Evaluation of Belgian Energy Market Models with Demand Response

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***Abstract*—Energy markets worldwide are evolving towards smart grids. The value network of the current energy market will be subject to changing actors and roles in the evolution towards smart grids. There are several ways in which the market could respond to these changes, depending on who will take up newly emerging responsibilities. We consider the architecture of a large-scale pilot that was conducted within the Flemish Linear project and model the current energy market. Drawing upon the insights derived from the pilot and the current models, we propose several possible future market models that could take place when smart meters will be implemented and opportunities for demand response will emerge. Subsequently, the different models are evaluated by means of a PEST analysis.**

I. Introduction

The current energy market is subject to several disruptive changes. There is the current society battle against climate change in which the energy market has an important role to play. Other challenges include generation diversification, optimal deployment of expensive assets, demand response, energy conservation, and reduction of the industry's overall carbon footprint [1]. One of the proposed measures to meet these demands is the conversion of the current energy grid towards a smarter grid.

Literature suggests great possibilities when evolving towards a smart grid. Introducing Automated Meter Reading (AMR) at the residential household level can be considered as a first step in the process could result in automated billing. Taking this one step further, the introduction of Advanced Metering Infrastructure (AMI) that allows two-way communication, makes applications possible such as Demand Response, Outage Detection and Restoration, Asset Management, Customer Information Systems and Distribution Automation [1]. To achieve these advantages, research on smart grids has taken off on a global scale. [2], [3], [4], [5] Several countries have already gone beyond research and have implemented smart meters for their residents. The European Commission defines a smart meter as "An electronic system that can measure energy, consumption, providing more information than a conventional meter, and can transmit and receive data using a form of electronic communication." In Europe, there are currently close to 45 million of these smart meters installed. These meters are mostly located in Finland, Italy and Sweden. 16 other European states will proceed with a large-scale roll-out by 2020 or earlier[6].

In Belgium, we are still at the start of this changing energy market. From the policy declaration of the current minister of Energy Annemie Turtelboom, we learn that there are currently 41.000 smart meters in Flanders [7]. In this paper, we will discuss and present several possibilities on how to proceed with smart metering and demand response on the Belgian energy market.

We start by providing more information about the project in which this research has taken place. The Linear project was a Flemish smart grid project that investigated different possibilities to realize residential demand response. A large-scale pilot was set up to evaluate the technical feasibility and user acceptance of this new kind of technology and evaluate the economic viability of several business cases that are based on residential demand response. The setup of this pilot and the actors and roles involved provided us with a first starting point to construct market models. We present the current market models for households with and without sub metering devices to model the current situation. Starting from this basic model, we then further elaborate on possible ways to introduce the new demand response functionality in the market. We identified two main ways to do so: (i) by applying a centralized market model which involves the creation of a party on the energy market, the independent aggregator and (ii) a market driven model. We then bring both types of models together in a mixed model and discuss strengths and weaknesses of all models proposed by means of a PEST analysis.

II. Linear Project

Linear is a Flemish smart grid project that investigated new ways to make use of energy flexibility of residential consumers [8]. By evaluating two remuneration models and four business cases in a large-scale pilot, Linear studied how households, energy producers and power grid operators could better match energy consumption with energy generation and local grid constraints. These remuneration models included both automated demand-side management (an automated system in which Linear switches on the equipment) and rate control (charging the customer with based on dynamic tariffs). The business cases that were evaluated were the following:

1) **Portfolio Management:** Pass on the variations in energy prices in the form of dynamic day ahead tariffs to the consumers
2) **Wind Balancing:** Absorb production surpluses or shortages due to incorrect wind predictions to reduce intra-day imbalance costs
3) **Transformer Aging:** By distributing power over time, peak loads are reduced, which in turn reduces the temperature of the transformers and thus extends their lifespan

4) **Line Voltage Management:** Automated droop control to optimize the voltage level at the points where individual homes are connected to the grid

For this project a pilot was set up consisting of 240 Flemish households to test both the technical and the economical feasibility of residential demand possibilities. The infrastructure of this pilot [9] will be briefly explained further in the paper as a starting point for future market models.

III. Roles and Actors

Before diving into the architecture of the pilot for Linear, we will first take a look at the relevant roles and actors in the value network of the energy market. This will provide the necessary background for both the pilot architecture and the proposed market models.

A. Roles

In this network, the most important roles for the future demand response market are identified. These include:

- **Smart LDP (SLDP)**: Smart component within the Local Delivery Point which is able to send regulated data, and receive and cope with request signals based upon grid related issues (can steer HEC in case of emergencies)
- **Home energy controller (HEC)**: Decision system inside a home using individual rules to cope with signals from the request management and other parties (depending on the market model, infra), with ability to automatically switch appliances. Visualization of local consumption/production data and other relevant/commercially interesting information(e.g. dynamic tariffs, provided flexibility).
- **Regulated data management**: Storage and distribution of regulated meter data e.g. consumption, network usage, network issues, ...
- **Non-regulated data management**: Commercially interesting information: storage and selling of non-regulated data e.g. flexibility information, more detailed consumption information, etc.
- **Request management**: Matching grid and commercial requests with available flexibility

B. Actors

Similarly, we also present the most important actors in the future demand response market. It is important to notice here that this is merely a simplification of reality to increase the comprehensibility of the models. Other important actors on the energy market (e.g. regulator, producers, etc.) will therefore not be used here.

- **Distribution Grid Operator (DGO)**: Responsible for the distribution grid. Builds, manages and maintains the distribution network in a certain geographical region for electricity.
- **Energy Service Provider (ESP)**: Sells the energy to the end consumer (retail function)
- **Energy Service Company (ESCO)**: Selling services to end customers e.g. apps for energy consumption, pricing, ...
- **Balance Responsible Party (BRP)**: Actor in control of maintaining the real-time balance between energy generated and consumed.
- **Aggregator**: Actor in control of aggregating the flexibility offered by the households

IV. Pilot Infrastructure

In this section, we explain the ICT infrastructure that was constructed in the Linear pilot into further detail. An overview is provided in Figure 1.

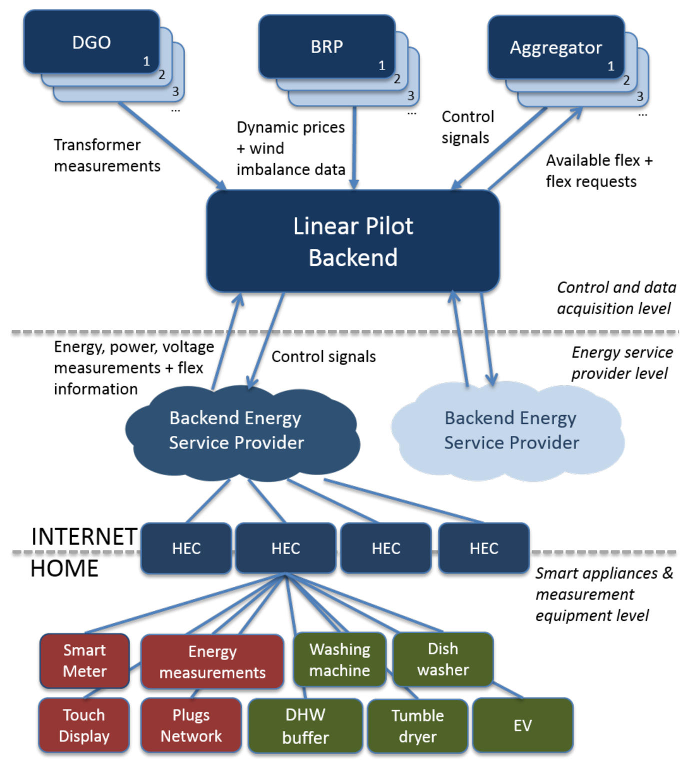

Fig. 1. Pilot Infrastructure

From Figure 1 it can be noticed that the architecture was divided into three separate layers. The bottom layer is identified as the Smart Appliance & Measurement Equipment level. This includes everything behind the home gateway within a residential household (appliances, smart meter, energy measurements, etc.). This home gateway exchanges information with a centralized backend of the ESP on the Energy Service Provider level. The information flow from the gateway to the ESP backend includes measured consumption, production and flexibility data. To communicate with the other actors involved, there was also a backend present in Linear (Linear pilot backend) and this backend is situated at Control and Data Acquisition level. This backend receives the data from the ESP backend concerning the households and combines it with data coming from the DSO (transformer measurements) and the BRP (dynamic prices and wind imbalance data). All this data is sent to the server of the aggregator. Here the available flexibility is aggregated and used as optimally as possible to support the outlined business cases. As a result of the optimization algorithms control signals are sent via the Linear pilot and the ESP backend towards the home gateways to activate or deactivate appliances or inform the customer.

V. Current Market Models for Residential Households

The market models will be represented by means of schematic overviews like in Figure 2. Two horizontal layers can be identified that are present in the energy market. Similar to in telecommunication models, these can be labeled as a Network and a Service Layer [11]. The Network Layer contains the required energy delivery infrastructure on which the Service Layer can rely. Services in this layer may include demand response and directly providing customers with information.

A. No Sub Metering Model

In Figure 2, we identify a typical household where the SDP (Service Delivery Point) consists currently of an electricity module that keeps track of the aggregated energy consumption in the household. This regulated market data on energy consumption is communicated manually to the DGO on a yearly basis.

The data is also exchanged with the suppliers or BRPs that supply these customers by means of the Belgian data platform Atrias, primarily for billing and settlement purposes.

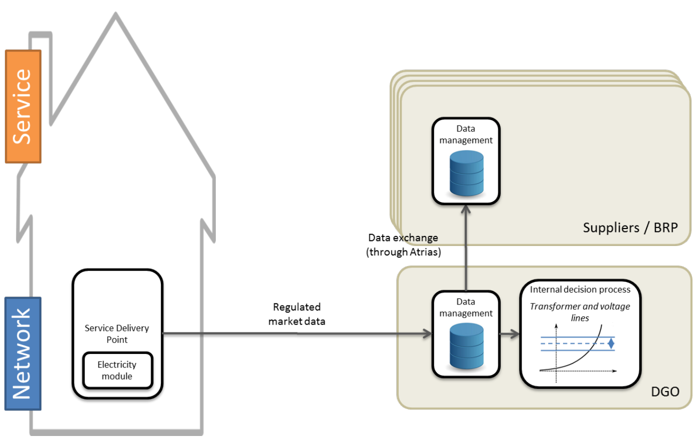

Fig. 2. No Sub Metering Model

B. Sub Metering Model

In Figure 3 we see the representation of a current market tendency for Energy Service Companies to allow submetering for the customers. These sub-metering devices are installed separately from the Service Delivery Point. Instead, they typically consist of simple devices, to be plugged into the electricity outlet that could be turned on or off by the supplier's / ESCO's applications. These smart energy devices allow you to control the usage of your household devices by online applications. The devices allow users to monitor several appliances in their household online and turn them on or off. The data exchange between DGO and Suppliers or ESCOs could currently take place by means of the Atrias platform. In the future however, it might be possible that certified third parties have immediate access to the customer's data. The customer is after all owner of its own data and can decide who gets access to it.

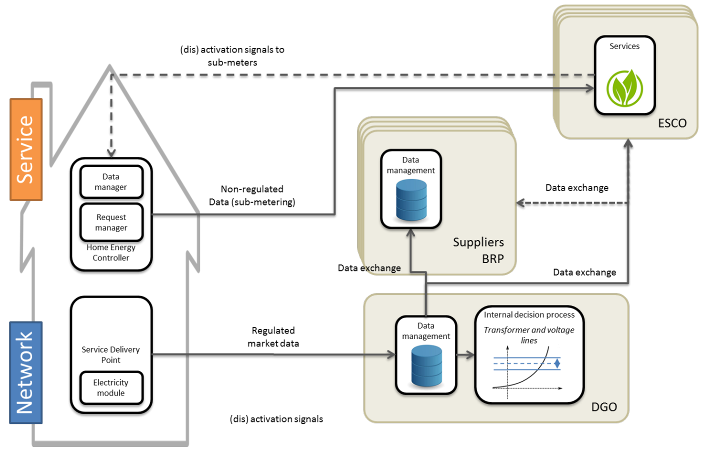

Fig. 3. Sub Metering Model

These devices form a first version of what we identify as a Home Energy Controller (HEC) [10]. This concept models the functionality of activating in-house device, for example to reduce the local injection of solar energy in case the line voltage becomes too high. The HEC consist of two main parts. A Data Manager that gathers information on the activity level of the devices and a Request Manager for controlling the devices. The HEC concept is depicted in Figure 4. The ESCO gets the sub metering data by means of the HEC and can send steering signals to the connected devices. The data can be shared with Suppliers and BRPs to allow a further insight in the clients' energy consumption. The clients themselves can use this information on their energy consumption pattern for monitoring purposes and use the steering functionalities for their personal gain. Customer binding and the change in mindset (as a first step towards demand response) are the main reasons for the suppliers to offer this extra service.

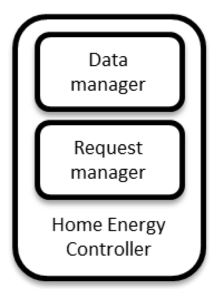

Fig. 4. Home Energy Controller

VI. Potential Smart Meter Market Models for Residential Households

So far, we have sketched the current situation in the previous two models. We have also introduced the HEC as a new functionality to allow the monitoring and steering of appliances. In the following models, we elaborate on this concept and demonstrate how this functionality can be used for different parties in the market to gain value out of it. To be able to do so, a new functionality is introduced in the SDP, namely the Communication Module (Figure 5). This increases the functionality of the meter, capable of reading and sending consumption data and voltages every 15 minutes towards the DGO. This can help the DGO in monitoring the line voltage at a residential level. The DGO should also have the possibility to send signals towards the smart meter, for example to reduce the local injection of solar energy in case the line voltage becomes too high.

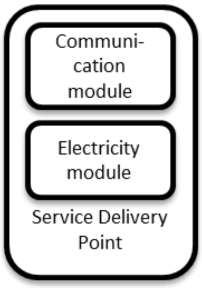

Fig. 5. Service Delivery Point

This development from a one-way system to the DGO towards a two-way systems overcomes the economical barrier for demand response. Before the smart meter roll-out, there was no gain for the Suppliers / BRPs to steer the customer's demand, since the customer always get charged by Synthetic Load Profiles (SLP). It would not matter if a customer's consumption is being shifted, as this will not be reflected in his energy bill. The introduction of smart meters that send validated information on a regular basis opens up opportunities for demand response.

A. *Centralized Model*

In this slightly more complex representation of a possible market model, we identify a central role for an independent aggregator that gathers data from both the SDP (regulated data) and from the HEC (non-regulated data). This data could be requested by both the Suppliers / BRPs and the DGO. They can use this data to benefit from the available flexibility to improve their operations. A DGO might gain on a local scale by applying the Transformer Aging or the Line Voltage Management business case. The Suppliers / BRP might gain regionally or nationally by making use of the principles of the Portfolio Management and Wind Balancing case. Both their requests concerning the usage of available flexibility can then be passed on to the independent aggregator that combines all inputs and will send out request signals towards the HECs to turn devices either on or off.

In this scenario, the DGO still receives the network related data that allows him to fulfill his role as a distribution network operator and control the network. To guarantee that the network keeps up and running, the DGO should have a contractual agreement with the independent aggregator so that their urgent network related requests (within certain predefined, reasonable thresholds) get priority over the requests coming from the Suppliers / BRPs.

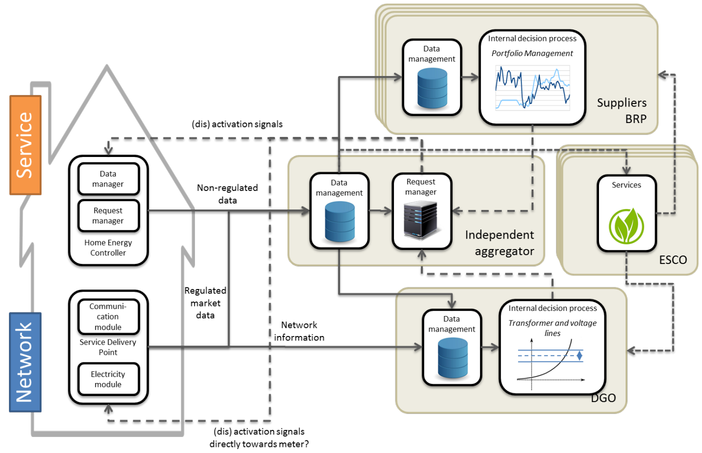

Fig. 6. Centralized Model

From a political point of view, one independent aggregator on the market guarantees stability concerning demand side management. The need for constant control for this independent aggregator from the government might be troublesome. Economically, the biggest concern would be the increased complexity on billing customers. Several questions can be raised on who gets charged for using flexibility (Per request towards the independent aggregator? Per fulfilled request?). On a social level, we identify the pros and cons of a governmentally regulated market, opposed to a free market. The last factor is the technological perspective. On the one hand the Single Point of Contact and the global optimization possibilities can be great advantages. On the other hand, there might be some concerns on technical scalability that could be identified for this approach.

B. *Supplier Driven Model*

A first variation of a market driven model allows the Suppliers / BRPs to send their flexibility usage requests through the HEC. The DGO on the other hand sends their request signals towards the SDP, which passes the requests on to the HEC. This situation is depicted in Figure 7.

In a supplier driven model, the DGO has less responsibilities concerning the handling of data. This data includes both Regulated market data and Network information. All Non-Regulated data (data involving flexibility) ends up with the Suppliers / BRPs in this model, who will use this data to decide on the next requests to be sent to the HECs. In this scenario, the Suppliers / BRPs are responsible for the distribution of the HECs and get nearly all of the value that comes from using the flexibility. The DGO however, has the potential to send signals immediately to the SDP when network problems arise to overrule other requests (e.g. through voltage droop control). Notice that the DGO and Suppliers / BRP might be completely independent of each other for this matter.

This market driven model handles the data in a very logical manner. The regulated data flows directly to the DGO, while non-regulated data goes directly to the suppliers / BRPs. This distributed approach seems also a more scalable solution from a technical point of view than the centralized model. The

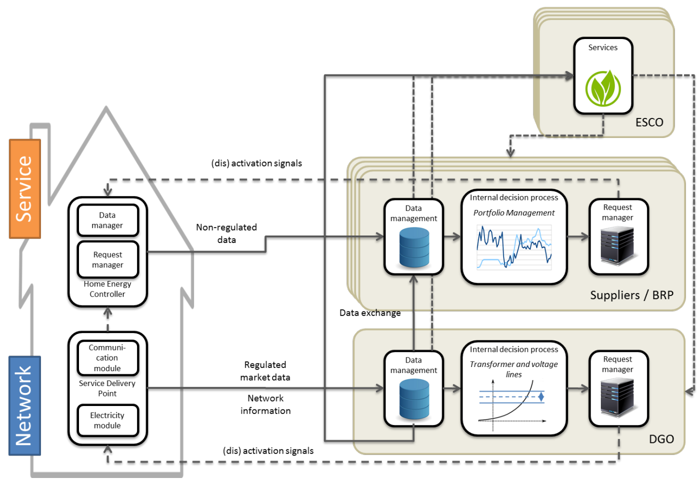

Fig. 7. Supplier Driven Model

disadvantages of this model come from the fact that the non-regulated data is scattered across different parties. This makes it harder to control, but also provides practical obstacles, for instance for ESCOs who might need all data for their services.

C. *Combination of Centralized & Market driven model*

A final market model that can be considered is a mix-up of both the centralized and market driven models. This model is depicted in Figure 8 and re-introduces an independent aggregator to the market. The aggregator is now seen entirely as a data broker that collects both non-regulated data from the HECs and regulated data from the SDPs. Also other kinds of data can be collected, like data concerning the sent signals by the ESCO or data concerning customer's feedback.

The HECs themselves are implemented by the ESCOs in a market driven way, but the ESCO takes up only the role of a request manager. This can be realized by providing the ESCO with the non-regulated data from the independent aggregator and the accumulated requests from the Suppliers / BRPs. Another option for the ESCO is to do the optimization as subcontractor for BRP / Supplier, based on the necessary data coming from the supplier / BRP.

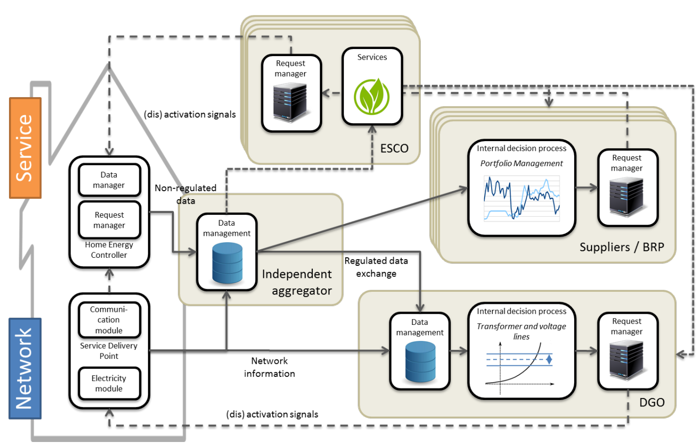

Fig. 8. Combination of centralized & Market driven model

This hybrid model combines most of the advantages we have discussed before. It brings the centralization of data as a potential advantage without the possible scaling issues. The ESCOs facilitate the flexibility services for the Suppliers / BRPs, which is a clear advantage from their point of view. The DGO however, still copes with a lack of foresight since it has no clear insight in the decision making process of the independent aggregator.

VII. Evaluation overview of proposed models

When we put the three models under consideration next to each other and evaluate them by means of a PEST analysis (considering the Political, Economic, Social and Technological factors), we get the following overview summarized in Tables I - III.

	Centralized Model	
	Advantages	Disadvantages
Political	One independent aggregator for data and demand side management (steering)	No free market for non-regulated data. Should be controlled / monitored in order to make everything work correctly in a fair way
Economical		Payment/billing for using flexibility might be very complex. Large Investment for an unclear Cost Benefit Analysis
Social	Governmentally regulated instance controls the flexibility market	No market driven approach on the flexibility market
Technical	One actor as Single Point of Contact for ESCO data request. Most optimal request manager based upon all information available	Technical scalability

TABLE I. PEST Analysis of the Centralized Model

	Supplier Driven Model	
	Advantages	Disadvantages
Political	Data gathered at logic places: regulated at DGO, non-regulated at suppliers/BRP.	
Economical	Market driven: only steering by DGO if absolutely required.	ESCO services possible but have to deal with distributed data
Social	Customer has a central position in a market driven model. Market driven approach concerning flexibility.	
Technical	Scalable. Nice split between network and service layer.	Distributed non-regulated data management

TABLE II. PEST Analysis of the Supplier Driven Model

	Combination Model	
	Advantages	Disadvantages
Political	Centralized data management (regulated).	
Economical	Partially Market driven model	Large investment for an unclear return on investment
Social	ESCO driven model	No free market for non-regulated data.
Technical	Scalability	

TABLE III. PEST Analysis of the Combination Model

VIII. Conclusion

In this paper we presented the infrastructure that was applied in the large-scale pilot for the Flemish smart grid project Linear. Next we presented the current market models of the Belgian energy market that does not involve smart metering. Based on the insights derived from both the pilot and the current market models we expand the models by adding automated metering and demand response possibilities. We identified three possible market models that could emerge from this situation, which include a centralized model, a supplier driven model and a combination of both. These models are then evaluated by means of a PEST analysis. The analysis shows that there is no optimal market model but rather it seems that each model has important consequences for the different actors involved and they should be considered accordingly.

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