THE PRACTICAL AND THEORETICAL POTENTIAL OF DEMAND SIDE MANAGEMENT IN SME'S TO BALANCE WIND POWER

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ABSTRACT

In this study, we have investigated both the theoretical and the practical potential of demand side management at SME's (small and medium enterprises) to balance wind power. Our models and experiments indicate that the practical potential for demand side management for this goal is limited. This has several reasons: (1) The willingness and technical potential of SME's to apply demand side response is limited; (2) Due to the wide variety of processes in SME's, the application of demand side management demands custom made solutions, which makes large scale application difficult; (3) The available potential of demand side management is hardly suitable to follow the electricity production of wind turbines; (4) The local balancing of wind power results in using more electricity at expensive moments and therefore higher energy costs.

INTRODUCTION

Many Dutch municipalities and provinces aim to consume the electricity from photovoltaic panels and wind turbines within the region of origin. One of the drivers to do this is to be economically more independent from international energy companies. Demand side management is one method to increase the consumption of locally generated electricity.

Most of the studies either deal with consumers or with large industries. Not much research is done on the potential of demand side management at small and medium enterprises (SME's). In this study we both experimentally and theoretically investigate the potential of SME's to adapt their electricity consumption to the electricity generation of wind turbines.

Looking at the consumption of electricity in the Netherlands, we see that more than one third of the electricity is consumed by small and medium consumers (see Figure 1). This electricity is consumed by much fewer entities: 7.000.000 households versus 700.000 other consumers. This illustrates the relevance of industrial en SME's in demand side management applications.

In this paper we first discuss some relevant literature about demand side management in SME's. Then we present and discuss the field experiments and simulations we have carried out. Finally we summarize our conclusions and we recommend some further research.

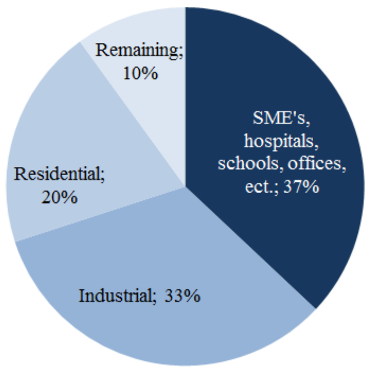

Figure 1: Distribution of electricity use in The Netherlands [1]

LITERATURE OVERVIEW

There is extensive literature available on demand side management. Research on this topic has been triggered by the California electricity crisis in 2000/2001 and has been increased ever since [2]. Siano [3] and O'Connell et al. [4] give broad overviews of the demand side management playing field. They do not present quantitative figures about demand side management.

Torriti et al. [5] present an overview of the demand side management programmes in Europe. They acknowledge that most current demand side management programmes aim on industries by automated control of the electricity demand. They mention a pilot in Oslo, Norway in which commercial end-users reduced the peak load by 4.5 MW. Lund et al. [6] present an extensive overview, citing almost 400 sources, in which they mention quantitative data of the potential of demand side management. Most attention goes to households and industrial consumers, but they mention the potential of the service sector as well. Hans Christian Gils [7] also estimated the potential of demand side management in industries, residences and SME's.

In short:

- most research is focused on the theoretical potential of industrial and domestic consumers. Information about practical potential at SME's is scarce;
- In SME's, high potential processes seem: heating, ventilation, air-conditioning and waste water treatment.

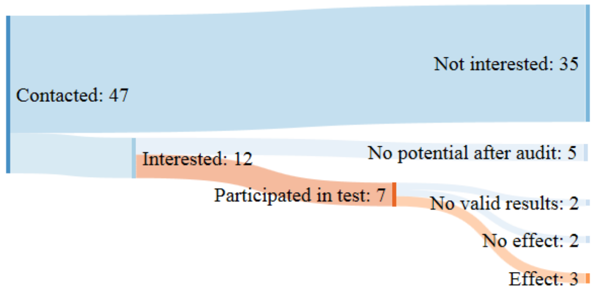

Figure 2: Summary of the results of the experiments

FIELD EXPERIMENTS

Method

To test the degree to which SME's are willing and able to modify their electricity consumption, we took the following steps:

1. Based on estimated theoretical potential to modify electricity consumption, we selected 47 SME's in the Dutch municipalities Zeewolde and Almere;
2. These SME's were contacted and asked to participate in the experiment. No financial reward was involved. Twelve SME's were interested to participate in the experiment.
3. These twelve SME's were audited by the company Laborelec to determine their ability to modify their electricity consumption. Seven out of the twelve enterprises appeared to have this ability based on their specific process;
4. During one week these seven enterprises were asked to increase or decrease their electricity consumption at three blocks of two hours. We determined the start of those blocks and informed the contact person one day ahead;
5. The electricity demand during this week was monitored and analyzed to see whether the electricity demand during the three blocks was significantly different than one might expect based on historical data. Three out of seven participating enterprises did show a deviation of the expected electricity demand.

Results and discussion

The results of the field experiments are shown in Figure 2. Despite the absence of a financial reward to participate, a quarter of the contacted companies (12 out of 47) were interested in the project. This interest was mainly based on sustainability branding and gaining knowledge on the companies perspective towards energy transition.
After an audit of the energy demand at the location of the enterprise, five enterprises were lacking of technical possibilities to adapt their electricity demand on request. This shows that the theoretical potential based on high potential processes (i.e. heating, cooling, ventilation and

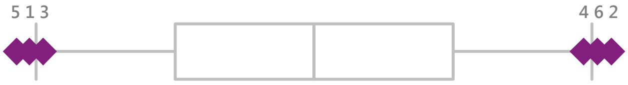

Figure 3: A series of tests where the deviation in electricity demand at the start of the tests (the purple diamonds) are clearly outside the normal range of electricity demand during that time (the boxplot). The response to three requests for increased consumption and three requests for decreased consumption can be seen.

Figure 4: A series of tests where the deviation in electricity demand at the start of the tests (the purple diamonds) are within the normal range of electricity demand during that time (the boxplot). It cannot be concluded that the requests are not followed up, but it seems not very likely.

waste water treatment) does not equal the practical potential. Illustrative is that one food cold storage we contacted did not have the potential to adapt the electricity demand at all, while another food cold storage which participated showed very clear and predictable responses to our requests to adapt the electricity consumption.
The seven enterprises with audited potential participated in the field trial. The following types of companies participated:

- Office heated by a heat pump;
- Food cold storage;
- Diary processor;
- Waste water treatment plant;
- Food processor.

The participants were asked to either increase or decrease their electricity demand during two hours. The enterprises were notified one day ahead about the timeslots. We repeated this test three or six times during one week. The electricity demand at the head meter during the days of the tests were compared with historical trends from the participants. We compared the drop or increase in electricity demand at the start of the test with the historical trends at these moments. Figure 3 shows a series of tests where an effect of the requests can be seen and Figure 4 shows a series of experiments where no effect can be distinguished.
With the office, cold storage and waste water treatment plant the deviation of the historical trends during the test moments were clearly distinguishable and reproducible.
The food processor has audited potential to adapt the electricity demand and was willing to participate in the test. However, they were not able to respond to all requests. This shows that even when there seems potential after an audit and there is willingness to adapt the

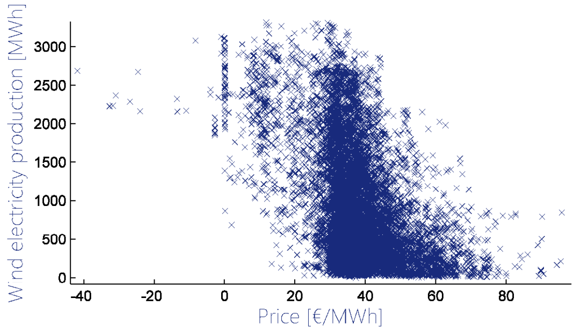

Figure 5: the correlation between the production of electricity by wind turbines and the day-ahead price in the DK1 area of the ELSPOT day-ahead electricity market. It can be seen that when there is a lot of electricity from wind turbines, the prices are generally lower than when there is less electricity produced by wind turbines.

electricity consumption, the response in not guaranteed. Unfortunately, at two participants the measurement data was not valid due to technical problems.

SIMULATIONS

Method

Based on the electricity demand of the industrial area Trekkersveld in Zeewolde, The Netherlands, we simulated the day-ahead buying prices of electricity when demand side management is applied to consume more electricity at moments when there is a large share of electricity produced by wind turbines. In 2013, 80.000 MWh electricity was consumed at Trekkersveld with a maximum collective peak load of 15 MW. Note that the possible peak load resulting from demand side management can be higher when all suitable appliances are switched on at certain times.

Because the Dutch day-ahead electricity market is hardly influenced by the production of electricity of wind turbines, we used the Danish day-ahead market (ELSPOT, area DK1) prices of 2013 together with the profiles of electricity produced by wind turbines in Denmark.

We scaled the electricity production profiles of the wind turbines from the ELSPOT area to produce the 80.000 MWh which is demanded at Trekkersveld. In effect, we simulate a yearly energy-neutral system by combining the measured electricity demand of Trekkersveld and the scaled electricity production of the wind turbines in the DK1 area of the ELSPOT. Figure 6 shows the demand and supply profiles during one month in this simulated energy-neutral system.

In the simulations we assume that the total consumption of a day can be completely altered with a restriction of a

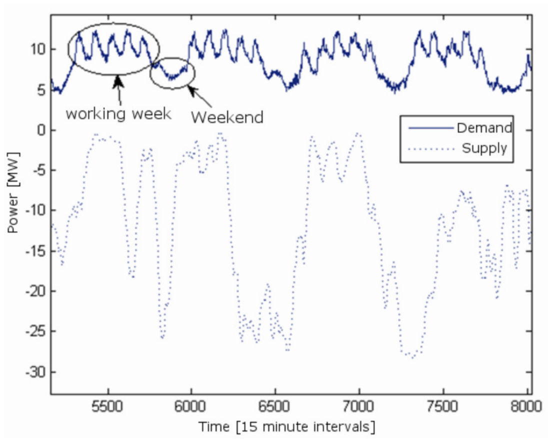

Figure 6: Demand and supply in the simulated yearly energy-neutral Trekkersveld. The demand are actual measurement data from 2013 and the supply is the scaled electricity production of the wind turbines in the DK1 area of the ELSPOT of 2013.

certain maximum power (which we will vary in the simulations). For example: when we assume a flexible demand of 20 MW and the daily usage is 200 MWh, that means that the 200 MWh can be consumed freely over the day with a maximum of 20 MW. We realize that this is a best-case situation for demand side management, because in practice, not all consumption can be freely shifted in time during a day.

Results and discussion

Figure 7 shows the needed import of electricity at Trekkersveld (which is a measure for the amount of locally electricity which is consumed) as a function of the costs for electricity on the ELSPOT. The dot shows the reference situation in which no demand side management is applied.

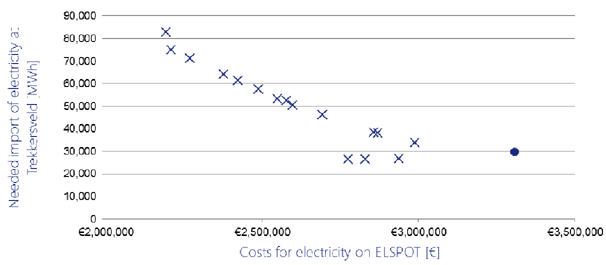

Figure 7: The needed import of electricity in Trekkersveld as a function of the costs for electricity. The dot shows the reference situation in which no demand side management is applied. The more to the left side of the graph, the higher the power of the flexible demand (15 MW at the right to 150 MW at the left)

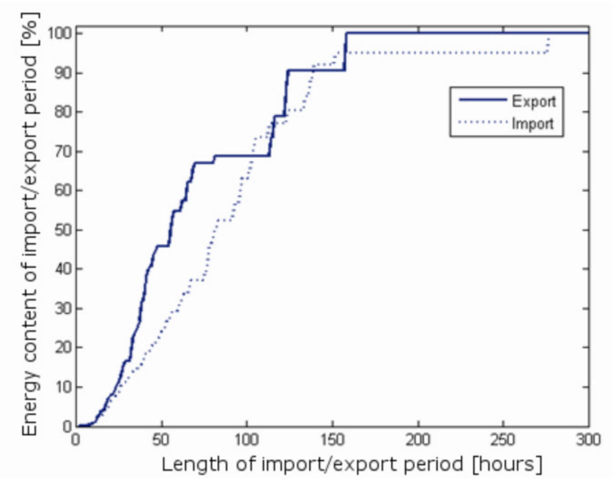

Figure 8: length of import/export periods and their cumulative energy content. Only about 10% of the energy is either imported or exported during periods shorter than 24 hours.

In the figure, two application of demand side management can be seen:

1. demand side management to consume a larger share of electricity from wind turbines. This is represented by the crosses below the dot in which the needed import is reduced
2. demand side management to consume less electricity at expensive moments. This is represented by the crosses above the dot in which the needed import is increased and the costs for electricity are reduced.

The figure shows that using demand side management to consume a larger share of electricity generated by wind turbines, reduces the needed import only slightly, even with a best-case assumption for the potential of demand side management as described before. This only slight reduction can be explained by the fact that the over- and under-production of electricity by wind turbines is generally longer than one day as can be seen in Figure 8. From Figure 7 we can conclude as well that when demand side management is enabled, it is the most economic to apply it to shift the consumption to cheaper periods. However, this decreases the consumption of locally produced electricity and thus more is exported.

CONCLUSIONS

The presented field trial and the simulations indicate that the practical potential for demand side management at SME's to consume a larger share of locally produced electricity is limited. This has several reasons: (1) The willingness and technical potential of SME's to apply demand side response is limited; (2) Due to the wide variety of processes in SME's, the application of demand side management demands custom made solutions, which makes large scale application difficult; (3) The available potential of demand side management is hardly suitable to follow the production of electricity of wind turbines; (4) The balancing of wind power results in using more electricity at expensive moments.

RECOMMENDATIONS

Regardless of the seemingly limited potential of demand side management in this case. There are local situations in which demand side management has its advantage. The applicability on economic, technical and societal perspective of demand side management in these situations has still to be investigated.
Because the potential of demand side management at SME's seems little, we encourage research to other forms of flexibility, for example the storage of excess electricity in the form of heat in a district heating system.

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