HOUSEHOLD AGGREGATORS DEVELOPMENT FOR DEMAND RESPONSE IN EUROPE

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ABSTRACT

This work is aimed at studying the profitability of Household DSM which is a Demand Response (DR) solution aiming at providing power margins to the non-automatic Balancing Market (BM) by load-shedding of domestic electric heaters. After a large literature review aiming at better understanding the balancing market context in Europe, a deterministic model has been applied on the Swedish case in the 2020 timeframe, considering as well the involvement of Electric Vehicles (EVs) flexibility margins. It finally shows that due to investment costs distributed in each household, such solution is not feasible in short-term in locations which are not suffering a significant shortfall risk.

INTRODUCTION

The feasibility of demand flexibility for grid operation is investigated in several locations in Europe. The main driver being the connection to the grid of large amount of non-dispatchable renewable energies. Some companies (Voltalis, etc.) are already offering such DR solutions commercially, but their profitability is not really clear yet. This work is aimed at analysis these business models, based on domestic heaters load-shedding, in the Swedish framework.

MODEL

The model developed to access the profitability of Household DSM is a deterministic model considering as use case the Swedish ten past years Balancing Market (BM) data, the real location of Swedish private households heated by electrical convectors and the Electric Vehicles Initiative (EVI) assumptions for EVs deployment in Sweden by 2020 [6].

Hourly Household DSM potential Calculation

The hourly Household DSM potential has been assumed by considering on the one side a theoretical unique household thermal behaviour, having the following characteristics:

- λ = 160 W/°C/household, the global household temperature losses coefficient.
- τ = 160hr, the household time constant.
- P_{max} = 6kW, the mean heating potential per household.
- P_{boost} = 9kW, the heating system's maximal power, only deployed in situation of too low temperature compare with the reference temperature, and only out of heaters load-shedding period (cf *Boost* coefficient in fig. 3).

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These data has been based on Swedish studies from KTH and Energimyndigheten (calculation methodology developed in [1]).

On the other side, the method considers the hourly outside temperature of Southern Sweden (Malmö), which correspond to the area where flexibility margins are required first and two different inside temperature profiles displayed in fig. 1.

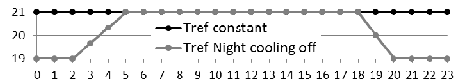

Figure 1: Inside daily T_{ref} profiles (in °C)

Household DSM could provide up to 1.400MW of margins in Sweden (240.000 hous. × 6kW/hous.), compare to up balancing volume of 360MW activated on average 1hr or more per day.

Hourly EVs potential Calculation

The model assumes only margins coming from EVs load-shifting but no battery discharging strategies since such solutions have a non-null marginal cost to due batteries ageing. Then the hourly load-shifting potential is calculated as presented in fig. 2.

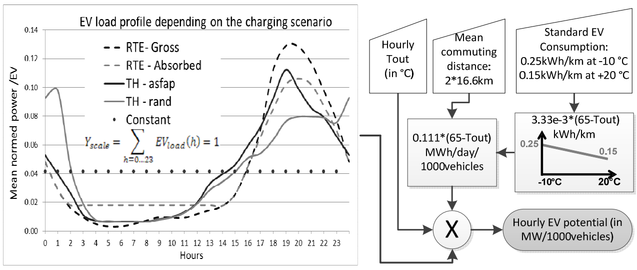

Figure 2: EVs load-shedding potential calculation

It assumes five different load profiles, based on two different papers [2] [3], a mean commuting distance of 33.2km/day and a thermal dependency according to manufacturers' data (Nissan Leaf and Volvo C30). Both commuting journeys and load profiles are applied seven days a week, disregarding working day or week-end impact. According to EVI assumptions for 2020, it has been assumed several different EVs penetration rates from 0 up to 600.000 vehicles in Sweden.

In the case of EV's shedding, the load is postponed for one hour and caught up equally during the three next hours. Moreover, a maximum power withdrawal limit is set. The volume exceeding this limit is postponed by one hour. If this limit is reached four hours in a row, the shedding potential of the fifth hour is cancelled to limit the loading delay.

Household DSM sales strategies

The models studies three different sales strategies:

- *Capacity market* assumes the sale of Household DSM volumes on an hourly both energy and capacity market, in direct competition with EVs margins.

- *Effektreserven* assumes the sale of a base-load on a winter peak reserve market. This emergency market, which already exists in Sweden, is paid at a fix capacity price and no activation of Household DSM volume has been assumed on it since this one is activated less than 10hr a year. Any bidding of household volume on this market implies potentially start of forced heating into households to guarantee a contractual shedding capacity available 24hr per day during this winter four months long contract. The household volumes left, in or out of the peak-load market period are sold on the hourly energy market, without any capacity price and again in direct competition with EVs as above.

- *Joint-bidding* assumes merging of EVs and Household DSM capacity to bid larger volume on the peak-load market and so use EVs potential instead of forced heating during period of lack of electrical convectors turned-on. EVs and household volumes left are sold again on the hourly energy market.

These two last scenarios are runnable now in Sweden, whereas there is only an hourly energy market and no capacity market existing at the moment.

DSM potential & sales calculation

The main model displayed in fig.3 is based on a simple process. First the hourly heaters normal load is defined depending on the temperatures T_{ref} (fig 1), T_{in}, T_{out}, T_{min} the minimum limit for load-shedding for BM purposes and T_{max} the maximum limit not to exceed for overheating. In case of overheating, the dwellers are paid back for the additional costs incurred. Then the sales depend on a merit order selection giving priority to EVs margins and if needed Household DSM volume allocation for the peak-load market. Regarding overheating situations, the households are split into two groups, so that only half of the heaters are activated during each hour of overheating. Each Household DSM sale is finally supplied by a reduction of the mean hourly power value fed into the heaters: $P \in [0; P_{max}]$ during load-shedding periods. $P = 0$ or P_{max} otherwise.

The net income assumed for both EVs and Household DSM is the product (balancing price – spot price)*volume, so that the retailers are paid back for the power they bought but which has not been used by their customers.

DSM Operation costs

Three DSM costs scenarios have been assumed (table 1), based on current data (Sc "2010") [4], and assumptions from 2020 (Sc "2020" and "50% 2020").

The operation costs of EVs have been assumed as null, considering that EVs load-shifting will be based on facilities already deployed for global EVs load management.

Table 1: investment & operation costs for Hous. DSM

Cost assumption: (1€ = 9.0SEK)	**50% 2020**	**2020**	**2010**
Hardware costs	75€	150€	290€
Installation costs	60€	120€	120€
Telecom + customers deal costs	4.5+5€/a.	9+10€/a.	18+10€/a.
Contract & devices lifetime	6 years		
Consumers acquisition cost	Neglected		
Final cost (in k€/MW/a)	5.33	10.67	16.06
Final cost (in €/hous./a)	32	65	96

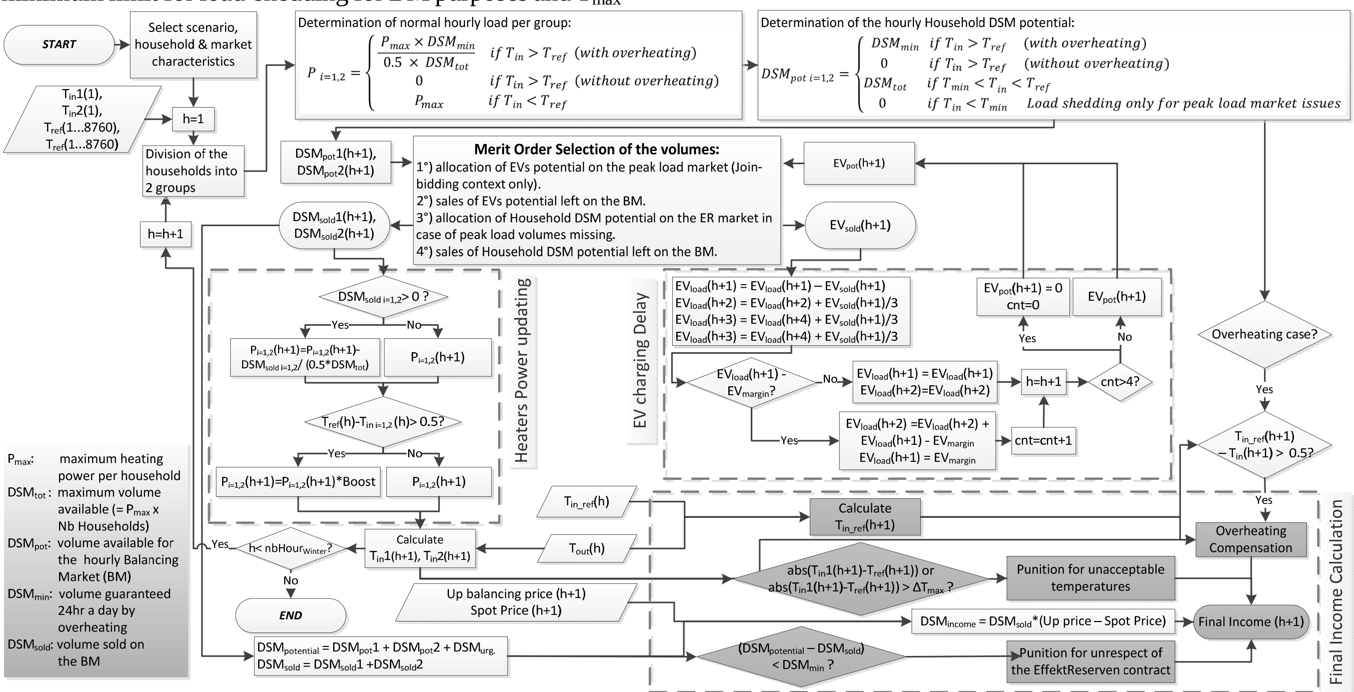

Figure 3: Model flowchart for the Effektreserven and joint bidding contexts

RESULTS

Basic Profitability of Household DSM

The three sales strategies studied lead to a wide analysis of the market opportunities in Sweden and in other countries having the same characteristics regarding heating systems, energy mix and power system configuration.

The first output is a specific case regarding the Capacity Market scenario which does not assume a paying back of the volume sold to the retailer (DSM_{income} = BM price * DSM_{sold} instead of DSM_{income} = (BM price – Spot price) * DSM_{sold}). With such billing method, which should stay applied in France up to 2015, the solution is for sure highly profitable, since the aggregator does not buy the power before selling it ("France" plot, null capacity price).

Considering now a conventional market, fig. 4 shows that Household DSM is not profitable with a 2020 cost assumption and a capacity price lower than 2.2€/MWh, whereas the mean capacity price paid on the peak reserve market is of only 2.4€/MWh (market price range: [2 ; 3.8€/MWh]). So by looking at this really low capacity price applied on the reserve market, it can be thought that there is no need at middle-term to commission a capacity market above this price on the Swedish hourly BM.

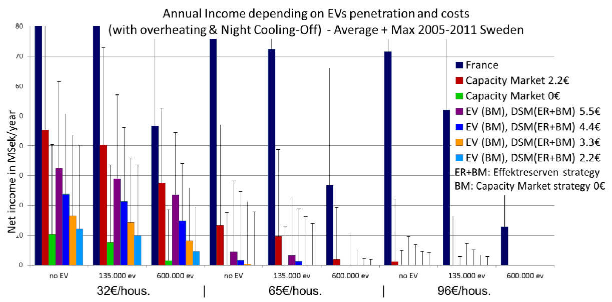

Figure 4: Mean profitability output of different market contexts. Average + Max value 05-11 (Hous. DSM with night cooling-off and overheating)

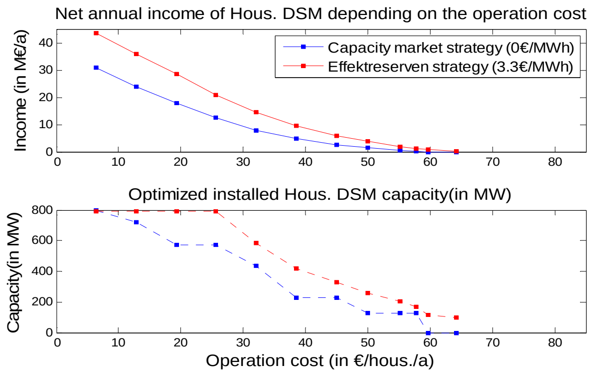

Figure 5: Mean annual income of Hous. DSM with the Capacity market & Effektreversen sales strategies – Sweden 05-11 (Hous. DSM with night cooling-off and overheating)

Household DSM on peak reserve markets

An involvement on the peak reserve market could contribute to increase the income in Household DSM, thanks to the annual fix capacity price paid. Despite over operation costs due to forced overheating of the households, this market stays more profitable than the current hourly market, and would lead to bigger Household DSM margins as seen in fig. 5.

Cooperation opportunities with EVs flexibility

An interesting output of the model is that, whereas EVs and Household DSM are competitors on the hourly market, both solutions can finally benefit from each other as soon as they get involved on the peak reserve market. This is due to their natural load curves, whose respective peak loads have a time off-set (fig. 6).

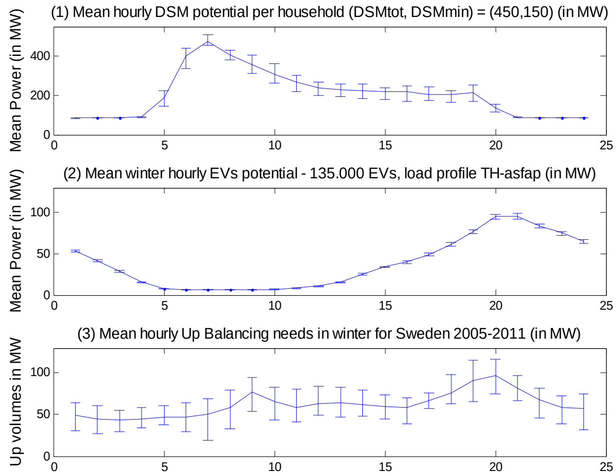

Figure 6: Mean hourly Hous. DSM (1) and EVs (2) potential compared to the hourly balancing needs (3) (max, average, min value – Sweden 05-11).

Consequently the sum of the total volume lead to guarantee a larger minimum power withdrawal 24hr a day in case of margins merging and so bid larger join-bids on the peak reserve market. Moreover, joint-bidding leads to spare household overheating costs by using EVs margins instead, whereas it should have been quite constraining for EVs aggregators to guaranty a minimum load 24hr a day in case of self-bidding. Fig. 7 shows the additional value of joint-bidding on the total annual income of Household DSM and EVs.

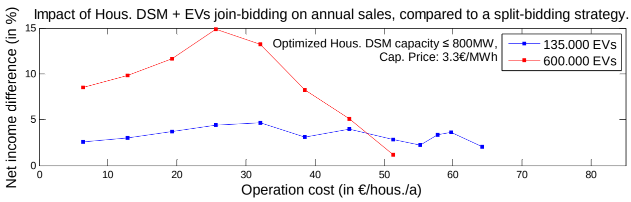

Figure 7: Impact of Hous. DSM + EVs joint-bidding on mean annual sales, compared to split-bidding with two EVs penetration rates – Sweden 05-11. (Hous. DSM with night cooling-off and overheating).

The peak reserve market to secure investments

More so than the value provided by the capacity price, an involvement on the peak reserve market is interesting for its associated fixed annual income. This leads to secure the DSM investments whereas the hourly BM is much more instable from one year to the other. Fig. 6 displays the instability: the hourly (BM price - Spot price) differences which provides the DR net incomes can vary a lot depending on the year.

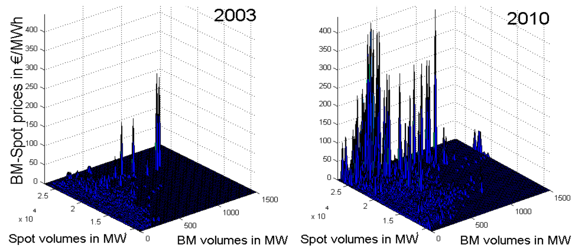

Figure 6: Displaying of the hourly (BM price – Spot price) depending on the hourly BM and Spot volumes sold for the years 2003 and 2010 in Sweden

Impact of DR on the annual energy consumption

One risk with changing residential load curves is to impact the household behaviour and thereby changing potentially the energy bill in the wrong direction. The simulations finally show that neither night-cooling off, heaters load-shedding or overheating significantly impact the energy bill. This is largely due to the good mean thermal characteristics of the Swedish households:

- the activation of overheating for DR purposes increases the annual consumption by around 1% in a night cooling-off context and have no impact without night cooling-off.
- a night cooling-off of 1°C or more reduces the annual consumption by only 1.5% (with τ = 160hr).
- the load-shedding event reduces the annual consumption from -1% to -2% without overheating and less than -0.5% with overheating.

Finally any combination of heating strategies leads to an annual energy variation within a range [-2%; +1%] (both *Effektreserven* and *Capacity Market* sales strategies), compared to a reference case without load-shedding, neither night-cooling off or overheating. These results confirms several studies, including the one of King and Delurey [5], claiming that any potential energy conservation observed after DR facilities commissioning is due to the associated consumption monitoring provided to the dwellers and not due to the shedding events.

On the contrary, any heating strategies leading to reduce or increase the heating period impacts in a significant way the balancing volume sales and thereby the annual income. Night cooling-off commissioning can reduce the volume sales by around 20%, leading to potential income variation up to 50%, regardless an overheating context or not.

CONCLUSION

The analysis of the Swedish power consumers made in this work shows that Household DSM holds a potentially good position among the low voltage DR solutions in Sweden. This is mainly due to its availability in winter, a transparent impact on end-users energy consumptions and a reduced competition from office & apartment buildings.
However, it seems that the value of DR on the regulating market mainly comes from grid weaknesses, and so such solutions are not profitable enough in Sweden.
The comparison made during this work with the French and German BM contexts confirms this assumption: the affected TSOs are willing to commission an hourly capacity market to guaranty power flexibility supplying in these countries, whereas the Swedish TSO does not plan it. So, although DR appears suitable in Sweden, the emergence of a market is unlikely.
Finally, the main short-term solution to promote Household DSM should be to work on the operation cost side, by trying to reach total costs around 55€/household/year, thanks to an updating of the already deployed facilities, like household smart-meters. Such price level should lead to a profitability of ca. 13%, with the *Effektreserven* or *Joint-bidding* sales strategies, whereas Germain [4] assumes costs for 2010 between 95 and 120€/household/year, whether the costs for consumer acquisition are included or not.
The last model's output to recall here is that, whereas EVs and Household DSM are competitors on the hourly markets, the both solutions can actually benefit of each other as soon as they get involved on a peak reserve market.

Acknowledgments

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