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An electricity market in transition

- demand flexibility and preference heterogeneity

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1 Introduction

In a recent report to the Swedish Energy Markets Inspectorate (Broberg et al., 2014) consumer behavior and consumer flexibility concerning energy use were analyzed. Two main conclusions were drawn. First, electricity consumption follows a regular pattern over the day, week, and year, which to a large extent reflects household living patterns and climate variations over the year. Second, the average household needs a substantial economic compensation to voluntarily reschedule its electricity use away from peak demand hours. The required compensations were found to be far higher than the economic incentives households face today when exposed to real-time pricing. In addition, it was found that households are more flexible in the use of electricity for heating than in the use of electrical appliances. Finally, households were found to be more flexible during the morning peak hours than during the evening hours. These findings led to the overall conclusion that both the possibilities and incentives are such that we cannot expect any substantial change in energy use patterns from technical reforms that creates incentives for demand response in line with the current price variation on the wholesale market for electricity.

In the above-mentioned report we also analyzed people's attitudes towards information dissemination. We concluded that many households do not wish to have their electricity use scrutinized by experts and other households. We found that people, on average, required a compensation to allow such information sharing. Again, new technologies open for various demand response policies, although it does not necessarily imply substantially higher demand flexibility. New technologies need to be combined with consumer interest to be successful in a market economy.

The overall objective of the current report is to further scrutinize consumer behavior and flexibility. The first part focuses on Swedish households' choice of electricity supplier contracts. Specifically, we analyze what types of households choose a fixed price contract.[1] The choice of contract implicitly reveals a consumer's flexibility since a fixed price contract works as an insurance against price variation. So, by studying what type of households chose a fixed price contract we are able to infer on which type of households are relatively inflexible. This part of the analysis is policy relevant since it touches on the question of what to expect from real-time pricing reforms. A central question is whether a household who uses relatively more electricity is more likely to have a fixed price contract. If this is the case, future access to real-time pricing and a greater price variation may not be a guarantee for a substantial increase in demand response as important consumers (from a policy perspective) are more likely to insure against such circumstances. From this perspective the market for price insurances (fixed price contracts) is a market for inflexibility.

While the analysis above considers the effectiveness of future energy policies to promote demand response, it is also relevant to study the question of how the peak demand problem may develop over time. This question is explicitly addressed in the current report by studying how consumer behavior varies across income levels. The existing literature suggests that electricity consumption is positively related to income, although the income elasticity[2] is fairly small. However, almost all studies concerning income

[1] A fixed price contract is here defined as a contract in which the price is fixed for a year or longer.

[2] The income elasticity of electricity demand measures how much electricity demand changes in percent when income increases with e.g. 10 percent.

effects have studied aggregate electricity use on monthly or yearly basis. The present study departs from the existing literature by studying how daily household electricity use patterns vary across income levels. This approach is novel since it allows us to analyze how the peak load problem may develop in the future as a result of higher income levels, which is commonly expected.

By studying the choice of electricity contracts and by estimating hourly income elasticities, the report approach demand flexibility in an indirect way. In the third analysis of the report we address these issues again, although with a somewhat more direct approach. The choice experiment part in Broberg et al. (2014), which focused on the economic incentives needed in order to change people's energy consumption in a pre-defined way, is now deepened. The focus is on how socio-economic factors such as e.g. age, gender, education and income may explain preference heterogeneity among the Swedish population. Energy related factors such as living conditions and heating systems are also considered in the analysis. This analysis will inform us about what types of households are inclined to reschedule their energy use when given relatively small economic incentives, and what household's that are relatively inflexible and thus require large compensations to change their behavior. We also study preference heterogeneity regarding information dissemination in purpose of anonymous peer comparisons.

In the final part of the report we deepen our analysis of households' demand for information about their own and others electricity use. Besides creating incentives for demand response, new technologies included in the smart grid concept also make it possible for policy makers to use tailored information to help consumers to use energy more efficiently. A number of studies highlight inefficiencies in the households' use of energy (see e.g. Broberg and Kazukauskas, 2014). One highlighted reality is that people seem to pay little attention to energy issues. Of course, if people pay little attention to the price of electricity, the effectiveness of policy measures that work through the price-channel is limited. In this part of the report we address four basic questions of great relevance for energy efficiency policies worldwide. The questions are (1) What knowledge do people have about the marginal cost of electricity use in terms of everyday electrical appliances? (2) Are the cost perceptions biased and in what direction? (3) Do inattention to energy issues play a significant role in this bias? (4) Do households want information that may help them de-bias their perceptions about energy costs and use?

The report is structured such that section 2 gives a brief background on the issues analyzed in the report. The following sections correspond to the issues outlined in the introduction. Section 7 works to tie the analyses together and conclude our results.

2 A changing electricity market

The main challenge for the electrical power system is to secure instantaneous balance between consumption and production of power. Recently this challenge has become greater as the power production mix is changing in Sweden, as well as in other parts of Europe. The share of decentralized, small scaled and intermittent production such as wind and solar power has increased substantially, while the use of coal and oil, but also nuclear power, have declined over time. This trend is expected to continue for the foreseeable future. On the political arena the focus is turning from energy supply to power supply as the balancing problem has become obvious to most stakeholders. Intermittent power has to be balanced with flexible power production (e.g., hydro or gas power) or with demand side flexibility. From a regulatory perspective, demand side flexibility means that firms and households electricity consumption adjust and mirrors fluctuations in power scarcity. From the market perspective, increased demand flexibility means improved adaptability of consumers to short-term price variation, which result from changes in supply and/or demand for power.

It is not only more intermittent power supply that invoked the request for more demand side flexibility. Every year the Swedish transmission system operator (Svenska Kraftnät, SvK) procures an operating reserve in accordance with the act (2003:436) on preparedness for the threat of wintertime power shortages. In 2013 SvK purchased 1700 MW, of which 64 percent was production capacity and 36 percent agreements on power reductions in major industries. The total cost for the operating reserve was MSEK 130, which, when divided by the total use of electricity in Sweden, translates to 0.1 öre per kWh. The cost of one MW of power reduction was about 28 percent higher than one MW of production reserve in 2013. In SvK's view it is appropriate to have both production capacity and power reduction in the operating reserve, since these measures work as complements (SvK, 2013). Production capacity is generally slow in upstart but can provide large volumes during long time periods, while power reductions can be made at short notice but are instead harder to sustain.

The Swedish government intends to gradually phase out the operating reserve by 2020. Already by 2017, the planned operating reserve is to be capped at 750 MW which is about half of today's level. After 2020 the idea is that actors in the electricity market should provide balance themselves and guarantee no instantaneous power shortages. Note however that it was decided in 2003 that the operating reserve would be phased out by 2008, although this deadline was subsequently postponed since the market was assessed incapable of full balance provision. Increased demand flexibility is expected to make the phase out of the Swedish operating reserve by 2020 possible.

From the discussion above the challenge for the power system can be divided into two main challenges:

1. To secure power balance in a system with increased small-scaled intermittent power production.
2. To secure power balance in times of severe power scarcity, such as e.g. during cold winters and when part of the large scaled production capacity is not functioning.

The Swedish operating reserve addresses the second challenge, while the first challenge demands a much more flexible operating reserve that is available all time of the year and adjustable on short notice. Demand flexibility will likely play a role in the future treatment of both these challenges.

In order to make consumers more active, a framework must be created in which they are given incentives and opportunities to be flexible in their electricity use. Such a framework can be based on contracts with dynamic pricing, agreed power reductions or other incentive-based or mandatory measures. The actual characteristics of the playing field will of course depend on both the available technology and consumer preferences. Although consumer preferences play a key role in strategies to create more demand side flexibility, the discussion so far has been technology-oriented focusing on the power system, while leaving consumers' needs on the periphery. In a system that is market-based, however, the consumer's role cannot be disregarded. From a societal perspective it is important to look at benefits and costs in a broader sense. A crucial consideration in this context is how the subjective well-being of individuals are affected by different policies. This means that lifestyle, attitudes, values and social norms all play important roles. In order to succeed with reforms and ensure that they are economically motivated, it is therefore crucial to have a good understanding of how electricity consumers really are affected. Given that electricity is a necessity in modern societies, any reform affecting the electricity market is politically important. Consequently it would be difficult to carry out reforms that are good for the electricity system as such, while perceived bad among electricity consumers (and potential voters).

Technology development increases the possibilities for electricity consumers to control and influence their electricity costs, e.g. by remote, time or price control of their heating, ventilation or use of other appliances. Technology also enables companies to sell new energy related services to consumers (e.g. control and energy efficiency). Still, these possibilities may also imply problems related to informational stress and integrity. Some consumers may simply not want to be flexible if it requires an increased mental effort, or may not want their electricity use to be monitored or externally controlled. At the same time, of course, there may be consumers with other preferences who want certain services, or offer their flexibility free of charge for the purpose of doing what they perceive as their social responsibility.

In summary, we currently know very little about how smart grids, increased demand flexibility and information dissemination are perceived among electricity consumers. It will be important to bridge this gap if we are to gain an understanding of the effects of different reforms in a market-economy context. This report attempts to bridge part of that gap by examining demand flexibility and information dissemination from electricity customers' point of view.

3 Fixed contracts - a market for inflexibility?

From the 1990s and onwards electricity markets have been deregulated in many European countries, including Sweden. This has opened up the markets for both production and sale of electricity, thereby changing the conditions for producers, suppliers and consumers in quite fundamental ways. Perhaps the most obvious change for consumers in Sweden is that they can now choose freely from a large number of suppliers who offer them a multitude of different contracts. Most households in Sweden utilize the possibility to choose an electricity contract. Still, about 15 percent of the households stick to the default contract, which often is an economically bad decision. Those who chose a supplier also decide on whether or not to insure themselves against price changes in the future. It is possible for households to agree on a fixed price during a predefined time period, typically up to five years. The alternative to having a fixed price contract is to agree on real-time pricing, or most commonly to agree on a variable price. The latter is typically the monthly average of the spot price on the wholesale market Nordpool. From the households perspective the variable price is likely perceived as a monthly fixed price. Today there also exist hybrid contracts where households agree on a fixed price contract during the winter and a variable price during summer. In 2014 about 38 percent had a fixed price contract. Only 0.2 percent (8600 households) had agreed to real-time pricing. About 40% have signed a variable price contracts (Energimarknadsinspektionen, 2014).

Households that, for some reason, prefer a fixed price contract over other type of contracts self-select themselves away from demand flexibility. Hence, understanding why some households prefer a fixed price contract is important as it will inform us about which households that are more or less likely to choose electricity contracts with real-time pricing in the future. In the discussion of real-time pricing and demand response, households with some sort of electrical heating have received more attention than others as they typically have relatively high electricity consumption. Besides being of great interest to those responsible for securing balance in the power system, households with high electricity consumption also have the largest economic incentives to re-allocate load over time (Energimarknadsinspektionen, 2010). However, we expect these households to also have the greatest incentives to choose a fixed price contract, given that these households share the same risk preferences as the rest of the population. A household that today prefers a non-flexible contract is unlikely to choose contracts with prices varying by hour. If this is the case real-time pricing reforms run the risk of ineffectiveness due to the possibility that the targeted group of households may be prone to self-select themselves into inflexibility. Furthermore, if the choice of electricity contracts reflects flexibility, knowledge about why households prefer certain contracts helps policy makers to promote real-time pricing contracts to households that are more susceptible to flexible alternatives.

The question we now set out to analyze is whether households with large electricity consumption are more likely to choose fixed price contracts (fixed for a year, or longer), compared to other households. Put differently, are households with large electricity consumption more willing to pay a risk premium to avoid price variation? A priori, we would expect this to hold true as these households have higher stakes at risk. The current analysis adds to the very sparse literature on determinants of electricity contract choices by exploring how household characteristics such as quantity of electricity used, household size, heating system and income affect the probability of choosing a fixed price contract (see Juliusson et al., 2007 and to some extent Ek and Söderholm, 2008 and Gamble et al. 2009). Juliusson et al. (2007) finds that both loss aversion and concerns about price volatility are negatively correlated with attitudes to variable price contracts.[3] They find that age and education have a negative and significant impact on preferences for variable price contracts, but no significant effects from neither household income nor electricity expenditure. Our study adds to the previous literature by using a larger sample and more recent data, e.g. after the winters of 2010/2011 where prices were very high.

Related results can be found from the financial sector and the housing market concerning the choice between adjustable rate mortgages (ARM) and fixed rate mortgages (FRM). The general findings in this literature are that variables such as age and education reduce the probability of choosing ARM, whereas this probability increases with the income level. However, the effects of borrower characteristics are generally believed to be small compared to mortgage attributes (see e.g. Dhillon et al., 1987 and Campbell and Cocco, 2003). If the choice between fixed and variable price contracts is seen as an indicator of risk preferences, this study also adds to the literature by exploring how household- and individual characteristics are related to risk preferences in a context different from standard insurances and financial investments.

[3] Loss aversion refers to the tendency for people to strongly prefer avoiding losses than acquiring gains. As a result, in this context, it would mean that people tend to choose fixed rate contracts in order to avoid a loss, even if acquiring a gain is equally probable.

The data we use here to study contract choice was collected during 2014 as part of a web-based survey including 918 respondents in Sweden.[4] We specify a logit model explaining how different covariates affect the probability of choosing a fixed price contract, which here is defined as a contract with the electricity price fixed for one year or longer .The dependent variable is equal to 1 if respondent has such a contract and zero for variable price contract. In general, we would expect the probability of choosing a fixed price contract to increase with the level of electricity consumption. We estimate two separate models; one with annual consumption in MWh and one with heated floor area in square meters and a dummy for electric heating. The reason for this is that many households have answered "don't know" on the question about their annual consumption, and that we in general expect the variable "annual consumption" to be more prone to measurement errors. We therefore estimate these two models as a sensitivity analysis. We would expect the probability of choosing a fixed price contract to decrease with income, as high-income households have a less tight budget constraint and may afford price spikes. The prevalent stereotype is that people behave less risky by being more cautious with age (see e.g. Halek, 2001 and Heckhausen, 1989), which is reasonable to hold for the choice of electricity contract to. In addition, there are interaction effects such as between annual consumption (or heated floor area) and income that are of interest. Electricity consumption is believed to increase with income, but at the same time we expect high-income households to care less about price variation and therefore to a lesser extent choose fixed price contracts. A hypothesis would then be that such interaction is having a positive but decreasing effect on the probability of choosing a fixed price contract.[5] A dummy variable is also included to control for geographical location (price area 1, 2 and 3 coded as one).

Detailed estimation results are presented in table A1 in appendix 1. Table 1 below displays the marginal effects, i.e. the percentage change in the probability of choosing a fixed price contract as a result of a unit change in the independent variable. The interaction effects of interest are illustrated graphically in figure 1 and 2.

First, from model specification 1 we see that an increase in annual consumption by 1000 kWh (e.g. roughly a ten percent increase for the average household in the sample) leads to a 1.4 percentage point increase (the marginal effect is 0.014) in the probability of choosing a fixed price contract. A similar example can be made with heated floor area in model 2, which increases the probability of choosing a fixed price contract. The marginal effect is 0.0025, meaning that an increase in floor size by 10 m^2 increases the probability of choosing a fixed price contract by 2.5 percent. To illustrate this estimate, consider two households that only differ in size, where household *A* has a larger floor area than household *B* by 50 m^2. Then, our results indicate that household *A* is roughly 13 percentage points more likely to choose a fixed price contract. We also see that electric heating increase the probability of choosing a fixed price contract. The intuition is the same as with e.g. annual consumption. Household income is insignificant for all specifications, which is in line with the findings of Juliusson et al. (2007). Age has a positive and significant effect for all specifications. Again, even if the marginal effects appears small, a person that is 70 years old is 14 percentage points more likely to choose a fixed price contract compared to a person that is 50 years old.

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[4] See detailed description of the data in Broberg et al., 2014.

[5] For a more complete description and analysis see Vesterberg, 2015.

Table 1: Marginal effects of logit model on electricity contract choice.

	Model 1	**Model 2**
Variables	*Marginal effects*	*Marginal effects*
Annual consumption (MWh)	0.014**	
Heated floor area (square meters)		0.002**
Electric heating		0.099**
Household income	0.000	0.000
Age	0.007***	0.007***
Geographical location	0.070	0.069*
No of persons	0.062**	0.037

*Notes: i) * p<0.1 ** p<0.05 *** p<0.01*

Figure 1 illustrate the marginal effects of the interaction terms between annual consumption (in MWh) and income, and square meters and income, respectively. For annual consumption (a), we see that the marginal effect of electricity usage is decreasing with income, as hypothesized above. For the interaction between square meters and household income, the marginal effect of square meters (b) is rather constant over household income levels.

(a) (b)

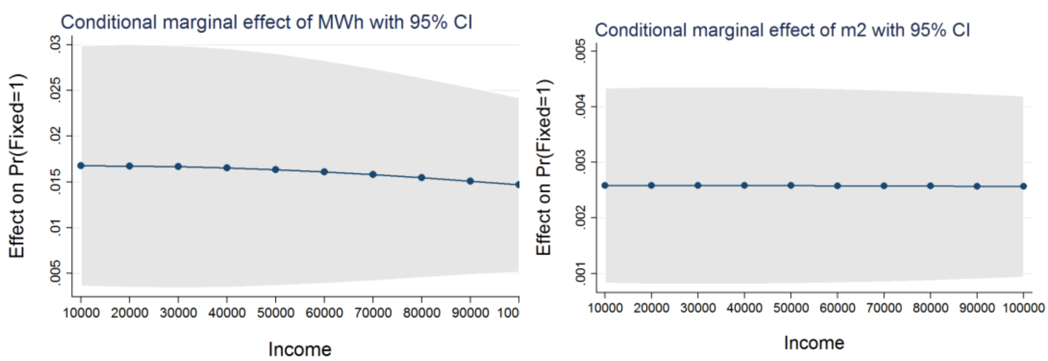


Figure 1: Conditional marginal effects of the interaction term between annual consumption in MWh and household income (a), and between heated floor area in square meters and household income.

To summarize, our results support the hypothesis that a household with large electricity use (i.e. large electrically heated villas) is more likely to choose a fixed price contract. From this we conclude that this type of households may be less likely to engage in dynamic pricing of electricity.

4 Hourly income elasticities of electricity demand

Previous literature suggests that residential electricity consumption increase with income, but at a slow rate. The general finding of previous studies using either monthly or annual data is that the income elasticity of electricity is roughly 0.1, meaning that a ten percent increase in income leads to a one percent increase in electricity consumption. For example, Dubin and MacFadden (1984) find an income elasticity of 0.02, while Parti and Parti (1980) find an elasticity of 0.15. The results in Krishnamurthy and Kriström (2015) are similar, between 0.05 and 0.12, using OECD data. Using Norwegian data, Nesbakken (2001) finds an income elasticity of 0.13 for households with electricity heating, while roughly 0.05-0.06 for mixed heating. Damsgaard (2003) finds similar results using Swedish data. Bartels and Fiebig (2000) is one of few studies estimating end-use specific income elasticities and they find that the income elasticity is 0.68 for lightning, 0.26 for peak water heating and 0.68 for pool pump.[6]

No previous literature, however, addresses the question of when during the day the increased electricity use occurs. This question is relevant to policy makers as it may help predict the development of peak demand. If the real income level continues to grow, and this leads to more electricity consumption, this may further increase the peak load problem if the increase in electricity consumption occurs during peak hours. This could be the case if, for example, high-income households use more appliances during peak hours, or use appliances that consume more electricity, compared to low-income households. Hence, from a policy perspective it is of importance not only to know whether income leads to higher monthly or annual electricity consumption but also to understand when (within a day) consumers increase their use of electricity as their income improve.

We address the above research question using a unique data set on households' electricity consumption metered hourly on appliance level and for all months (as compared to Broberg et al. 2014 where only data for February working days are used).[7] Using this data we estimate hourly and end-use specific income elasticities for electricity demand. Such estimates provide insight on how within-day electricity consumption *patterns* may change with income, and whether this effect is expected to differ across end-uses, i.e. appliances grouped into heating, kitchen, lighting and other.

To explore how the income elasticity of electricity differ between hours and end-uses, we estimate separate equations for each hour and end-use (i.e. 24 equations for each end-use) using a Seemingly Unrelated Regression framework. In addition to household income we also control for living area in square meters, number of persons in the household and age of the oldest person living in the household, housing type (i.e. detached/semi-detached house or flat) and potential seasonal effects. For the estimation of income elasticity of heating, we also include indicators for heating system and outdoor temperature.

The estimated income elasticities are illustrated in figures 3-6[8]. Starting with the income elasticity of heating, figure 3 illustrates how the point estimate does not significantly differ from zero in any of the hours. Intuitively, this can be explained by heating being a necessary good or service; when a comfortable indoor temperature is obtained there is no need to further increase the temperature - irrespective of income changes. The income elasticity of lighting is significant for morning and evening hours. Since we

[6] See Kriström (2008) for a methodological discussion and a summary of the relevant literature estimating income elasticities of energy demand.

[7] The data was collected by the Swedish Energy Agency in 2005-2008. See Vesterberg et al. (2014) for a more detailed description of the data.

[8] Detailed results for each end-use are available upon request.

control for living area, these results should not be interpreted as high-income households having larger houses and thereby have more rooms to light up. Rather, the intuition for our results could be that high-income households use more lighting for each room, or perhaps care relatively less about turning off lights when not in a room. For kitchen, the income elasticities are significant for evening hours, and peaks (about 0.4) during traditional dinner hours (7 pm). The interpretation of these results is that high-income household use additional appliances and/or use those they have more intensively, or possibly have a different consumption pattern and different timing of consumption than low-income households. Finally, the income elasticity of other load is significant and positive during evening hours. As this "other" category is made up of many different appliances, it is a bit hard to interpret these results. However, we note that TV's and computers are all included in this category, while it is reasonable to believe that high-income households possess a higher number of, and more energy intensive, appliances. All in all, the hourly income elasticities for all end-uses except heating suggest that an increase in income will typically lead to an even more distinct evening peak.

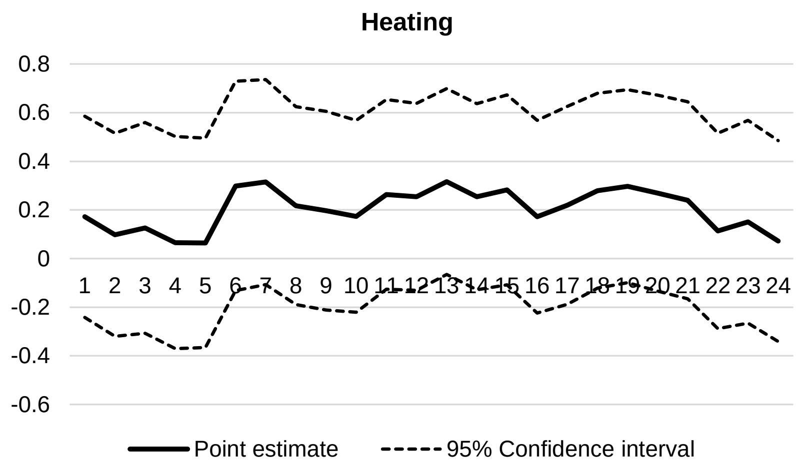


Figure 3: Hourly income elasticities of heating with 95% confidence interval.

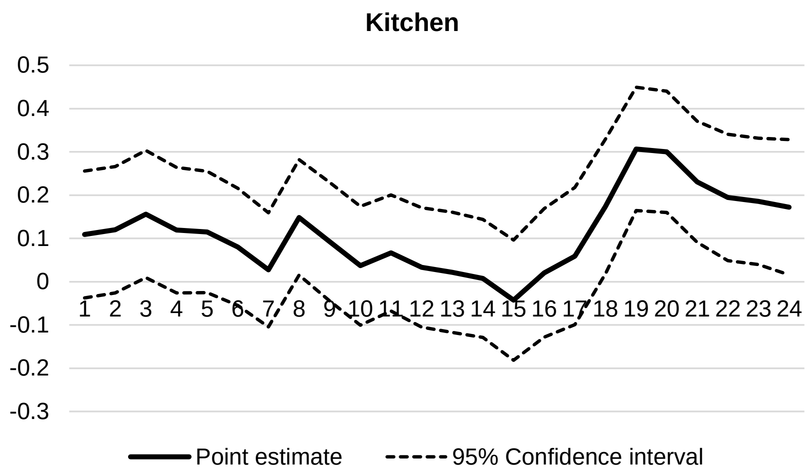


Figure 4: Hourly income elasticity of kitchen with 95% confidence interval.

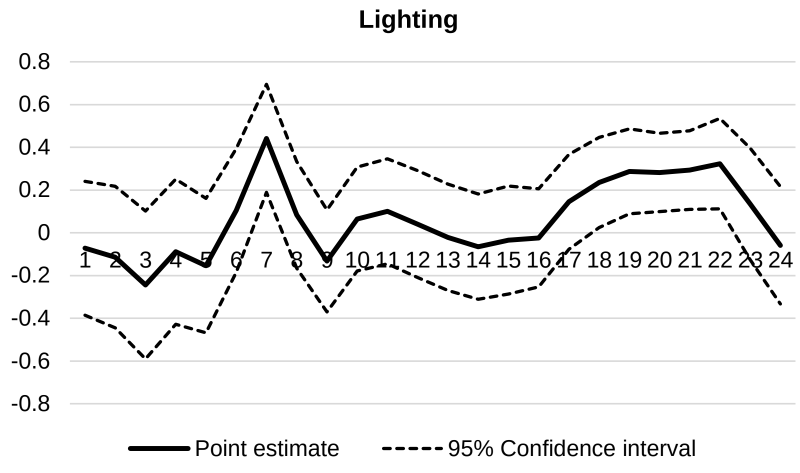


Figure 5: Hourly income elasticity of lighting with 95% confidence interval.

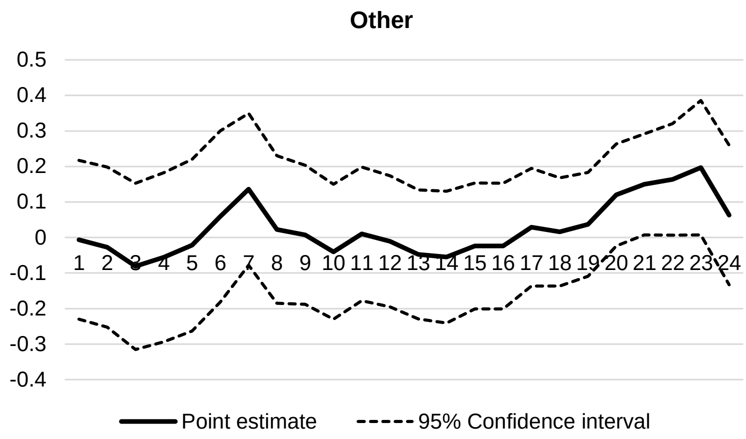


Figure 6: Hourly income elasticity of other with 95% confidence interval.

To validate our results regarding the hourly income-elasticities we calculate aggregate (across hours, as well as end-uses) income elasticities. Intuitively, the daily end-use income elasticity is a weighted sum of the hourly elasticities for that end-use, with weights being the share of the particular end-use consumption during hour *t* of daily end-use load. Note that since the daily elasticities are for an *average* day, these elasticities can also be interpreted as the monthly elasticity or even annual. This is perhaps best illustrated with a simple example. Consider a month with two days and where the household consumes 100 kWh each day. Further, assume that the daily income elasticity is unity. An income increase of 10 percent leads to an increase in consumption of 10 percent for each day, or 20 kWh in total; from 200 to 220. Hence, the monthly elasticity is the same as the daily – unity. However, note that this only holds when the daily elasticity is for an *average* day. In the remaining of this text, we refer to the aggregate estimates as daily income elasticities and keep in mind the previous discussion and interpretation.

The calculated daily elasticities, together with computed standard errors, are illustrated in Table 2. The results show that only kitchen and lighting are significant for the full sample and for detached houses, whereas heating and other are insignificant. The intuition for heating being insignificant is, as discussed above, that once the indoor temperature is comfortable there is no further reason to use more heating, irrespective of income levels.

Concerning kitchen and lighting the estimated elasticities are 0.120 and 0.151 for the full sample, and 0.579 and 0.302, respectively, for detached/semi-detached houses only. The calculated end-use specific income elasticities are smaller in size than those in Bartels and Fiebig (2000) who report elasticity estimates, albeit for a very different usage pattern and context, of 0.68 for lighting and 0.26 for water heating. Finally, the calculated total income elasticity of 0.207 for detached/semi-detached houses are close to estimates in the previous literature (see above).

Table 2: Daily end-use specific and total income elasticities for full sample, detached/semi-detached houses and flats.

End-use	Income elasticity	Standard error
Detached/semi-detached houses		
Heating	0.205	0.195
Kitchen	0.579***	0.101
Lighting	0.302**	0.138
Other	0.021	0.150
Total	0.207	n/a
Flats		
Kitchen	-0.225**	0.095
Lighting	0.038	0.099
Other	0.057	0.109
Total	-0.045	n/a
Whole sample		
Kitchen	0.120*	0.065
Lighting	0.151*	0.079
Other	0.034	0.084

*Notes: i) * $p<0.1$ ** $p<0.05$ *** $p<0.01$*
ii) Standard errors for calculated daily income elasticities are calculated using the lincom command in Stata
iii) Note that calculating total elasticity for the whole sample would be problematic as it would be hard to compare heating for detached/semi-detached houses and flats.

Our results, while novel and plausible, suffer from a few data-related drawbacks calling for caution in interpretation as well as in direct application to policy. In particular, the absence of household price data and contract type information adds "noise" to our estimates in addition to not allowing an exploration of price sensitivity of households. All in all, our results suggest that an increase in income will lead to higher electricity consumption, and in particular that this increase will occur during peak hours, thus magnifying peak demand.

5. Demand side management - who is the flexible consumer?[9]

As mentioned in the introduction, Broberg et.al. (2014) present results from a choice experiment focusing on consumer flexibility and demand side management. The analysis was based on hypothetical energy contracts including one or several restrictions on households' to make them reschedule their energy use away from typical peak demand periods in the power system. By repeatedly choosing one out of three possible contracts respondents implicitly was assumed to reveal their perceived disutility from being

[9] This section is to a large extent based on Broberg and Persson (2015), where a more comprehensive and thorough description of data, methods, etc. can be found.

restricted in the energy use. The disutility was reported and interpreted as the minimum economic compensation needed to accept individual restrictions. From the results it was concluded that the compensation demanded by the consumer to become flexible was rather high, especially in the evening, implying a high cost for the society as a whole. It was also found that people on average demand lower compensations to accept externally controlled heating systems, compared to being restricted in their domestic electricity use. Finally, people require SEK 44 per day of preparedness to accept seemingly random restrictions in extreme occasions, e.g., in very cold winter days.

The above reported results are not very surprising. Previous research have shown that demand response measures, like real-time pricing and time-of-use pricing, have led to little load shifting and mostly to energy savings in peak hours (Allcott, 2011a and Torriti, 2012). Research have also shown that Swedish households on average demand SEK 8 to SEK 123 per black-out, depending on the time within week and year it occurs and for how long it lasts (Carlsson and Martinsson, 2008).

In the previous report we also showed that people on average demand a compensation for anonymously sharing personal information about their energy use with other households. In the previous analysis we reported average values without addressing the question of heterogeneity among the respondents. The main results from the previous study are summarized in Table 3.

In this section we further develop the choice experiment analysis and study preference heterogeneity. That is, does the disutility from external control of energy use (and thus compensation levels) differ systematically across households?

Table 3: Results of the choice experiment in terms of estimated compensations required to agree on external control and information sharing.

Valuation of contract characteristics	Annual compensation
Compared with no control of heating…	
• It is unclear if any compensation is required for control 07.00-10.00	Not sign.
• A compensation is required for control 17.00-20.00	SEK 630
Compared with no control of household electricity…	
• A compensation is required for control 07.00-10.00	SEK 829
• A compensation is required for control 17.00-20.00	SEK 1 435
Compared with no control in extreme conditions…	
• A compensation is required for each "preparedness day" with control	SEK 44/day
Compared with no dissemination of information about a household's electricity consumption	
• A compensation is required for permission to disseminate such information	SEK 244
In order to opt out of a contract which is the "same as today"…	
• A compensation is required	SEK 2746

The analysis of preference heterogeneity has, in this case, three main purposes. First, it can be used to validate our results by pointing at systematic variations explained by logical reasoning. Second, it gives information about for which households we should expect certain types of flexibility. Third, knowledge about preference heterogeneity may help to predict future development of consumer flexibility as income and demographic factors change. As an example, Section 4 presented results predicting increasing peak loads as household income increases. An analogous analysis with focus on consumer flexibility could be made based on the results in this section.

From a methodological perspective we now test whether observable socioeconomic factors to some extent can be used to explain the heterogeneity around the mean of the main effects attribute levels. Specifically, socioeconomic variables are interacted with the attributes (levels), which result in a number of interaction terms. This gives pairwise combinations of socioeconomic variables and attribute levels, e.g. age*external control of heating system in the evening. To decide on which interaction terms to include, our basic model was tested for preference heterogeneity around the mean of one attribute at the time. A model including all significant (or close to significant) interaction terms was then estimated.[10] It should be noted that each attribute level has been interacted with a unique set of interaction terms although all sets included age, gender, household income, adults, children and apartment. The attributes related to heating have been controlled for indoor temperature and whether the household use electric heating. While almost all respondents stated that someone in their household usually is at home 5-8pm this is not the case for 7-10am. If people are in their homes when the energy use is controlled, more discomfort is expected. Motivations for all of the different interaction terms are given in Table 4.

Table 4: Results of the choice experiment in respect of estimated compensation demands.

Socioeconomic parameter	Scope and hypotheses
Age	Interacts with all attributes. Although we expect age to play a role in some cases, we do not necessarily expect a general age effect.
Gender	Interacts with all attributes. We expect females to be more sensitive to restrictions in domestic electricity as they traditionally, on average, do more of the household work.
Household income	Interacts with all attributes. We expect high-income respondents to be more sensitive to restrictions in general. We expect high-income respondents to care more for their own ability to use energy when they wish given stricter time constraints.
Adults	Interacts with all attributes. We expect households with more than one adult to be more sensitive to restrictions as more people are affected.
Child 0-12 years	Interacts with all attributes. We expect respondents living with 0-12 year old children(s) to be more sensitive to restrictions on their domestic electricity use.
Apartment	Interacts with all attributes. We expect respondents living in apartments to be less sensitive concerning restrictions of the heating system as they typically are subjects to such restrictions.
Electrical heating	Interacted with heating related attribute variables. No expectation a priori. Households with electrical heating use much electricity and thus have relatively high energy bills.
Indoor temperature >21 degrees	Interacts with heating related attributes. We expect people with currently high indoor temperature to be more sensitive to restrictions in the heating system.
Home 7-10am	Interacts with the external control in the morning attributes. We expect people being at home when the restrictions occur to be more sensitive to the restrictions.

[10] It should be emphasized that signs and significance levels remain stable moving from the individual attribute variable models to the final model.

The interaction effects are reported in Table 5 as + and – signs illustrating how the compensation level varies across respondent characteristics (socioeconomic parameters). To exemplify, a + sign means that the disutility from a specific restriction is higher for the respective characteristic, and thus the respondent require a greater compensation. Detailed estimation results are presented in Table A3 in the appendix 2. The reader of the report should notice that all interaction terms are not exclusively significant at the ten percent level (**bold**). All reported coefficients did however show a tendency to vary systematically with respondents' preferences for attribute levels in the estimations underlying the final interaction model. As can be seen in Table 5 there is no general preference heterogeneity related to the socioeconomic factors (such as a general age or income effect). Each attribute seem to follow its own logic. Much heterogeneity seems to be related to individual characteristics unrelated to factors not easily captured by socio-economic variables, e.g. time-constraints, ideology, life-style etc. Maybe some heterogeneity exists because respondents may have interpreted the restrictions differently.

External control of heating system 7-10am
Although we found that the respondents on average do not require a compensation for having their heating system controlled in the morning, we would expect some households to require compensation, e.g. households that are at home when the restriction binds. The socioeconomic variables we control for do not, at any reasonable statistical significance, explain the heterogeneity underlying the preferences related to control of heating 7-10am.

External control of heating system 5-8pm
Respondents in high-income households and respondents currently experiences indoor temperatures of more than 21 degrees Celsius seem to experience more disutility from external control of heating in the evening than do other respondents. On the other hand, if there is more than one adult in the household, the control of heating 5-8pm causes less disutility.

External control of domestic electricity 7-10pm and 5-8pm
Age, gender and being at home are significant factors underlying preferences. Specifically, older people are less negative to being controlled with respect to domestic electricity use during all times, while women and households where someone is at home 7-10am are more reluctant to being controlled 7-10am. The latter two findings are to some extent expected given basic intuition and that women to a larger extent do household related work. The age effect has several plausible explanations, e.g. older people have fewer children at home, may have less time-constraints and there might be life-style issues. We should also mention here that we expected respondents living with children (0 to 12 years old) to be more sensitive to restrictions of their domestic electricity use. However, this variable turned out to be statistically insignificant.

External control at random extreme occasions
Respondents living in high-income households experience more discomfort from control due to random extreme occasions. A subjective guess is that high-income people work more and have stressful lives, which make them less flexible. For example, both parents working full time may imply less flexibility.

Information sharing
Disutility from sharing personal information about electricity use is negatively correlated with age, if there are more than one adult in the household and if the respondent lives in an apartment. The underlying reasons for these results are not obvious although older people perhaps are less used to sharing personal information in general. The result here is in line with results in section 6 showing that old people are less willing to receive information about other households electricity use. Concerning people living in apartment buildings they may experience a higher social cost from peer comparisons in the neighborhood since physical and technical conditions in the apartments are identical or very similar which makes comparisons easier.

Table 5: The relationship between socio-economic variables and required compensation level to agree to specific restrictions in energy use.

Attribute-to-socioeconomic interactions
Random parameter logit specification

Interactions	Sign
Heat, 7-10am*Adults	-
Heat, 7-10am*Children (0-12y)	-
Heat, 5-8pm*Household income	+
Heat, 5-8pm*Adults	-
Heat, 5-8pm*Electric heating	+
Heat, 5-8pm*High indoor temp	+
Dom. el., 7-10am*Age	-
Dom. el., 7-10am*Gender	-
Dom. el., 7-10am*Home, 7-10am	+
Dom. el., 5-8pm*Age	-
Dom. el., 5-8pm*Apartment	+
Ext. occ.*Household income	+
Ext. occ. *Apartment	+
Information*Age	+
Information*Adults	+
Information*Apartment	+
Information*Electric heating	+

6 Are consumers fit to play the new game and do they want to?

Households have multiple electrical devices and appliances, while receiving utility bills monthly, or quarterly, in which all electricity costs are lumped together. As a result, households get insufficient feedback on how efficient they are in their use of electricity. This kind of insufficient feedback may lead consumers to systematic mistakes in the use of electricity. For example, Sexton (2014) finds that a change to automatic bill payments causes a 4 to 6 percent increase in electricity consumption for U.S. households. Sexton (2014) theorizes that consumers underestimate electricity prices because of inattention and therefore consume too much electricity. Still, there is only a few empirical studies on household perceptions of electricity cost, and if systematic misperceptions (if any) are related to inattention.

The survey presented in the previous section, which was also used in Broberg *et al.* (2014), included several questions related to knowledge about costs of using electricity, priorities when buying different types of electrical appliances and the willingness to receive more information about the household's own and other households' electricity use. The purpose of asking households these questions was to analyze and possibly answer the following questions. (1) What knowledge do people have about the marginal cost of electricity use in terms of everyday electrical appliances? (2) Are the cost perceptions biased, and if so, in what direction? (3) Does inattention play a significant role in this bias? (4) Do households want information that may help them de-bias their own perceptions and beliefs about energy costs and use? While potentially biased believes about energy costs and the role of behavioral issues such as inattention have been frequently addressed in theoretical academic work and in actual energy policies worldwide, all of the above mentioned questions are to date typically ignored or sparsely investigated empirically in the context of private electricity use.

The first two questions are partly addressed in Attari *et al.* (2010). They investigate the perception of energy consumption and savings for a variety of household activities using a survey approach. Their results show that for a sample of 15 activities, participants overestimated energy savings for low-energy activities (like turning off lights) and underestimated energy saving potentials for high-energy activities (like using electric cloth dryer). There is also a considerable literature on empirical evidence of so-called "MPG[11] Illusion" (see, for example, Larrick and Soll 2008; Allcott 2011b). In general people think, for example, that increasing fuel efficiency from 13 to 14 MPG is equivalent to increasing fuel efficiency from 33 to 34 MPG. However, it is a misperception/illusion as fuel savings do not increase linearly with changes in MPG. Allcott (2011b) conducted a survey and found that the respondents in U.S. devote little cognitive effort to calculating fuel costs when choosing between vehicles. Allcott (2011b) speculates that this result is mainly driven by inattention. Investigating whether inattention is related significantly to biased perceptions on electricity costs is one of the issues addressed in this report.

The potentially biased perception of electricity consumers may necessitate so-called soft policy actions to correct these potential biases. Recent research suggests that more detailed information on household energy use can be a powerful policy instrument to influence people's behavior concerning their consumption of energy. For example, it has been shown that information alluding to social norms lead to significant energy savings. Numerous studies have shown that households decrease their electricity consumption when they receive information about other people's electricity use (e.g. Allcott 2011c; Delmas et al. 2013; Dolan and Metcalfe 2013). This opens up a promising possibility of policies based on customized information that incur negligible costs on the wider society. So-called social nudges change the framing of specific decisions without restricting actual choices, which means that they do not cause inefficiencies in terms of economic surplus. However, this is only true as long as people are not negatively affected by being nudged. Camerer et al. (2003) promote an approach to evaluating paternalistic regulations and doctrines that they call "asymmetric paternalism." They suggest evaluating not only the benefits of any paternalistic regulation but also less salient nonmonetary cost, such as unwelcomed emotions incurred by policy targeted people. These costs or "side effects" of nudges are usually ignored by the numerous empirical studies investigating nudges effectiveness in energy conservation and generally in other fields.

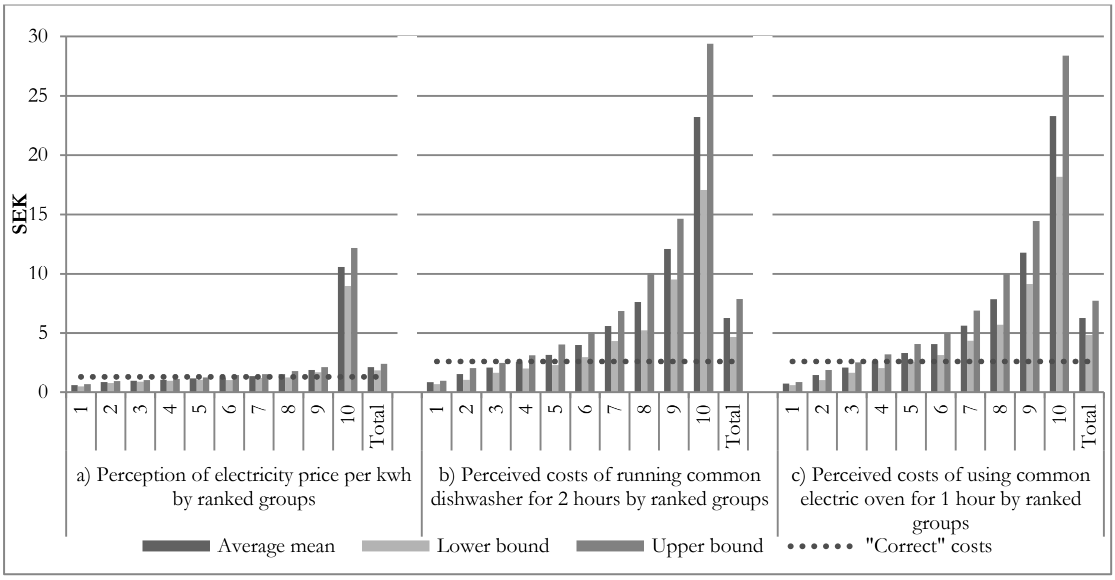
To get an idea of potential misperceptions concerning energy costs we asked people about their perceived cost of using one kWh electricity and the electricity costs of running common home electric appliances. The respondents were asked to state intervals, but to simplify the analysis we mainly focus on the means of these intervals.

[11] Miles per gallon

Figure 7 shows the scale of variation in perceived cost of using one kWh electricity. To illustrate the variation the respondents have been divided into 10 groups of equal size. Each group have then been ranked by their average perceived costs (the group with the lowest average cost perception to the left and the group with the highest average cost perception to the right).

Concerning the cost of using one kWh electricity the stated costs differs by a factor of more than 17 between the group with the lowest cost perceptions and the group with the highest cost perceptions, ranging from 0.59 to 10.55 SEK/kWh. Interestingly, about half of the respondents refused to provide their perceptions by stating that they have no understanding (in Swedish "ingen uppfattning") about the cost of electricity. Among the respondents stating an interval , a majority were quite close to the "correct" reference cost of using one kWh electricity. However, a considerable number of respondents gave quite unrealistic numbers.

We also asked the respondents to report their perceived costs of using a dishwasher and an electric oven. The answers to these questions shows substantially more variation compared to the case of the perceived cost of using one kWh electricity. The mean of the reported interval costs now differs by a factor of about 30 between the group with the lowest cost perceptions and the group with the highest cost perceptions (ranging from SEK 0.84 to 23.21 and SEK 0.75 to 23.28 for dishwasher and electric oven, respectively).



Note: a number of respondents were removed from this illustrative graph as these respondents stated incredibly high beliefs or answers were missing. The respondents were divided to 10 same size groups and ranked by their average perceived costs of energy starting with the lowest cost average perception and ending with the highest average level of cost perception. Each group contains 45, 80 and 82 respondents for (a), (b) and (c) cases, respectively. The suggested "correct" costs of energy use is based on Vattenfalls "Stora Elräknaren", online energy cost calculator, estimates.

Figure 7: The average beliefs about electricity price and running common electric appliance costs by respondent same size ranked groups: (a) perceptions of electricity price, (b) the costs of running common dishwasher; and (c) the costs of using common electric oven.

In general, the results of the survey suggest that many households base their decisions regarding energy use on poor and generally biased knowledge.[12] In order to test our hypothesis that biased perception about the cost of electricity to some degree can be associated with inattention we use basic econometrics. The results are presented in Table 6.

In our analysis of the relationship between inattention and perceptions of electricity related costs we distinguish between rational inattention and inattention related to unawareness. We reason that while rational inattention is the result of a deliberate ignorance of some information this is not the case for inattention in form of unawareness. The first type of inattention (rational) can be related to the costs (efforts) of gathering information about relatively small electricity cost savings. Meanwhile, the second type of inattention (unawareness) is related to cognitive abilities and systematic mistakes (for a more extensive discussion about different types om inattention see Broberg and Kazukauskas, 2014). We use two binary variables as proxies to distinguish between rational inattention and inattention due to unawareness. First, as a proxy for rational inattention we use a binary variable where the value 1 represents households stating that they pay attention to energy saving when considering buying electricity consuming white goods, such as a fridge, but NOT paying attention to energy efficiency when buying other less electricity consuming products, such as a stereo or TV. Second, as a proxy for unawareness we use a binary variable, where value 1 represents households which have no idea about how much electricity they use per year.

The results, presented in Table 6, show that inattention can be a significant factor explaining perceptions of costs related to electricity use. People with inattention characteristics due to unawareness have upward biased perceptions of all the three stated costs. This result somewhat contradicts that inattention likely causes lower price perceptions and too much energy use. Our results raise doubts about such beliefs. The results, to some extent, confirm that the price perceptions among people who sometimes rationally ignore energy costs are somewhat lower than the perceptions of others. This result is however not statistically significant.

Table 6: Determinants of respondents' perception on (1) electricity price, (2) two hours running costs of common dishwasher and (3) the cost of using ordinary oven for one hour (at 200C)

Variable	el price	dishwasher	oven
	(1)	(2)	(3)
Higher education[a]	-0.0398	0.1087	0.1753**
Age	-0.0020	-0.0063**	-0.0053**
Woman[a]	0.0752	0.2348***	0.1264*
Household size	0.0559	0.0861*	0.1071**
Direct electric heating[a]	0.0751	0.1456	0.1811
Income	-0.0181*	-0.0073	-0.0123
Inattention RATIONAL[a]	0.0084	-0.0398	-0.1376
Inattention UNAWARENESS[a]	0.2624**	0.2485***	0.1974**
Observations	431	750	770

*Note: significance levels indicated by *** p<0.01, ** p<0.05, * p<0.1,* [a] *indicates a dummy variable*

[12] There is empirical evidence that our perceptions are sometimes systematically biased not only in energy use related context but also in other common everyday activities. For example, people tend to overestimate the calories in drinks and underestimate the calories in food (Bollinger *et al.* 2011).

We also find that high-income respondents and those with university education on average do not have different cost perceptions than others.[13] This finding somewhat contradicts our expected outcomes, although it is in line with results of Attari *et al.* (2010) who find that both income and education are not reliable predictors of perceptions on energy saving activities. We find that in our specific case older people tend to be less biased in their perceptions.

The results of low awareness and the households' upward-biases beliefs about energy costs raises the question of customised information in the form of nudges. This question can be explored by directly asking whether people wish to receive information that (i) compares their energy use with other similar households, (ii) compares their energy use with their own past consumption, and (iii) provides specific operating cost information for each electric appliance. Although the respondents are in favour of receiving more detailed information about their energy use, they are not as enthusiastic about getting information on energy use of similar households. Almost half of the participants of the survey expressed negative opinion on the possibility of being compared to peers. To understand the factors possibly associated with the (un)willingness to receive information on private energy use, an econometric analysis based on probit models is performed. See Table 7 for the results.

The results show that a socioeconomic variable such as age seems to play a large role explaining unwillingness to get more information. This result can be related to a general stereotype that older people tend to be more conservative and less enthusiastic in embracing changes. As expected, education and higher incomes have generally positive effects.

Table 7: Marginal effects of determinants explaining willingness to *get certain* information (probit models)

VARIABLES	willing to *receive* information on		
	Comparison	past consumption	appliance use
	(1)	(2)	(3)
Higher education[a]	0.0732*	0.0683**	0.0303
Age	-0.0042***	-0.0024**	-0.0042***
Woman[a]	0.0243	-0.0712**	0.1064***
Household size	-0.0033	-0.0164	-0.0015
Direct electric heating[a]	0.1114**	0.0761*	0.0742
Income	0.0004	0.0047	0.0012
Inattention RATIONAL[a]	0.0351	-0.0063	0.0945*
Inattention UNAWARENESS[a]	-0.0412	-0.1630***	-0.0680
Distrust[a]	-0.1964***	-0.2771***	-0.2433***
Paying no electricity bills[a]	-0.0406	-0.0867	0.0079
Observations	847	847	847

*Note: robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*
[a] indicates dummy variable

It is somewhat worrying that respondents being identified as being inattentive due to unawareness about their energy use are less willing to get more information. Thus, targeted policies to correct biased perceptions on the basis of inattention among

[13] Descriptive statistics and description of actually used variables of interest are provided in table A4 in appendix 2.

households by customized information campaigns might not be an effective and efficient policy since people who do not pay attention to energy issues seems to be less willing to be guided by policy makers.

We also find that respondents with the tendency for rational inattention are somewhat more likely to be willing to receive information that is currently less accessible to them, i.e. peer comparison and detailed electric appliance use costs. This result is somewhat expected as this type of inattentive persons are unlikely to willingly put extra effort in paying attention to information which is already relatively accessible for them (past consumption) compared to other types of information.

Another interesting finding is that paying no electricity bills is not an issue when it comes to willingness to receive more information. One could expect that tenants who do not pay for their electricity would be less willing to receive information on their presumably higher energy consumption patterns relatively to other households. However, it is not the case in our sample. This could reflect that tenants have nothing to worry about because either they are confident in that their energy consumption is in line with other households consumption patterns, or because they do not care too much about it.

The distrust in data handling process is another key determinant of unwillingness to get customized data on private energy use. We proxy this distrust by the "None of above" answers provided by respondent to the following question: which of the specified institutions would you trust to analyse the information collected via your electricity meter. The institutions mentioned included universities, central and local public authorities and private companies. About 18 percent of the respondents answered that they did not want anyone to analyse their energy use. The policy implication of his finding is that to make energy policy nudges more effective policy makers must address distrust among households in organisations that handle private energy use data.

7 Final discussion and conclusions

In this report we have analyzed consumer flexibility from different angles and perspectives. First we analyzed Swedish households' choice of electricity contracts to see whether or not households with high electricity consumption are more likely to choose fixed price contracts and thereby signaling a tendency towards inflexibility. Our results lend support to that hypothesis. Risk preferences seem to be important in the choice of insuring against price variation and future price changes. It is perhaps reasonable to expect that if real-time pricing were to become the default contract, a large share of households would choose fixed price contracts, (perhaps more households than today considering that the price-volatility facing the households would increase). Hence, the availability of this type of insurances limits the effectiveness of real-time pricing reforms. In this study we are not able to give the full picture on the scope for real-time pricing as we would expect that more intermittent power production leads to an increase in price variation, which may cause a higher demand for price insurance (and inflexibility). It is one of the major challenges for policy makers to balance the consumers demand for certainty and the power system's demand for flexibility. The wrong set of policy actions may cause a counter-productive outcome if it pushes households into inflexibility. In this perspective it seems important to gather knowledge about consumers' risk-preferences and how they really perceive price variation.

In this report we also, to our knowledge, presented the first set ever of hourly income elasticities for end-use electricity consumption. Furthermore, the appliance-specific nature of the data provides a unique opportunity to gain a better understanding of appliance-specific consumption patterns. The results provide an insight not only to how higher income will lead to higher electricity consumption, but also when during the day the increase is likely to occur. A key question for the analysis is whether a higher future income will amplify peak demand in the power system. The results indicate that this is the case. The income elasticities are positive and significant for peak hours for kitchen and lighting, albeit insignificant for heating. Further, we use the estimated hourly elasticities to calculate daily income elasticities, which can be thought of as annual estimates. The results range from insignificant for heating and 'other' to significant and positive for kitchen and lighting; 0.152 and 0.215, respectively. Finally, the total daily income elasticity is estimated to 0.139, which is in line with previous literature.

By studying the choice of electricity contracts and by estimating hourly income elasticities, we approach demand flexibility in an indirect way. Additional to these analyses we also applied a more direct approach to study consumer flexibility. Using the method of choice experiments we asked people to repeatedly choose between three different hypothetical energy contracts featuring different demand-side management restrictions. By choosing contracts the respondents reveal their preferences for different characteristics of the contracts. By using econometric techniques we were then able to measure (in monetary terms) the disutility from certain restrictions in energy use, presented as minimum compensation levels required. In a recent report to the Swedish Energy Markets Inspectorate we presented average values of compensation levels and highlighted the presence of preference heterogeneity. In the current report we have studied if compensation levels differ systematically with respect to household characteristics (socioeconomics). The main conclusion from this analysis is that the observed preference heterogeneity is not easily explained by socioeconomic variables such as age, gender and income. Each restriction seems to follow its own logic. Among other things we find that high-income households require a larger compensation to agree to restrictions in their energy use at random occasions, e.g. when the power system is stressed. This may indicate that the attractiveness of dynamic pricing will erode as the real income level increase. We further speculate that preferences related to consumer flexibility are possibly largely explained by life-styles, habits, individual time-constraints and ideology.

Finally, we analyzed four questions related to peoples' ability and will to change behavior to be more efficient in their energy use. (1) What knowledge do people in fact have about the marginal cost of electricity use and the cost of using every day electrical appliances? Our results point at a wide range of perceptions, and that many people use energy under imperfect knowledge about costs. (2) Is the perception of the costs of electricity use and the costs of using electric appliances biased, and if so, in what direction? We find that people on average have upward-biased believes about the cost of using electrical appliances. The result indicates that policies informing people about the cost of using energy may be quite ineffective and possibly even counter-productive if the aim is to reduce energy use. (3) Can inattention explain potential misperceptions? Yes, people who pay little attention to energy issues seem to have upward-biased beliefs about energy costs. However, this is only true as long as people do not rationally ignore the cost of energy. (4) Do households want to receive information which may help them de-bias their beliefs? Surprisingly many households, and in particular inattentive people, do not want to have more information about their energy use and the cost of using it.

Furthermore, even more people do not want to have information about other peoples energy use. We find that the willingness to share or receive personally tailored information about energy use with other similar households decrease with age.

Together with the previous report (Broberg et al., 2014), this report provides several insights about consumer flexibility. It is fair to say that the conclusions drawn are rather conservative, highlighting several problems that demand response policies have to overcome. The results must however be interpreted in the contexts underlying our analyses and the current circumstances on energy markets, especially the power market. Throughout history, new technology, in particular information technology, has changed our way of living in many ways. Whether or not this will be the case for smart grids technology is outside the scope of the study, but is indeed a relevant question for future research. Our hope is that such research will embrace a market orientated perspective where the needs and wants of the households are reflected.

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Appendix 1

Table A1: Results from the multinomial logit on contract choice

	Model 1		Model 2	
	b/se	dy/dx	b/se	dy/dx
Annual consumption (in MWh)	0.062**	0.014**		
	0.029			
Heated floor area			0.086**	0.002**
			0.038	
Electric heating			0.413**	0.099**
			0.206	
Household income	0.000	0.000	0.000	0.000
	0.000		0.000	
Age	0.031***	0.007***	0.027***	0.006***
	0.008		0.006	
Geographical location	0.297	0.080	0.288*	0.069*
	0.199		0.171	
No of persons	0.262**	0.062**	0.153	0.037
	0.111		0.093	
income * kwh	- 0.000**	-0.000**		
	0.000			
income * m2			-0.000	-0.000
			0.000	
Constant	-2.468***		-2.595***	
N	488		656	
Percent correctly predicted	0.634		0.562	
Log likelihood	-309.581		-421.005	

Notes: i) Electricity contract type is dependent variable with fixed price contract defined as 1 and all other contracts defined as 0

ii) β ^ refers to estimated coefficients, se to standard errors and dy/dx to marginal effects (evaluated at the mean).

*iii) * p<0.1 ** p<0.05*** p<0.01*

iv) Percent correctly predicted (using estimated coefficients to predict outcome) referes to threshold value of 0.5 (see Wooldridge 2010).

v) Note that we loose half of the sample size when using annual consumption in kWh instead of heated floor area and dummy for electric heating.

Appendix 2

The choice experiment

The choice experiment part of this report strictly rests on the methods and survey issues presented in the previous report, Broberg et al., 2014. Below is a short summary of the statistical framework and methods.

Each question in the choice experiment involved a discrete choice between three different contracts, where each of these is characterized by the various attributes presented in Table 6, Broberg et al., 2014. It is assumed that each choice is associated with a specific utility level for the respondent, and that he/she will choose the contract that provides the greatest expected utility. From a statistical perspective this can be interpreted as the probability that the respondent will choose one of the three contracts, given the attribute levels they are described with. The analysis of such data such is usually done within the framework of "logit models", where multinomial logit (MNL) is the most fundamental. In MNL, it is assumed that non-observable factors that affect the choice between the contracts are totally independent of each other, which is not always appropriate. For example, it may be the case that things that affect the benefit in more than one of the contracts correlate with the attributes in the choice experiment, which means that the non-observable factors are no longer independent of each other. In order to avoid this problem, a model known as "random parameter logit" (RPL) is used. On the whole one could say that RPL is a generalized version of MNL which allows for heterogeneity among respondents' preferences. Non-observable factors are allowed to be random and to emerge from a statistical "distribution".[14] In the RPL model, point estimates are made for the chosen parameters, but estimates are also made of their distribution. There are other advantages to using RPL as well, such the avoidance of making strong assumptions about context independence. On the basis of various statistical tests, we have chosen to focus on the results from the RPL model when presenting results in the text of the report.

The results presented in the text are mean values, which are more or less uncertain in the statistical sense. Normally, statistical uncertainty is measured illustrated using standard deviation and significance. In this context (related literature) it is relevant to talk about significance at the 1, 5 and 10 percent levels, which mean that a parameter estimate is significantly different from zero if it is associated with a standard deviation that is not greater than what is required for any of the above levels to be met.[15] For example, it could be the case that a parameter value (mean value) of, say, 200 is not statistically different from zero because the uncertainty (standard deviation) is too large. In such a case the significance would not be below 10 per cent.

In our models, most attributes have been specified as "dummy variables". These variables are interpreted in relation to a base level, which, in this case, is intended to describe the current electricity market. The base levels for the remote control attributes are "No control" and for the information attribute "No dissemination". The compensation demands calculated on the basis of the parameter estimates for these

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[14] See e.g. Train (2009).

[15] Significance is a measure of the risk of committing what is known as a Type 1 error. Given a zero hypothesis that a parameter is zero, a Type 1 error is committed if the hypothesis is rejected despite the parameter actually being zero. Compared with a 5 per cent significance, a 10 per cent significance implies a greater risk of a Type 1 error.

variables are thus to be interpreted as the average compensation necessary in order for households to accept a change to their electricity use, or that depersonalized information about their energy use is spread to other households.

Table A2: Results from the choice experiment without explanation variables for status quo (same as in Broberg et al., 2014).

	MNL		**RPL**		
	Coeff .	**Compensation demand (WTA)**	**Coeff .**	**RP St.d.**	**Compensation demand (WTA)**
RCH_M	-0,1971*** (0,0723)	597** (248)	-0,0255 (0,1251)	0,6782*** (0,1772)	41 (207)
RCH_E	-0,2749*** (0,0500)	833*** (208)	- 0,3932*** (0,0897)	0,4469** (0,1951)	630*** (156)
RCHE_M	-0,2280*** (0,0667)	691*** (189)	- 0,5177*** (0,1005)	0,5462** (0,2194)	829*** (136)
RCHE_E	-0,3464*** (0,0594)	1049*** (194)	- 0,8956*** (0,1070)	1,0712*** (0,1397)	1435*** (171)
RCEC	-0,0203*** (0,0064)	61*** (21)	- 0,0275*** (0,0991)	0,3634 (0,3198)	44*** (17)
INFO	-0,0297 (0,0487)	90 (150)	-0,1520* (0,0792)	1,0063*** (0,1064)	244* (129)
COMP (SEK '000)	0,3301*** (0,0307)	--	0,6243*** (0,0485)	--	--
ASC_SQ	0,8917*** (0,0750)	-2701*** (250)	1,7141*** (0,2172)	4,9423*** (0,2617)	-2746*** (341)
LLH	-5351,657		-3782,999		
AIC	1,946		1,379		
Psuado R^2	0,018		0,375		
Halton			1000		

***,**,* Significant at 1.5 and 10 per cent, respectively.

Table A3. Attributes and socioeconomics variables

Attributes	Main effects RPL		Attribute-to-socioeconomic interactions RPL	
	Coeff (s.e.)	Std dev	Interactions	Coeff (s.e.)
Heating, 7-10 am	-0.323* (0.187)	***	Heat, 7-10am*Adults	0.316 (0.208)
Heating, 5-8pm	-0.318 (0.194)	*	Heat, 7-10am*Children (0-12y)	0.328 (0.240)
Domestic electricity, 7-10am	-1.518*** (0.308)	**	Heat, 5-8pm*Household income	-0.046** (0.023)
Domestic electricity, 5-8pm	-1.563*** (0.340)	***	Heat, 5-8pm*Adults	0.535*** (0.197)
Extreme occasions	0.234 (0.224)	*	Heat, 5-8pm*Electric heating	-0.433 (0.297)
Information, yes	0.962*** (0.351)	***	Heat, 5-8pm*High indoor temp	-0.295* (0.177)
ASC (status quo)	1.681*** (0.222)	***	Dom. el., 7-10am*Age	0.021*** (0.005)
Annual compensation	0.628*** (0.051)		Dom. el., 7-10am*Gender	0.262* (0.157)
			Dom. el., 7-10am*Home, 7-10am	-0.457** (0.178)
Log-likelihood	-3508.233		Dom. el., 5-8pm*Age	0.015*** (0.005)
Restricted Log-likelihood	-5635.881		Dom. el., 5-8pm*Apartment	-0.182 (0.176)
McFadden Pseudo R^2	0.378		Ext. occ.*Household income	-0.056** (0.022)
AIC	1.380		Ext. occ. *Apartment	-0.209 (0.162)
BIC	1.421		Information*Age	-0.011** (0.005)
No. of respondents	855		Information*Adults	-0.495*** (0.180)
No. of observations	5130		Information*Apartment	-0.328* (0.177)
No. of Halton draws	1000		Information*Electric heating	-0.487 (0.321)

***, **, *: Significant at 1, 5 and 10%-level, respectively.

Table A4. Descriptive statistics of the variables of interest

Variable	Measure	Obs	Mean	Std. Dev.	Min	Max
Comparison	the respondents willing to receive information on similar peers' use of electricity	918	0,423	0,494	0	1
Past consumption	the respondents willing to receive more detailed information on their own past use of electricity	918	0,662	0,473	0	1
Appliance use	the respondents willing to receive information on the electricity cost of running their appliances	918	0,597	0,491	0	1
L_bound_kWh	lower bound of perception of electricity price per kWh in SEK	451	1,920	4,634	0,2	40,4
U_bound_kWh	upper bound of perception of electricity price per kWh in SEK	451	2,519	5,584	0,3	50
Average_kWh	average perception of electricity price per kWh in SEK	451	2,219	5,072	0,25	45
L_bound_dish	lower bound of perception of electricity costs for running dishwasher for 2 hours in SEK	823	4,814	6,052	0,01	45
U_bound_dish	upper bound of perception of electricity costs for running dishwasher for 2 hours in SEK	823	7,989	9,381	0,01	60
Average_dish	average perception of electricity costs for running dishwasher for 2 hours in SEK	808	6,460	7,537	0,01	50
L_bound_oven	lower bound of perception of electricity costs for using oven at 200C for 1 hours in SEK	848	5,057	6,223	0	44,44
U_bound_oven	upper bound of perception of electricity costs for using oven at 200C for 1 hours in SEK	848	8,078	9,765	0,02	100
Average_oven	average perception of electricity costs for using oven at 200C for 1 hours in SEK	829	6,617	7,758	0,015	50
Higher education	University equivalent education of more than 3 years	918	0,321	0,467	0	1
Age	age	918	54,793	16,788	18	85
Woman	gender of the respondent	918	0,452	0,498	0	1
Household size	the self-reported household size	914	2,177	1,099	1	8
Direct el heating	direct electric heating	906	0,146	0,353	0	1
Income	households income index based on self-reported income intervals	855	8,227	3,705	1	16
Inattention (rational)	respondent approx. knowing their household annual energy use quantities, consciously NOT paying attention to energy efficiency attributes of white goods BUT considering energy efficiency attributes of other electric appliances such as PC, TV or stereo	918	0,377	0,485	0	1
Inattention (unawareness)	respondents having NO idea about their annual energy use quantities	918	0,181	0,385	0	1
Distrust	the share of household not trusting any authorities to analyze their personal energy use data	918	0,059	0,235	0	1

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