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SOCIAL COMPARISON AND ELECTRICITY CONSUMPTION: EVIDENCE FROM A RANDOMISED EXPERIMENT ON SWEDISH HOUSEHOLDS

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ABSTRACT: This thesis examines whether social comparison is an effective tool to lower households' electricity consumption during peak hours on the electricity grid. A randomised control experiment was conducted with 196 households in Umeå, Sweden. All households were sent an email with information about electricity consumption during peak hours as well as electricity conservation tips. The emails to the treated households also consisted of a comparison of their average electricity consumption during peak hours relative to the equivalent of similar households. Our results indicate that social comparison can be used to lower electricity consumption during peak hours by on average 7 percentage points for households consuming more than the average prior to the treatment. An even larger effect of on average 8 percentage points can be found when only examining villas. Furthermore, we can observe a boomerang effect where treated villas benchmarked below average increased their average peak consumption with 9 percentage points on average.

Keywords: demand flexibility, social comparison, energy demand management, demand response, electricity

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Contents

1. Introduction

The Swedish energy system is changing towards a more sustainable and efficient system with a goal of zero net emissions of carbon dioxide year 2050. The European Union has also set environmental targets to by 2020 achieve a minimum share of 20% renewable production, a 20% reduction of greenhouse gas emissions and energy efficiency to be improved by 20% from 1990 levels (Council of the European Union, 2009). These targets are the main drivers of today's change towards a sustainable energy system with a larger share of renewable production.

The Swedish energy system has historically depended heavily on flexible and reliable energy sources like hydropower and nuclear power (Statistics Sweden, 2015). To reach the environmental targets, Sweden is gradually moving towards a future with a larger proportion of renewable energy sources, such as wind and solar power (Government Offices of Sweden, 2016). These energy sources are intermittent in nature and generates larger variations in the production. This increases the challenge of keeping the balance between electricity demand and supply at any given moment. One of the solutions identified is to increase the flexibility in demand.

A flexible demand is needed for many reasons. It can to a large extent adjust to the available production and thus lower the risk of power shortage.[1] A more flexible demand can subsequently lower the need to reinvest in power plants to secure the electricity need during peak hours. Furthermore, the need to activate production based on fossil energy sources during hours of power shortage will decrease. In short, a more flexible demand would result in a more efficient use of resources and contribute to the achievement of climate and energy political goals.

As of today, demand flexibility in electricity-intensive industries is already in use, with several companies being compensated by Svenska Kraftnät to lower their consumption in situations of power shortage. Demand flexibility in the household sector has however been identified as a close to unutilised resource. If all Swedish households were to agree on being flexible in their electric heating, yearly savings are estimated to 1 760 MSEK (Swedish Energy Market Inspectorate, 2016).

[1] Power shortage occurs when the electricity demand is higher than the available production.

Swedish households have previously shown environmental consciousness and cooperativeness when it comes to increasing flexibility in demand (Broberg et. al., 2014; Bartusch and Alvehag, 2014). Even so, there is limited empirical evidence when it comes to fully utilizing this potential. Only two prior field studies, both using monetary incentives, have been done on the subject (Pyrko et. al. 2006; Bartusch et. al. 2011). We wish to contribute with further empirical evidence using non-monetary incentives.

Using social comparison as an incentive to lower total electricity consumption has previously shown great effects on the US market (Alcott, 2011; Schultz et. al., 2008; Petersen et. al. 2007). By comparing households' electricity consumption to the average of similar households in the US, total electricity consumption was lowered by an average of 2.0%. The effect is equivalent to a short-run electricity price increase of 11–20% (Alcott and Rodgers, 2014).

We wish to build on Alcott's findings by analysing how informing Swedish households about their electricity consumption during peak hours relative to similar households can affect their peak electricity consumption. As improving the demand flexibility is an area of increased importance with Sweden's movement towards a larger share of intermittent energy sources, we contribute with empirical evidence on how to improve the flexibility and cost-effectiveness of the Swedish electricity system and subsequently, contribute to the achievement of environmental targets. The research question has thus been stated as:

Is social comparison an effective tool to reduce peak electricity consumption?

To test this a randomised control experiment was conducted including 196 households, divided into one treatment group and one control group, in Umeå, Sweden. The households in the control group were given solely information about peak hours on the electricity grid and electricity conservation tips to lower these. The households in the treatment group did on top of this, receive feedback on their average electricity consumption during peak hours the last quarter, as well as a comparison of the corresponding consumption of similar households in the experiment.

The thesis is organised as follows. Section 2 provides the setting for this study with a description of the current energy market in Sweden and the flexibility of the electricity system. In Section 3, the existing literature, theories and prior research are reviewed, followed by our approach and presentation of our research question. Section 4 further defines the method of our experiment and presents a framework for the decision-making process of peak electricity consumption in Swedish households. It also describes the foundation for our econometric analysis. In Section 5 our data is thoroughly explained. Section 6 presents the results of our experiment. In Section 7 the results are analysed and discussed. Our final conclusions are presented in Section 8.

2. Background

In this section background information about the electricity market will be presented. This will hopefully provide enough knowledge for the reader to fully comprehend the thesis. First, the characteristics of electricity and its sources will be presented to then be followed by the different tools used today to increase flexibility on the market.

2.1 Characteristics of electricity

Electricity differs from most other commodities. First of all, electricity has to be produced and consumed simultaneously. It must be an instant balance between supply and consumption at all times. Therefore, it is not possible to have a real-time market for electricity. The price has to be set either ex-ante or ex-post. Second, electricity can not be stored in significant quantities in an economic manner. The solutions for large-scale electricity storage as of today are either too expensive or inefficient. Third, production levels, mainly within the renewable energy sector, vary with external factors. For example, the electricity production from wind power is intermittent and varies with the speed of wind. Also, the electricity consumption has a pattern that varies for day and night, weekly and annually (Wangensteen, 2007).

2.2 Load profile

Households' electricity consumption over 24 hours, creates a load profile. The curve shows that there are two periods of peak hours for the average customer. This is mostly due to lighting, cooking, laundry and use of equipment and other devices such as dishwashers and TVs. The first period of peak electricity consumption in Umeå occurs between 07:00 and 09:00 and the second one between 18:00 and 21:00 during weekdays. The first period of peak hours occurs later during weekends, between 09:00 and 11:00, whilst the late period occurs during the same hours as on weekdays (Umeå Energy, 2017). During the peak hours, the electricity consumption is high and the electricity grid is temporary more strained, especially on a local level (Swedish Energy Market Inspectorate, 2016).

Fig. 1. Average load curve for households in the experiment, Umeå, Jan–Mar 2017.

2.3 Pricing schemes on the electricity market

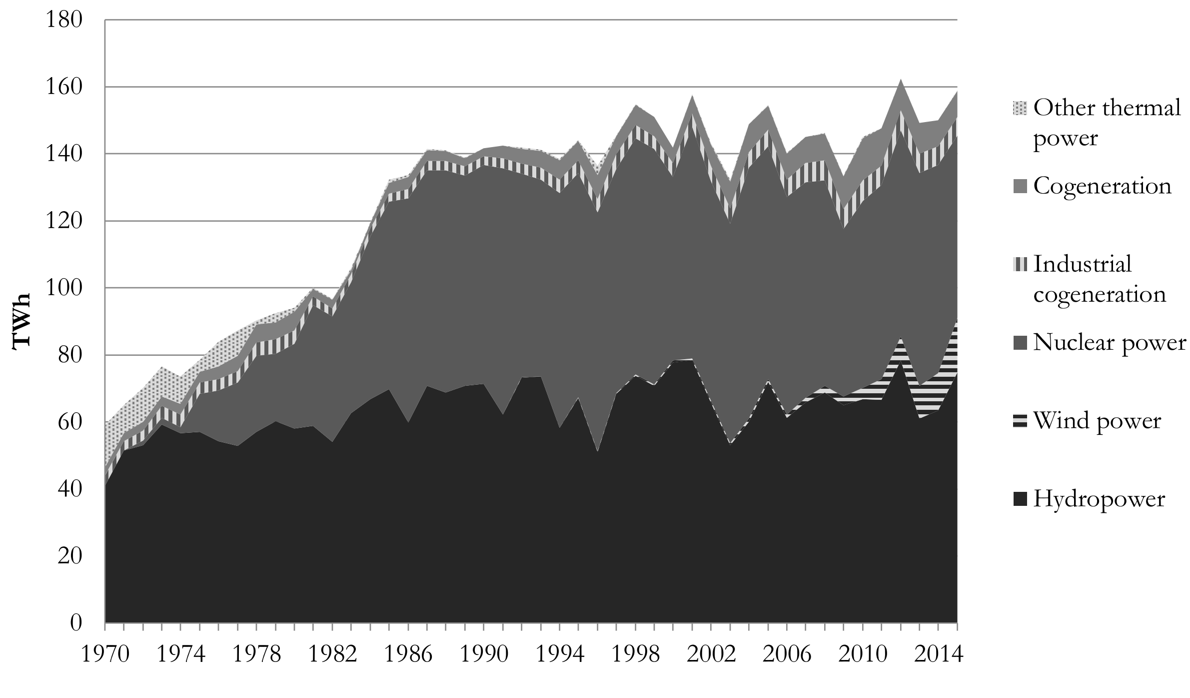
The pricing of electricity is another factor that makes it differ from other commodities. Today various forms of electricity subscriptions with different pricing models are offered. The most common form of electricity contract in Sweden is with variable pricing where the price is indexed on the Nord Pool Spot market. The price that the customer pays is the monthly average of this price and an additional mark-up added by the retailer. Approximately half of the Swedish electricity customers have this type of contract. The second most popular alternative among Swedish electricity customer is to have a one-, two-, or three-year fixed rate. This agreement is used by approximately 29% of the customers. On top of the electricity price the customers, regardless of type of subscription, pay a fee to the grid operator. This fee is charged to cover the costs for the electricity grid and is not connected to the Nord Pool Spot market (Swedish Consumer Energy Markets Bureau, 2017a, 2017b, 2017c).

For the customers with the type of subscriptions described above, the price for the customer is not affected by during which hours the electricity is consumed. However, there is a new form of subscription that all retailers are obliged to provide from 1 October 2012, usually referred to as time-of-use tariff. With this subscription, the customer pays for the actual hourly consumption. Since the prices vary with supply and demand during the day, there are usually monetary incentives to shift consumption from peak hours to off-peak hours. However, a follow up on the new regulation showed that less than 10 000 customers had this type of contract 2014 (Swedish Energy Market Inspectorate, 2014).

2.4 Electricity production on the Swedish market

Figure 2 shows the development of different electricity production sources. The electricity production in Sweden is mainly based on hydropower and nuclear power, accounting for 45% and 32% of the total electricity production, respectively (Statistics Sweden, 2015). Nuclear power in the Swedish electricity system has historically been a suitable base load power source to satisfy the minimum demand. However, the future for nuclear power is uncertain. The Swedish government has a target to achieve an electricity system with 100% renewable production before 2040. To reach this, several policy instruments to promote renewable energy production, such as investment subsidies, tax reliefs and the introduction of the electricity certificate system in 2003, has been introduced (Government Offices of Sweden, 2015a, 2016).

Fig. 2. The electricity production, by energy source (Swedish Energy Agency, 2017).



The change from a production based on hydropower and nuclear power towards larger portions of renewable and intermittent energy sources creates challenges to match supply and demand in every given moment. This might lead to increased challenges with keeping a constant frequency on the grid as well as handling situations of power shortage or undesired surplus. To lower the risks of this happening, Sweden can either import or export electricity, or resort to the flexibility resources in the electricity system. The flexibility resources can be organised into *(i)* flexibility in production; *(ii)* flexibility in demand and *(iii)* electricity storage (Denholm et. al., 2010). These will be presented more thoroughly below.

2.5 Flexibility in production

Flexibility in production, mainly from hydropower, is the most common form of flexibility used in the Swedish electricity system. Hydropower is a suitable energy source to achieve flexibility in production, as it is easy to manage its production levels (Söder, 2013). Production can quickly be decreased in times of demand deficit and increased in times of excess demand. By automatically adjusting the levels produced, the supply can be monitored to respond to sudden changes to maintain the frequency on the electricity grid. Sweden, with a large capacity of hydropower, has thus a solid foundation for an increase in wind and solar power. However, the hydropower is located in northern Sweden and due to transmission bottlenecks, there is an increased need for resources to maintain the frequency on the electricity grid in the middle and southern parts of Sweden (Svenska Kraftnät, 2015).

Another part of the flexibility in production is the strategic backup power reserve that is ready to be activated during system failure or to meet the increased demand of extremely cold winter days. The strategic power reserve is purchased every year, one year in advance by Svenska Kraftnät. The strategic power reserve for 2016/2017 consists of 994 MW and should be available 14 hours after a request from Svenska Kraftnät. Due to the high costs of maintaining the reserves, the Swedish government has decided to phase out the strategic backup power reserve by 2025 (Government Offices of Sweden, 2015b). There is also an interruption reserve, consisting of gas turbines that manually can be started within 15 minutes after an interruption in the ordinary production facilities (Svenska Kraftnät, 2016a).

During the last years, the volatility of the frequency on the Swedish electricity grid has increased. This is most likely explained by the combination of an increased share of wind power and the decrease in automatic reserves (Svenska Kraftnät, 2015). An alternative to counter the increased volatility in the system could be to improve the flexibility in demand.

2.6 Flexibility in demand

The infrastructure for the electricity grid is highly capital intensive and demand flexibility could be a cost-effective solution to lower investment needs (Swedish Energy Market Inspectorate, 2016). The largest effects from demand flexibility can be achieved in electricity-intensive industries and among households. Demand flexibility in the industry sector is already in use, with Svenska Kraftnät having formed agreements with large electricity users, such as paper mills. These agreements, where industrial customers are willing to lower their electricity consumption substantially within 14 hours, accounts for 34% of today's strategic backup power reserve (Svenska Kraftnät, 2016b). Demand flexibility in Swedish households has however been identified to be an unexploited resource. The largest effects are believed to be found in households with electric heating. This makes the effects highly seasonal and the largest potential savings are during the winter. By fully utilizing the flexibility in the heating of Swedish households, yearly savings have been estimated to be 1 760 MSEK (Swedish Energy Market Inspectorate, 2016).

2.7 Electricity storage

Another solution to increase the flexibility in the Swedish electricity system is electricity storage. At times when more electricity is produced than demanded, it can be stored and later consumed when demand is higher than the levels produced. Integrated energy storage in an electricity system could make wind and solar farms operate as baseload plants. For example, attaching wind turbines to compressed air energy storage can improve their capacity factor with over 70% (Denholm, Kulcinski and Holloway, 2005). Electricity storage could also be integrated into the system on a household level. Integrated batteries in Swedish households would give the opportunity for households to buy electricity when the price is low and consume when the price is high. This would decrease the peaks and smoothen the load curve on the electricity grid. However, the interest for this kind of solution is low and the payback time is estimated to be 16 years, based on a household with electric heating that lowers the load during peak hours with 40% (Swedish Energy Market Inspectorate, 2016).

With the current movement towards a less flexible production, based on the larger proportion of intermittent energy sources, together with the current inefficiency and high costs of electricity storage, demand flexibility in the household sector has been identified as one of the sectors with largest potential for improvements. This sector will be further discussed in the next section.

3. Previous research

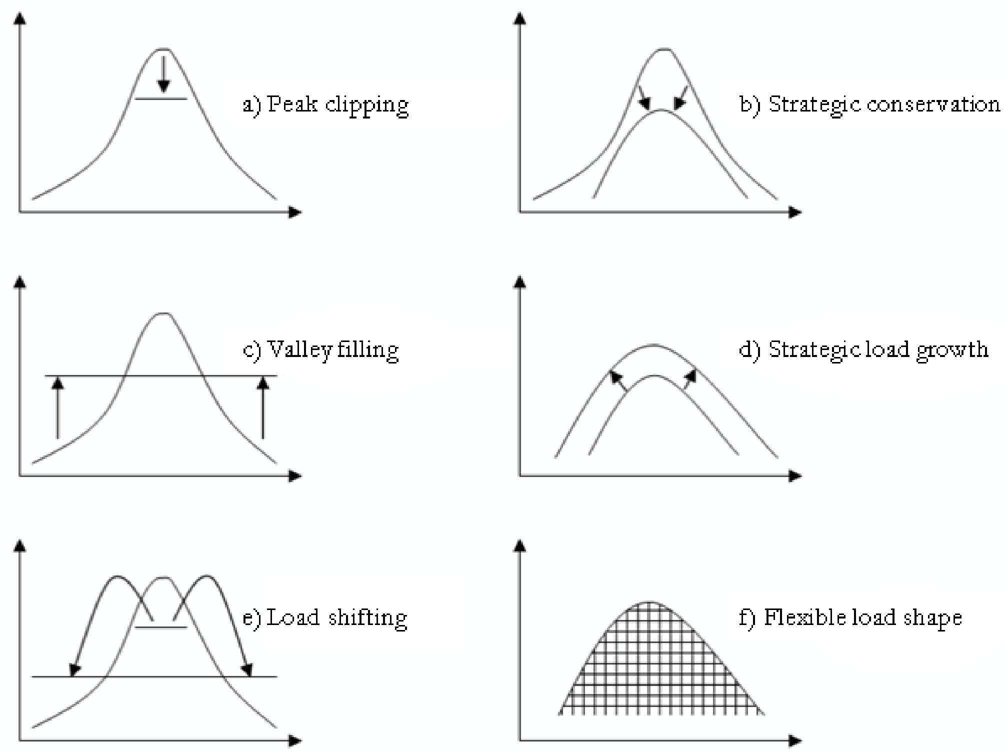
In this section, previous research on the electricity market will be presented. The section will start by further explaining demand flexibility. We will then proceed to discuss different incentives previously tested on the energy market, to thereafter focus on prior studies on the Swedish energy market. The section ends with an explanation of how we aim to contribute to the current state of knowledge.

3.1 Understanding flexibility in demand

There are two different ways to impact the flexibility in demand, indirect and direct load control. With indirect load control, customers are influenced to make *active* decisions concerning electricity demand. This could be achieved through, for example, dynamic prices or by customer feedback. Direct load control requires less involvement by the customer. The customers agree to let another part steer their electrical appliances (Pyrko, 2005).

There are different types of demand flexibility strategies to influence the load profile. Figure 3 shows six typical strategies to influence the load curve developed by Gellings and Chamberlain.

Fig. 3. Six typical strategies to influence the load curve.



With *peak clipping* (a), there is a reduction of load during peak hours. This is done by households who can lower their electricity consumption during peak hours, without compensating for this by consuming more electricity during other hours.

Strategic conservation (b), implies a lowering of the entire load curve by a more efficient electricity consumption.

Valley filling (c), means an increased consumption of electricity during off-peak hours, without reducing consumption during peak hours. This is typically done by households with several heating systems that can switch from, for example, biomass fuel to electric heating.

Strategic load growth (d), is a controlled increase of electricity supply. This is an expanded version of valley filling.

Load shifting (e), means that households move their consumption from peak hours to off-peak hours. This is applicable for activities that households can not be without, but can be done at a different time, such as heating, charging electric cars, cooking, washing and doing laundry.

Flexible load shape (f), is the type when a customer agrees to let an external actor take control of the equipment and be flexible on the customer's behalf (Gellings & Chamberlain, 1993).

3.2 Previous research on incentives used on the energy market

Distinguishing intrinsic from extrinsic motivation is fundamental when looking at incentives to affect people's behaviour. Intrinsic motivation is often referred to as motivation coming from within and could be driven by an interest in the task or subject itself. In this case, for example an interest in lowering the impacts on the environment. Extrinsic motivation, on the other hand, is driven by external factors, for example monetary rewards (Ryan and Deci, 2000).

3.2.1 Monetary incentives on the energy market

Using extrinsic motivation in the form of monetary rewards have been widely used to try to lower electricity consumption during peak hours. Several studies have established significant evidence that households reduce their electricity consumption during peak hours when given price signals. A state-wide experiment in California showed that residential households conclusively reduced electricity consumption with on average 4.7% during peak hours when stimulated with time-varying prices[2] (Faruqui and George, 2005). A subsequent study covering the 15, at the time, most recent pricing experiments done in the US indicated that the use of time-of-use tariffs induce a drop in electricity demand during peak hours of 3–6% and the use of critical peak pricing[3] solutions resulted in cuts ranging from 13% to 20% (Faruqui, 2010a; 2010b). Another meta-study done in the US, supplementing the above-mentioned study with even more recent studies, concluded that critical peak pricing methods, under certain conditions, can induce reductions in peak electricity consumption by as much as 30% (Newsham and Bowker, 2010).

3.2.2 Information and social comparison campaigns on the energy market

A strategy that previously has been used to affect people's behaviour is information campaigns, based on the assumption that increased knowledge itself changes behaviour. The results from this have however varied largely (Ek and Söderholm, 2010; Weiss and Tschirhart, 1994; Syme, Nancarrow and Seligman, 2000; Henryson, Håkansson and Pyrko, 2000).

Combining information with *social comparison* has in prior field studies and experiments yielded a powerful mechanism to influence individuals' behaviour. The basic idea behind the concept of social comparison is that people want to comprehend and define their own behaviour and they do so by comparing themselves to others (Corcoran et al., 2011, p. 119). The comparison is usually with individuals similar to oneself, as this offers the best information for self-evaluation. Downward comparison (comparing oneself to individuals performing worse) has been seen to protect or enhance self-evaluation, but comparing oneself with upward standards have historically yielded the best base for self-improvement (Bandura, 1986; 1997).

Previous research has revealed that incentives based on social comparison can induce people to vote (Gerber and Rogers, 2009), stop littering (Cialdini, Reno and Kallgren 1990) and there is wide research suggesting effects on households' total electricity consumption. An experiment performed by Schultz et. al. 2008 pioneered on the subject. Randomly assigned energy conservation messages were left on door hangers in 271 homes in San Marcos California. The findings were that the door hangers that compared a household's electricity consumption to that of its neighbours reduced total electricity consumption with 10% more than the ones that just presented energy conservation tips.

[2] Umbrella term for all pricing schemes depending on during which hour the electricity is consumed.

[3] Tariffs where prices for electricity consumption during peak hours are substantially raised.

Based on these findings, Opower, an American energy software company, initiated a large social comparison programme in the US with 600 000 treatment and control households. Households receiving the treatment were sent home energy report letters comparing their electricity consumption to that of their neighbours. Treated households consumed on average 2.0% less electricity than untreated ones, an effect equivalent to that of a short-run electricity price increase of 11–20% (Alcott 2011). Furthermore, the effect on treated households was relatively persistent, decaying at only 10–20% per year (Alcott and Rodgers, 2014).

Even larger effects have been found on US dormitories where a competition based feedback system resulted in an average decrease in electricity consumption by 32% on treated dormitories (Petersen et. al. 2007).

3.3 Demand flexibility on the Swedish energy market

Swedish households have in general showed signs of cooperativeness when it comes to being flexible in their electricity consumption. The main drivers for this have in various surveys been identified to be monetary saving, the possibilities to contribute to positive environmental effects and a more sustainable development for future generations (NEPP, 2013; Bartusch and Alvehag, 2014). Also, an extensive survey in Umeå ordered by the Swedish Energy Market Inspectorate showed that two-thirds of the households were positive on receiving feedback on their own electricity consumption. Additionally, households have shown willingness to let an external part, through direct load control, monitor the heating of the house between 07:00 and 10:00 for no monetary compensation as long as the comfort is not affected negatively. A yearly compensation of approximately 630 SEK would however be needed for the hours between 17:00 and 20:00 (Broberg, et. al. 2014).

As of today, only two field studies testing households' responsiveness to incentives on peak electricity consumption have been conducted on the Swedish market. One in Sollentuna, a suburb of Stockholm and the other in Sala, a country town in mid-Sweden. (Pyrko et. al. 2006; Bartusch et. al. 2011). Similar for the two were that both were based on monetary incentives and special time-of-use tariffs were used. The tariffs were based entirely on peak demand and involved a unit price on the average of the household's three and five highest measurements of electricity consumption during peak hours, respectively. An internal investigation of the effects in Sollentuna done by the distribution system operator in question indicated a drop in peak electricity consumption of 5% (Pyrko et. al. 2006). As for Sala, an empirical study showed some indications that single-family households, in particular, shifted their electricity consumption from peak hours to off-peak hours due to the tariff (Bartusch et. al. 2011).

3.4 Our approach

We contribute to previous research by analysing how incentives based on social comparison can be used to lower the electricity consumption during peak hours on the Swedish electricity grid. To the best of our knowledge, this subject has been given limited attention when it comes to field studies. As this is an area of increasing importance and the effects from monetary incentives, due to today's relatively low electricity price (Nordpool, 2017), are close to non-existent we recognize the importance of investigating this further. The research question has thus been stated as follows:

Is social comparison an effective tool to reduce peak electricity consumption?

To test this, an experiment was conducted on the Swedish market in April 2017, where the treatment and control group were contacted via email. The Swedish market was chosen for mainly three reasons. First, Sweden is moving towards a future with a larger proportion of intermittent energy sources, thus increasing the need for an increased flexibility in other resources, such as demand. Second, we wish to analyse if social comparison can be used as an incentive on a different and more environmentally conscious market than the US, where most of the previous studies have been conducted. We believe Sweden to be perfect in that sense, being the country in Europe ranking the climate change highest among the World problems. 81% of the people in Sweden consider the climate change as one of the world's most serious problems, compared to the average in Europe of 50%. (European Commission, 2014). Third, although given this environmental consciousness and the cooperativeness showed in previous research (Broberg, et. al. 2014; NEPP, 2013; Bartusch and Alvehag, 2014), no prior field studies have shown results fully utilizing this potential. Subsequently, there is an apparent research gap when it comes to non-monetary incentives on the subject in the country.

The main reasoning behind performing the experiment during the spring was to minimize the possibilities of spillover effects from monetary incentives. The electricity prices and hence also the media coverage of the pricing situation, are more apparent during the winter and could influence customers' reasoning. On the contrary, the summer does not offer load peaks as apparent as during the rest of the year. The spring provides the perfect combination of low temperatures, clearly defined peaks and a limited impact of monetary influences.

Previous research estimating social comparison's influence on households' electricity consumption has mainly been tested using mail or other paper-based information tools (Alcott, 2011; Schultz et. al., 2008). We wish to analyse if these results also could be obtained using email, a more cost-effective, environmental-friendly and time-flexible tool of communication and in that sense, contribute to the findings of Alcott and Schultz.

We see three primary ways through this treatment could work. First, the information alone could provide enough knowledge for the households to lower their peak demand. If information solely has significant effect, this suggests that households previously have been imperfectly informed or just inattentive. On the contrary, if the information has no effect, this suggests that households either are already perfectly informed, that imperfect information and inattention are irrelevant, or that information campaigns are a dubious source for motivation. Second, if households are uncertain of some parts of their electricity consumption pattern, comparison with similar households may facilitate learning about their private optimal electricity consumption pattern, as suggested in other contexts by for example Darby (2001) and Beshears et. al. (2009). Third, the social comparison could directly affect the household's normative beliefs around electricity consumption. This could possibly work in both ways, with households that consume less than the average increasing and households that consume more decreasing.

4. Method

In this section, the method of testing our research question will be explained. A framework for the decision-making of the households will then be presented, providing insights on how we aim to influence with our treatment. Finally, the econometric approach to present the results of our experiment will be presented.

4.1 Experimental design

To investigate whether social comparison could be used to motivate customers to be more flexible in their electricity consumption and lower their consumption during peak hours, a randomised control experiment was conducted. It was performed in cooperation with a local distribution system operator, Umeå Energy, who assisted in obtaining our test groups as well as the measurements of their electricity consumption.

The experiment was initially conducted using 237 households in Umeå, Sweden. The eligible experimental population included households that had a valid email address registered at Umeå Energy. The households were also required to have had an electricity meter that reads per hour installed for at least 3 months prior to the experiment. The households were randomly assigned to two groups, one control group and one treatment group. By randomly allocating the households between the groups, the impact of endogenous variables such as household-specific factors is minimised. There was also no influence from self-selection bias, as the households could not choose whether to participate or not. All households receiving the email are considered treated.

4.2 The treatment

The treatment in our experiment was based on two modules. One information module and one social comparison module. The information module consisted of information about peak hours on the electricity grid, their implications and electricity conservation tips on how to lower these. A graph was used to display the general electricity consumption during peak hours relative to the general electricity consumption over 24 hours of all households. Below the graph, suggestions on how to lower electricity consumption, or shift the consumption to off-peak hours were presented. The suggestions given were *(i)* to smoothen electricity consumption by using the dishwasher and washing machine during off-peak hours; *(ii)* to lower the inside temperature and *(iii)* to turn off unnecessary lights (see Appendix I).

The social comparison module consisted of two parts. The graph on the left side of the module compared the household's average electricity consumption during the last three months to the mean of its comparison group. Both the average consumption over 24 hours as well as the average consumption during peak hours were displayed. A household's comparison group consisted of households with similar characteristics such as characteristics of estate (apartment vs villa), same size of fuse and the same heating system in the cases where the information was available. There was also a ranking included on the right side of the graph, where the households were categorised by being labelled *great*, *good* or *above average,* based on their peak electricity consumption over the last three months. The households with the lowest electricity consumption during peak hours (bottom 20-percentile) were labelled *great*, accompanied by two happy smileys, the households consuming less than average were labelled *good*, accompanied by one happy smiley and the households with a level of consumption above average were labelled *above average*, accompanied by no smileys (see Appendix II).

We believe that for households to really act on the social comparison treatment, information about the problem was close to as important as the social comparison part. The treatment group was, therefore, sent an email consisting of both modules. However, to separate the potential impact of the information alone from the social comparison, the control group was only sent the information module.

4.3 Framework for decision-making

In order to better understand the factors behind the electricity decisions of households, a decision-making framework is constructed. When constructing a framework for individuals' decision-making process, the concept of individual utility has found extensive applicability in economic theory. The framework is based on the assumptions of a rational, fully informed decision-maker that has clear preferences between different choices and takes decisions to maximize individual expected utility (Edwards, 1954).

The aim of our experiment is to influence households to change their electricity consumption through social comparison. The basic idea of social comparison is that individuals define their own behaviour by comparing themselves with the behaviour of others (Corcoran *et al.*, 2011, p. 119). Households are therefore believed to change their behaviour depending on their difference in consumption from the level perceived as normal. A pattern that is empirically seen in previous research (Alcott, 2011; Schultz et. al., 2008).

Furthermore, in our Swedish setting, several prior studies have identified what households perceive as the most important factors when changing their electricity consumption pattern. These factors can be grouped into the possibilities to make monetary savings, social and environmental responsibilities and social factors (Bartusch, et al., 2014; NEPP 2013).

By combining these drivers, a simplistic model for the decision-making process of households' peak electricity consumption can be derived.

The model is based on the decision of how much electricity each household chooses to consume during peak hours. In this simplistic model, mainly two benefits for households that decrease their electricity consumption have been distinguished. First, the intrinsic gain of contributing to the environment and the society by lowering peak electricity consumption. This is mainly based on the households' willingness to help and the perceived benefit of the action. The perceived benefit is believed to increase with a higher exposure to information. The second is the potential benefits from the social comparison of other similar households' electricity patterns. This is expected to influence in two ways. First, it could change the perception of what is the normal level of consumption, and second, it could influence the household to either decrease or increase the consumption based on the difference from the average consumption.

The expected costs can also be separated into two parts. First, the simple monetary cost of consuming electricity during peak hours. The monetary cost decreases as households lower their electricity consumption during peak hours and could subsequently be perceived as a benefit for the right household. Second and opposed to the first, the cost of efforts the households need to take to either lower their overall electricity consumption or to move it from preferred peak hours to less preferred off-peak hours. Estimating this cost is mainly based on the flexibility of the household. This could be affected by several factors, such as the number of kids in the household, time spent at home or specific regulations for residents in for example apartments.

Our treatment aims to influence households' electricity consumption through social comparison. By allocating the households among the two groups through a randomised process the only thing differing between the groups is their exposure to social comparison. In order to test the effects of our treatment, all other variables are therefore assumed to be held constant. The expected utility for the household *i* based on their electricity consumption during peak hours can thus be defined as:

$$E[U_i] = F\left(kW_i, sc_i, \overline{kW}\right) = \alpha \times SC(kW_i, sc_i, \overline{kW}) + \beta \times ES - (\gamma \times E + \theta \times C), \qquad \text{(Eq. 1)}$$

where

F = function for expected utility
SC = function for social comparison
sc_i= household *i*'s influence from social comparison
kW_i= electricity peak consumption for household *i*
$\overline{kW}$= average peak electricity consumption for similar households
ES = environmental and social influences
E = effort from changing behaviour
C = monetary costs

and $\alpha, \beta, \gamma\ and\ \theta$ are weights where $\alpha + \beta + \gamma + \theta = 1$.

When choosing peak electricity consumption, a rational and informed decision-maker in our treatment group will choose the level of electricity that maximizes utility based on the household's influence from social comparison and the current difference from the average of similar households.

4.4 Econometric model

Our aim is to estimate the causal effect our applied social comparison treatment has on households' electricity consumption during peak hours on the electricity grid. Previous research on the subject has mainly looked at the difference in means, but due to our, in comparison, small sample and short test period, we have chosen the approach of estimating the difference in percentage between the average peak electricity consumption during the test week with the corresponding average consumption the week before. Through this approach, the possibility of potential household-specific factors and irregularities, more apparent in smaller and shorter samples, is minimised.

With the same reasoning, the week before was chosen as the comparison window in order to mimic the characteristics of the test week and subsequently minimize potential influence from uncontrolled or unobservable factors.

Due to the abnormality of the test week with more holidays than a normal week, the effects will only be measured during the peak hours that are the same for both weekdays and holidays, that is the later peak hours (18:00–21:00). Our dependent variable, relative electricity consumption during late peak hours ($y_{rel.}$), is defined as in Equation 2.

$$y_{rel.,i} = \frac{\bar{y}_{t,i} - \bar{y}_{t-1,i}}{\bar{y}_{t-1,i}} \qquad \text{(Eq. 2)}$$

$$\bar{y}_{t,i} = \frac{1}{n_{t,i}} \sum_{i=1}^{n} y_{t,i} \qquad \text{(Eq. 3)} \qquad\qquad \bar{y}_{t-1,i} = \frac{1}{n_{t-1,i}} \sum_{i=1}^{n} y_{t-1,i} \qquad \text{(Eq. 4)}$$

Where $y_{t,i,j}$ and $y_{t-1,i,j}$ are the average hourly electricity consumption during late peak hours for household *i*, expressed in kW, during the test week (*t*) and the week before (*t-1*), respectively. The number of days our estimations are based on is denoted as *n* and is for most households seven.

With a clearly stated dependent variable, the Average Treatment Effect (ATE) of our applied treatment on the households can now be estimated. The ATE of a treatment (T) on the outcome ($y_{rel.}$) of each household *i* can be defined by comparing the outcomes the household would get if treated ($y_{rel.,T,i}$) and if not treated ($y_{rel.,0,i}$). The outcome for the treated household *i* ($y_{rel.,T,i}$) is then defined as

$$y_{rel.,T,i} = y_{rel.,0,i} + (y_{rel.,T,i} - y_{rel.,0,i}) \times T_i \qquad \text{(Eq. 5)}$$

The value $y_{rel.,T,i} - y_{rel.,0,i}$ is the treatment effect for household *i* and T_i is a binary variable that takes the value of 1 if treated and 0 if not. If one could observe $y_{rel.,T,i}$ and $y_{rel.,0,i}$ for every household, one could easily estimate the ATE by comparing the difference in output for each household. However, as every household is either treated or not treated, either $y_{rel.,T,i}$ or $y_{rel.,0,i}$, can be observed, but not both. Thus, to estimate the ATE, Ordinary Least Squares estimation (OLS) needs to be used. Eq. 5 can be rewritten as

$$y_{rel.,i} = \beta_0 + \delta_1 T_i + \varepsilon_i, \qquad \text{(Eq. 6)}$$

where β_0 is the average relative electricity consumption during late peak hours for untreated households, δ_1 is the average causal effect of our applied treatment and ε_i is the residual.

The results are controlled for the size of the household and whether the household is heated through district heating or not. Due to the anonymity of our tested households, the size of the households could not be obtained. However, the size of the fuse could be identified for each household and is believed to be a suitable proxy for the household size. The sizes of the fuses in our sample range from 16A, to 20A (F20) and 25A (F25) and increases with household size. The variables are qualitative, with 16A chosen to be our benchmark group. The district heating variable (DH_i) is also a qualitative variable, where (DH_i) takes the value 1 for the households heated through district heating and 0 otherwise. We also wish to analyse the effects on apartments and villas separately, therefore the independent variable $apartment_i$ is included in the model. The variable is also of the qualitative nature and takes on 1 for apartments and 0 for villas. The average causal effect of our treatment is thus estimated from the following model:

$$y_{rel.,i} = \beta_0 + \delta_1 T_i + \delta_2 F20_i + \delta_3 F25_i + \delta_4 DH_i + \delta_5 apartment_i + \varepsilon_i \qquad \text{(Eq. 7)}$$

The model shows no signs of endogeneity and together with the complete randomization when assigning households to the treatment and control group the estimators are to be seen as unbiased. The model, however, shows signs of heteroscedasticity and is therefore estimated in OLS using Huber-White (robust) standard errors. These standard errors are consistent in the presence of any correlation pattern in the error term. A RESET test was also conducted showing no signs of misspecification of the model in any of the tests.

5. Data

In this section, the dataset of our experiment will be introduced and discussed.

The experiment was carried out via email to 237 households in Umeå, Sweden. Some of the emails (32) were not delivered due to invalid email addresses registered at Umeå Energy. The 32 households that could not receive the email were excluded from the experiment.

Data on the households' hourly electricity consumption for the first four months of 2017, together with information on size of the fuse as well as heating system for the households using district heating, were obtained from Umeå Energy.

The electricity consumption was measured the next seven days after our treatment. Since the treatment was tested on a week with a larger share of holidays than our comparison week, there is a large risk of bias in our results from, primarily, people being away from home for longer periods. To minimize the possible influence from this irregularity, days which showed signs of no human activity were excluded from the test. To identify these days, four decision rules were designed and if the household's activity during the chosen day satisfied three out of these four, the day was omitted. The decision rules were:

(i) $\frac{\text{the average hourly consumption during the day}}{\text{the average hourly consumption for the latest 3 months}} < 0.53$ (Eq. 8)

(ii) $\frac{\text{the average hourly consumption during the day}}{\text{the minimal hourly consumption during the day}} < 1.23$ (Eq. 9)

(iii) $\text{the hourly average consumption during the day} < 0.5 \text{ kW}$ (Eq. 10)

(iv) $\text{the standard deviation of the hourly consumption during the day} < 0.06$ (Eq. 11)

If the household was believed to be away from home more than four days of the week, the household was omitted from the test. If less, the household was retained and the average consumption was estimated using the remaining days. In total 88 days were omitted from the test week and 53 from the week before. Six households were believed to be on vacation the majority of the test week and thus omitted. On the contrary, households could possibly increase their electricity consumption during the Easter week due to, for example, visitors. We chose not to adjust our sample for this likelihood for two reasons. First, having visitors is believed to mainly affect the lighting and use of cooking equipment of the household. These appliances represent less than 5% of the overall electricity consumption, respectively (Broberg, et. al., 2014), and is therefore assumed to have a low impact on the results. Second, identifying these increases is difficult as an increase could without further information originate from several different factors.

Furthermore, three households showed repeatedly perfect patterns not consistent with human behaviour and were omitted to not bias the result. Our final dataset therefore consisted of a total of 196 observations. Of our 196 observations, 154 were villas and 42 were apartments. 72 of the villas were identified to be connected to district heating. The distribution between the treatment and control group can be found in Table 1. To see the distribution between villas and apartments, based on fuse size, see Appendix III.

Table 1. Distribution of observations between treatment group and control group.

	Treatment group	**Control group**	**Total**
Villas	74	80	**154**
Apartments	22	20	**42**
Fuse 16	46	43	**89**
Fuse 20	45	50	**95**
Fuse 25	5	7	**12**
Total	**96**	**100**	**196**

6. Results

In this section, the results of our experiment will be presented to then be followed by an investigation of what strategies the households used to lower their peak electricity consumption.

6.1 Results from econometric model

Table 2 shows the econometric model of how the relative electricity consumption during late peak hours was affected by our treatment, both when controlled and not controlled for by our control variables.

The analysis is performed in two stages. First, all households who received the social comparison treatment in which they had an average peak electricity consumption *below average* are analysed. This group includes both the households being labelled *great* and *good*. This is due to the small sample sizes of the two. Second, all households who received the social comparison treatment and had an electricity consumption *above average* during peak hours are analysed.

Table 2. Regression on samples with households below and above average. The impact of the social comparison treatment on villas and apartments.

	All Below Average		**All Above Average**	
	Without Controls	With Controls	Without Controls	With Controls
Social Comparison Treatment	0.048	0.051	-0.073*	-0.066
	(0.043)	(0.044)	(0.043)	(0.046)
Fuse 20		0.025		0.049
		(0.069)		(0.057)
Fuse 25		-0.035		0.097
		(0.113)		(0.080)
District Heating		-0.019		0.020
		(0.064)		(0.051)
Apartment		-0.100		-0.050
		(0.085)		(0.083)
Constant	-0.032	-0.012	0.071**	0.0407
	(0.025)	(.075)	(0.027)	(0.063)
N	99	99	97	97
R2	0.012	0.061	0.030	0.076

Note: The table reports OLS estimates. Robust standard errors are displayed in brackets. Asterisks next to coefficients indicate the significance of the coefficient, where (* $p<0.10$, ** $p<0.05$, *** $p<0.01$). This table is available with p-values of all coefficients in Appendix IV.

Table 2 shows that the effect of the treatment on households *below average* prior to the experiment is not distinguishable from zero at a ten percent significance level. However, for the households *above average,* our treatment induces an average decrease in peak electricity consumption of 7.3 percentage points more than the control group, ceteris paribus. This effect is significant at a level of ten percent. When expanding the econometric model to include the control variables fuse size, heating system and apartment or villa, the effect from the social comparison treatment is not significant at a level of ten percent.

Table 3. Regression on sample of villas below as well as above average. The impact of the social comparison treatment on villas.

	Villas Below Average		**Villas Above Average**	
	Without Controls	With Controls	Without Controls	With Controls
Social Comparison Treatment	0.079	0.087*	-0.085*	-0.083*
	(0.049)	(0.051)	(0.045)	(0.049)
Fuse 20		0.027		0.049
		(0.069)		(0.057)
Fuse 25		-0.031		0.096
		(0.113)		(0.078)
District Heating		-0.025		0.017
		(0.065)		(0.051)
Constant	-0.025	-0.030	0.094***	0.049
	(0.026)	(0.075)	(0.026)	(0.064)
N	76	76	78	78
R2	0.032	0.047	0.047	0.066

Note: The table reports OLS estimates. Robust standard errors are displayed in brackets. Asterisks next to coefficients indicate the significance of the coefficient, where (* p<0.10, ** p<0.05, *** p<0.01). This table is available with p-values of all coefficients in Appendix IV.

Table 3 shows the effect of our social comparison treatment when limiting our analysis to only examine villas. When analysing the effect of the social comparison treatment on *villas below average*, the coefficient is 0.087 and is significant at a level of ten percent, when including control variables. This indicates that households receiving feedback of them performing better than the mean of similar households, on average increases their electricity consumption with 8.7 percentage points more than the control group, ceteris paribus. This increase is to be seen as an unintended consequence of the treatment, an effect social psychologists refer to as a boomerang effect (Clee and Wicklund, 1980).

When estimating the effect of the treatment on *villas above average,* the econometric model estimates the social comparison treatment coefficient to be -0.083, when control variables are included. This indicates that households receiving feedback of them being worse than the average of similar households on average decrease their peak electricity consumption with 8.3 percentage points relative to households only receiving information, ceteris paribus. The effect is distinguishable from zero at a ten percent significance level. This shows that being compared to households consuming less electricity during peak hours motivates people to decrease their peak consumption.

A separate analysis of the sample only including apartments was made, but due to the low number of observations, 23 below average and 19 above average, we chose to not draw any conclusions from this analysis. The econometric outputs can be found in Appendix V.

6.2 Load curves

Figure 4 and 5 show the average load curves for the treated households and the households in the control group, respectively.

Fig. 4. Load curve for all households in treatment group

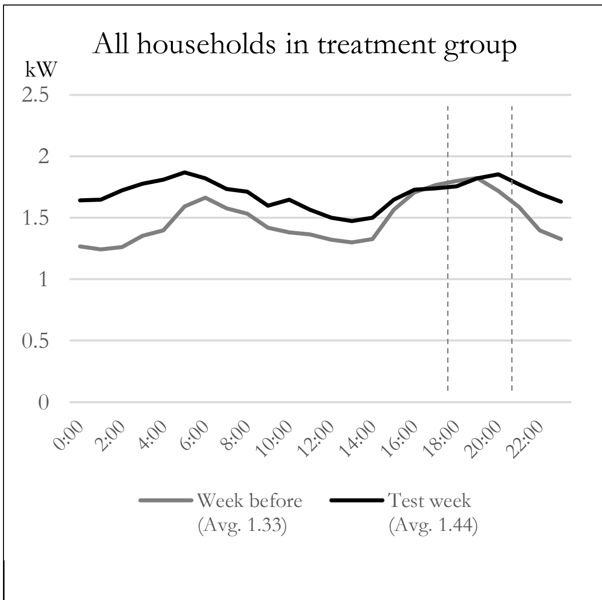
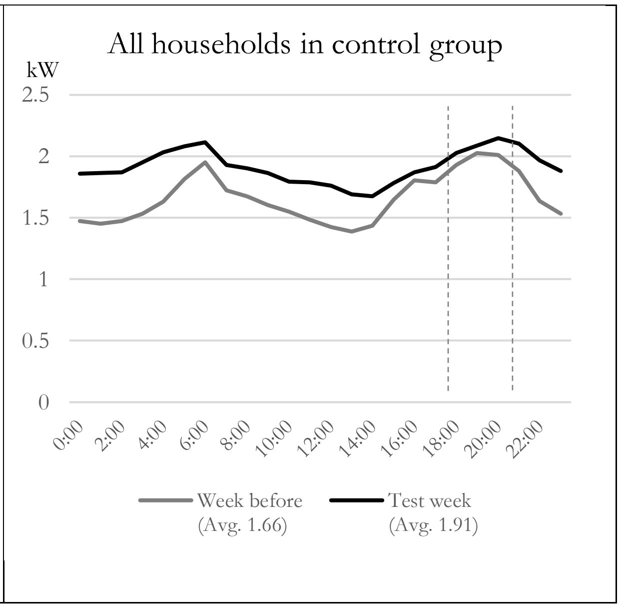


Fig. 5. Load curve for all households in control group



As can be seen above, the average electricity consumption is higher during the test week, for both groups, compared to the week before. This is believed to be mainly because of the relatively lower temperatures during the test week (see Appendix VI).

Examining the load curves, one can see that the average consumption of the control group during the test week mimics the consumption pattern of the week before, although a bit higher (15%). The same can be said for the treated households for the first half of the day, but as the day approaches the later peak hours, a small relative decrease can be found and the curve is actually below the comparison week at the beginning of the peak hours. The average hourly consumption is nonetheless higher during the test week relative to the week before (8%). This is although a difference smaller than for the control group. This shows that the treated households *(i)* decreased their average hourly consumption more than the control group and *(ii)* to a larger extent lowered their peak consumption and shifted some of the load to off-peak hours.

Fig. 6. Load curve for decreasing households in treatment group

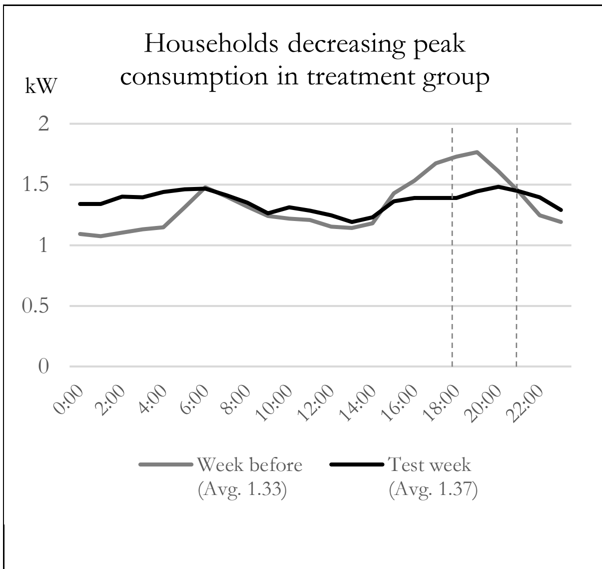
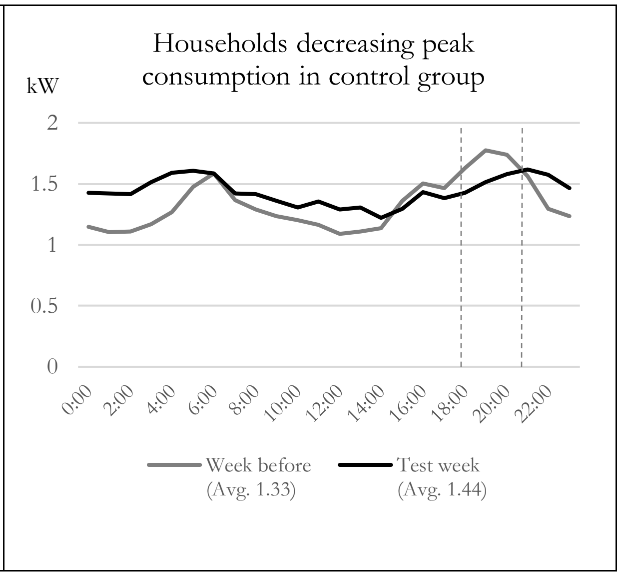


Fig. 7. Load curve for decreasing households in control group



When changing our scope to only analyse the households that responded positively to our treatment by decreasing their average consumption during late peak hours, even more apparent effects can be seen. Positively responding households in the treatment group have a distinctly smoother load curve and the later peak is significantly lower compared to the week before. Again, the largest difference is in the beginning of the peak period, around 18:00. The average total hourly consumption is higher (3%), but the difference is again not as large as for the control group (8%). This indicates that the treatment group has increased their flexibility by mainly shifting their load from peak hours to off-peak hours.

The households decreasing their average peak consumption in the control group did also show signs of demand flexibility, however, not as apparent as the treatment group. This could nonetheless indicate that some households responded solely to the information in the email and lowered their peak demand by shifting their consumption.

7. Discussion

In this section, the results of our experiment will be analysed and discussed. First, an analysis of the results will be presented followed by a wider discussion focusing on implications of our results. The section will then be completed with a discussion regarding limitations of our study.

7.1 Discussion on the results

The results of our experiment show that social comparison can be used as an incentive to lower electricity consumption during peak hours. Sending an email with the household's peak electricity consumption compared to the corresponding electricity consumption in similar households induces the residents to change their consumption pattern. In the households that received the social comparison treatment where they were *above* average, a *decrease* of 7.3 percentage points in electricity consumption relative to the control group was observed.

When changing our scope to only analyse villas, an even larger effect of 8.3 percentage points on the villas that received the social comparison treatment where they were *above* average can be seen. However, for villas that received the social comparison treatment where they were *below* average, there was an *increase* of 8.7 percentage points in relative electricity consumption compared to the control group. The latter is to be seen as a boomerang effect.

We are not able to provide insights on how the treatment works on residents in apartments due to the low number of observations. Nevertheless, the average decrease for just villas was larger than the average decrease including apartments. This suggests that villas are more responsive to our treatment. One possible explanation for this could be that apartments, in general, have smaller possibilities to be flexible. It is not unusual for apartments to have noise regulations, prohibiting some electric devices like washing machines to be used late at night. On the same note, apartments tend to have common areas like laundry rooms where the use of these does not add to the specific household's electricity consumption. Also, as apartments tend to consume less electricity, the electricity consumption from non-flexible devices like refrigerators and freezers are relatively larger, resulting in a smaller fraction of potentially flexible load.

An analysis on how the households that responded positively to the treatment changed their load curve, showed that the average household tended to shift their load from peak hours to off-peak hours, smoothening their load curve. This is an example of load shifting, one of the six typical changes in the load curve developed by Gellings and also one that was advised on in the email.

One important factor to take into consideration when examining the results is that some households likely did not open, understand or act on the email. This implies that the effects on those who did must be much larger, given that all receiving an email are considered treated.

7.2 General discussion and implications

This version of indirect load control where an email is sent with social comparison has proven to be an effective tool to lower peak demand. Our results indicate that peak electricity consumption can be lowered when sent to households consuming more than the average prior to the treatment. However, it is not appropriate to use when the demand response needs to be achieved immediately, as the households need time to react on the comparison.

If this method with social comparison is to be used on a larger scale with the goal to lower electricity consumption during peak hours, our results indicate that households below average should not be included since a boomerang effect can be observed for villas. The social comparison treatment would not achieve its goal of lowering peak demand if these households were to be included. This needs to be taken into consideration when designing social comparison programmes with goals to lower peak or overall electricity consumption. Nonetheless, we believe a social comparison programme on a national scale, aimed at households consuming more than the average, could generate large savings for the society as well as contribute to achieving environmental targets.

7.3 Limitations

The result from our analysis presented above is subject to limitations that must be considered when examining robustness and external validity. Even though the experimental design circumvents the problems of selection bias and offers the credit of internal validity, it does present some potential issues regarding environmental dependence and replicability. The results can therefore not be guaranteed to be valid if the experiment is to be duplicated in a different context. Since the experimental design poses a threat to the external validity, the results should not be interpreted as what *will* happen, but rather what *can* happen in an external environment where other variables and factors could influence the results.

Accordingly, the experiment suffers from different forms of attritions. One attrition is people being on holiday. The experiment was conducted in the middle of April 2017 and a part of the measurement week was during the Easter holiday. The consumption pattern therefore varies from regular weekends as well as weekdays. On the one hand, some households will be traveling and have no ability to be flexible in their electricity consumption, but on the other hand, some households will be home and have better conditions to lower their consumption during peak hours. To circumvent these problems, decision rules were constructed excluding these observations where the residents were assumed to be on holiday. However, our decision rules are not designed to identify the households that had an increase in consumption due to, for example, visitors. We do not take these into considerations as these households are both difficult to identify and a large increase in electricity consumption can depend on several different factors. Also, the potential increases would mainly come from increased lighting and use of kitchen equipment, two areas of electricity consumption historically representing less than 5% of households' total electricity consumption, each (Broberg, et. al., 2014). Nonetheless, although possibly apparent, the results should not be affected severely as the experiment was designed as a randomised control experiment and the households were randomised into the two groups.

Our measurement period of seven days is also very short. One consequence of this is that treated households might not have enough time to change their behaviour. This effect would have been captured if the measurement period would have been longer. Given the short period, the analysis is also more sensitive to individual extreme measurements.

By giving all recipients in our experiment the same treatment except for the social comparison, we based our experiment on the assumption that all other variables were held constant. However, the possibility of other factors impacting the results can not be ignored. For example, the information provided in the emails could both directly induce a change or indirectly remind the households of other factors impacting the decision of peak electricity consumption, like monetary savings, or environmental and social responsibilities. Furthermore, there is also a possibility that the feedback part of the treatment alone could account for parts of the identified change.

Even though the study suffers from limitations, we believe that the result of this study is not only able to offer a contribution to the existing literature in the field, but also provide agents in the Swedish electricity industry with useful insights in ways to lower peak demand.

8. Concluding remarks

This thesis evaluates the effects of social comparison as a tool to lower electricity consumption during peak hours on the Swedish electricity grid. This was researched through a randomised control experiment where households were sent emails with their electricity consumption during peak hours benchmarked to average peak electricity consumption in similar households. The study is different from other studies that have been done in Sweden in the sense that we, with insights from behavioural economics, analyse non-price interventions by using a randomised control experiment.

We find that households that were benchmarked above average electricity consumption during peak hours lowered their electricity consumption with approximately 7 percentage points more than the control group. When analysing villas, the effect is more apparent and a decrease in electricity consumption of 8 percentage points compared to the control group can be observed. There is also signs of a boomerang effect. Villas benchmarked below average increased their electricity consumption with approximately 9 percentage points more than households in the control group.

Previous researchers in the energy field and energy sector policy makers have historically mainly been focusing on supply and how price interventions affect demand. Our experiment shows that something as simple as an email with a comparison of electricity consumption can be used to lower peak demand on the electricity grid. This offers a cost-effective way to monitor demand response. The exact effects on welfare are uncertain but are highly likely to be positive. It could also be used to achieve environmental targets if to be used on a larger scale. However, one should consider the possibility of a boomerang effect when designing a social comparison programme with a goal to lower total peak consumption.

8.1 Further research

This experiment is to be considered as a pilot study on the subject. Our results indicate that it could be deeply beneficial to expand the experiment and test this on a larger scale as well as during a longer period. The experiment could also benefit from controlling for the number of residents in the household, a more accurate description of the heating systems and construction year of the estate. It would also be interesting to control for socio-demographic factors such as the number of kids, age of the residents, employment, yearly salary, educational level and political preferences.

We believe that further studies on this topic are necessary to design a policy with a goal to lower peak electricity consumption. There might be even more cost-effective ways to change households' electricity consumption pattern. Future scholars could include other motivational incentives such as different forms of monetary incentives as well other non-monetary incentives as rankings, grades, or feedback on environmental impact.

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A. Appendix

Appendix I: Email sent to the control group

Hej!

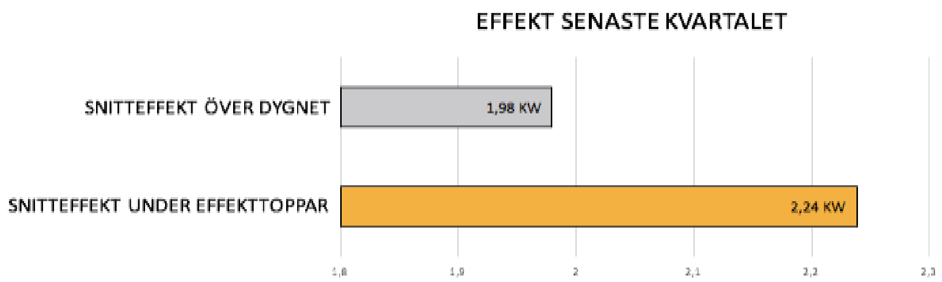
Du har blivit utvald att vara med i en undersökning som vi genomför i samarbete med Handelshögskolan i Stockholm.
Hi!
You have been chosen to participate in an experiment that we perform in cooperation with Stockholm School of Economics.

Som du säkert vet har du som elhandelskund till Umeå Energi alltid 100 % förnybar el från sol, vind och vatten. För att klara samhällets behov av energi och samtidigt minska miljöpåverkan behöver andelen förnybara energikällor öka i systemet i stort. Då blir effekttoppar i energisystemet en större utmaning än det är idag. Effekttoppar inträffar när behovet av el och värme är stort t.ex. under en verkligt kall dag eller när vi efter middagen startar diskmaskinen ungefär samma tid. Dessa inträffar vanligtvis på morgonen 07:00 – 09:00 och senare på kvällen 18:00 – 21:00.

As you probably already know, you as an electricity customer of Umeå Energy always get your electricity from 100 % renewable sources like sun, wind and water. To be able to cope with society's need of energy and at the same time lower the effects on the environment does the proportion of renewable energy sources in the system need to increase in general. This will increase the challenge of peak hours on the system. Peak hours occur when the demand for electricity and heating is large, e.g. during an extremely cold day or when vi all after dinner start the dishwasher at approximately the same time. These occur usually at 7am–9am in the morning and later at night at 6pm–9pm.

Vi vill ge våra kunder möjligheten att bidra till minskade effekttoppar i systemet så att vi tillsammans kan skapa ett mer hållbart energisystem. Därför vill vi undersöka intresset av att få information om det egna hushållets effektuttag. Så här såg effektuttaget ut för Umeå Energis kunder under det senaste kvartalet:

We would like to give our customers the possibility to contribute to a lower electricity consumption during peak hours, so we together can create a more sustainable energy system. Therefor we wish to investigate the interest of receiving information about one's household's electricity consumption. This is how the power in general looked for for Umeå Energy's customers during the latest quarter.



Peak electricity consumption during the latest quarter

Average hourly consumption over the day: 1.98 kW

Average hourly consumption during peak hours: 2.24 kW.

Hur kan man bidra till att minska effektbehovet?

Jämna ut förbrukningen

Kör diskmaskinen och tvättmaskinen under andra tider än 07:00 – 09:00 och 18:00-21:00. T.ex. under natten eller mitt på dagen.

Sänk inomhus-temperaturen 1°C

En grads skillnad märks väldigt sällan, men ger en otrolig skillnad för energiförbrukningen.

Släck lampor i rum du inte är i

Lampor som lyser när det inte behövs drar mycket el i onödan.

How can one contribute to lowering the peak electric consumption?

Smoothen the load curve

Use the dishwasher and washing machine during other hours than 07:00–09:00 and 18:00–21:00. For example, during the night or the middle of the day.

Lower the indoor temperature with 1°C

A difference of one degree is seldom noticeable, but induces a major difference in the electricity consumption.

Turn of the lights in rooms you have left

Lights in rooms you're not using consumes a lot of electricity in vain.

Du kan följa din energianvändning på www.umeaenergi.se/mina-sidor

You can follow your electricity consumption on www.umeaenergi.se/mina-sidor

Du kommer i slutet av månaden att få en länk till en kort webbaserad enkät. Vi är tacksamma om du tar dig tid att svara på frågorna.

You will at the end of this month receive a link to a short web-based survey. We are grateful if you could take the time to answer these questions.

Har du frågor kontakta kundservice@umeaenergi.se

If you have any questions contact kundservice@umeåenergi.se

Med vänlig hälsning,

Best regards,

Umeå Energi

Umeå Energy

Appendix II: Email sent to the treatment group

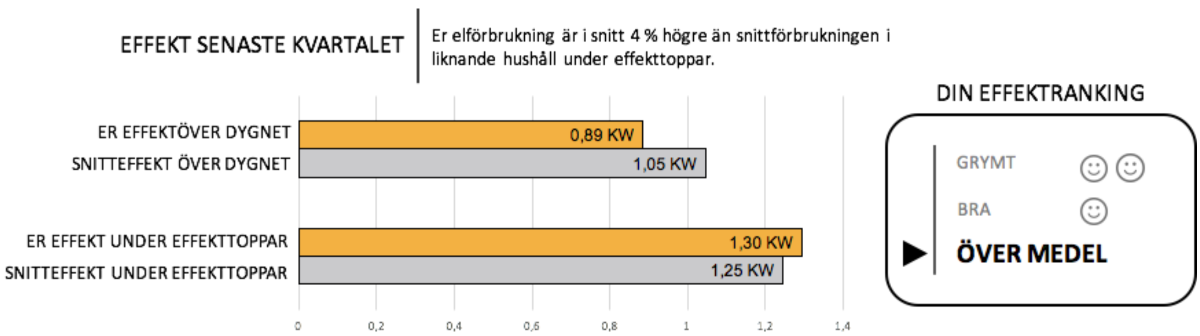
Hej!
Du har blivit utvald att vara med i en undersökning som vi genomför i samarbete med Handelshögskolan i Stockholm.
Hi!
You have been chosen to participate in an experiment that we perform in cooperation with Stockholm School of Economics.

Som du säkert vet har du som elhandelskund till Umeå Energi alltid 100 % förnybar el från sol, vind och vatten. För att klara samhällets behov av energi och samtidigt minska miljöpåverkan behöver andelen förnybara energikällor öka i systemet i stort. Då blir effekttoppar i energisystemet en större utmaning än det är idag. Effekttoppar inträffar när behovet av el och värme är stort t.ex. under en verkligt kall dag eller när vi efter middagen startar diskmaskinen ungefär samma tid. Dessa inträffar vanligtvis på morgonen 07:00 – 09:00 och senare på kvällen 18:00 – 21:00.

As you probably already know, you as an electricity customer of Umeå Energy always get your electricity from 100 % renewable sources like sun, wind and water. To be able to cope with society's need of energy and at the same time lower the effects on the environment does the proportion of renewable energy sources in the system need to increase in general. This will increase the challenge of peak hours on the system. Peak hours occur when the demand for electricity and heating is large, e.g. during an extremely cold day or when vi all after dinner start the dishwasher at approximately the same time. These occur usually at 7am–9am in the morning and later at night at 6pm–9pm.

Vi vill ge våra kunder möjligheten att bidra till minskade effekttoppar i systemet så att vi tillsammans kan skapa ett mer hållbart energisystem. Därför vill vi undersöka intresset av att få information om det egna hushållets effektuttag. Så här såg effektuttaget ut för Umeå Energis kunder under det senaste kvartalet:

We would like to give our customers the possibility to contribute to a lower electricity consumption during peak hours, so we together can create a more sustainable energy system. Therefor we wish to investigate the interest of receiving information about one's household's electricity consumption. This is how the power in general looked for for Umeå Energy's customers during the latest quarter.



Peak electricity consumption during the latest quarter | Your electricity consumption is on average 4% higher than the mean of similar households during peak hours.

Your average hourly consumption over the day: 0.89 kW *Average hourly consumption over the day: 1.05 kW* *Your average hourly consumption during peak hours: 1.30 kW* *Average hourly consumption during peak hours: 1,25 kW*	***Your efficiency ranking*** ***Great ☺ ☺*** ***Good ☺*** ***Above average***

How can one contribute to lowering the peak electric consumption?

Smoothen the load curve

Use the dishwasher and washing machine during other hours than 07:00–09:00 and 18:00–21:00. For example, during the night or the middle of the day.

Lower the indoor temperature with 1°C

A difference of one degree is seldom noticeable, but induces a major difference in the electricity consumption.

Turn of the lights in rooms you have left

Lights in rooms you're not using consumes a lot of electricity in vain.

Du kan följa din energianvändning på www.umeaenergi.se/mina-sidor
You can follow your electricity consumption on www.umeaenergi.se/mina-sidor

Du kommer i slutet av månaden att få en länk till en kort webbaserad enkät. Vi är tacksamma om du tar dig tid att svara på frågorna.
You will at the end of this month receive a link to a short web-based survey. We are grateful if you could take the time to answer these questions.

Har du frågor kontakta kundservice@umeaenergi.se
If you have any questions contact kundservice@umeåenergi.se

Med vänlig hälsning,
Best regards,

Umeå Energi
Umeå Energy

Appendix III: Table displaying the distribution of villas and apartments

	Villas	Apartments	Total
Treatment group	74	22	**96**
Control group	80	20	**100**
Fuse 16	47	42	**89**
Fuse 20	95		**95**
Fuse 25	12		**12**
Total	**154**	**42**	**196**

Appendix IV: P-values of our econometric model

	All Below Average		All Above Average	
	Without Controls	With Controls	Without Controls	With Controls
Social Comparison Treatment	0.048	0.051	-0.073*	-0.066
	(0.269)	(0.248)	(0.091)	(0.159)
Fuse 20		0.025		0.049
		(0.715)		(0.393)
Fuse 25		-0.035		0.097
		(0.756)		(0.229)
District Heating		-0.019		0.020
		(0.774)		(0.700)
Apartment		-0.100		-0.050
		(0.240)		(0.553)
Constant	-0.032	-0.012	0.071**	0.0407
	(0.207)	(0.872)	(0.011)	(0.522)
N	99	99	97	97
R2	0.012	0.061	0.030	0.076

Note: The table reports OLS estimates. P-values are displayed in brackets. Asterisks next to coefficients indicate the significance of the coefficient, where (* p<0.10, ** p<0.05, *** p<0.01).

	Villas Below Average		Villas Above Average	
	Without Controls	With Controls	Without Controls	With Controls
Social Comparison Treatment	0.079	0.087*	-0.085*	-0.083*
	(0.108)	(0.094)	(0.065)	(0.093)
Fuse 20		0.027		0.049
		(0.698)		(0.387)
Fuse 25		-0.031		0.096
		(0.788)		(0.224)
District Heating		-0.025		0.017
		(0.704)		(0.740)
Constant	-0.025	-0.030	0.094***	0.049
	(0.350)	(0.694)	(0.000)	(0.446)
N	76	76	78	78
R2	0.032	0.047	0.047	0.066

Note: The table reports OLS estimates. P-values are displayed in brackets. Asterisks next to coefficients indicate the significance of the coefficient, where (* p<0.10, ** p<0.05, *** p<0.01).

Appendix V: Econometric results, apartments

Regression on the sample of apartments below as well as above average. Impact of treatment on apartments. The first table shows robust standard error in brackets, and the second table shows p-values in brackets.

	Apartments Below Average	**Apartments Above Average**
	Without Controls	Without Controls
Social Comparison Treatment	-0.060	0.004
	(0.084)	(0.122)
Constant	-0.054	-0.045
	(0.064)	(0.096)
N	23	19

Note: The table reports OLS estimates. Robust standard errors are displayed in brackets. Asterisks next to coefficients indicate a significant difference of means, where (* p<0.10, ** p<0.05, *** p<0.01).

	Apartments Below Average	**Apartments Above Average**
	Without Controls	Without Controls
Social Comparison Treatment	-0.060	0.004
	(0.481)	(0.974)
Constant	-0.054	-0.045
	(0.412)	(0.644)
N	23	19
R2	0.024	0.000

Note: The table reports OLS estimates. P-values are displayed in brackets. Asterisks next to coefficients indicate the significance of the coefficient, where (* p<0.10, ** p<0.05, *** p<0.01).

Appendix VI: Graph, temperature test and comparison week.

Graph displaying the daily average temperature for the test week and the comparison week (the week before).