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Economic potential of demand response at household level—Are Central-European market conditions sufficient?

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H I G H L I G H T S

- Calculation of economic potential of domestic DR at Central European market conditions.
- Model and case-study of spot market-oriented load shifting from supplier's perspective.
- Derivation of supplier's cost savings and upper cost limits for ICT infrastructure.
- Results show economic potential of domestic DR to be restricted to significant loads.
- Shifting of washing machines economically does not pay off in contrast to heat pumps.

A R T I C L E I N F O

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A B S T R A C T

The aim of this paper is to show the economic potential of demand response (DR) on household level at Central European market conditions. Thereby, required economic benefits for consumers' participation, the realistic load shifting potential at household level and the estimation of essential intelligent infrastructure costs are discussed. The core of this paper builds a case-study applying spot market-oriented load shifting from the supplier's point of view by using Austrian electricity market data, household load profiles as well as a heat pump and e-car charging load profile. It is demonstrated which cost savings for suppliers can be derived from such load shifting procedure at household level. Furthermore, upper cost limits for intelligent infrastructure in order to break-even are derived. Results suggest to take a critical look at European discussions on DR implementation on household level, showing that at Central European market conditions the potential for DR at household level is restricted to significant loads and hence, the applied load shifting strategy is only beneficial with application to heat pumps. In contrast, the frequently discussed shifting of conventional household devices' loads (such as washing machines) economically does not add up.

1. Introduction

Load shifting by request of demand-side activation is also called demand response (DR) (Albadi and El-Saadany, 2008). According to the International Energy Agency DR is defined as *"a set of strategies which can be used in competitive electricity markets to increase the participation of the demand side, or end-use customers, in setting prices and clearing the market"*, IEA (2003), p.17. FERC (2008) differentiates between the two different DR types: incentive-based DR such as direct load control (DLC) or interruptible rates and time-based rates like time-of-use or critical-peak-pricing. The first type involves offering customers payments to reduce their electricity consumption in times of system stress. In the latter customers receive discounted retail rates or other incentive payments promoting DR based on price signals.

The activation of DR can either be reached by active reaction of consumers, whose consumption is decreased by switching off machines and devices on call or within predefined periods (OFGEM, 2010). Or it can be activated by automated Demand Side Management (DSM). DSM is enabled by 'smart' appliances which automatically control electricity consumption. They are either programmed to react to certain electricity price levels and so, curtail or increase consumption or, in the case of DLC (Guo et al., 2010), are linked to 'agents' (utilities, system operators, aggregators, etc.) who switch loads through a physical circuit.

According to the list of DR benefits highlighted in literature (Bartusch et al., 2011; Braithwait, 2003; DoE, 2006; IEA, 2003; FERC, 2008; Hogan, 2009; Ofgem, 2010; Torriti et al., 2010), load shifting by DR is seen as a possible measure to

- attune demand better to supply and hence,
- counteract volatile renewable electricity generation and by doing so,

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- alleviate grid infrastructure utilisation as well as decrease the need for deployment of additional generation capacities,
- reduce market actors' potential for exercising market power,
- increase price stability and permanent flattening of prices,
- replace peak load capacity,
- enhance reliability (security of supply) and finally,
- result in higher efficiency in electricity systems and reduced costs.

Despite these numerous benefits, DR in Europe is still limited to use cases for large energy users like industry. As a major barrier a limited number of incentives to respond to prices (Torriti et al., 2010) can be mentioned. However, the roll-out of smart metres is seen as a chance for domestic and small business customers to play an increasingly active role in the energy market. Additionally, the introduction of sharper financial incentives shall boost DR implementation for small consumers (Ofgem, 2010). Furthermore, demonstration and pilot projects in European countries attempt to find ways to activate and aggregate loads and inspire even small consumers to participate (MoMa, 2009; BAUM, 2012). A critical, but rather new role on the electricity market thereby is the aggregator: a kind of agent who collects and distributes necessary data and information from other market participants, especially consumers, acts as an intermediate between consumers and grid operators (and/or suppliers) as well as provides DR capacity through contracts with consumers. The European Commission's Task Force for Smart Grids (Expert Group 3: Roles and responsibilities of actors involved in the Smart Grids Deployment) defines the aggregator as an actor, who "[…] *offers services to aggregate energy production from different sources (generators) and acts towards the grid as one entity, including local aggregation of demand (Demand Response management) and supply (generation management).* […]" (EC, 2011, p. 6). Aggregators can also act market-oriented as in the case of spot market-oriented load shifting, which is analysed in detail in the course of this paper. Thereby, the goal of market players like an aggregator or a supplier (acting as an aggregator) could be to participate on the electricity market and to try to generate arbitrage applying different DR activation strategies. In addition, the aggregator enables DR participation of smaller consumers on the market due to their aggregation.

Coming back to the goal to introduce a more flexible demand side also at domestic consumers and small businesses, independent of type of DR strategy to be applied it has to be considered that *benefits have to outweigh costs*. First of all, this is valid for consumers who shall accept and adopt DR programmes, but dependent on the shape of the concepts, also for all other relevant stakeholders (such as grid operators, suppliers, aggregators, etc.). Since results for detailed economic performance of DR at (Central-) European market conditions are – in contrast to manifold technical studies and the appraisal of the availability of technical components – scarce in literature, this paper will contribute to close this gap.

The idea of this paper is to empirically examine the potential of monetary benefits vs. costs in the case of *spot-market oriented load aggregation and shifting* under Central European market conditions, i.e. using the example of Austria while at the same time taking into account the current electricity price level. This will be done from a supplier's perspective, although conclusions on basic applicability from a consumer's perspective can be drawn (such as the potential room for more beneficial electricity tariffs for end-consumers). Thereby, the supplier's goal, who simultaneously acts as an aggregator, is to buy electricity as low priced as possible at the spot market for as many of his customers as possible. By means of intelligent applications, adequate communication and information technology (ICT), such as smart metering technology in combination with remotely controlled sockets, loads of aggregated customers shall be shifted from a particular number of hours with highest prices per day to hours with lowest possible price of the same day (taking advantage of peak/off-peak price spreads).

The goal in subsequent analyses is to illustrate which cost savings for suppliers can be derived from such load shifting procedure at household (HH) level. Thereby, different HH load profiles, also accounting for the possible use of electric vehicles and heat pumps, different levels of hourly load shifting as well as a different number of activations per day are analysed. Results are then used to derive upper cost limits in order to break-even and compared to estimated ICT components' costs (Meisl et al., 2012) as well as to consumer's expected earnings from demand side measures (Paetz et al., 2012).

The remainder of this paper is structured as follows: Section 2 discusses above mentioned framework conditions for DR using available literature, Section 3 characterises the methodology of the load shifting strategy followed by the description of applied data as well as assumptions in Section 4. Section 5 presents the results and finally, Section 6 concludes.

2. Market conditions for demand response implementation

The potential of DR and the feasibility of DR benefits as listed in Section 1 (especially cost reduction) are dependent on the availability of technology and infrastructure, the numbers of customers participating as well as the availability of adequate pricing mechanisms (FERC, 2009). Besides that on one hand they are dependent on the shape of electricity markets, including the following influencing factors (Møller Andersen et al., 2006; Vasconcelos, 2008; Cappers et al., 2012):

- Constitution of the generation pool and type as well as amount of reserve capacity (generation plants in merit order replaced by DR).
- Amount of variable renewable generation and according capacity needed to balance fluctuating generation.
- Level of total and single end-consumers' peak demand (peak generation capacity needed to cover peak demand and amount of shiftable loads as well as time and duration).

For instance markets with expensive reserve capacities (compare e.g. threat of scarcity pricing in North American markets described in Joskow (2006)) or limited transmission and distribution grid capacity (such as e.g. in Italy, Torriti et al., 2010) potentially face higher benefits from peak-saving DR programs compared to markets with overcapacities or low peak–off peak price spreads.

Furthermore, in countries with intensive use of electrical heating or cooling, technical load shifting potentials at household level are higher than in other countries.

On the other hand the success of DR deployment depends on consumers' willingness and consumers' monetary incentives to participate in DR programs influencing the elasticity of demand (Ofgem, 2010; Stadler, 2003), i.e. the flexibility of consumers to change demand in response to changes in price or other monetary incentives.

The following subsections discuss mentioned framework conditions in more detail, starting with crucial economic benefits for small customers in Europe as an adequate incentive to participate in DR programs.

2.1. Economic benefits from DR for small consumers

The critical point in implementing demand side measures is to convince consumers to participate by introducing adequate