their load shifting potential. As it is still in the first phase, no evidence is available yet. However it developed a comprehensive strategy to effectively implement DR programs, considering the specific customer segment under analysis, coupled with a first economic evaluation. This is based on a number of assumptions that still needs to be validated through trial.

In parallel to the case study, a questionnaire has been developed to investigate the preferences of target customers for different services that could be offered within DR programs, providing at the same time a useful customer segmentation. It has been first spread out in Italy, specifically in the regions of Piemonte and Lombardia, in order to test its validity. It will also be applied to the case study during the first stage of user-experience design.

Generating a solution

To simplify the overall complexity of DR programs related to the large number of actors involved, we developed a **step-based approach**.

After a first stage of *user experience design*, supported by our questionnaire to segment customers and to tailor the communication strategy, an initial *customer engagement phase* is required. This strategy includes a wide service offering, so to increase their awareness in the energy field while making them ready to take action. These services range from the visualization of real-time and historical energy consumption, to detailed information on individual appliances, identifying possible inefficiency and providing useful advice to achieve savings in the electricity bill. The real *Demand Response* is implemented only in the last stage, asking customers to change their consumption habits, not only for a personal benefit as before (bill savings, increased self-consumption) but according to the need of the grid.

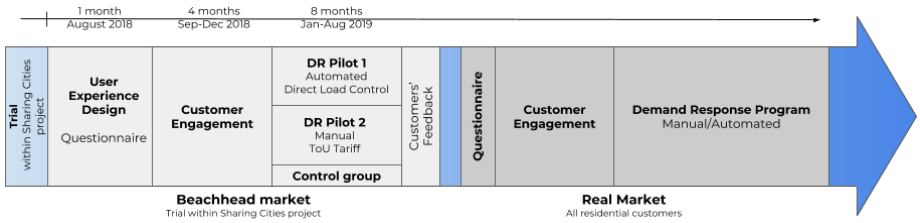

Figure 2: DR. BEAR concept timeline

Based on the current remuneration for demand flexibility, the financial incentive that can be given to each household is likely to be quite limited, given that a large number of customers need to be aggregated to reach a significant DR capacity. Therefore, different leverages have been identified, combined with gamification tools and social competition to trigger behavioral changes in end-users, keeping them engaged in the program.
The incentive scheme that we developed is based on the collection of virtual coins as a reward for each action that is undertaken by residential consumers.
The engagement strategy will be enabled by DR. BEAR platform, that connects all the different actors and represents the main communication channel to dispatch shifting request to customers through an app interface. The app has been designed by us, by referring to a previous version developed by our partner KiWi Power.

Figure 3: Real time interface is used to provide the users information about energy use in their household. Dr. Bear message box is accessible from each tab by tapping Dr. Bear icon in the top menu.

Figure 4: A comparison between current energy use and previous trends in the household is displayed in a graph. The users can choose which time frame to use for the comparison. Dr. Bear's pop-up messages keep the customer engaged.

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