Aggregate Consumer’s Flexibility in Consumption and Generation to Create “Active Demand”

Corentin Evens  
VTT - Finland  
corentin.evens@vtt.fi

Seppo Hänninen  
VTT - Finland  
seppo.hanninen@vtt.fi

Fredrik Pettersson  
Vattenfall Research & Development - Sweden  
fredrik.pettersson@vattenfall.com

Stefan Melin  
Vattenfall Research & Development - Sweden  
stefan.melin@vattenfall.com

Abstract
Residential electricity consumption varies throughout the day in a consumer-specific pattern. If a large number of consumers are aggregated, flexibility in their combined consumption and own generation, i.e. “active demand” (AD), may be used, e.g. for load reduction in certain areas. Since both the electricity markets and the physical electricity systems differ across Europe to some respect, preconditions may also differ for establishing efficient consumer participation in active demand activities.

This paper studies preconditions, possibilities and barriers for active demand in the Nordic countries. The analysis is based on preliminary findings of the EC FP7 project ADDRESS (ECGA no. 207643) commenced in 2008 and continuing until 2012. ADDRESS is an Official Partner of EC Sustainable Energy Europe Campaign. The project consortium counts 25 participants including ENEL, EdF, ABB, Iberdrola, VTT and Vattenfall.

One of the objectives of ADDRESS is to design technical and business conditions for an aggregator to enable active participation of domestic and small commercial consumers in power system markets. This will be achieved by aggregating flexible demand and generation of equipment installed at consumer’s premises such as electrical appliances, distributed generation and energy storage.

It is anticipated that active demand services could be valuable to network operators, balancing responsible parties, owners of non-controllable generation, a. o. ADDRESS will develop and test cost-effective technical solutions to enable active demand and evaluate business cases for exploiting its benefits. Utilising active demand will become increasingly important in conjunction with introduction of Smart Metering and Smart Grids.
1. Introduction

Vattenfall and VTT are presently participating in the ADDRESS project (ECGA no. 207643), co-funded by the European Commission within the 7th Framework Program, FP7. ADDRESS is framed in the Smart Grids European Technology Platform and is an Official Partner of EC Sustainable Energy Europe Campaign. Major participants in the ADDRESS consortium are ENEL, EdF, Iberdrola and ABB together with e.g. KEMA, VITO, Ericsson, Landis & Gyr, Philips, Alcatel, Electrolux and universities of Manchester, Cassino, Comillas and Siena.

ADDRESS is an abbreviation for Active Distribution network with full integration of Demand and distributed energy RESourceS. The project commenced 2008 and will continue until 2012. The ADDRESS project focuses on small consumers’ possible flexibility of consumption to reduce load on command. If a large number of consumers are aggregated the total load reduction may become quite significant (see e.g. the WWF Earth Hour initiative on March 27).

The aggregated reduced load could be utilised at peak loads, at network congestions, to compensate voltage sags, etc but also for balancing fluctuating output of wind power generation and perhaps also for participating at the power exchange. It is anticipated that such load reductions could be sold to electricity market players, e.g. network companies, balancing responsible parties, owners of non-controllable generation (e.g. wind power and PV). Small consumers’ excess production from own generation such as small wind units, PVs and microCHPs could also be aggregated into larger amounts for participating in market sales. This elasticity in consumption and generation is in the project named “active demand” and abbreviated AD.

Utilising active demand may become increasingly important in conjunction with the introduction of Smart Metering and Smart Grids. Smart Metering will allow a monitoring of the loads and DG units with a higher time resolution while Smart Grids will require distributed intelligence and reactivity from the local loads and generating units. The ADDRESS project will lead up to full scale demonstrations of achieved technology and concepts for aggregated active demand at three sites in Italy, France and Spain.

This paper will present the ADDRESS project, its scope and possible implications for the Nordic market.

2. ADDRESS architecture – Active demand, the aggregator and other market participants

The ADDRESS scope along with a simplified representation of the proposed architecture is shown in Figure 1 below. It shows the participants, the main components and, in a very simplified way, how they interact via technical and/or market channels.

In this architecture, the aggregator is the key mediator between the consumers on the one side and the markets and the other power system participants on the other side, namely:
- The aggregator gathers the flexibility capacity from its panel of consumers.
- The aggregator aggregates the consumers’ loads and uses them to form AD products (see further).
- The aggregator collects the requests and signals for AD-based services coming from the markets and the different power system participants.

If one of his available products matches a service request, the aggregator provides the service to the interested actor or market.

Figure 1 – Simplified representation of the ADDRESS scope and architecture

It should be emphasized that the “flexibilities” and contributions of consumers are provided in the form of modifications of their consumption profile. Aggregators therefore form their AD services and offers using consumers’ “demand modifications” and not consumers’ energy profiles as such. Or in other words, an aggregator sells a deviation from the forecasted level of demand, the "base load", and not a specific level of demand.

In the ADDRESS architecture, all the power system participants are considered with respect to the services provided by active demand, but particular attention is paid to the aggregator, the consumers and the Distribution System Operator (DSO), which will be the subjects of detailed studies.

At the consumer level, the Energy Box is the interface between the consumer and an aggregator. It receives the price and volume signals from the aggregator as well as local information about some individual load consumption and displays them to the consumers. In addition, it carries out the optimisation and the control of the loads and local distributed energy resources at the consumer’s premises. It “represents” the consumer from an aggregator’s perspective (Figure 2).
The Distribution System Operators (DSOs) also play an important role because the consumers involved in AD (as developed in the project) are connected at the distribution level. It is expected that DSOs in the future will have to face increasing challenges with for example the increasing penetration of distributed generation and the apparition of electrical vehicles. They will however still have to ensure a secure and efficient network operation. A basic premise for the ADDRESS concept is that interactions with other power system participants, especially the aggregator, will become, to some extent, more cost effective than network reinforcements. The DSOs will also maintain direct interactions with the TSOs for this purpose.

As mentioned above the project will develop algorithms and prototypes in details for the consumers, aggregators and DSOs. The interactions with the other power system participants will be simulated using simplified models at a level of detail sufficient to allow the proper validation of the solutions.

Through the aggregator, AD demand can offer services to different actors classed in two categories:
- Regulated participants: DSOs and TSOs,
- Deregulated participants or participants in competition. Nine players have been identified and can be divided into three main categories:
  - Producers: central producers, decentralised electricity producers, producers with regulated tariff and obligations (reserve, volume, curtailment, etc.)
  - Intermediaries: retailers, production aggregators, electricity traders, electricity brokers, Balancing Responsible Parties (BRPs).
  - Consumers: large consumers.

For all the participants, their needs and expectations with respect to active demand are analysed on the basis of their functions. The stakes and the possible services that AD could provide them
are identified and described. This leads to a large number of different AD services, more specifically:

- 24 different AD services for the 9 deregulated players,
- 7 different AD services provided to DSOs and TSOs.

The aggregators anticipated business outline is schematically described in Figure 3 below.

![Figure 3 – Aggregator's anticipated business outline](image)

### 3. Description of the services provided by Active Demand

Before going further in the description of the services provided by AD, it is necessary to define standardized AD products able to meet the requirements of the identified services.

First, the product and services are:

- AD products (or product for short) are what aggregators provide (sell) to the players and which the players use to create the services. It is a specific “power against time” demand response shape to be provided by an aggregator during a specific time period. In the case of AD and ADDRESS, changing the consumption pattern of groups of consumers, in other words “re-profiling” the demand, via the diffusion of appropriate price and volume signals broadcast by aggregators.
- AD products become AD services (or services for short) when they are acquired and used by players. It is a specific instance of the use of basic Active Demand products. The terminology here is such that the services actually refer to the fulfilment of specific needs.
of the players. This differentiation stems from the fact that some identical AD product can have different applications (i.e. provide different services) when used by different players.

Second, three different products that could be expected from an aggregator are identified:

- **Scheduled Re-Profiling (SRP).** The aggregator has an obligation to deliver the specified power shape during the specified delivery period; this means that the product delivery is effectively “scheduled”.

- **Conditional Re-Profiling (CRP).** The power delivery associated with the product has to be “triggered” by the buyer based on a pre-agreed power volume range to be delivered by the aggregator. In other words, the buyer and the aggregator agree on an available capacity that the buyer can choose to call or not when the time comes.

- **Bi-directional Conditional Re-Profiling (CRP-2).** It is similar to the normal CRP, but it allows for adjustments in terms of demand reduction or of demand increase. It can be argued that a bidirectional flexibility product is simply the combination of two unidirectional ones with their appropriate calling conditions. However, in order to reduce transaction costs, it may be more reasonable and practical to allow for bidirectional flexibility.

An SRP product would typically have a single price for the delivered power. A CRP, on the other hand will have a first fee to reserve the capacity and a second one if the service is activated. In all cases, the specification of the volume to be delivered can either be fixed or as a range within which the delivered power has to be. The schematic active demand product profile is presented in Figure 4.

Finally, appropriate templates for describing the AD services in a standardized form are also defined within the ADDRESS project.

![Figure 4 – Profile of an Active Demand product](image)

4. Preconditions and possibilities in the Nordic countries

The free power market access in the Nordic region facilitates the participation of new market players. This enables the contribution of AD to bidding and auction procedures for almost all
reserve, regulation and balancing TSO activities as well as to NordPool’s long- and short-term markets although a minimum volume and a maximum response time is required.

Regarding balancing and regulation service auctions by the TSO, the bids will be selected according to their price. On the Nordic market where low-cost and easy regulated hydropower is the major source for system balance and regulation, competition can be fierce for additional resources such as AD. In a market-adapted structure it is quite obvious that active demand will receive the highest financial compensation for regulation and balancing participation during peak loads or during disturbances when power price is highest. However, these situations occur only a few times per year. That is why the aggregator will most likely rely on more common but less profitable situations for its base revenue.

It should be noted that, in Sweden, an existing aggregator had a contract to supply reserve power for the TSO, Svenska Kraftnät (SvK). The service similar to AD was performed in a way that medium size enterprises were disconnected from the main power line and consumption was fed by in-house generation. An alternative was that in-house generation was fed to the main network.

In the case of supplying AD services to distribution network operators the business case is somewhat less complicated as compared to supplying services to the TSO. This is mainly due to the fact that fewer consumers are involved and these consumers are located in a specific geographical area, i.e. network area, well known to the distribution network operator.

There are a few activities of the regional and local network companies that may be of interest for active demand services, namely power flow control, load shedding and voltage regulation. Power flow control is in general only performed at the connection points between the national grid and the regional networks in order to make sure the subscription levels for the contracts with the TSO are being kept within agreed limits. Today power flow control is primarily achieved by network reconfiguration during periods of high loads in general or in certain regions. In the future, AD could be utilised for carrying out power flow control, at least to a certain extent.

The regional and local network operators can perform load shedding by disconnecting loads such as electric boilers at industrial, municipal or other premises but is effectuated very rarely these days. Load shedding services could very well instead be performed by active demand at smaller consumers. Although there is little need for load shedding today, it may be quite another situation in the future taking into account commonly utilisation of intermittent power sources, various energy efficiency commitments, etc as well as SmartGrid implementation and the apparition of electrical vehicles.

Voltage regulation for regional networks is primarily performed by transformer tap changers as well as connecting and disconnecting of capacitor banks. For radial feeders of local networks, voltage regulation is most commonly achieved by tap changers. An increase in consumer demand for improved power quality may affect the future requirements for voltage regulation. It seems that voltage regulation could be the services of most interest and benefit to the regional and local network operators that AD could provide in the future, especially in combination with the implementation of Smart Grids.

Active demand and Smart Grids are most likely to be very linked to each other. In fact active
demand may be regarded as a prerequisite for complete Smart Grid implementations. It may also be argued that the reverse could apply and that certain Smart Grid implementations may be necessary for the introduction of full-scale AD services.

This paper targets the services that AD could offer to distribution network operators. It should however be noted that demand services could also be utilised for balancing the fluctuating output of wind power generation or for other balancing purposes. Active demand could thus be sold to other electricity market players e.g. balancing responsible parties, owners of non-controllable generation (e.g. wind power & PV). Small consumers’ storage units and local generators (e.g. small wind units, PVs and microCHPs) could also be aggregated to the consumption in order to increase the traded volumes and reduce the risk for the aggregator.

5. Barriers

As for all changes, there are certain obstacles or barriers to be overcome. There are currently some regulatory barriers that could oppose to the implementation of a full scale AD system. However, it can be expected that those barriers will be eased over time since AD is viewed to have a positive environmental impact and to be advantageous in terms of CO$_2$ emissions compared to alternative options. Some examples of other barriers are described below.

Metering is essential to detect the response of the consumers to a signal from the aggregator as well as to assess the delivery of the aggregated service. In the Nordic countries the network companies own the electricity meters and are responsible for metering of consumers’ electricity consumption. AMR (Automatic Meter Reading) devices are not yet installed at consumers’ facilities in all Nordic countries. In Sweden AMR meters are installed at all consumers’ premises as of July 1, 2009. In Finland, the legislation started an AMR rollout in 2009 and by 2013 all Finnish consumers should have AMR meters installed.

Hourly metering values may be sufficient for detailed monitoring of consumers’ AD. A higher resolution will probably be required to monitor each consumer’s activity properly. Metering may be regarded as a barrier for AD implementation.

The Swedish Energy Market Inspectorate (EI) (2008) notes that even though the Swedish market has been deregulated for almost 15 years, customers have not really utilised existing possibilities to increase their flexibility of demand in spite of various time-of-use tariffs (ToU), both regarding the network tariffs and energy tariffs being available for an even longer period of time. EI concludes that the immaturity of the market is one of the problems and with time the consumers will learn how to make use and financial gain of these ToU tariffs. Such tariffs have however been in place for over 20 years. The low rate in consumers switching to ToU tariffs is most likely due to a lack of interest in or understanding of the electricity bills and of the possibilities they could use. When proposed a ToU tariff, consumers may refuse because of a fear of the incurred discomfort, a fear of receiving too complex bills or a lack of trust in the electricity companies.

If these reasons, fear-of-discomfort, complexity, lack of trust and lack of economical incentives, are the background for not utilising ToU tariffs, they will also be barriers, most likely to a greater extent, also for AD and aggregator services.
Finally, EI also notes that one obstacle for increased flexibility in demand and consumption is the matter of “returning load” or the “pay-back effect”. See the right part of AD profile in Figure 4. For instance, during an AD request cycle the power demand of an electric space heating system is reduced, which consequently will reduce the indoor temperature. After the AD cycle the heating system will bring the temperature back to the original temperature, which will cause the power demand to increase rapidly and will cause a sharp demand peak. This may cause reduced benefit of AD depending on tariff structure, length of the AD cycle and size of returning load peak. These load swings will also affect network companies and balance responsible parties if high peaks of returning loads will occur at many AD participating consumers simultaneously.

6. The Nordic market and consumer flexibility

The way markets and contracts allow for the exchange of AD services is not very different between the different EU countries. What makes the Nordic countries different in regard to AD are the composition of the production capacity and the type of loads that can be found at the consumers’ premises.

The most promising consumer loads for AD in the Nordic countries are space and water heating. It would need very little technology for AD to be used. In fact, before the market liberalisation some consumers in Finland used to have their heating system remotely controlled by the utility. Air conditioning and auxiliary heating could also be included in this category.

White goods such as dishwashers, washing machines and dryers also show a potential for AD. In a near future perspective, the needs for AD in the Nordic countries would be mainly in the wintertime and the white goods flexibility tends to be negligible compared to that from heating systems. However, we can expect in a more distant future that, with an increase in uncontrollable DG and the apparition of smart grids, the potential from white goods could be used, especially in summer time when other resources are not available.

In the Nordic countries there is a very large AD potential in the form of space heating installations. In the case of Finland we have estimated that the total electricity consumption used for heating during a ‘normal’ winter day (temperature of -8.7º) amounts to about 1GWh/h during daytime and peaks to over 2.5GWh/h during the night (see Figure 5). It is anticipated the situation is similar in the other Nordic countries.

Grande et al. (2008) present various cases in Norway where load control, similar to active demand, yields positive outcomes for both the single consumer and for the other actors of the power system. They conclude that temporary reduction in space heating and load shifting of water heaters are the most convenient demand response objects and that improved metering is needed to secure that the responsive consumer really gets lower bills in periods of high prices. The authors also report that dynamic price signals (as in the case of AD) will give incentives to reduce loads in peak hours. Although the authors do not specifically target AD, the conclusion is that similar demand response activities are advantageous in Norway and subsequently this should also be the case for other Nordic countries.
7. Summary and conclusions

In the ADDRESS project the basic architecture and prerequisites for services and products based on consumers’ active demand has been developed and presented in a report publically accessible of the projects official website. This paper has briefly described the work of the ADDRESS project during the first year and the project will continue until 2012.

In this paper the preconditions, possibilities and barriers existing on the Nordic market have been briefly presented. Although there are some barriers to overcome in regard to regulation, metering and public opinion, it is considered that active demand would be an advantageous addition to the Nordic power market both for the consumers and market players. It would seem to be especially profitable for consumers with electric space heating and electrical water heaters. These types of loads would also provide the most benefits to network owners and other market actors taking advantage of the services provided by active demand.

Active demand could be utilised at peak loads, at network congestions, to compensate voltage sags, etc but also for balancing fluctuating output of wind power generation and perhaps also for participating at the power exchange. It is anticipated such load reductions could be sold to electricity market players, for instance network companies, balancing responsible parties, owners of non-controllable generation (e.g. wind power and PV). Small consumers’ excess production from own generation such as small wind units, PVs and microCHPs could also be aggregated into larger volumes and used by the aggregator to bid on existing markets or sold bilaterally.

Utilising active demand may become increasingly important in conjunction with Smart Metering and Smart Grids since controlling and monitoring of the system requires detailed assessment of load and generation at every instance of time.
References

Grande, Owe S., Saele, Hanne, Graabak, Ingeborg; Market Based Demand Response. Research Project Summary. SINTEF Energy Research, TR A6775, December 2008

Lundgren, Jens; Elkunden som marknadsaktör. Åtgärder för ökad förbrukningsflexibilitet. Swedish Energy Market Inspectorate, EI R2008:13 (In Swedish)

Official website of the ADDRESS project: www.addressfp7.org